Study on Serious Road Traffic Injuries in the EU

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The study has been presented to Member States during the CARE meeting on the 17th of October 2016 in Brussels.

Disclaimer

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Executive summary

It is the ambition of the EU to reduce the number of killed and seriously injured on the roads over time. It has turned out that, especially in relation to serious injuries, there is still a significant knowledge gap on how to reduce these numbers in the EU. The Commission is therefore committed to develop a particular focus on the serious road traffic injuries, to better understand their causes and effects. One of the first actions the Commission has undertaken is to develop a common definition of 'serious traffic injury' within all Member States as injuries scoring 3 or more on the medical *Maximum Abbreviated Injury Scale (MAIS3+)*. While the EU Member States are proceeding in estimating the total number of serious injuries for their country, there is the need to know more about main crash circumstances of MAIS3+ casualties in order to make a start with the formulation of strategies and measures that are effective in the prevention of these injuries.

Aim of this study

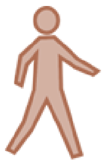
The general objective of this study is to collect knowledge that will enable the future identification of measures for effective prevention of serious road traffic injuries. The specific objective is to provide fact-based analysis on the most common circumstances and types of road traffic crashes leading to serious injuries of MAIS3+ severity. More specifically, the study is directed at providing an understanding of the main circumstances and factors that affect the emergence of serious road traffic injuries, medically coded as MAIS3+, for the following road traffic modes in the EU: pedestrians, bicyclists, motorcyclists and car occupants.

Approach of the study

The study has been performed on data of MASI3+ cases linked with crash information, which was available for the following countries: Austria, Czech Republic, France, Germany, Italy, Netherlands, Spain, Sweden and England. Data are gathered from in-depth sources, hospital discharges, trauma registers and police records linked to medical registers.
For each database, the available main crash characteristics have been extracted and used to define common scenarios for each traffic mode. Also the most affected body regions of the severely injured casualties have been gathered per traffic mode and per database. Furthermore, differences in injury patterns per crash scenario have been studied in order to find first clues for effective measures.

Results of the study

Most common characteristics of crashes with severely injured pedestrians:



- Gender: about equal division between male/female;
- Age: elderly people and children;
- Crash opponent: cars and heavy vehicles;
- Location: urban 50 km/h road section;
- Time: afternoon and winter months;
- Contributing crash factors: looking or judgement failures, speed-related and psychoactive substances;
- Head and upper body injuries: heavy vehicles and higher speed roads;
- Lower extremity injuries: cars and lower speed roads.

Severely injured bicyclists have the following common characteristics:

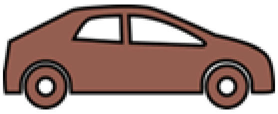
- Gender: slight to heavily male dominated;
- Age: elderly, youngsters, middle aged, children;
- Crash opponent: car, no crash opponent;
- Location: urban area, 50 km/h, intersections;

- Time: summer, afternoon;
- Contributing crash factors: failures in looking or judgement, reckless driving and loss of control;
- Head injuries: dominant in all crash scenarios;
- Lower extremity injuries: single vehicle crashes, elderly people and crashes with lower impact speed;
- Thorax injuries: side-impact crashes in urban areas and at junctions.

Common characteristics of severely injured motorcyclists are:

- Gender: >90% male;
- Age: youngsters and middle aged people;
- Crash opponent: car, no opponent, fixed objects;
- Location: rural and urban roads;
- Time: summer and spring;
- Contributing crash factors: failures in looking or judgement, speeding and loss of control;
- Thorax injuries: single, fixed object, rural areas;
- Lower extremity injuries: car crash.

Common characteristics for severely injured car occupants:



- Gender: two thirds males;
- Age: youngsters;
- Crash opponent: cars, no opponent and fixed obstacles;
- Location: rural roads, speeds >70 km/h;
- Time: afternoon and winter months;
- Contributing crash factors: loss of control, speeding and psychoactive substances;
- Thorax injuries: car to car, wearing seat belt but no airbag available;
- Head injuries: crash with fixed object and heavy vehicles, not wearing a seat belt and no airbag available;
- Lower extremity injuries: car to car crashes, also in lower speed zones.

A first comparison with main features of fatal crashes in the EU has revealed that the MAIS3+ results are probably quite representative for the entire EU, although it is expected that there will be country specific differences, as was also found in some results in this study (e.g. differences in travel purposes of certain traffic modes like two-wheelers resulting in particular crash characteristics, differences in share of road types and differences in shares of crash opponents which may be influenced by modal split, travel behaviour and country characteristics). Injury patterns seem to be largely influenced by these crash characteristics.

Recommendations

Although this study was not directed at defining effective measures to prevent serious injuries, the findings provide support that a number of measures that are known to be effective for the prevention of fatal crashes could also help reduce serious injuries. A more detailed study of the causes of serious road injuries, linked to the actual policy and the state of the road traffic system in Member States, could reveal more specific keys to reduce the number of serious injuries in the EU.

Policy recommendations at EU level are to help Member States in creating awareness of the specific characteristics of MAIS3+ casualties and tune their policy to the prevention of these crashes. Research into effective measures is therefore a next important step. Defining a severe injury target could help to increase awareness, information gathering and policy efforts directed at the reduction of serious injuries. Benchmarking between Member States can provide further opportunities to learn from each other.

Résumé

L'UE nourrit l'ambition de réduire le nombre de tués et de blessés graves sur les routes au fil du temps. Il s'est avéré que, particulièrement en ce qui concerne les blessures graves, bon nombre de connaissances font encore défaut quant à la façon de réduire ces chiffres au sein de l'UE. La Commission s'engage dès lors à mettre davantage l'accent sur les blessures graves dues aux accidents de la route, afin de mieux en comprendre les causes et les effets. L'une des premières actions entreprises par la Commission est l'élaboration d'une définition commune des « blessures graves de la route » au sein de tous les États membres comme blessures de catégorie 3 ou plus sur l'échelle médicale *MAIS 3+ (Maximum Abbreviated Injury Scale)*. Alors que les États membres de l'UE procèdent à l'estimation du nombre total de blessures graves sur leur territoire, on relève la nécessité d'en savoir davantage sur les principales causes d'accident des blessés MAIS 3+ en vue d'initier la formulation de stratégies et de mesures efficaces dans la prévention de ces blessures.

Objet de cette étude

L'objectif général de cette étude est de rassembler des connaissances qui permettent l'identification future de mesures efficaces en matière de prévention des blessures graves par accident de la route. L'objectif spécifique est de fournir une analyse factuelle sur les circonstances et les types d'accidents de la route les plus courants induisant des blessures de gravité MAIS 3+. L'étude vise plus spécifiquement la compréhension des principaux facteurs et circonstances qui influent sur la survenue de blessures de la route graves, codées médicalement MAIS 3+ pour les principaux modes de circulation routière au sein de l'UE, à savoir les piétons, les cyclistes, les motocyclistes et les occupants de voitures.

Approche de l'étude

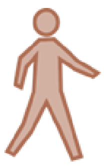
L'étude a été réalisée sur les données de cas MAIS 3+ couplées aux informations sur les accidents qui étaient disponibles dans les pays suivants: Autriche, République tchèque, France, Allemagne, Italie, Pays-Bas, Espagne, Suède et Royaume-Uni. Les données sont collectées de sources d'informations détaillées, de sorties d'hôpitaux, de registres de traumatismes et de dossiers de police liés à des registres médicaux.

Les principaux scénarios et caractéristiques d'accident disponibles ont été extraits par base de données. De même, les zones corporelles les plus touchées des victimes grièvement blessées ont été collectées par mode de circulation et par base de données. En outre, les différences des types de blessures par scénario d'accident ont été étudiées afin de trouver les premiers signaux pour des mesures efficaces.

Résultats de l'étude

Caractéristiques d'accidents les plus courantes avec piétons grièvement blessés:

- Sexe: répartition pratiquement identique entre hommes et femmes;
- Âge: personnes âgées et enfants;
- Opposant: voitures et véhicules lourds;
- Où: zone urbaine à 50 km/h;
- Quand: l'après-midi et les mois d'hiver;
- Facteurs accidentogènes: erreur d'attention ou d'appréciation, vitesse excessive et substances psychoactives;
- Blessures au niveau de la tête et de la partie supérieure du corps: poids lourds et routes à vitesse élevée;
- Blessures au niveau des extrémités inférieures: voitures et zones à 30 km/h.



Les cyclistes grièvement blessés présentent les caractéristiques courantes suivantes:

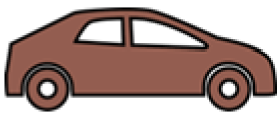
- Sexe: légèrement à fortement plus fréquent chez les hommes;
- Âge: personnes âgées, adolescents, âge moyen, enfants;
- Opposant: voiture, pas d'opposant;
- Où: zone urbaine, 50 km/h, carrefours;
- Quand: l'été et l'après-midi;
- Facteurs accidentogènes: erreur d'attention ou d'appréciation, conduite imprudente et perte de contrôle;
- Blessures à la tête: dominantes dans tous les scénarios d'accident;
- Blessures au niveau des extrémités inférieures: accidents à un seul véhicule, personnes âgées et accidents à faible vitesse d'impact;
- Blessures thoracique: accidents à impact latéral dans des zones urbaines et aux carrefours.

Les caractéristiques communes de motocyclistes grièvement blessés sont:

- Sexe: hommes à plus de 90 %;
- Âge: adolescents et personnes d'âge moyen;
- Opposant: voiture, aucun opposant, objets fixes;
- Où: routes rurales et urbaines;
- Quand: l'été et le printemps;
- Facteurs accidentogènes: erreur d'attention ou d'appréciation, vitesse excessive et perte de contrôle;
- Blessures thoraciques: un seul véhicule, objet fixe, zones rurales;
- Blessures au niveau des extrémités inférieures: accident de voiture.

Les caractéristiques communes des occupants de voiture grièvement blessés sont:

- Sexe: deux tiers sont des hommes;
- Âge: adolescents;
- Opposant: voitures, aucun opposant et obstacles fixes;
- Où: routes rurales, vitesses > 70 km/h;
- Quand: l'après-midi et les mois d'hiver;
- Facteurs accidentogènes: perte de contrôle, vitesse excessive et substances psychoactives;
- Blessures thoraciques: entre deux voitures, port de la ceinture de sécurité, mais pas d'airbag disponible;
- Blessures à la tête: accident avec objet fixe et véhicules lourds, pas de port de ceinture de sécurité et pas d'airbag disponible;
- Blessures au niveau des extrémités inférieures: accidents entre deux voitures, même dans les zones à vitesse réduite.



Une première comparaison avec les principales caractéristiques des accidents mortels au sein de l'UE a révélé que les résultats MAIS 3+ sont probablement assez représentatifs pour l'ensemble de l'UE, bien que l'on s'attende à des différences spécifiques par pays, comme l'indiquent également certains cas de cette étude (par ex. différences dans les motifs de déplacement de certains modes de circulation, comme les deux-roues, induisant des caractéristiques d'accident particulières, différences dans la répartition des types de route et différences dans les répartitions des opposants qui peuvent être influencées par la répartition modale, le comportement de déplacement et les caractéristiques nationales). Les caractéristiques de blessures coïncident avec ces caractéristiques d'accident.

Recommandations

Bien que cette étude n'ait pas pour objectif de définir des mesures efficaces pour prévenir les blessures graves, les résultats soutiennent le fait qu'un certain nombre de mesures réputées efficaces en matière de prévention d'accidents mortels pourraient également contribuer à réduire les blessures graves. Une étude plus approfondie des causes des blessures de la route graves associée à la politique actuelle et à l'état du système de trafic routier au sein des États membres pourrait révéler des clés plus spécifiques permettant de réduire le nombre de blessés graves dans l'UE.

Les recommandations politiques au niveau de l'UE doivent aider les États membres à sensibiliser sur les caractéristiques spécifiques des blessés MAIS 3+ et à ajuster leur politique pour la prévention de ces accidents. La recherche de mesures efficaces constitue dès lors une prochaine étape importante. Il pourrait s'avérer utile de définir une cible de blessure grave pour accroître la sensibilisation, la collecte d'informations et les efforts politiques visant à réduire les blessures graves. Une analyse comparative entre les États membres peut apporter davantage d'occasions d'apprendre les uns des autres.

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Introduction

The costs of road safety to society are substantial and the suffering of the victims and their families huge. Therefore, it is the ambition of the EU to reduce the number of people killed and seriously injured on the roads over time. However, the number of seriously injured casualties seems not to have decreased as quickly as the number of road fatalities in the last decades. As more knowledge on road safety issues and data of high quality becomes available, it turns out that there is still a significant knowledge gap on how to solve the problem of serious road traffic injuries in the EU. The EU-wide data on serious road traffic injuries have not been reliable and comparable and less analysis has been performed on the road crashes causing serious injury than on the fatal crashes.

The Commission is therefore committed to develop a particular focus on the serious road traffic injuries, to better understand their causes and effects. One of the important steps that has been made within the EU, is the development of a common definition of 'serious traffic injury' within all Member States as injuries scoring 3 or more on the medical *Maximum Abbreviated Injury Scale (MAIS3+)*. In March 2016, the first EU-wide estimate of the number of serious injuries was reported by the European Commission: 135,000 in 2014. First indications are that vulnerable road users and powered two-wheelers are dominating. Member States are proceeding now in estimating the total number of serious injuries for their country. In the meantime, there is the need to know more about main crash circumstances for those reported to have MAIS3+ road traffic injuries in all Member States. Ultimately, this type of information will be an important basis for the formulation of new road safety measures that can be more effective in the prevention of serious injuries on the roads.

As a first step the EU Member States are working within the CARE Experts Group to enumerate the total of seriously injured casualties according to the MAIS3+ definition. A range of methods can be used to achieve this and the results are expected to be available at the end of 2016. Moreover, within the H2020 project SafetyCube (SafetyCaUsation, Benefits and Efficiency), practical guidelines are being developed for determining the number of MAIS3+ casualties and an evaluation is being made of how differences in methodology influence the estimated number of serious road injuries. These guidelines should help the countries to further improve their MAIS3+ estimate and will provide insight into the comparability of numbers from different countries. The Commission also collaborates with FERSI in studies on uniform injury classification and state of the art of MAIS3+ assessment in the FERSI Member States and EU/EEA countries.

The total number of serious injuries alone will however not reveal the key factors that relate to the causation of serious crashes and further data is needed to improve knowledge and future policies. A second step will be to examine crash data that includes both details of the crash circumstances and a classification of injury severity using AIS. Some Member States are expected to have such data available in the near future however work is still ongoing for many and alternative approaches and different datasets must be examined to provide these first indications of serious crash characteristics.

Systematic data describing seriously injured casualties are not available for every EU country and therefore it is not yet possible to provide a comprehensive analysis that is representative of all EU crashes. The extent to which the results of analyses of the available MAIS3+ data can be generalized to the EU and the accurate specification of the data constraints will be important aspects of this first analysis of serious crashes and casualties.

Serious road traffic injuries are an important challenge for road safety policy making in the near future. For this reason, the research activities within this project are focussed on understanding the circumstances of crashes that result in serious injuries and to thereby contribute information to help reduce the numbers of serious road traffic injuries.

Objectives of the study

The general objective of this study is to collect knowledge and perform analyses that will enable the future identification of measures for more efficient prevention of serious road traffic injuries. The specific objective is to provide fact-based analysis on the most common circumstances and types of road traffic crashes leading to serious injuries of MAIS3+ severity.

More specifically, the study will provide information on the following issues:

- For pedestrians, cyclists, motorcyclists and car occupants respectively, what are the most common circumstances of a road traffic crash causing serious injury? E.g.: what other vehicles are most commonly involved, what location and in what situation did the crash occur, what serious injuries did the crash result in and, to the best extent possible to define, how were these injuries sustained?
- The assessed share of serious injury crashes accounted for by each identified most common crash scenario.
- Information on the most detailed level possible, e.g. differentiating between the most common serious injury crash scenarios per gender, for different age groups, crash opponents etc.
- Factors that could be found to impact the injury severity, for the crash types and crash scenarios found to be most common for each road user group.

Overall approach

The study on serious road traffic crash characteristics aims at understanding the main circumstances and factors that affect the emergence of serious road traffic injuries, medically coded as MAIS3+. As only a small number of countries have such data available at the moment, the study has some limitations in the number and geographical spread of Member States that are part of the analyses. Nevertheless, this study provides first main clues for policy makers for the following road transport modes within the EU: pedestrians, cyclists, motorcyclists and car occupants.

Data and variables included in the study

Four types of data sources containing stratified MAIS3+ data have been used in the study:

- In-depth crash data;
- Hospital discharges;
- Trauma registers;
- Police recordings of road traffic casualties which are linked to hospital data.

Furthermore, additional qualitative information available from in-depth specialists and medical experts has been used to fine-tune and interpret results.

Table 1 shows an overview of the data sources that have been used, including data of 9 different EU member states.

Table 1 *Overview of data sources on serious road traffic injuries with MAIS3+ information.*

Countries	In-depth source	Hospital discharge	Trauma register	Linked police-hospital data
Austria	Cases via IGLAD[1]			
Czech Rep.	CzIDAS[2] Cases via IGLAD			
France	Cases via IGLAD		Rhône road trauma registry[3]	
Germany	GIDAS[4] Cases via IGLAD			
Italy	Cases via IGLAD			
Netherlands	National in-depth studies (cyclists >50 years; run-off road crashes)[5]	Dutch Hospital Data (DHD)-traffic register		BRON-DHD[6]
Spain	Cases via IGLAD			
Sweden	Cases via IGLAD			STRADA[7]
England	RAIDS[8], OTS			STAST19-HES[9]

Meta-data

The data that are used in the analyses need to be well understood in order to provide a good understanding of the results of the study. For this purpose, Annex I provides an overview of the general characteristics of each of the datasets mentioned in Table 1. It also defines how the data is gathered, the more specific geographical coverage and the inclusion of crash types and crash characteristics.

[1] Initiative for the GLobal harmonisation of Accident Data, data provided by BASt

[2] Czech In-depth Accident Study, data provided by CDV. This data was produced with the financial support of the Ministry of Education, Youth and Sports within the National Sustainability Programme I, project of Transport R&D Centre (LO1610), on the research infrastructure acquired from the Operation Programme Research and Development for Innovations (CZ.1.05/2.1.00/03.0064).

[3] Rhône road trauma registry, France, IFSTTAR

[4] German In-depth Accident Study, data provided by BASt

[5] SWOV

[6] Ministry of Infrastructure and Environment, Dutch Hospital Data & SWOV

[7] Police reporting is regulated by Decree (1965: 561) on statistical information relating to road traffic accidents. Healthcare reporting is regulated by local or regional agreements signed between the health authority / hospital and the Swedish Transport Agency

[8] The Road Accident In Depth Studies (RAIDS) programme and associated database were commissioned by the United Kingdom Department for Transport in 2012 to consolidate data gathered from historic in depth collision investigation programmes dating back to the year 2000. Data collection is ongoing and since 2012, 1200 new cases have been investigated, the data is made available free of charge over the internet however conditional access is limited to those with a defined research need. For further information please contact RAIDS@dft.gov.uk.

[9]

In order to have a sufficient number of cases per database and per traffic mode, but also to provide results based on recent data, data have been used from the period 2000-2014 unless indicated otherwise.

Variables

In order to study common crash types, crash scenarios and crash circumstances of MAIS3+ casualties, the following variables have been used:

- Traffic mode of casualty (=pedestrian, cyclist, motorcyclist/PTW or car occupant)
- Traffic role of casualty (=driver or passenger)
- MAIS-score
- AIS body region
- Age of casualty
- Gender of casualty
- Month of crash
- Time of day/day or night of crash
- First crash opponent (if any)
- Number of active (= non-passenger) road users involved in the crash
- Age of vehicle of casualty
- Crash type
- Road type
- Carriage way type
- Speed limit of the road
- Junction type
- Road surface conditions
- Special situation
- Other contributing crash factors
- Other contributing injury factors
- Impact severity (speed difference)

Details about each variable and its labels can be found in Annex IIa. For the availability of each of these variables and labels per database, see Annex IIb.

MAIS3+ crash types and crash scenarios

To get first clues about common crash types and crash scenarios in which pedestrians, cyclists, motorcyclists or car occupants get severely injured databases that provide information on crash characteristics have been used. These are the following databases:

- Czech Republic: CziDAS
- France: Rhône road trauma registry, (France, IFSTTAR)
- Germany: GIDAS (DE)
- Netherlands: BRON-DHD and DHD traffic register
- Sweden: STRADA
- England: STATS19 linked to HES, RAIDS, OTS
- IGLAD (cases from AT, CZ, DE, FR, IT, SE, and ES)

Methodology

The analyses have been performed on data of MAIS3+ casualties that did not die within 30 days (=severe road traffic injuries). As not all databases have details available on all the variables and labels that have been defined for the study (see Annex IIa and IIb), databases have been analysed separately in order to have as much information available as possible. For details of preparation on the data, see Annex III.

First of all, the main characteristics of the crash and casualties were summarised per database for each of the traffic modes. Within variables, details with low numbers (rare characteristics) have been merged into combined classes where necessary. Cluster analysis has been used to determine main crash scenarios and circumstances per traffic mode. This is done by using a Two-Step clustering method (see also Annex III).

The results from the different databases have been merged by looking for commonalities as a starting point and by indicating the range that has been found in the most common characteristics. Where findings differed between databases, these have been highlighted.

Results

Detailed results per traffic mode and per country and database can be found in Annex IV. This section contains a summary of the results.

Pedestrians

In total, 10,317[10] severely injured pedestrian casualties have been analysed, with cases being contributed from 8 European countries: Austria, Czech Republic, France, Germany, Italy, the Netherlands, Sweden, and the England. From these databases, we get quite a homogenous picture of the most common crash characteristics and scenarios, which are as follows:

Pedestrian characteristics
From the databases that have been analysed, it appears that severely injured pedestrians are about equally often males as females, with a slight shift towards males (45-61% male). The elderly and in some countries also children (CZ, NL, England) are over-represented among those severely injured.

Crash opponents
Pedestrians mostly get hurt in a crash with a car: in most countries analysed, pedestrians hit by a car accounted for 60% to 84% of all cases. A second common crash opponent category for severely injured pedestrians is heavy vehicles (9% to 27%). In the Netherlands, powered two wheelers are the second most common crash opponent. This is not the case in other countries. In most cases, the pedestrian is hit by one traffic participant and in only a small number of cases, more traffic participants are involved. The Czech, German and UK data also show evidence for common manoeuvres and impact sides. These results show that most pedestrians get severely injured during a forward manoeuvre (of the crash opponent), resulting in a frontal or side collision with the pedestrian.

Location characteristics
A high proportion of the crashes resulting in a seriously injured pedestrian occur on urban roads (86-95%) where a speed limit of 50 km/h or equivalent in mile/h is most common. Most often, the pedestrian gets hurt on a road section, but also junctions are quite frequent locations where pedestrians get severe injuries. In Germany, junctions are the most frequent location type.

Time related characteristics

[10] With at least 10,203 unique cases, as the RAIDS/OTS and the IGLAD database contain data of one or more countries that are also central in one of the other databases.

A relative high proportion of pedestrians get severely injured during a crash that takes place in the afternoon, which was found to be the most common time of severe injury crashes in all transport modes that have been analysed. Most common months are winter months. In the Netherlands, also spring is a period where severe casualty numbers of pedestrians are relatively high.

Contributing crash factors
For some of the databases, there was evidence for other contributing crash factors. For severe pedestrian crashes, the following were found to be most common:

- Pedestrian failed to look properly (48-58%);
- Pedestrian careless/reckless behaviour (22-37%);
- Driver failed to look properly (21%)/ Vision affected (driver or pedestrian; 28%);
- Pedestrian failed to judge path/seed of vehicle (19-20%);
- Pedestrian under the influence (alcohol/drugs; 14-30%);
- Speeding of the crash opponent (7-9%).

Bicyclists

In total, 37,174[11] severely injured bicyclist casualties have been analysed from 8 European countries: Austria, Czech Republic, France, Germany, Italy the Netherlands, Sweden, and England. From these databases, we get the following picture of the most common crash characteristics and scenarios:

Bicyclist characteristics
The countries that were analysed show quite a large spread in dominant gender involved in severe bicyclist crashes: from 55% male in the Netherlands to 83% male in England. Elderly (CZ, FR, DE, NL), adolescents (FR, NL, SE), middle aged adults (FR, DE, SE) and children (England) are groups that are found to be dominant in different countries.

Crash opponents
Bicyclists in most analysed countries suffer the most severe injuries when hit by a car (45%-68%). In some countries (FR, NL), single vehicle crashes are more common (64%-85%). In the Netherlands, the car is the most common crash opponent in the police data (BRON) linked to hospital data (DHD), but from the DHD trauma register, it is known that by far the majority of severe bicycle crash injuries are crashes without a motorised crash opponent (or at least without an opponent that hits the bicycle). Especially these crashes appear to be largely missing in the police registration. Until now, there are no similar results known from other countries.

Most bicycle crashes occur when moving forward, but also rounding a bend is found to be a common manoeuvre preceding serious injury crashes.

Location characteristics
As with severely injured pedestrians, severe bicycle casualties also most often occur in urban areas (82%-93%) on roads with a speed limit of 50 km/h (or 30 mile/h). In most countries, intersections are in 39% to 61% of cases found to be the place for bicyclists to get severely injured. Intersections are a conflict location where bicyclists interact with other traffic such as cars.

Time related characteristics

[11] With at least 30,237 unique cases, as the BRON-DHD/DHD traffic register, RAIDS/OTS and the IGLAD database contain data of one or more countries that are also central in one of the other databases.

A high proportion of severe injuries are found in summer. As with the other transport modes, bicycle crashes occur most frequently in the afternoon.

Contributing crash factors
For some of the databases, there was evidence for other contributing crash factors. For severe bicycle crashes, the following were found to be most common:

- Failure to look properly (39-55%);
- Careless / reckless behaviour (19-28%);
- Vision affected (22%);
- Failure to judge path / speed of other road user (19%);
- Loss of control (12%);
- Poor turn / manoeuvre (12%);
- Speeding (9%);
- Red light running (7%).

Motorcyclists

In total, 9,186[12] severely injured motorcyclist casualties have been analysed and 1,790 powered two-wheelers (PTW; including mopeds) for those databases where motorcyclists could not be distinguished as a separate category. Data were available from 9 European countries: Austria, Czech Republic, France, Germany, Italy the Netherlands, Sweden, Spain and England. From these databases, we get the following picture of the most common crash characteristics and scenarios:

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

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

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

Location characteristics
In some countries, rural road crashes outnumber those on urban roads: 45%-55% rural crashes are observed in the Netherlands and Sweden. Other countries have most severe motorcyclist crashes on urban roads: 53%-60% urban crashes are observed in Germany and the UK but this finding may be due to biases related to the scope of in-depth data sources, which mainly cover more urban areas. At least, we can conclude

[12] With at least 9,119 unique cases, as the RAIDS/OTS database contain data of England which is also covered in the STATS10-HES database. Furthermore, the databases of CziDAS, Rhône and IGLAD 1839 powered two wheelers were analysed, also including mopeds.

from this that severe motorcyclist crashes are not a major problem on motorways. The Czech Republic data shows more crashes on urban roads, but this includes other powered two-wheelers like moped riders, which might account for this somewhat different pattern. All databases show that motorcycle crashes occur for 39% to 65% on road sections.

Time related characteristics
Summer and spring are the periods where high proportions of MAIS3+ motorcyclist crashes happen. As with all transport modes, crashes happen frequently in the afternoon, between 3 and 6 PM.

Contributing crash factors
For some of the databases, there was evidence for other contributing crash factors. For severe motorcycle crashes, the following were found to be most common:

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

Car occupants

In total, 21,557[13] severely injured car occupant casualties have been analysed, with contributions from 9 European countries: Austria, Czech Republic, France, Germany, Italy the Netherlands, Sweden, Spain and England. From these databases, we get a quite homogenous picture of the most common crash characteristics and scenarios, which is as follows:

Car occupant characteristics
Of all road users that get severely injured in traffic as a car occupant, around two thirds are male (59-69%) and about one third female. About two thirds to three quarters of these car occupants are drivers of the car, the others are passengers. In Germany, the share of drivers is somewhat lower than in other countries. Furthermore, a high proportion of casualties are among youngsters.

Crash opponents
A crash with another car is one of the most common circumstances (34% to 45%) in which car occupants get severely injured in the countries that were analysed. Furthermore, single vehicle crashes (22%-49%) and crashes with a fixed object (15-35%) are also very common but there are differences in the shares when comparing countries: in Germany and the Netherlands most frequently car occupants are injured in a single vehicle crash (44%-49%), followed by a car to car crash (34%-35%) and crashes with a heavy vehicle (16%-18%). In Sweden, England and the French Rhône region, car to car crashes are most common (37%-42%), followed by single-vehicle crashes (England and Rhône 22%-30%) or crashes with a fixed object (15%-35%).

In most countries, the involvement of another traffic participant is most common (45%-66%). In Sweden, the involvement of only one vehicle is about equally common as the involvement of two vehicles. Another common finding in all datasets is that frontal impacts are most common (61%-69%) followed by side-impacts (22%-29%) in crashes where car occupants get severely injured. Some databases also have

[13] With at least 21,296 unique cases, as the RAIDS/OTS and the IGLAD database contain data of one or more countries that are also central in one of the other databases.

information on manoeuvres, which show that the majority of crashes that result in severe injury for the car occupant happen during straight forward movement (64%-80%).

Location characteristics
Most crashes where car occupants get severely injured occur at road sections (66%-79%) and on rural roads (50%-69%). This agrees with the fact that car occupants get particularly severely injured at roads where the speed limits are high (≥70km/h). There are some small speed limit differences between countries, but the general picture shows mainly a large number of severely injured car occupants with high speed limits.

The combination of crash opponent and location characteristics is most prominent in crash scenarios of severely injured car occupants. One of the most common crash circumstances is where a car has a frontal collision with another car or a fixed object on a rural road, mostly on a road section or a curve. Another common crash situation is on urban roads where cars have a frontal or side impact collision with another car or crash with an obstacle when going ahead on a road section or when making a turning manoeuvre at a cross section. A third scenario is on motorways, where cars crash against a fixed obstacle or have a rear-end crash when driving ahead.

Time related characteristics
As with all other transport modes, a high proportion of crashes in which car occupants get severely injured occur in the afternoon. The most common period in the year in which crashes happen varies per country, but winter months are quite common.

Contributing crash factors
For some of the databases, there was evidence for other contributing crash factors. For severe crashes leading to severely injured car occupants, the following were found to be most common:

- Loss of control (40-58%);
- Speeding and/or inappropriate speed (35-56%);
- Careless / reckless behaviour (23-49%);
- Driver under the influence (drugs/alcohol) (18%);
- Failed to look properly (17%);
- Road condition (wet/icy/poor surface; 14%);
- Fatigue (driver or opponent; 10%).

MAIS3+ injury factors

Injury types of MAIS3+ injuries and factors that influence common types of injuries have been analysed by making use of the following databases:

- Czech Republic: CziDAS
- France: Rhône road trauma registry (IFSTTAR, France)
- Germany: GIDAS
- Netherlands: BRON-DHD, DHD trauma register, and in-depth studies (NL)
- Sweden: STRADA
- England: RAIDS and OTS in-depth data
- IGLAD (cases from AT, CZ, DE, FR, IT, SE, and ES)

Methodology

To get an indication of the main injuries per transport mode, the share of injuries per AIS body region per road traffic mode has been summarised. For each casualty, the body region most severely injured has been used as the unit for the injury analysis. Casualties may have had a serious (MAIS3+) injury in more than one body region and/or they may have had multiple (MAIS3+) injuries to the same body region. Where two or more body regions rank equally high in severity, the casualty injury outcome has been classified as 'multiple'.

Secondly, differences in the most severely injured body region per crash scenario have been tested by using a Chi-square test (see Annex III). Medical and in-depth experts have added their experiences to get first explanations for the findings.

Results

To get some feeling for the type of injuries that are coded as MAIS3+, analysis of the in-depth databases shows the following details:

- Fractures of the head;
- Head and brain injuries;
- Fractures to the leg, ankle or foot (parts which are indicated as 'lower extremities');
- Fracture of the pelvis (part of 'lower extremities');
- Rib fractures (part of 'thorax injuries');
- Organ injuries (part of 'thorax injuries');
- Fracture of the arms, wrists or hands (indicated as 'upper extremities').

Detailed results per traffic mode and per country and database can be found in Annex IV. This section contains a summary of the results.

Pedestrians

Pedestrians get most often severely injured to the head and to the lower extremities, but also their upper extremities often get injured. Lower extremities particularly get injured when the pedestrian is hit by a car or in a crash on a 30 km/h zone.

Another finding is that during night time crashes the thorax and pelvis are more often injured, while during daytime crashes, the head is more often injured, (particularly in males) as well as the upper extremities (particularly females).

Bicyclists

Head injuries are found to be the most frequent for severely injured cyclists. From the different databases, there is no clear profile that becomes apparent for certain types of crashes where head injuries are more common: in some databases evidence was found that single vehicle crashes can be associated with more head injury, but in other databases, head injuries were found more in crashes with a car.

Some evidence was found that the lower extremities are particularly injured in single vehicle crashes and crashes with lower impact speed (e.g. in urban areas or in crashes where the cyclist is hit by another bike). From in-depth studies, there is evidence that these are mainly hip fractures, which are inflicted due to an impact with the ground, especially when the cyclist is elderly. Younger cyclists are more using their arms during a fall in single–bicycle crashes and crashes with another bicycle. This is also visible in the somewhat higher share of injuries of the upper extremities in these scenarios compared to other scenarios.

In some databases, thorax injuries were seen more frequently in side-impact injuries in urban areas and/or at junctions, when the cyclist was hit by a car than in other situations.

Motorcyclists

For motorcyclists, the body regions most severely affected are most frequently the thorax and lower extremities. Also head injuries and injuries to the upper extremities are common.

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

Car occupants

The most severely injured body regions for car occupants are most often found to be the thorax, the head and lower extremities.

In some of the databases that were analysed, indications were found that injuries to the thorax occur more often in crashes with another car and when a seatbelt is used but the car has no airbag. Head injury also more often occurs in crashes with a fixed object or with heavy vehicles. The study showed indications that lower extremities are more often affected in car to car crashes and are also found more in crashes at lower speeds (e.g. 50 km/h roads).

Representativeness of the findings for the EU

This study was based on the available databases with MAIS3+ casualties and crash details, which turned out to be available only for countries that are more located in the West and middle part of Europe (see map). There was no information available from the Eastern part of Europe that could be used for this study.

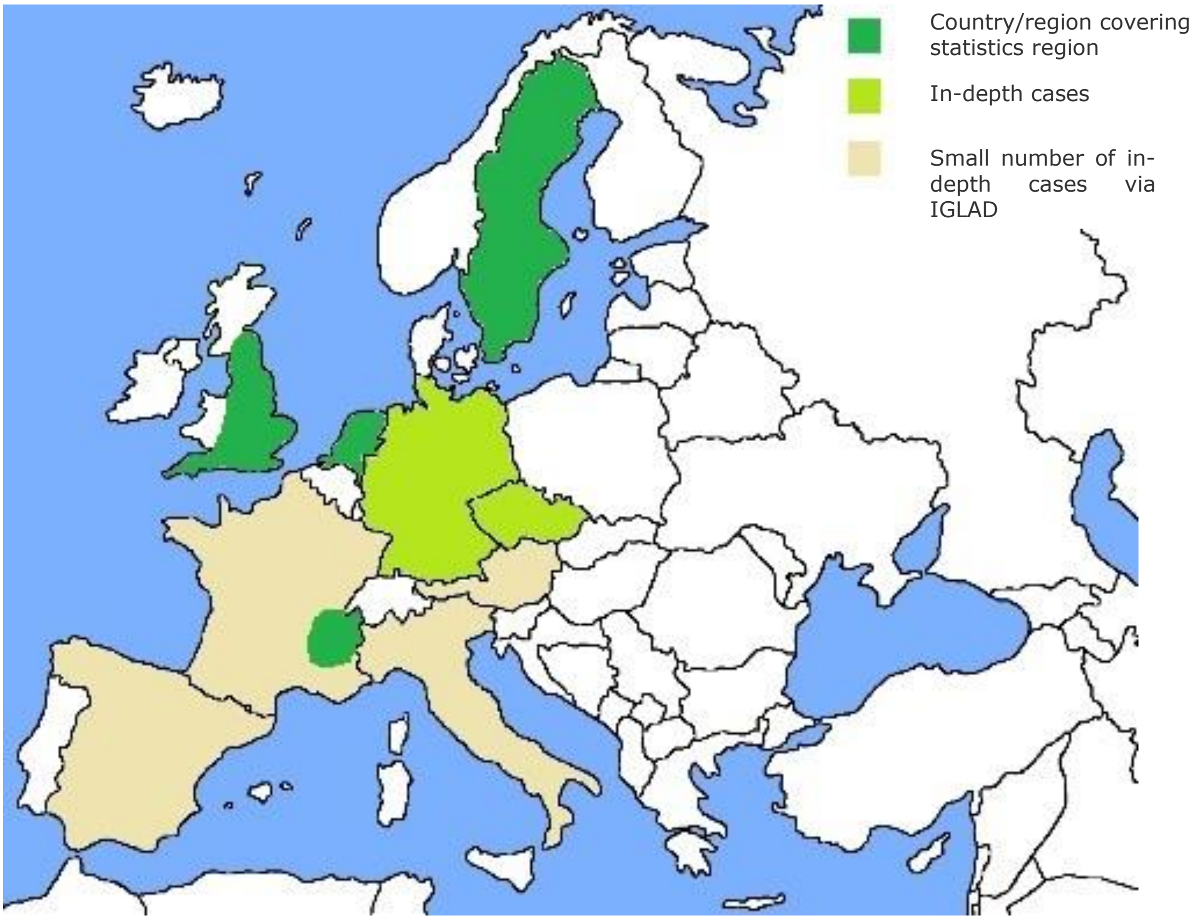

Figure 1: Overview of data of Member States included in this study.

This brings in the question how valid the results of this study are for all Member States of the EU. It is possible that the profile of key demographics in the countries from which data has been analysed differs from the countries that could not be included. From composite index research, countries in Europe appear to differ in their profile, for instance distinguishing between countries that are mainly in the North-West, the centre of Europe, the East or the South (see also Wegman et al., 2008), but also somewhat other clusters of comparable countries have been found (Bax et al., 2012).

Methodology

To get an idea of the representativeness, the results have been reviewed qualitatively against main fatal crash characteristics and scenarios per traffic mode, covering all EU Member States (sources: ERSO webtexts): information of main fatal crash characteristics and scenarios provide an EU wide picture as well as providing more detailed information on countries that show different profiles, which can be compared to the results of this MAIS3+ study.

It should be mentioned here that this method is speculative and only a first step in getting an idea of what the situation in Europe looks like. The best way to get an EU wide picture is by collecting facts and performing evidence-based analyses. With the current attempts of the EC and Member States to collect MAIS3+ injury statistics, such an analysis might be possible in the future.

Results

Pedestrians

When looking at the profile of crash characteristics and scenarios that are found in fatal crashes the following findings appear:

- About 60% of the fatal pedestrian casualties in the EU are male (Pace et al., 2012; EC, 2016a), while the MAIS3+ study found about an equal division between males and females being severely injured (some countries more males, other countries more females or equal shares). It might be the case that the travel behaviour of females and males and therefore exposure is somewhat different in the countries that were analysed, but this is just speculation.
- Fatal pedestrian crashes in the EU are mainly among elderly (Pace et al., 2012; EC, 2016a), while the MAIS3+ results show both elderly and children to be dominant age groups. As there is evidence that both children and the elderly are the main age groups that travel by foot in the EU (DaCoTA, 2012l), it is supposed that the MAIS3+ findings are quite representative for the whole of the EU. The somewhat different finding of mainly elderly in fatal crashes might particularly reflect the fact that the elderly are more likely to die as the result of their injuries (see DaCoTA, 2012l).
- Most pedestrian fatalities occur in urban areas (see DaCoTA, 2012l), and similar results were found for MAIS3+ injuries. In both cases, there are individual countries with a somewhat different profile.
- Most fatalities in the EU occur in the afternoon (EC, 2016a) as was also found in the MAIS3+ study.
- Autumn and winter time have the highest frequencies of fatalities in the EU (Pace et al., 2012; EC, 2016a), which is more or less similar with the MAIS3+ findings.

Bicyclists

When looking at the profile of crash characteristics and scenarios that describe fatal crashes the following findings appear:

- In fatal bicycle fatalities, males are found to be the dominant group in 80% of the cases, but large differences in countries have been reported with the Netherlands and Belgium having a relative large share of females (30 to 40%) while Romania and Portugal show very low shares of females (8-10%; Candappa et al., 2012; EC, 2016b). In the MAIS3+ results, also large differences in gender involvement were reported (55 to 85% male). However it could be the case that countries with a larger share of male bicycle casualties are somewhat underrepresented in this study.
- Dominant age groups in fatal bicycle crashes are found among elderly and youngsters (Candappa et al., 2012; EC, 2016b). Also for this rider characteristic, a similar pattern has been found in the MAIS3+ cases, but also with differences in the most dominant age group in different countries.
- Looking at EU figures of area characteristics where most fatal bicycle crashes occur, in 60% of the cases this is an urban area but large differences between countries are reported here ranging from nearly 80% urban crashes in Romania to about 20 to 30% urban crashes in Spain and even no urban crashes reported in Estonia and Croatia (Candappa et al., 2012; EC, 2016b). In the MAIS3+ study, urban areas have been found to be dominant as well, but with a larger share (>80% urban) than the results of fatal crashes show.
- A high proportion of fatal bicycle crashes occur in the afternoon (Candappa et al., 2012; EC, 2016b) and this is also the finding for the MAIS3+ crashes.
- During the summer months, most fatal bicycle crashes occur in the EU (Candappa et al., 2012; EC, 2016b) and similar results were found for the MAIS3+ casualties.

Motorcyclists

When looking at the profile of crash characteristics and scenarios that describe fatal crashes the following findings appear:

- More than 90% of fatal motorcyclists has been found to be male (Yannis et al., 2012; EC, 2016), although larger shares of female fatalities were found in Ireland and Sweden (EC, 2016c). In general, this is a similar finding to the MAIS3+ study.
- Fatal motorcyclists crashes are dominant in young adults and in some countries also older riders, especially in central European countries (Yannis,et al., 2012; DaCoTA, 2012n; EC, 2016c).
- The majority of fatal motorcyclist crashes occur on rural roads (Yannis et al., 2012; EC, 2016c). In the MAIS3+ study, the results were not conclusive as a number of countries reported most motorcycle crashes on urban roads (e.g. Germany and UK) while others showed rural road crashes to be dominant (e.g. the Netherlands and Sweden).
- During spring and summer, most fatal motorcycle fatalities occur (Yannis et al., 2012; EC, 2016c) and a similar period found to be most common in this MAIS3+ study.

Car occupants

When looking at the profile of crash characteristics and scenarios that are found in fatal crashes the following findings appear:

- In crashes fatal for car occupants, about 80% of the drivers and about 50% of the passengers were found to be male in the EU, with large differences between countries: about 30% female drivers in Sweden and about 60% passengers in Greece to about 5% female drivers in Bulgaria and Romania and

30% passengers in Ireland (EC, 2016d). In the MAIS3+ analysis, also a majority of male occupants was found: about 65% of all severely injured car occupants and a more homogenous picture was seen among the countries analysed.

- Adults (25-49) have been found to be dominant in fatal car occupant crashes (EC, 2016d). In the MAIS3+ injuries, youngsters have been found to dominate the data.
- Fatal car occupant crashes occur mostly on rural roads (70%), although there also are exceptions (e.g. Malta, Cyprus, Croatia; EC, 2016d). The general picture is very similar to what was found in the MAIS3+ analysis.
- Both in the fatality statistics (EC, 2016d) and in the MAIS3+ study, the afternoon was found to be the time period where, in general, most crashes occur.
- The fatality statistics of car occupants show a fairly even distribution of crashes over the course of the year (EC, 2016d). In the MAIS3+ study, winter months were found to dominate.

Concluding remarks

Overview of the findings and possible explanations

This study on MAIS3+ injured pedestrians, bicyclists, motorcyclists and car occupants has been performed on the crash data of 9 European countries. Below, we first summarise the main findings for each of the studied transport modes.

The results that have been found do not provide direct evidence for explanations and clues for road safety measures. In order to provide initial explanations, assumptions have been made either linked to 'risk' (hazards on the road) or 'travel behaviour' (the amount of time spent on the road). The assumptions are based on general road safety expertise and findings in literature. As there is little to none literature on MAIS3+ casualties and their background, the literature used is based on general travel behaviour patterns and other severity levels such as road traffic fatalities.

Pedestrians

Common crash factors and scenarios

Pedestrians that get severely injured in road crashes, appear to have the following most common characteristics:

- Gender: about equal division between male/female
- Age: elderly people and children
- Crash opponent: cars and heavy vehicles
- Location: urban 50 km/h road section
- Time: afternoon and winter months

Possible explanatory factors

The pedestrian characteristics that were found may in the first place reflect both travel behaviour as well as risk factors related to these groups: children and elderly often participate in traffic as pedestrians (see also DaCoTA, 2012l) and they both represent relatively vulnerable age groups, with elderly also having a higher probability of functional disabilities with increasing age (see DaCoTA 2012k for an overview).

In general, the pedestrians specific risks in relation to all other road users are the unprotected road use, differences in mass and speed (see also DaCoTA, 2012l). Pedestrians get particularly injured by cars. As cars are generally found to be the dominant group in modal split statistics (in DaCoTA 2012l), travel behaviour could be a first explanation for the findings that pedestrians are most often severely injured in a crash with a car.

The finding that most severe injured pedestrians result from a crash on an urban road with a 50 km/h speed limit can have several explanations. First of all, it may reflect travel behaviour: pedestrians may have most trips inside urban areas, where a 50 km/h speed limit is also very common. A second possibility is that crashes with a pedestrian on rural roads are more frequently fatal, leaving more pedestrians alive on urban roads with less severe injury on the access roads with lower speed limits (e.g. 30 km/h roads) and more severe injury on the higher speed roads (e.g. 50 km/h). There is indeed evidence for the idea that rural pedestrian crashes are more often fatal than urban pedestrian crashes (see DaCoTA, 2012l). Furthermore, in relation to the posted speed limit and actual speeds on the roads, we can also look at this factor from a 'risk' perspective. From crash statistics, it is known that pedestrians and other unprotected road users sustain more severe injury and a higher probability of a fatal outcome when they are hit at a greater speed (e.g. Rosèn et al., 2011).

In all traffic modes, the afternoon has been found as the time where a high proportion of severe injury crashes occur. Possible explanations for this might be travel behaviour - more pedestrian activity in the afternoon (e.g. children walking back from school) - as well as to risk factors such as fatigue that builds up during the day or circadian fluctuations (afternoon dip; see DaCoTA, 2012h for an overview). In most countries, winter months were found to have the highest frequencies of severely injured pedestrians, which might be explained by reduced visibility of pedestrians due to increased hours of darkness, as well as more people traveling by car because of low(er) temperatures. Further research could provide more evidence-based explanations.

EU representativeness
Most of the comparisons that have been made show more or less similar patterns for fatal pedestrians in the EU as a whole and the analysis of severely injured pedestrians from a selection of EU countries. There might however be a slight gender bias towards females in the MAIS3+ cases that were analysed, but further research should provide more evidence for this. Other differences that have been found (time of day) are expected to reflect differences between fatal and serious injury crashes but also this would need further examination to be sure.

Common injury factors
- Injury: Head and lower extremities;
- Head and upper body parts: heavy vehicles and higher speed roads;
- Lower extremities: cars and 30 km/h roads.

Also differences have been found during night time and daytime crashes but this gave a less clear picture over the different databases.

Possible explanatory factors
From in-depth studies, medical experts and crash tests, there is evidence that cars hit a pedestrian first at the lower extremities. In a crash at higher speed, also the upper body parts and the head are injured in a second impact with the bonnet of the car (see also Martin et al., 2011). Impacts with higher speeds also increase the throw distance and severity of the secondary impact with the ground. Low speed impacts could be more associated with 'hit and fall over' whilst higher speed could be 'hit and thrown'.

In a crash with a truck, the pedestrian is hit higher up on the body, which has been related to the structure of the vehicle (e.g. Zang et al., 2008).

During night-time the pedestrian may not be seen so easily, certainly because most countries have no specific measures for pedestrians to be clearly visible (see also DaCoTA, 2012l). Where visibility is an issue, there is a higher probability that there is less time to brake and the impact speed may therefore be greater. If the pedestrian is thrown and then run over by another vehicle, this will affect the location of most severe injury, which might explain less clear findings in different databases than in other scenarios related to crash opponents and location/speed.

To conclude: vehicle design and impact speed are supposed to be two important factors that influence the type of pedestrian injury.

Bicyclists

Common crash factors and scenarios
Severely injured bicyclists have the following common characteristics:

- Gender: slight to heavily male dominated;
- Age: elderly, adolescents, middle aged, children;
- Crash opponent: car, no crash opponent;
- Location: urban area, 50 km/h, intersections;
- Time: summer, afternoon;

Possible explanatory factors
The gender and age pattern that has been found among bicyclists is likely to reflect at least partly the travel behaviour of bicyclists in different countries. First of all, it is known that in the Netherlands and Denmark, the bicycle is used much more for road transport than in other countries (see DaCoTA, 2012l). There is also evidence that this relates to the type of use, which differs among countries from daily use and commuting to very occasional use (e.g. sports, shopping). Cycling has been found to be mainly a common transport mode for older children (i.e. teenagers; see DaCoTA, 2012l), which might explain at least some of the age-related findings. The fact that for some countries, the elderly have also been found as a group with a large prevalence might be related to the increased population numbers of this group (demographic development) in combination with an increasing vulnerability and functional disabilities with growing age (DaCoTA, 2012k). Added to that, cycling is also a more risky travel mode than car driving, requiring balance, the cyclist being some distance from the ground, and the combination of unprotected traffic participation.

As we concluded also in the pedestrian analysis, the fact that cars are commonly found as an important crash opponent might in the first place reflect travel behaviour. Evidence for this possibility is found from the fact that cars are the dominant group in modal split statistics (in DaCoTA 2012l). However, in some countries, single vehicle cycle crashes were found to be most dominant, which holds for the Netherlands and France (Rhône region). It is remarkable that such figures become apparent when looking at hospital discharges or trauma registers and do not appear from official country statistics, which might explain why the importance of single bicycle crashes in injury crashes has for a long time be unknown (e.g. Schepers et al., 2013a).

The fact that most severe injury bicycle crashes occur on urban roads might in the first place reflect travel behaviour of bicyclists who often use urban roads (DaCoTA, 2012l). It is also known that rural road crashes more frequently lead to fatal injury, especially for unprotected road users such as pedestrians and bicyclists, due to higher speeds (see DaCoTA 2012l; Rosèn et al., 2011). Also, the design of the traffic system might play a role here, with a higher probability of severe injury where the bicyclists is not protected from motorised vehicles (like on intersections; Schepers et al., 2013b) or the role of infrastructure in disturbing good control of balance on the bicycle (e.g. holes in the pavement, height differences between the pavement and the road side can cause loss of control of the bicyclist, important for single bicycle crashes; Schepers & Klein Wolt, 2012).

The finding that a high proportion of severe bicycle crashes occur during summer might reflect the fact that this is most of the time and in most countries a period when the weather is nice, which might increase the number of bicycle journeys made. As with the other transport modes, bicycle crashes occur most frequently in the afternoon, which might reflect both travel behaviour as well as the increase of fatigued road user participation (see DaCoTA, 2012h for an overview).

EU representativeness
The results of the MAIS3+ bicycle casualty analysis show in general a very similar pattern to the bicyclist fatalities in the EU. There is only some evidence that the MAIS3+ study has a slight gender bias towards females, which means that it might be the case that in an EU wide study, a somewhat larger share of males could be found than in the current study. This is however still speculative and needs further study. It is unclear what we can conclude from the fact that the MAIS3+ study had a somewhat larger urban frequency than fatal bicyclist statistics. This might reflect differences in the profiles of countries included to those not included, but it can as well reflect that crashes in urban areas are less often fatal than crashes on rural roads, in part due to lower speeds in urban areas, for which some evidence exists (see DaCoTA, 2012l).

Common injury factors
- Injury: head, lower extremities and thorax;
- Head: dominant in all crash scenarios;
- Lower extremities: single vehicle crashes, elderly people and crashes with lower impact speed;
- Thorax: side-impact crashes in urban areas and at junctions.

Possible explanatory factors
The finding that head injuries are dominant in all bicycle scenarios that have been identified may particularly reflect the unprotected cycling in many countries: only Finland, Spain, Czech Republic, Iceland and Sweden have (partly) mandatory helmet wearing laws for bicyclists. From the few databases were helmet wearing rates were available, 5 to 30% of the severely injured bicyclists (properly) wear a bicycle helmet. But, although a helmet provides protection to the head, from a well reported Irish study (Fingleton and Gilchrist, 2013) we know that cyclists with a helmet are largely protected against the effects of the impact of hitting the pavement but are hardly protected against the first impact when hitting a car or other vehicle.

Regarding the lower extremities, most often the most severely injured body region in single vehicle crashes, crashes with elderly people and crashes with lower impact speed, this might have to do with a different chain of actions but may also be correlated with these characteristics. For instance, from the Dutch in-depth studies (Boele-Vos et al., 2016) into severe bicyclist crashes, it is known that the elderly show a somewhat different pattern than younger people: elderly people have more difficulties in remaining a good balance on their bicycle and when they fall (single bicycle crash), they are less likely to defend themselves with their arms unlike younger people. Due to this, and maybe also supported by the fact that their bones are becoming more vulnerable, they are more prone to hip injuries, which is regarded as part of lower extremities.

The thorax injuries are more difficult to explain and may be run-overs or a combination with severe injuries to other body parts as well. Further study is required in order to gain a better understanding.

Motorcyclists

Common crash factors and scenarios
Most common characteristics of severely injured motorcyclists are:

- Gender: >90% males;
- Age: youngsters and middle aged people;
- Crash opponent: car, no opponent, fixed objects;
- Location: rural and urban roads;
- Time: summer and spring.

Possible explanatory factors
The fact that men are dominating the severe injuries in motorcyclist might reflect travel patterns (men drive more on motorcycles than women; e.g. SWOV, 2014) as well as risk taking behaviour which is known to be more common in men than in women (e.g. DaCoTA, 2012j) and is known to be also more common in riders of motorcycles than other transport modes (see also DaCoTA, 2012n).

Taking more risk is also known to be more common in younger people due to their inexperience and their tendency for thrill seeking (e.g. DaCoTA, 2012j). This might explain why youngsters are one of the age groups found to be more dominant in severe motorcyclist crashes. Travel behaviour can be another explanation. The minimum age at which youngster can start driving a motorcycle differs between 16 and 18 years within the EU (e.g. DaCoTA, 2012n) and from this age, it could be expected that crash numbers rise as well since the number of journeys undertaken on a motorcycle increases with age. Travel patterns can also be seen as a possible explanation for more crashes in the middle aged category. This group might be a combination of motorcyclists that return after a period of non-motorcyclist driving and even novice drivers who decide to take up motorcycling later in life, which involves somewhat higher risks. This middle aged group also may be at more risk because of the road types this group likes to ride (rural and curving roads; e.g. Jamson et al., 2005).

As with pedestrians and cyclists, a possible explanation for a car as most common crash opponent might be the frequency of cars in traffic (e.g. DaCoTA, 2012l). Furthermore, cars provide a risk to relatively unprotected road users (motorcyclists do not have a cage such as car occupants have) since the cars combine power to speed and quite high mass. Besides cars as a common crash opponent, single vehicle crashes with or without hitting an obstacle are also found to be very common in severe motorcyclist crashes. As with cycling, a motorcyclist requires balance and can easily suffer from instability when something unexpected happens or the rider misjudges the road situation (see DaCoTA, 2012n). Fixed objects are a danger to all road users, especially those who drive relatively unprotected at high speed. Country characteristics and the design of the road traffic system can play a role here as explanation for the frequency with which such crashes are found. For motorcyclists, guard rails (especially the rail posts) can be dangerous as they are primarily designed for preventing cars from hitting an obstacle behind the rail (DaCoTA, 2012n).

The fact that both urban and rural roads were found to be dominating, depending upon the country where the data came from, might reflect both travel patterns (motorcyclists, particularly older motorcyclists like to ride on rural roads; e.g. Jamson et al., 2005) and the availability of road types (some countries are more urban than others). Also design quality and hidden motorcycle risks (e.g. curves, obstacles and traffic calming measures on the pavement such as speed humps) in the road design and direct road environment might play a role here (e.g. DaCoTA, 2012n).

Summer and spring are most common time periods for severe injured motorcyclists and this is probably related to the nicer weather and the fact that the unsheltered transport mode is more comfortable to use when it is dry and sunny. There is indeed evidence that the higher numbers in this period are related to travel behaviour (see also Baughan et al., 2004; De Craen et al. 2013). As in the other transport modes, the afternoon was found to have the highest crash frequency which might be related to travel behaviour as well as a build-up of fatigue. Further in-depth analysis of the motorcyclist crashes could reveal other interesting and important factors.

EU representativeness
While there is clear evidence that the use of motorcycles and the number of motorcyclist fatalities is much higher in Southern European countries than in North-West European countries (Yannis et al., 2012), dominant characteristics in fatal motorcyclist crashes seem to be quite similar to those of the studied MAIS3+ cases. Differences between countries have been found for dominant area types and age groups, but such differences were also found in the MAIS3+ study. From this, we might conclude that this MAIS3+ study can be regarded as quite representative of the EU.

Common injury factors
- Injury: thorax and lower extremities;
- Thorax: single, fixed object, rural areas;
- Lower extremities: car crash.

Possible explanatory factors
As with crashes where a pedestrian or bicyclist is hit by a car, the firs impact point is mostly the legs (lower extremities). This can lead to the motorcyclist falling down and landing awkwardly. Impact with the ground may cause further injury, depending upon how the motorcyclist falls.

Motorcyclists tend to wear helmets (as this is regulated in most countries) whereas cyclists don't (not regulated in most countries). So we see severe head injuries particularly to bicyclists but not so much to severely injured motorcyclists. If a motorcyclist was not wearing a helmet the chances were he would die, and therefore would not be apparent in a severe (non-fatal) injury study (see also DaCoTA 2012n).

In single vehicle crashes, a common injury scenario is that the motorcyclists is thrown on his handle bars or thrown over the bike into the object. In cars, the first action would be prevented by an airbag, but this is generally not available on motorcycles.

Car occupants

Common crash factors and scenarios
Car occupants that get severely injured in road crashes, appear to have the following most common characteristics:
- Gender: two third males;
- Age: youngsters;
- Crash opponent: cars, no opponent and fixed objects;
- Location: rural roads, speeds >70 km/h;
- Time: afternoon and winter months;

Possible explanatory factors
Youngsters and male occupants are found to be more common among severely injured car occupants which might be explained by travel behaviour (differences in trips and distances travelled between men and women) as well as risk factors: young drivers and especially young men are known to take more risks due to inexperience and thrill seeking tendencies (e.g. DaCoTA, 2012j).

As with the other traffic modes, cars also have (another) car most frequently as the crash opponent, which has been supposed to reflect at least partly the modal split and the frequency of cars in traffic (e.g. DaCoTA, 2012l). Single vehicle crashes were the second most common finding and this might be related to the traffic density in the country (e.g. with low traffic density the probability might be higher to have no crash opponent such as might be the case in Sweden), road design and road related risks in the country (e.g. road surface conditions, safety of the shoulders, availability of obstacle free zones etc.). Behavioural factors can also play a role in single vehicle crashes (e.g. more speeding and reckless driving as a contributing factor in single vehicle crashes, as this study shows). These characteristics are particularly relevant on rural roads, where the posted speed limit may not always be appropriate for the road design (e.g sharp bends in the road where high speed is permissible; Tingvall an Haworth, 1999; Lynam et al., 2004).

Another common finding in all datasets is that frontal impacts are most common followed by side-impacts in crashes where car occupants get severely injured. This might be related to the differences in impact and the force at which the cage of the car protects the occupant when hit from different sides (see also EuroNCAP norms) as well as a reflection of the probability that a car is hit on a particular side.

Crashes with severely injured car occupants occur more frequently in winter months. This might reflect travel behaviour (people may prefer to travel by car rather than by other transport modes during winter) as well as risks associated with winter months (e.g. snow, ice, larger periods of darkness and reduced visibility). The finding that a high proportion of severe injuries were found in the afternoon probably reflects fatigue during the day and circadian rhythm effects (the after-lunch or afternoon dip; e.g. DaCoTA, 2012k) but other factors that need further study might be involved as well.

EU representativeness
As with the other transport modes, for the car occupants, the general picture is that fatality statistics provide about the same pattern as the MAIS3+ analysis. For some variables (e.g. gender, road type) remarkable differences between countries were found when looking at fatalities; these were not so apparent for the MAIS3+ study. Evidence-based explanations for this are hard to give. It could be the case that the MAIS3+ study did not include countries that divert from some of the patterns (like Malta, Cyprus, Croatia, Romania and Bulgaria). On the other hand, the general results are fairly comparable to that of the EU pictures presented from the fatality statistics. Furthermore, it might also be the case that crashes resulting in fatality have somewhat different characteristics than crashes resulting in severe injury. This might for instance well be the case for the division of rural versus urban roads: on rural roads, speeds are mostly higher and this increases the probability of more severe impacts and gives an increased risk of fatality compared to crashes on urban roads.

Common injury factors

- Injury: Head, thorax and lower extremities;
- Thorax: car to car, wearing seat belt but no airbag available;

- Head: crash with fixed object and heavy vehicles, not wearing seat belt and no airbag available;
- Lower extremities: car to car crashes, also in lower speed zones.

Possible explanatory factors
From trauma experts, it is known that thorax injuries (rib fractures and internal organ injury) can be the result of seat belts and airbags that press on or hit the upper part of the body with large force when the car crashes at high speeds. In the data that was analysed, indications were found that injuries to the thorax occur more often in crashes with another car and when a seatbelt is used but the car has no airbag.

The head can get injured in a car by impact to the windows of airbags in case of a hard blow, for instance when crashing with high speed, particularly when not wearing a seat belt and in cars without an airbag. Head injury also more often occurs in crashes with a fixed object or with heavy vehicles, either because the impacting object has intruded car occupant's space, or there is partial ejection through the window of the head onto the object (particularly in side impacts). This is also the case with large vehicles but less likely in car to car impacts.

Lower extremities of car occupants, particularly for front seated car occupants, can get injured by hitting the dashboard of the car. Medical experts note that it is often seen that this causes rupture of the lower part of the leg, just below the knee. Foot and ankle injuries can occur due to interaction with the pedals and loading via the dashboard up through the limb can cause skeletal and joint injuries.

Discussion of the study and ideas for further research

The analysis of severely injured road users has used data sources currently available across the EU Member States. These were chosen as firstly it is possible to distinguish non-fatal severely injured casualties within the data using a MAIS3+ criteria, and secondly they are able to offer at least some insight into the accident circumstances for each of the transport modes; pedestrians, cyclists, motorcyclists and car occupants. There are variations in the way in which data are gathered and the databases populated and this in turn impacts upon the richness of the available data and potentially the quality of the data.

The in-depth data sources generally contain the greatest level of detail due to the nature of the data collection using accident investigation methods. These studies tend to be geographically limited and provide data samples aimed at being representative of the national picture. Data sources linking police records to hospital records benefit from being able to provide information about the accident circumstances and injury outcomes and have the potential to give a good national picture. However the accident circumstance data tends to be less detailed than for the in-depth studies. Linked data sources are also dependent upon a match being found between the hospital and police records; this match is often made using key variables available in both data sources. The matching process is therefore not 100% certain in all cases and an indication is given of the confidence in the matching process. The researcher makes a judgment on the required level of confidence for case inclusion in the analysis, but there is still a small chance that the data sources are incorrectly matched. Hospital discharge data and trauma register data are able to provide a rich source of injury information but can be very limited in relation to accident circumstances.

Data have been used from each of these collection methods for the analyses presented in this report and hence the extent to which each data source has contributed to the results varies. Despite these limitations, the data are able to provide the best picture possible at this time relating to severe injury accidents in Europe.

Proposal for further research

This study gave some first clues relating to common crash characteristics, scenarios and injury factors for MAIS3+ injuries among the most prominent traffic modes in the EU. As the previous discussion shows, explanations for the findings and also good understanding of the detailed mechanism that are behind the facts that have been found are still in the phase of infancy, as is the case with most literature on road traffic MAIS3+ injuries. Furthermore, the time available to perform and finalise this study was limited, leaving a number of interesting questions unanswered.

The team that has performed this study would like to suggest the following interesting issues to study further at EU level:

- Detailed research into the injury causation mechanisms, taking into account the cause of events before the injuries occurred, differences in injury patterns between fatal and non-fatal severe injuries and more extensive review of all body parts that are injured by crash scenario.
- A thorough review of the influence of travel patterns and risk factors that have been suggested in this study as possible explanations for the findings.
- A study into measures that are known to be effective in reducing (severe) injuries as well as differences and commonalities in effective measures directed at preventing fatalities and severe injuries.
- A policy review and benchmarking study to identify how Member State’s characteristics and efforts have had an influence on the number and type of severe injuries.

Recommendations

This study provides an overview of the main crash characteristics, crash scenarios and injury factors for severely injured pedestrians, bicyclists, motorcyclists and car occupants in a number of European countries. It provides some starting points for further policy that is explicitly directed at the reduction of severe injuries. Although a number of the findings need further study to really understand the detailed mechanisms that go behind important crash scenarios and injury factors, some preliminary recommendations can be made from this study.

Starting points for measures to prevent severe injuries

Although this study was not directed at defining effective measures to prevent serious injuries, the findings provide support that a number of measures that are known to be effective for the prevention of fatal crashes could also help in reducing at least some of the serious injuries. Examples are:

- Reduction of the number of conflicts between VRU and motorised traffic: implement sidewalks, pedestrian areas, cycling tracks, loading- and unloading areas and time zones, separation in time by traffic lights in order to decrease the number of conflicts with motorised traffic.
- Speed reduction to protect VRU: implement credible 30 km/h zones in urban areas, roundabouts and plateaus on intersections in order to reduce the probability of sustaining severe injury.
- Forgiving infrastructure to all vehicle modes: e.g. shielded or obstacle free road sides, motorcycle-friendly guard rails and poles.
- Smooth infrastructure for two-wheeler vehicles (bicyclists, powered two-wheelers): prevention of single vehicle crashes for modes were balance is an issue; bicycles and motorcycles might benefit from sufficiently wide cycling

lanes, well maintained pavements and prevention of road surface defects such as potholes and differences in height between the pavement and the road side.
- Enforcement for the prevention of risky behaviour such as speeding and drink-driving.

For some Member States, these measures might already be implemented on a large scale, for other Members States, implementation might be a real challenge. Nevertheless, the injuries show that for all Member States, improvements can be made.

More detailed study of the causes of serious road injuries linked to the actual policy and the state of the road traffic system in Member States could reveal more specific keys for reducing severe injuries in the EU.

Policy recommendations at EU level:

- Help Member States by creating awareness of the main crash scenarios and injury factors that have been found for MAIS3+ pedestrian, bicyclist, motorcyclist and car occupant casualties;
- Develop further knowledge on specific MAIS3+ crash causes and effective road safety measures;
- Support Member States with advice regarding measures that could be taken to tune policy to reduce fatalities as well as severely injured road traffic users.;
- Stimulate benchmarking between Member States in order to find effective strategies and best practices that are tuned to country specific characteristics, and provide a forum for learning from each other;
- In addition to a target for road fatalities, define a severe injury target at EU level in order to stimulate the awareness, data collection and policy efforts to reduce severe injuries in Member States.

Policy recommendations at national, regional and local level

- Develop a disaggregated data management system (in depth, link police data with hospital data);
- Formulate targets at serious injury level;
- Implement effective, evidence based measures;
- Learn from other countries how data can be gathered, what specific issues need specific attention and what effective measures can be taken.

Recommendations for further research:

- Study into the travel patterns and risks that are suggested as possible explanations for common severe injury patterns;
- Review of current country characteristics that influence severe injury numbers and specific injury patterns;
- Further study of mechanisms behind severe injuries patterns;
- Study of effective measures directed at severe injuries;
- Benchmarking of policy efforts to reduce severe injuries.

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Annex I Meta-data of the databases used in the study

Meta-data of macroscopic databases (trauma registers, hospital discharges and linked databases)

Characteristics	BRON linked DHD	DHD traffic register	Rhône road trauma registry	STATS19 linked HES	STRADA
Country	Netherlands	Netherlands	France	England	Sweden
Regional coverage	National	National	Rhône county	National	National
Main objective	Improve severity indication of police by AIS	Injury surveillance, injury research, selection of road traffic casualties within the national database	Injury surveillance, injury research	Adding injury data to national statistics	National Statistics
Years available	1993-2014	1993-2014	2006-2012	2000-2011	2003 to present
Source	Police and Hospital	Hospital discharges	Trauma (emergency departments, pre-hospital acre, forensic institute)	Police and Hospital	Police and Hospital
Injury population	All	All	All	All road users	29/80 hospitals reporting to STRADA in 2003 to 68/80 in 2012
Selection criteria	Linked casualty to patient	Broad selection of external causes, focus on road crashes	'Road crash' and 'Injured' All hospitals surrounding Rhône	Successful linkage of hospital and police reports	Traffic crash with person injury
Injury coding	ICD9, ICD10 as of 2012	ICD9, ICD10 as of 2012	AIS 90	ICD10 – AIS	ICD10 / AIS
Road user available	√	√	√	√	√
Reference to owner	SWOV, the Netherlands	Dutch Hospital Data DHD-DHD/LBZ, the Netherlands	IFSTTAR, France	Health and Social Care Information centre (NHS Digital)	Swedish Transport Agency with contribution of other institutes

Meta-data of in-depth databases

Characteristic	CziDaS	GiDaS	IGLAD	OTS	RAIDS	SWOV in-depth: cyclists	SWOV in-depth run of road
Country and Regions	Czech Republic, areas of Brno and Pardubice/ Hradec Králové	Germany, areas of Hanover and Dresden	Phase 1 (2013): Australia, Austria, Czech Republic, France, Germany, India, Italy, Spain, Sweden, USA Phase 2 (2014): Austria, China, Czech Republic, France, Germany, India, Italy, USA Phase 3 (2015): Austria, Czech Republic, China, France, Germany, India, Italy, Sweden, USA	England, East Midlands and Thames Valley	England, East Midlands and Thames Valley	Province of Zuid-Holland and Zeeland	Province of Zuid-Holland and Zeeland
Principle Focus	Active/ Passive	Active/ Passive	Active/Passive	Active	Active/Passive	Active/Passive	Active/Passive
Objective	In-depth crash data representative for the Czech crash situation	In-depth crash data representative for the German crash situation	Collection of international in-depth crashes	Collecting in-depth data about crashes and injuries	Collecting in-depth data about crashes and injuries	Elderly cyclists of 50 years and older involved in an crash without motorised vehicles;	Run-off-road crashes on rural roads
Collection Dates	2011 to present	2000 to present	Ph1: 2007-2012 Ph2: 2012-2013 Ph3: 2013-2014	2000-2009	2012 to present	2012-2013	2009-2010
Selection Criteria	Road crashes with at least one person injured	Road crashes with at least one person injured	Road crashes with at least one person injured	On-Scene – any crash including damage only reported during investigation shift.	On-Scene – any crash including damage only reported during investigation shift. Retrospective – car or derivative < 7 years old, injured occupant, towed	Road crashes with at least one 50 year old bicyclist injured	Road crashes outside urban areas that occurred after a passenger car ran off the road and as a result of which at least one person was taken to hospital

Characteristic	CziDaS	GiDaS	IGLAD	OTS	RAIDS	SWOV in-depth: cyclists	SWOV in-depth run of road
Sampling method	Representative sample of crashes from specified regions, statistic approach	Representative sample of crashes from specified regions	As representative as possible of the national statistics of included countries	Representative sample of crashes from specified regions	Specified regions – On-scene all vehicle types, 25% KSI - Retrospective, injury occurred in car < 7 years old or crashes involving a Large Vehicle.	Specified regions. Crashes with at least one of the people involved willing to participate in the study. Sampling until ca. 40 cases were included in that region; includes about 20% MAIS3+	Specified regions. Crashes with at least one of the people involved willing to participate in the study. Sampling until ca. 30-60 cases were included in that region; includes 15% MAIS3+
Cars involved	√	√	√	√	√	X	√
Bicycles involved	√	√	√	√	√	√	X
Motorcycles involved	√	√	√	√	√	X	√
PTW if motorcycle NA						X	X
Pedestrian involved	√	√	√	√	√	X	X
Injuries	√	√	√	√	√	√	√
Injury causes	√	√	X	√	√	√	√
Vehicle technology	√	√	√	√	√	√	√
Crash situation	√	√	√	√	√	√	√
Road user	√	√	√	√	√	√	√
Infrastructure	√	√	(√)	√	√	√	√
Human factors/Cause of crashes	√	√	√	√	√	√	√

Annex IIa Variables and labels used in the study

Year of the crash: all years available within 2000-2014.
For each label, the priority is indicated. This has been used in the case that individual cases could not be included from a database for privacy reasons of persons involved.

Variable Name	Values for labels
Traffic mode of casualty (based on work description of EC and details on CADAS, somewhat clustered) **HIGH PRIORITY**	01 = Pedestrian (shoe vehicle: pedestrians, person on roller skates or skateboard, non-motorized scooter (autoped), pushing a bike or a wheelchair) 02 = Bicycle (including pedelec, speed pedelec or e-bike) 03 = Moped (motorized vehicles with motor volume ≤ 50 cc and speed ≤50 km/h: slow moped, moped, mini car) 04 = Motorcycle (motorcycle with motor volume > 50cc; motor scooter, motorcycle type unknown) 34 = Motorised two wheeler - type unknown 05 = Car (including taxi, private hire car)
Casualty Role	1 = Pedestrian / Driver/ Rider 2 = Front passenger 3 = Rear passenger 4 = Passenger, position unknown 99 = Unspecified
MAIS-score **HIGH PRIORITY**	1 2 3 4 5 6
alternativ — **MAIS range (added for databases that only have a range distinction)** **HIGH PRIORITY**	2- for less serious injury 3+ for serious injury
Deceased (within 30 days; Commission prefers inclusion) Priority	01 = hospitalized and deceased within 30 days 02 = hospitalized and not deceased within 30 days 99 = Unspecified
Month in which the crash occurred **low priority**	01 = January 02 = February 03 = March 04 = April 05 = May 06 = June 07 = July 08 = August 09 = September 10 = October 11 = November 12 = December 99 = Unspecified

To be continued on the next page.

	Variable Name	Values for labels
	Time of day the crash occurred **low priority**	0001 = between 00:00 AM and 00:59 AM 0102 = between 01:00 AM and 01:59 AM 0203 = between 02:00 AM and 02:59 AM … 1112 = between 11:00 AM and 11:59 AM 1213 = between 12:00 AM and 12:59 PM … 2324 = between 11:00 PM and 11:59 PM 9999 = Unspecified
alt.	**DayNight (of time of day not available)**	1 = DayTime 2 = NightTime 99 = Unspecified
	Head severity (Max severity in this region; AIS 2005, update 2008) **HIGH PRIORITY**	MAIS 0-6 999 = Unspecified or other
	Face severity **Etc.**	MAIS 0-6 999 = Unspecified
	Neck severity	MAIS 0-6 999 = Unspecified
	Thorax severity	MAIS 0-6 999 = Unspecified
	Abdomen and pelvic severity	MAIS 0-6 999 = Unspecified
	Spine severity	MAIS 0-6 999 = Unspecified
	Upper extremity severity	MAIS 0-6 999 = Unspecified
	Lower extremity	MAIS 0-6 999 = Unspecified
	Whole surface area severity (external, burns; inhalation injury; high voltage electrical injury; crashal hypothermia)	MAIS 0-6 999 = Unspecified
alternative	**Body region most heavily affected (based on first figure of the AIS code)** **HIGH PRIORITY**	1 = Head 2 = Face 3 = Neck 4 = Thorax 5 = Abdomen and pelvic contents 6 = Spine 7 = Upper extremities 8 = Lower extremities 9 = Whole surface area: external, burns; inhalation injury; high voltage electrical injury; crashal hypothermia 10 = Multiple regions (serious injuries with the same severity on more than one body region) 99 = Unspecified

To be continued on the next page.

Variable Name	Values for labels
First crash opponent (based on CADAS, somewhat clustered) **Priority**	01 = Pedestrian (shoe vehicle: pedestrians, person on roller skates or skateboard, pushing a bike or a wheelchair) 02 = Bicycle (including pedelec, speed pedelec or e-bike) 03 = Moped (motorized vehicles ≤ 50 cc and ≤50 km/h, slow moped, moped, mini car) 04 = Motorcycle (motorcycle over 50cc; motor scooter, motorcycle type unknown) 34 = Motorised two wheeler - type unknown 05 = Car (including taxi, private hire car) 06 = Bus (including minibus, coach, trolley) 07 = Rail transport (tram, light rail, train) 08 = Agricultural vehicles 09 = Vans (light goods vehicles under 3.5 tonnes maximum gross weight 10 = Trucks (heavy goods vehicles over 3.5 tonnes) 19 = Goods vehicle - type unknown 11 = Ridden horse. 12 = Non-fixed objects (animal other than ridden horse, vehicle debris, fallen cargo) 13 = Fixed object 90 = No crash opponent (not even a tree or other fixed object) X = [please assign a unique number and label if your dataset does not contain the labels that have been defined here or cannot be matched to the labels that are defined. If more labels are different, please repeat this procedure as often as possible. These categories will be grouped later. NOTE: *The category 'other' is prohibited, as the EC wants to see meaningful groups*] 99 = Unspecified [remark: *will be divided over all final groups, as we will not include them as a category in the final results*].
Number of active (= non-passenger) road users involved in the crash **Low priority**	01 = One road user 02 = Two road users … 99 Unspecified
Age of vehicle **Low priority**	0001 = 0 to less than 1 year 0102 = 1 to less than 2 years …. 9999 = Unspecified
Crash type (location of impact) **Priority**	1 = Front 2 = Rear 3 = Side 4 = Rollover 5 = Single/skidding 99 = Unspecified
Vehicle Manoeuvre	01 = Reversing 02 = Parked 03 = Waiting to go ahead but held up 04 = Slowing or stopping 05 = Moving off 06 = U turn 07 = Turning 08 = Waiting to turn 09 = Changing lane 10 = Overtaking moving vehicle 11 = Overtaking stationary vehicle 12 = Going ahead round curve 13 = Going ahead other 99 = Unspecified

To be continued on the next page.

Variable Name	Values for labels
Demography-age (of casualty) **Priority**	00 = 0 to < 1 year 01 = 1 to < 2 years 02 = 2 to < 3 years … 999 = Unspecified
alternative — **Demography – age groups (if no exact ages are available)** **Priority**	0011 = 0 to 11 years 1218 = 12 to 17 years 1824 = 18 to 24 years 2534 = 25 to 34 years 3544 = 35 to 44 years 4554 = 45 to 54 years 5564 = 55 to 64 years 6574 = 65 to 74 years 7500 = 75 years and older 9900 = Unspecified XXXX = [please assign a unique number and label if your dataset does not contain the labels that have been defined here or cannot be matched to the labels that are defined. If more labels are different, please repeat this procedure as often as possible. These categories will be grouped later. NOTE: *The category 'other' is prohibited, as the EC wants to see meaningful groups*
Demography-gender **priority**	1 = Male 2 = Female 9 = Unspecified
Road type (based on CADAS) **priority**	1 = Urban 2 = Rural 3 = Motorway 99 = Unspecified
Location – carriage way type (based on SafeyNet) **Low priority**	1 = One-way traffic (for motorized vehicles) 2 = Two-way traffic not physically divided. 3 = Physically divided roadway 9 = Unspecified
Location - Speed limit of the road (in km/h if this applies) **Priority**	Numeric [in case of no speed limit, the advised speed limit should be provided] 999 = Unspecified
Alt. — **Location - Speed limit of the road (in mile/h if this applies** priority	Numeric [in case of no speed limit, the advised speed limit should be provided] 999 = Unspecified
Location – junction type (based on CARE labels) **Priority**	01 = At grade – crossroad 02 = At grade roundabout 03 = At grade T or staggered junction 04 = At grade – multiple junction 05 = Not at grade (interchange) 06 = At level crossing 77 = At a junction – type not specified 88 = Not at a junction but at a road section 99 = Unspecified
Location - Surface conditions (based on CARE categories) **Priority**	1 = Dry 2 = Wet 3 = Snow, frost, ice, slush 4 = Slippery (mud, leaves, sand, oil) X = [please assign a unique number and label if your dataset does not contain the labels that have been defined here or cannot be matched to the labels that are defined. If more labels are different, please repeat this procedure as often as possible. These categories will be grouped later. NOTE: *The category 'other' is prohibited, as the EC wants to see meaningful groups* 99 = Unspecified

To be continued on the next page.

Variable Name	Values for labels
Location – special situation (based on CARE) **Priority**	1 = Tunnel 2 = Bridge 3 = Work zone (work zone, maintenance zone, construction zone) 4 = Bus stop 5 = Crossing facility for vulnerable road users (e.g. pedestrian crossing, cyclist crossing, pelican crossing, etc.) X = [please assign a unique number and label if your dataset does not contain the labels that have been defined here or cannot be matched to the labels that are defined. If more labels are different, please repeat this procedure as often as possible. These categories will be grouped later. NOTE: *The category 'other' is prohibited, as the EC wants to see meaningful groups* XY = If more than one special situation applies, please, use a combination of the single situation labels in order of appearance in the list: e.g. A work zone (3) on a bridge (2) will be coded as 23 then. 99 = Unspecified
Contributing crash factors (take the five most important variables (similar to IGLAD) **HIGH PRIORITY**	01 = Road condition (wet, icy, poor road surface) 02 = Road design (curve radius, road width, road gradient,) 03 = Reduced visibility due to road layout (parked vehicles, trees, buildings, alignment) 04 = Misleading traffic situation (signs, markings, …) 05 = Weather condition (high winds, fog, rain, snow) 06 = Vehicle condition (defective brakes, tires, steering, lights) 07 = Vehicle load (falling from vehicle, insecure load, overhanging load) 08 = Reduced view caused by obscured windows or glare (sun or headlights) 09 = Inconspicuous two-wheeler (lack of bright clothing, headlights) 10 = Driver under influence (alcohol, drugs, medication) 11 = Fatigued driver 12 = Medical impairment 13 = Distracted driver (telephone conversation, audio control, …) 14 =Inadequate information acquisition (not caused by other factor such as reduced visibility or distraction) 15 = Inexperience 16 = Speed above speed limit 17 = Following too close (tailgating) 18 = Road racing or aggressive driving (careless, reckless driving, …) 19 = Deliberately running red light (also pedestrians and bicyclists ignoring red lights) 20 = Wrong way driving 99 = Unspecified
Contributing injury factors (take the five most important variables (similar to IGLAD) **HIGH PRIORITY**	01 = No helmet used 02 = Helmet not properly secured 03 = No seat belt used 04 = Improper use of seat belt 05 = No child restraint used 06 = Child restraint not properly used or fastened 07 = No protective clothing (PTW) 08 = Airbag not deployed 09 = Ejected from vehicle 10 = Trapped within vehicle 11 = Contact with obstacle (two-wheeler) 12 = Road side not forgiving (obstacles within shoulder, steep slope) 99 = Unspecified
Impact severity Delta V (in km/h where this applies; otherwise mile/h) **Low priority**	Numeric 999 = Unspecified

Annex IIb: Availability of variables and labels per database in this study

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Traffic mode of casualty	Pedestrian (shoe vehicle: pedestrians, person on roller skates or skateboard, non-motorized scooter (autoped), pushing a bike or a wheelchair)	√	√	√	√	√	√	√	√	√
	Bicycle (including pedelec, speed pedelec or e-bike)	√	√	√	√	√	√	√	√	√
	Moped (motorized vehicles ≤ 50 cc and ≤50 km/h: slow moped, moped, mini car)	√	√	√	√	X	√	√	X	Moped (heavy/ light)
	Motorcycle (motorcycle over 50cc; motor scooter, motorcycle type unknown)	√	√	√	√	X	√	√	X	Motorcycle (heavy/ light)
	Motorised two wheeler - type unknown	√	√	√	√	√	√	√	√	X
	Car (including taxi, private hire car)	√	√	√	√	√	√ (+van)	√	√	√
Casualty Role	Pedestrian / Driver	√	√	√	√	√	X	√	X	√
	Front passenger	X	√	√	√	√	X	√	X	
	Rear passenger	X	√	√	√	√	X	√	X	
	Passenger, position unknown	√	√	√	√	√	X	√	X	
MAIS3+ including or excluding deceased	Including deceased	√	√	√	√	√	√	√	X	√
	Excluding deceased	√	√	√	√	√	√	√	√	√
Month in which the crash occurred	12 months	√	√	√	√	X	√	X	X	√

To be continued on the next page.

Variable Name		Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Time of day the crash occurred		hour	√	√	√	√	√	√	X	X	√
alt.	**Day/ Night time**	Day time / night time	√	√	√	√	√	√	√	√	√
Head max. severity (AIS 2005, update 2008)		MAIS 0-6	√	√	√	X	√	√	√	X	√
Face severity Etc.		MAIS 0-6	√	√	√	X	√	√	√	X	√
Neck severity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Thorax severity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Abdomen and pelvic severity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Spine severity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Upper extremity severity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Lower extremity		MAIS 0-6	√	√	√	X	√	√	√	X	√
Whole surface area severity (external, burns; inhalation injury; high voltage electrical injury; crashal hypothermia)		MAIS 0-6	√	√	√	X	√	√	√	X	√

To be continued on the next page.

Variable Name		Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
alternative	**Injury type (body region most heavily affected**	Head	√	√	√	X	√	√	√	√	√
		Face	√	√	√	X	√	√	√	√	√
		Neck	√	√	√	X	√	√	√	√	√
		Thorax	√	√	√	X	√	√	√	√	√
		Abdomen and pelvic contents	√	√	√	X	√	√	√	√	√
		Spine	√	√	√	X	√	√	√	√	√
		Upper extremities	√	√	√	X	√	√	√	√	√
		Lower extremities	√	√	√	X	√	√	√	√	√
		Whole surface area: external, burns; inhalation injury; high voltage electrical injury; crashal hypothermia	√	√	√	X	√	√	√	√	√
		Multiple regions (serious injuries with the same severity on more than one body region)	√	√	√	X	√	√	√	√	√

To be continued on the next page.

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES-STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
First crash opponent	Pedestrian (shoe vehicle: pedestrians, person on roller skates or skateboard, pushing a bike or a wheelchair)	√	√	√	X	√	X	√	√	√
	Bicycle (including pedelec, speed pedelec or e-bike)	√	√	√	√	√	X	√	√	√
	Moped (motorized vehicles ≤ 50 cc and ≤50 km/h, slow moped, moped, mini car)	√	√	√	√	X	X	√	X	√
	Motorcycle (motorcycle over 50cc; motor scooter, motorcycle type unknown)	√	√	√	√	X	X	√	X	√
	Motorised two wheeler - type unknown	√	√	√	√	√	X	√	√	√
	Car (including taxi, private hire car)	√	√	√	√	√	X	√	√	√
	Bus (including minibus, coach, trolley)	√	√	√	√	√	X	√	√HV	√
	Rail transport (tram, light rail, train)	√	√	√	√	√	X	√	√HV	√
	Agricultural vehicles	√	√	√	√	√	X	√	√HV	√
	Vans (light goods vehicles under 3.5 tonnes maximum gross weight	√	√	√	√	√	X	√	√	√
	Trucks (heavy goods vehicles over 3.5 tonnes)	√	√	√	√	√	X	√	√HV	X
	Goods vehicle - type unknown	√	√	√	√	X	X	√	√HV	X
	Ridden horse	√	X	X	√	X	X	√	√	√
	Non-fixed objects	√	√	√	√	√	X	√	√	√
	Fixed object	√	√	√	√	√	X	√	√	√
	No crash opponent (not even a tree or other fixed object)	√	√	√	√	√	X	√	√	√
	Other (specified)	Mobility scooter Moped car	X	Motor-home	Mobility scooter	X	X	X	Heavy vehicles	√

To be continued on the next page. * HV = group Heavy vehicles

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Number of active (= non-passenger) road users involved in the crash	Count	√	√	√	√	√	X	√	X	√
Age of vehicle	Annual age groups	√	√	√	√	√	X	√	X	X
Crash type (location of impact)	Front	√	√	√	√	√	X	√	X	X
	Rear	√	√	√	√	√	X	√	X	X
	Side	√ turning, overtaking, other	√	√	√	√	X	√	X	X
	Rollover	X	√	√	√	√	X	√	X	X
	Single/skidding	√	√	√	√	X	X	√	X	X
Vehicle manoeuvre	Reversing	X	√	√	√	√	X	√	X	√
	Parked	X	√	√	√	√	X	√	X	√
	Waiting to go ahead but held up	X	X	X	√	X	X	√	X	X
	Slowing or stopping	X	X	X	√	X	X	√	X	X
	Moving off	X	X	X	√	X	X	√	X	X
	U turn	X	√	√	√	√	X	√	X	√
	Turning	X	√	√	√	√	X	√	X	X
	Waiting to turn	X	X	X	√	X	X	√	X	X
	Changing lane	X	√	√	√	√	X	√	X	X
	Overtaking moving vehicle	X	√	√	√	√	X	√	X	Over-taking
	Overtaking stationary vehicle	X	√	√	√	√	X	√	X	
	Going ahead round curve	X	√	√	√	√	X	√	X	X
	Going ahead other	X	√	√	√	√	X	√	X	X

To be continued on the next page.

Variable Name		Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Demography-age of casualty		Annual age groups	√	√	√	√	√	√	√[14]	X	√
alternative	**Demography – age groups**	0 to 11 years	√	√	√	√	√	√	√[14]	√	√
		12 to 17 years	√	√	√	√	√	√	√[14]	√	√
		18 to 24 years	√	√	√	√	√	√	√[14]	√	√
		25 to 34 years	√	√	√	√	√	√	√[14]	√	√
		35 to 44 years	√	√	√	√	√	√	√[14]	√	√
		45 to 54 years	√	√	√	√	√	√	√[14]	√	√
		55 to 64 years	√	√	√	√	√	√	√[14]	√	√
		65 to 74 years	√	√	√	√	√	√	√[14]	√	√
		75 years and older	√	√	√	√	√	√	√[14]	√	√
		Other (specified)	√	√	√	√	√	√	√[14]	√	√
Demography-gender		Male/Female	√	√	√	√	√	√	√	√	√
Road type		Urban	√	√	√	√	√	X	√	X	√
		Rural	√	√	√	√	√	X	√	X	√
		Motorway	√	√	√	√	√	X	√	X	√
Location – carriage way type		One-way traffic (for motorized vehicles)	√	√	√	X	X	X	X	X	X
		Two-way traffic not physically divided	√	√	√	X	X	X	X	X	X
		Physically divided roadway	√	√	√	X	X	X	X	X	X
Location - Speed limit of the road (in km/h)		Numeric	√	√	√	X	X	X	X	X	√
Alt.	**Location - Speed limit of the road (in mile/h)**	Numeric	X	X	X	√	X	X	√	X	X

To be continued on the next page.

[14] Available in RAIDS, available in OTS upon special request.

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES–STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Location – junction type	At grade – crossroad	√	√	√	√	X	X	√	X	X
	At grade roundabout	√	√	√	√	X	X	√	X	√
	At grade T or staggered junction	√	√	√	√	X	X	√	X	X
	At grade – multiple junction	X	X	X	√	X	X	√	X	X
	Not at grade (interchange)	X	X	X	X	X	X	X	X	√
	At level crossing	X	√	√	X	X	X	X	X	X
	At a junction – type not specified	√	√	√	√	X	X	√	X	√
	Not at a junction but at a road section	√	√	√	√	X	X	√	X	√
Location - Surface conditions	Dry	√	√	√	√	√	X	√	X	√
	Wet	√	√	√	√	√	X	√	X	√
	Snow, frost, ice, slush	√	√	√	√	√	X	√	X	√
	Slippery (mud, leaves, sand, oil)	X	√	√	X	√	X	X	X	X
	Other (specified)	X	X	X	X	X	X	X	X	X
Location – special situation	Tunnel	√	√	√	X	X	X	X	X	√
	Bridge	√	√	√	X	X	X	X	X	√
	Work zone	√	√	√	√	X	X	√	X	√
	Bus stop	√	√	√	X	X	X	X	X	X
	Crossing facility for vulnerable road users	√	√	√	√	X	X	√	X	X
	Other (specified)	√ junction with traffic lights	√ No specialty at location	√ No specialty at location	None, signal defective, road surface defective	X	X	None, signal defective, road surface defective	X	Cross-walk Bicycle lane Bicycle overpass
	Combined situations	√	X	X	X	X	X	X	X	X

To be continued on the next page.

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES-STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Contributing crash factors (five most common factors)	Road condition (wet, icy, poor road surface)	√	√	√	√	√	X	√	X	√
	Road design (curve radius, road width, road gradient,)	√ curve	√	√	√	√	X	√	X	X
	Reduced visibility due to road layout (parked vehicles, trees)	X	√	√	√	√	X	√	X	X
	Misleading traffic situation (signs, markings, …)	X	√	√	√	√	X	√	X	X
	Weather condition (high winds, fog, rain, snow)	√	√	√	X	√	X	X	X	√
	Vehicle condition (defective brakes, tires, steering, lights)	X	√	√	√	√	X	√	X	X
	Vehicle load (falling from vehicle, insecure load..)	X	√	√	√	√	X	√	X	X
	Reduced view caused by obscured windows or glare	X	√	√	√	√	X	√	X	X
	Inconspicuous two-wheeler (lack of bright clothing, lights)	X	X	X	√	X	X	√	X	X
	Driver under influence	√	√	√	√	√	X	√	X	√
	Fatigued driver	√	√	√	√	√	X	√	X	X
	Medical impairment	√	√	√	√	√	X	√	X	X
	Distracted driver	X	√	√	√		X	√	X	X
	Inadequate information acquisition	X	√	√	√	X	X	√	X	X
	Inexperience	X	X	X	√	X	X	√	X	X
	Speed above speed limit	√	√	√	√	√	X	√	X	X
	Following too close (tailgating)	X	√	√	√	√	X	√	X	X
	Aggressive driving	X	X	X	√	√	X	√	X	X
	Red light running	√	√	√	√	√	X	√	X	X
	Wrong way driving	X	√	√	√	√	X	√	X	X

To be continued on the next page.

Variable Name	Values for labels	BRON-DHD	CziDaS	GIDAS	HES-STATS19	IGLAD	DHD trauma register	RAIDS/ OTS	Rhône road trauma registry	STRADA
Contributing injury factors (take the five most important variables (similar to IGLAD)	No helmet used	X	√	√	X	√	X	√	√	√
	Helmet not properly secured	X	√	√	X	√	X	√	X	X
	No seat belt used	X	√	√	X	√	X	√	√	√
	Improper use of seat belt	X	√	√	X	√	X	√	X	X
	No child restraint used	X	√	√	X	√	X	√	√	X
	Child restraint not properly used or fastened	X	√	√	X	√	X	√	X	X
	No protective clothing (PTW)	X	√	√	X	√	X	√	X	√
	Airbag not deployed	X	√	√	X	√	X	√	√	X
	Ejected from vehicle	X	√	√	√	√	X	√	X	X
	Trapped within vehicle	X	√	√	√	√	X	√	X	X
	Contact with obstacle (two-wheeler)	X	√	√	√	√	X	√	X	X
	Road side not forgiving	X	X	X	X	X	X	X	X	X
Impact severity Delta V (in km/h)	Numeric	X	√	√	X	√	X	X	X	X
Alt. **Impact severity Delta V (in m/h)**	Numeric	X	X	X	X	X	X	√	X	X

Annex III: Details on methodology used

Preparation of the data

The analyses are performed on severely injured pedestrians, bicyclists, motorcyclists (if not specified otherwise) and car occupants. Severely injured traffic participants are defined as having injuries of MASI3+ severity and not being deceased within 30 days.

For each database, the following number of cases were available in total and per traffic mode:

Table 2: *Number of MAIS3+ cases that were analysed in this study.*

Database	Pedestrians	Cyclists	Motorcycles	Car Occupants
CziDAS	30	7	36[2]	64
Rhône road trauma registry	647	594	1429[15]	781
GIDAS	175	245	173	309
BRON-DHD	1,962	6,902	2,365	7,438
DHD traffic register		26,335		
STRADA	1,034	1,044	1,157	3,291
STATS19-HES	6,355	2,012	5,424	9,413
RAIDS + OTS	65	18	67	148
IGLAD	49	17	49	113

Before applying any analysing method, the database has been be cleared of missing data, which is especially a requirement for the cluster analyses used. For databases where too much data was missing (30% to 40% of all cases) these cases are left out. For databases with only a few data missing (<5%), imputation of missings has been done by taking the average or mode of that variable in the database. If the amount of missings has been in between, the Multiple Imputation procedure of SPSS23 has been used. What the SPSS Multiple Imputation procedure does is to use the information available in the complete variables in order to obtain an "educated guess" for the categories to which the missing entries in the incomplete variables belong.

Specific notes on the datasets used:

Czech data: CziDAS
From the CziDAS database, cases of the years 2012 – 2015 were available.

For pedestrians, the variables Injury Factors, Impact speed and VehicleAge were not available and the variable RoadSurface was not imputable due to too many missing values. The final list of variables was: Month, Time, CrashOpponent, ActiveRoadUsers, Manoevre, Age, Gender, RoadType, CarriageWay,SpeedLimit, JunctionType, Location.

Only 7 bicycle cases were available in this database and only the following variables were analysed: Gender, Age, CrashOpponent, ActiveRoadUsers, RoadType, RoadCondition, DayNight.

[15] Powered two wheelers

In the CziDAS database, 33 powered two-wheelers could be distinguished. The group includes 1 moped, 3 PTW type unknown and 29 motorcyclists. The following variables were not imputable for this traffic mode: VehicleAge, CrashType, ContrInjuryFactor and ImpactSpeed, leaving the following variables available for analysis: Role, Month, Time, CrashOpponent, ActiveRoadUsers, Manoevre, Age, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, Location, CrashFactor.

For car occupants, the following variables could not be imputed: VehicleAge, Age, and ImpactSpeed. Analyses were performed using the following variables: Role, Month, Time, DayNight, CrashOpponent, ActiveRoadUsers, Manoevre, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, Location, CrashFactor, ContrInjuryFactor.

French data: Rhône road trauma registry, France, IFSTTAR
For the pedestrian data the variable DayNight had 5,6% missing cases, which have been imputed as the most common variable, which is Daytime.

For the bicycle data, the variables DayNight with 127 missing cases (21.4%) and Helmet use with 128 unspecified cases (21.5%) have been imputed.

Since the Rhône data consisted of only a small number of motorcyclist cases, these could not be delivered as data to the Consortium, but where included in the data of powered two wheelers.

For the car data, the variables Seatbelt and Airbag contain 12% and 27% missing data, which have been imputed by the Multiple Imputation method.

German data: GIDAS
From the GIDAS data, information of the years 2005 – 2016 was used.

Notes to the coding of variables

- CrashOpponent: The first crash opponent is encoded, which means the *first contact* of the casualty during the crash- with an opponent, object, the road etc.
- Vehicle Manoeuvre: The Manoeuvre was encoded using the *3-digit Crash Type.* This holds some uncertainties which participant was in which role of the crash type. For example if the manoeuvre is coded turning or overtaking in a car to motorcyclist crash it is not necessarily clear who actually was the turning/overtaking traffic participant...
- Crash Factor: The Crash factor was encoded using the main crash causation but it is not explicitly known which participant caused it. E.g. if the Crash factor is "driver under influence" in a car to moped crash it is no certain who was under influence...

For the clusters analyses, the following variables could be used, leaving out the variables that were not available for that particular traffic mode or had a missing rate larger than 20%:

- For pedestrians: Month, Time, CrashOpponent, ActiveRoadUsers, CrashType, Age, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, (special situation of the) Location, CrashFactor;
- For bicyclists: Role, Month, Time, CrashOpponent, ActiveRoadUsers, Manoeuvre, Age, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, Location, CrashFactor;

- For motorcyclists: Role, Month, Time, CrashOpponent, ActiveRoadUsers, Vehicle age, Crash type, Manoevre, Age, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, Location, CrashFactor;
- For car occupants: Role, Month, Time, CrashOpponent, ActiveRoadUsers, Vehicle age, CrashType, Manoevre, Age, Gender, RoadType, CarriageWay, SpeedLimit, JunctionType, Surface, Location, CrashFactor.

Data of the Netherlands: BRON linked with DHD, and DHD traffic register
For the traffic participants that sustained severe injuries in the Netherlands, the BRON database linked to the DHD traffic register was used primarily. As this database is known for a reasonable quality regarding motorised vehicles, there was no need to do similar analyses on the DHD traffic register only for motor vehicles. Linkage with the finding of BRON-DHD indeed showed similar results.

For the severely injured bicyclists, BRON-DHD is known for a large underreporting of single bicycle crashes. Therefore, DHD traffic register data was used here as well in order to get additional information of certain variables such as age, gender and type of crash opponent (motorised vehicle versus non-motorised vehicle). As the DHD traffic register does not contain location information, BRON-DHD is the only source for this and these results could not be validated to the larger DHD traffic register database.

Swedish data: STRADA
Hospital and Police data have been combined in order to derive as many of the required SUSTAIN variables as possible. Tables are matched using a common crash reference table and only those where the level of match (Q-Value) was at least 65/100 – in these cases the match between records is considered successful.

Crash opponent was missing for around 30% of the car occupant cases, however a cross tabulation of crash opponent against an alternative description of the crash scenario showed that 99 consistently appears as a 'single vehicle crash'. Single vehicle crashes have been added as a category but it cannot be assumed that these had no non-vehicle impact partner.

England data:
STAT19 linked HES
These databases were used to find common crash circumstances and scenario's.

RAIDS and OTS
These databases were combined, providing 65 pedestrian cases, 18 cyclist cases, 67 motorcyclist cases and 148 car occupant cases. The combined datasets were used for common crash characteristics in addition to the STATS19 linked HES data, crash scenarios and the analysis of injury factors.

Crash opponent was vague in the OTS dataset – coded as 'vehicle' and the further layer of detail missing. This is considered an important, high priority variable and so each case was reviewed by reading the text file describing the crash scenario in order to provide this variable for the analysis.

IGLAD database
IGLAD data were used of the period 2007-2014. From the IGLAD database, only the data of European countries was analysed. The data originate from the countries Austria, Czech Republic, Germany, France, Italy, Sweden, and Spain and were analysed together, not per country. The table below shows the availability of cases per traffic mode and per country:

Table 3: *Number of MAIS3+ cases in the IGLAD database per country and traffic mode.*

Country	Pedestrian	Bicyclists	PTW	Car occupants
FR	26	1	5	12
AT	4	3	12	30
CZ	2	1	3	16
DE	11	11	14	18
IT	6	1	9	18
SE	0	0	1	2
ES	0	0	5	17
Sum	**49**	**17**	**49**	**113**

From the IGLAD database, the following variables were available: TrafficMode, Role, Time, DayNight, InjuryType, CrashOpponent, ActiveRoadUsers, VehicleAge, CrashType, Manoevre, Age, Gender, RoadType, SpeedLimit, Surface, CrashFactor, InjuryFactor and ImpactSpeed.

Motorways are defined in this database as principal arterials.

Main characteristics of crashes

To get the best results from the MAIS3+ databases, each of the included variables per traffic mode was analysed by the descriptives procedure of SPSS. To get to the main crash characteristics per traffic mode and prevent relative small or meaningless categories, characteristics with small numbers were merged with other characteristics and given a meaningful name by a road safety expert.

For example, if the results of crash opponent contained only a few cases such as moped-car (a rare type of car), this was merged with car; the relative small numbers of powered two wheeler subtypes were merged into one category 'powered two wheelers'; low numbers of crash opponents such as agricultural vehicles, busses, trams were merged with trucks into the category 'heavy vehicles'. Characteristics with low numbers differ per transport mode and per country (database).

Crash types and crash scenarios

To get the main crash scenarios, we used TwoStep cluster analysis in SPSS (see IBM SPSS Statistics Base 23). Generally, cluster analysis is a set of techniques for the classification of objects or individuals (in our case: injured road users) into a number of homogenous clusters. Usually, the objects or individuals have all been scored on a number of characteristics or variables (such as crash type, gender, speed limit, etc. in our case). In a first step the scores of the individuals on these variables are used to calculate the distance between each pair of individuals in the dataset, pairs with very similar scores resulting in a small distance and pairs with very different scores yielding a large distance for the corresponding pair of individuals. In a second step all the thus obtained distances are used to determine an optimal set of clusters of individuals simultaneously satisfying the following two properties:

- Individuals within each cluster should have pairwise distances that are as small as possible;
- Individuals in different clusters should have pairwise distances that are as large as possible.

For further technical details on cluster analysis we refer to IBM SPSS Statistics Base 23 (2014, Chapters 23 and 24) and Everitt et al. (2011).

The important advantage of this classification technique compared to K-Means and Hierarchical clustering is that it can handle variables of different measurement levels (i.e., both continuous and categorical variables) and that it does not require the user to provide an a priori number of clusters to be found. It is possible to provide a maximum number of clusters to be found though, and we always set this maximum to 6 for pragmatic reasons.

In deciding whether a satisfactory cluster solution had been found we considered the following diagnostics provided by the TwoStep Cluster analysis procedure in SPSS:

1. The Akaike Information Criterion (AIC) value of the solution, where a lower AIC value indicates a better fitting solution;
2. The Cluster Quality of the solution which ranges from -1.0 to +1.0; we only accepted solutions whose Cluster Quality was qualified at least as “Fair” (Cluster Quality > 0.2) and preferably as “Good” (Cluster Quality > 0.5);
3. The predictor importance of each variable which ranges from 0 to 1. We generally kept the variables with a predictor importance close to or equal to 1 and dropped the variables with a low predictor importance. Repeating the analysis with a thus selected smaller number of variables usually yielded solutions with a lower AIC and a higher Cluster Quality score;
4. We also checked whether the obtained cluster sizes were not too skewed, e.g., we considered a solution where the largest cluster included more than 10 times more cases than the smallest cluster as too skewed to present most important crash scenario’s.

Clusters that are found can be described best on the basis of the values that are most common in that particular cluster. This means that the description of a cluster is a simplified version of all circumstances that are included.

Injury factors

To analyse the main injury factors of MAIS3+ casualties, first the AIS body part most heavily affected per casualty has been summed per traffic mode. Secondly, the share of most heavily affected body parts has been calculated per transport mode and within each transport mode per crash scenario.

In order to see whether crash scenarios accounted for different injury patterns, the results have been analysed per transport mode. Since “cluster” and “injury type” are both categorical variables (i.e., variables with values whose only purpose is to keep the categories apart, and nothing more) the standard procedure to investigate their possible relationship is to apply a Chi-square test to the contingency table containing the cell frequencies of the categories of the two variables. To this end, the frequencies are calculated which would have been obtained if the two variables were completely unrelated, and the latter frequencies (known as expected frequencies) are then compared with the observed frequencies. The larger the differences between the expected and observed frequencies the sooner the Chi-square test will be significant, indicating that the two categorical variables are indeed related. A significance level of < 0,05 has been used. For further details concerning Chi-2 tests we refer to any handbook on statistics.

Differences in results between transport modes and between scenario’s have been analysed using the knowledge from in-depth databases, road safety experts and medical experts.

Annex IV: Detailed results

Pedestrians

This section provides the most common crash characteristics and scenario's, and the injury factors of MAIS3+ injured pedestrians per country for which this information is available.

Czech Republic

Crash characteristics

Of the 26 pedestrian casualties in the CziDAS database nearly equal shares of males and females were involved (see Figure 2). A prominent group are children (38%; Figure 3).

In about three quarter of the cases a car was the first crash opponent, in the other cases it was a heavy vehicle (Figure 4) and most of the time two road users were involved (85%). Three quarter of the casualties were a side-impact collisions. Most of the crash occurred in urban areas (Figure 5) with a speed limit of 50 km/h (88%) and two third of the crashes happened on road sections (Figure 6), one third at a junction. Three quarter of the crashes happened in not physically divided two-way traffic and the special situation of the location was defined by a VRU crossing (38%), a bus stop (23%), no special situation (23%) or the pedestrian was behind/between parked cars (12%).

Concerning the crash factors, in most of the cases inadequate information acquisition of one of the participants contributed to the crash (61%), in one third the opponent-driver was under influence. The majority of crashes can be described by the manoeuvre of going ahead other or a round curve (77%), e.g. a vehicle driving along a road section and a pedestrian crossing the road. In 19% the opponent vehicle hit the pedestrian in a overtaking process.

The majority of casualties were seriously injured in January and August; Figure 7). Most of the crashes happened during daytime, mostly during commuter times (early morning, early afternoon; Figure 8).

Crash scenarios

A first TwoStep Cluster analysis of the pedestrian data with 26 cases and the above stated variables yields a 4 cluster solution with an AIC of 713 and a cluster quality labelled as poor (0.2). This solution suggests the removal of Month, Time, Age, and CrashFactor.

The second round yields a 4 cluster solution with an AIC of 358 and a cluster quality labelled as fair (0.4). This solution yields to the third round with the variables Crash Opponent, CarriageWay, CrashFactor and Location.

The third round yields a 4 cluster solution with an AIC of 155 and a cluster quality labelled as good (0.5). The variables (predictor importances) are Location (1.0), CarriageWay (0.74), CrashOpponent (0.53), and CrashFactor (0.1). The most common scenarios that were found (see Table 4) can best be summarised as:

- Pedestrian hit by a car at a VRU crossing with undivided driving directions in a situation with inadequate information acquisition (7 of 10);

- Pedestrian hit by a car on a road with undivided driving directions without any further specific characteristics in a situation with inadequate information acquisition (3 of 7);
- Pedestrian hit by a bus at a bus stop on a road with undivided driving directions in a situation where one of the traffic participants is under influence of alcohol (2 of 6);
- Pedestrian hit by a car in the vicinity of a parked car on a road with undivided driving directions in a situation with inadequate information acquisition (3 of 3);

Table 4: Crash scenarios and injured body regions for the Czech Republic pedestrian data (CziDAS).

Cluster nr.	1	4	3	2	
N	10	7	6	3	
Location	VRU crossing 10/10 =100%	No special location 5/7 =71.4%	Bus stop 4/6 =66.7%	Parked car 3/3 =100%	
Carriage Way	Not physically divided 10/10 =100%	Not physically divided 7/7 =100%	Not physically divided 3/6 =50%	Not physically divided 3/3 =100%	
Crash opponent	Car 10/10 =100%	Car 6/7 =85.7%	Bus 6/6 =100%	Car 3/3 =100%	
Crash Factor	Inadequate information acquisition 7/10 =70%	Inadequate information acquisition 5/7 =71.4%	Driver under Influence 6/6 =100%	Inadequate information acquisition 3/3 =100%	
Injury type					**Total**
Head, Face, Neck	6/10 =60%	2/7 =28.6%	2/6 =33.3%	1/3 =33.3%	11/26 =42.3%
Thorax	0/10 =0%	2/7 =28.6%	0/6 =0%	0/3 =0%	2/26 =7.7%
Abdomen and pelvic contents	0/10 =0%	1/7 =14.3%	0/6 =0%	0/3 =0%	1/26 =3.8%
Spine	0/10 =0%	0/7 =0%	1/6 =16.7%	0/3 =0%	1/26 =3.8%
Upper extr.	0/10 =0%	1/7 =14.3%	0/6 =0%	0/3 =0%	1/26 =3.8%
Lower extr.	4/10 =40%	1/7 =14.3%	1/6 =16.7%	2/3 =166.7%	8/26 =30.8%
Whole surf. + mult. regions	0/10 =0%	0/7 =0%	2/6 =33.3%	0/3 =0%	2/26 =7.7%

Injury factors

Body regions most commonly injured in pedestrians in the Czech Republic are the head (42%) and the lower extremities (31%; see also Figure 9).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square =28.875, df =21, p<0.117), indicating that for pedestrians there is no significant relationship between the injury type and the crash scenario.

England

Crash characteristics

STATS19-HES - The STAS19-HES linked dataset comprises 6,355 severely injured pedestrians. There is a bias towards male MAIS3+ pedestrians (61%) compared to female (39%; Figure 2). There is a high proportion of children among the casualties, with the age distribution being skewed towards younger casualties (Figure 3). There is another peak in the data for the elderly (75 to 90 years).

The most common crash opponent is a car (80%). The next most frequent opponent is a heavy vehicle (10%) (Figure 4). The vast majority of crashes involved one road user, defined as the number of vehicles in the crash (93%). In almost all cases, the opponent vehicle is moving forward without turning or overtaking. Ten percent of crashes occurred when the opponent vehicle was reversing.

Road type (Urban/Rural/Motorway) has been derived from the road classification and speed limit in this dataset and therefore the distribution is approximate. The indication is that the vast majority (95%) of the crashes with MAIS3+ pedestrians occur in an rural environment (Figure 5). Considering any junction layout, the most common scenario is where no junction is present (45%) whilst 37% of the crashes occur at T/Y or staggered junctions (Figure 6). The road surface was dry in almost three quarter of cases.

The months that appear with the highest frequency are October, November, December and January, winter months with fewer daylight hours (Figure 7). There is a distinct peak in the number of crashes during mid to late afternoon (Figure 8).

The most crash common factors are;

- Pedestrian failed to look properly (58%)
- Pedestrian careless/reckless behaviour (22%)
- Driver failed to look properly (21%)
- Pedestrian failed to judge path/seed of vehicle (19%)
- Pedestrian under the influence (alcohol/drugs) (14%).

RAIDS/OTS - The RAIDS/OTS dataset comprises 65 severely injured pedestrians. There are proportionally more male casualties (55%) than female (45%; Figure 2). Age data is only available for the RAIDS data (n=14) – in this small sample there is an even distribution of age category, child < 16 (5), adult (5) and senior > 60 (4).

The most common crash opponent is another car (78%). The next most frequent opponent is a bus (10%) (Figure 4). Heavy vehicles (Buses and Truck) account for 15% of the impact partners. The vast majority of crashes involved the pedestrian and one other road user (88%).

Considering the road type (Urban/Rural/Motorway) the vast majority (92%) of the crashes with MAIS3+ pedestrians occur in an urban environment (Figure 5). This is also reflected in the speed limit distribution where almost 84% are in a 30mile/h speed zone. Considering any junction layout, the most common scenario is where no junction is present (69%) whilst 20% of the crashes occur at T/Y or staggered junctions (Figure 6). However, almost half, 46% of the crashes resulting in a seriously injured pedestrian occurred in the vicinity of a pedestrian crossing facility. The road surface was dry in almost 72% of cases.

Considering the lighting conditions, 62% of the crashes occurred during the daytime.

Looking closer into the conditions that were found to contribute to the crash, the following common factors were found in pedestrian crashes:

- Pedestrian failed to look (48%)
- Pedestrian careless or reckless behaviour (37%)
- Vision affected (driver or pedestrian) 28%
- Pedestrian failed to look to judge vehicle speed / path (20%)

The crash opponent failed to look properly in 19% of cases and speed was a factor in 17% of cases.

Crash scenarios

STATS19-HES - A first TwoStep Cluster analysis of the Pedestrian data with 6,355 cases was undertaken using the nominal variables Month, Time, opponent, Gender, Junction, Surface, Manoeuvre, ActiveRoadUsers, pedestrian_crossing and SpeedLimit and the interval variable Age, a total of 11 input variables. This resulted in a 4 cluster solution with an AIC of 132562.4 and a cluster quality labelled as Poor.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5 (removing gender, speedLimit, ActiveRoadUsers and opponent). A 5 cluster solution was returned with an AIC of 99523.711 and a cluster quality labelled as Poor. In this solution Time had a predictor importance < 0.5.

A third analysis inputted the 6 variables Month, Junction, Surface, Manoeuvre, pedestrian_crossing and Age. A 5 cluster solution, still labelled Poor and with and AID of 61334.8 was returned. Age had a predictor importance < 0.5 and was removed.

The remaining 5 variables produced a 4 cluster solution labelled Fair and with AIC 60467.6. In this solution Manoeuvre had a predictor value < 0.5 and a further analysis was performed with the 4 variables Month, Junction, Surface and Pedestrian_crossing. These gave a 3 cluster solution again labelled fair with an improved AIC 50376.5. Removing Pedestrian_crossing (predictor < 0.5) gave a solution labelled Poor and so previous the 4 variable 3 cluster solution was chosen. The details are (see Table 5):

- Pedestrians is hit on a T/Y or staggered junction with no pedestrian crossing facility, in dry conditions (1642 of 2379 cases);
- Pedestrian is hit on a road section during dry conditions (2076 of 2185 cases);
- Pedestrian is hit on a road section in wet conditions (739 of 1791 cases).

The pedestrian's failure to look properly is by far the most reported factor. The driver failing to look is most common in the T/Y/Staggered junction cluster.

Table 5: Crash scenarios for England pedestrian data (STATS19-HES).

Cluster nr.	2	3	1
N	2379	2185	1791
Junction	T/Y/Staggered junctions (69%)	Road Section (95%)	Road Section (43%)
Surface	Dry (100%)	Dry (100%)	Wet (96%)

RIADS/OTS - A first TwoStep Cluster analysis of the Pedestrian data with 65 cases was undertaken using the nominal variables Roadtype Speed DayNight, opponent, Gender, Junction, Surface, ActiveRoadUsers, and pedestrian_crossing a total of 9 input variables. This resulted in a 4 cluster solution with an AIC of 558.465 and a cluster quality labelled as Fair. However, roadtype showed as the most important predictor and since only 5 of the crashes occurred in rural areas, the cluster size ratio was very high. Roadtype (and speed) were removed and the analysis repeated with the remaining 7 input variables.

This returned a 4 cluster solution labelled fair (AIC 465.23) with Surface, Gender and DayNight having predictor importance > 0.5. A further analysis used these latter 3 variables and resulted in a 4 cluster solution labelled good (AIC 91.901) with all three variables having importance > 0.5. Cluster analysis of the RAIDS/OTS data split the data into four relatively evenly split scenarios based upon Surface conditions, time of day and gender (see Table 6):

- Wet/Damp at night and even split of gender (9 of 18 cases)
- Dry at Night with 75% male (12 of 16 cases)
- Dry during the day all female (16 of 16 cases)
- Dry during the day all male (15 of 15 cases)

There are indications for differences in contributory crash factors between the clusters. In all clusters, the failure of the pedestrian to look properly is a major factor. In clusters featuring male pedestrians, the actions of the pedestrian dominate the contributory factors, including being under the influence and for the night-time lack of high visibility clothing. For clusters with female pedestrians factors relating to the vehicle driver are more apparent (failed to look, distraction – daytime accidents, speed and under the influence – night-time accidents).

Injury factors

Looking at the severe injuries MAIS3+ pedestrians in England sustain most injuries to the lower extremities (48%) and the head (32%; see also Figure 9).

Chi-square tests of association have been applied to establish if there is any association between cluster membership and injury type. This turned not out to be significant.

Looking at the injury types across the clusters lower extremity is the most frequent in the crashes during nighttime and crashes with female pedestrians. Crashes with males have a higher proportion of head injury type than injuries with female pedestrians.

Table 6: Crash scenarios and injured body regions for England pedestrian data (RIADS & OTS).

Cluster nr.	**1**	**2**	**3**	**4**	
N	18	16	16	15	
Road surface condition	Wet/damp 18/18 = 100%	Dry 16/16 = 100%	Dry 16/16 = 100%	Dry 15/15 = 100%	
Time of day	Night time 18/18 = 100%	Night time 16/16 = 100%	Daytime 16/16 = 100%	Daytime 15/15 = 100%	
Gender	Male/female 9/18 = 50%	Male 12/16 = 75%	Female 16/16 = 100%	Male 15/15 = 100%	
Injury type					**Total**
Head	33.3%	25.0%	25.0%	46.7%	32.3%
Thorax	11.1%	12.5%	0	13.3%	9.2%
Upper Extremities	0	6.3%	0	0	1.5%
Lower Extremities	50.0%	43.8%	68.8%	27.7%	47.7%
Multiple regions	5.6%	12.5%	6.3%	13.3%	9.2%

France, Rhône region

Crash characteristics

From the Rhône region, data of 626 severely injured pedestrians were analysed. The data showed that slightly somewhat more males than female pedestrians are severely injured (see Figure 2). Elderly people are dominating the number of serious pedestrian injuries (see Figure 3). By far most pedestrians get severely injured in an crash with a car (75%). Heavy vehicles are the second most common crash opponent (11%; see Figure 4). Most of the pedestrian crashes (ca. 70%) occur during daytime (Figure 8).

Crash scenarios

A first TwoStep Cluster analysis of the nominal variables DayNight, FirstCrashOpponent, DemograpyAgeGroup and DemographyGender yields a 4 cluster solution with an AIC of 3802.980 and a cluster quality labelled as Fair. In this solution the variables DayNight, FirstCrashOpponent, DemograpyAgeGroup and DemographyGender have a predictor importance of 1.0, 0.95, 0.08 and 0.65, respectively.

A second TwoStep Cluster analysis only using the variables DayNight, FirstCrashOpponent and DemographyGender yields a 4 cluster solution (see Table 7) with an AIC of 1027.552 and a cluster quality labelled as Good. In this solution the variables DayNight, FirstCrashOpponent and DemographyGender have a predictor importance of 0.85, 1.0 and 0.57, respectively.

The four clusters or crash scenarios could be described as follows:

- Male pedestrian hit by a car during daylight (174 of 174 cases);
- Female pedestrian hit by a car during daylight (166 of 166 cases);
- Male pedestrian hit by a heavy vehicle during daylight (31 of 162 cases);
- Male pedestrian hit by a car during night time (86 of 145 cases);

Table 7: Crash scenarios and injured body regions for the Rhône region pedestrian data (Rhône road trauma registry, France, IFSTTAR).

Cluster nr.	1	4	3	2	
N	174	166	162	145	
First crash opponent	Car 174/174 = 100.0%	Car 166/166 = 100.0%	Heavy vehicle 73/162 = 45.1%	Car 145/145 = 100.0%	
Time of day	Day 174/174 = 100.0%	Day 166/166 = 100.0%	Day 132/162 = 81.5%	Night 145/145 = 100.0%	
Gender victim	Male 174/174 = 100.0%	Female 166/166 = 100.0%	Male 84/162 = 51.9%	Male 86/145 = 59.3%	
Injury type					**Total**
Head+ Face	40 23.8%	29 17.7%	47 29.9%	34 24.8%	150 24.0%
Thorax	11 6.5%	3 1.8%	27 17.2%	12 8.8%	53 8.5%
Upper extremities	21 12.5%	34 20.7%	15 9.6%	10 7.3%	80 12.8%
Lower extremities	81 48.2%	89 54.3%	51 32.5%	64 46.7%	285 45.5%
Multiple regions	15 8.9%	9 5.5%	17 10.8%	17 12.4%	58 9.3%

Injury factors

The lower part of the Table displays the frequencies in the cross-table of injury type by cluster number. Pedestrians in the Rhône region suffer mostly from injuries of the lower extremities (45,5%), followed by injuries of head and face (24,0%) and injuries of the upper extremities (12,8%; see also Figure 9).

Since there is only one Face injury in this data set we added this to the Head injuries. Moreover, there are only 9 injuries of the Abdomen and pelvic contents in this data set and only 12 Spine injuries. We therefore dropped them from further analysis because these two types of injuries result in 8 cells in the cross-table with expected frequencies smaller than 5 cases. The Chi-square test for the cross-table of the remaining five categories of injury type by cluster number is very significant (Chi-square = 54.467, df = 12, p < 0.0001), indicating that for pedestrians there is a significant relationship between the variables injury type and cluster number.

There appear to be significant differences (see Annex IV for more details) in the most common type of injury and the four most common pedestrian crash scenarios that have been described in the previous chapter. The most important differences are:

- Lower limb injuries are most common in crashes with a car.
- Injuries to the head and face are nearly as common as lower injuries in crashes where pedestrians get hit by a heavy vehicle.
- Thorax injuries are more common when pedestrians get hit by heavy vehicle than by a car.

Germany

Crash characteristics

In total 175 MAIS3+ pedestrian casualties were found in GIDAS that were included in the analysis. Nearly the same shares of male and female pedestrians were severely injured in an crash (see Figure 2). The largest numbers of injured pedestrians were among the elderly (60+) (see Figure 3).

In about three quarter of the pedestrian crashes the first crash opponent is a car. In 14% of the crashes, heavy vehicles (bus, truck, rail, agricultural vehicles) are involved (see Figure 4). In 90% of the pedestrian crashes one other road user is involved. About 80% of the crashes the pedestrian was hit at his side ("side-impact collision") and collisions were the pedestrian was hit on his front side ("head-on collision") are common.

Most pedestrian crashes leading to severe injury occur in urban areas (see Figure 5), the majority on 50 km/h or 60 km/h roads with not physically divided two-way traffic. two third of the pedestrian crashes resulting in severe injury occur at junctions (see Figure 6) and about two third on dry road surface. Nearly half of the pedestrian crash occur at no special location, but about each one quarter occur at bus stops and VRU crossings and 6% with the pedestrian behind or between parked cars.

Regarding Crash Factors in 84% of the cases inadequate information acquisition[16] of one of the participants contributed to the crash, followed by speeding (of the opponent) with 9%.

During winter (October to February), the highest number of pedestrians get severely injured (see Figure 7). Most crashes occur in the afternoon between 3:00 PM and 6:00 PM (see Figure 8).

Crash scenarios

A first TwoStep Cluster analysis of the pedestrian data with 175 cases and the above stated variables yields a 6 cluster solution with an AIC of 4423 and a cluster quality labelled as poor. In this solution only the variables Location, Speed limit, Gender, Junction type, Type of carriageway have a predictor importance larger than 0.4.

[16] Inadequate information acquisition consists of actions like: heavy braking of the vehicle in front without compelling reason, overtaking though traffic situation is not clear, mistake during u-turn or reversing wrong behavior towards pedestrians at pedestrian crossings, wrong behavior of the pedestrian (ignoring the road traffic), other mistakes of the driver (very common).

A second TwoStep Cluster analysis with the variables Location, Speed limit, Gender, Junction type, Carriageway yields a 2 cluster solution with an AIC of 1233 and a cluster quality labelled just fair. In this solution only the variables Location, Junction type and Type of carriageway have a predictor importance larger than 0.4.

A third TwoStep Cluster analysis only applied the variables Location, JunctionType, CarriageWay yields a 6 cluster solution with an AIC of 309 and a cluster quality labelled as good. In this solution the variables have an acceptable predictor importance (1.0 JunctionType, 0.94 Location, 0.66 CarriageWay). The clusters could best be summarised as (see Table 8)

- Pedestrians on a road section where the two-way traffic is not physically divided and no special infrastructural situation applies (55 of 55 cases);
- Pedestrians on a road section where the two-way traffic is not physically divided, at a bus stop (32 of 32 cases);
- Pedestrians on a cross-road where the two-way traffic is not physically divided, at a VRU crossing facility (16 of 29 cases);
- Pedestrians on a road section where the two-way traffic is physically divided, at a VRU-crossing facility (6 of 25 cases);
- Pedestrian on a road section where the two-way traffic is not physically divided, behind parked cars (9 of 19 cases);
- Pedestrian on a T- or staggered junction in no special infrastructural situation where the two-way traffic is not physically divided (11 of 16 cases).

Injury factors

Table 8 shows the most common crash scenarios including the frequencies of the body region that are MAIS3+ injured per scenario. Most common pedestrian injuries in Germany are the lower extremities (47%), followed by the head (26%) and thorax (13%; see also Figure 9).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=31.31.311 df=30, p<0.4), indicating that for pedestrians there is no significant relationship between the injury type and the crash scenario.

Having a closer look into the injury distribution within the 6 scenarios shows:

- The lower extremity injuries always have a share of about half of the injuries in each scenario except for the VRU crossing scenario with physically divided roadways (e.g. by a tram station in the middle of the road) where the share is only one third but where we find the highest share in thorax injuries (24%)[17] and multiple serious injuries (16%).
- The highest share of head & face injuries is found in the scenario of a pedestrian crossing behind/between a car (42%).

For the 176 pedestrian casualties 1100 single injuries (mean of 6 injuries per casualty) were recorded of which 310 injuries (mean of 2 injuries per casualty) have a severity of AIS08=3 or larger. The majority of fractures were caused by the contact with the opponent car front (118/180=65.6%) or the contact with the road and environmental features (e.g. the curb) (44/180=24.4%). These causes are also the main causes for all injury types, that is 82/310=26.5% of all injuries were caused by hitting the road, 198/310=63.9% were caused by the impact to opponent which was in most cases a car.

[17] The numbers relate the share within each scenario, not the share on the total number of injuries of this type.

Table 8: Crash scenarios and injured body regions for the German pedestrian data (GIDAS).

Cluster nr.	6	1	3	4	5	2	
N	55	32	29	25	19	16	
Junction Type	Road section 55/55 =100%	Road section 32/32 =100%	Cross road 29/29 =100%	Road section 12/25 =48%	Road section 18/25 =95%	T or staggered junction 16/16 =199%	
Special Situation	No special situation 55/55 =100%	Bus stop 32/32 =100%	VRU crossing facility 16/29 =55%	VRU crossing facility 16/25 =64%	Parking car 10/19 =53%	No special situation 11/16 =67%	
Carriage Way	Two-way traffic not divided 55/55 =100%	Two-way traffic not divided 32/32 =100%	Two-way traffic not divided 29/29 =100%	Physically divided roadway 25/25 =100%	Two-way traffic not divided 19/19 =100%	Two-way traffic not divided 16/16 =100%	
Injury type							**Total**
Head, Face, Neck	14/55 =25.5%	7/32 =21.9%	4/29 =13.8%	7/25 =28%	8/19 =42.1%	5/16 =31.3%	45/175 = 25.7%
Thorax	4/55 =7.3%	5/32 =15.6%	5/29 =17.3%	6/25 =24%	0/19 =0%	3/16 =18.8%	23/175 = 13.1%
Abdomen and pelvic cont.s	0/55 =0%	0/32 =0%	1/29 =3.5%	0/25 =0%	0/19 =0%	0/16 =0%	1/175 = 0.6%
Spine	3/55 =5.5%	1/32 =3.1%	0/29 =0%	0/25 =0%	0/19 =0%	0/16 =0%	4/175 = 2.3%
Upper extr.	1/55 =1.8%	0/32 =0%	1/29 =3.5%	0/25 =0%	1/19 =5.3%	1/16 =6.3%	4/175 = 2.3%
Lower extr.	26/55 =47.3%	18/32 =56.3%	15/29 =51.7%	8/25 =32%	9/19 =47.4%	7/16 =43.8%	83/175 = 47.4%
Whole surf. + mult. Regions	7/55 =12.7%	1/32 =3.1%	3/29 =10.3%	4/25 =16%	1/19 =5.3%	0/16 =0%	16/175 = 9.1%

Netherlands

Crash characteristics

The data from 1,962 pedestrian cases in the Netherlands[18] showed that males and females are about equally involved in MAIS3+ pedestrian crashes (see Figure 2). Especially elderly road users (70 to 85 years of age) and children (3 to 10 years of age) sustain severe injury (see Figure 3).

By far most pedestrians get injured in an crash with a car (>60%). Powered two-wheelers, vans, heavy vehicles and bicycles are other important crash opponents (see Figure 4). Most pedestrian crashes involve one other road user.

[18] Linked police-hospital data (BRON-LMR).

Most MAIS3+ pedestrian crashes occur on urban roads (see Figure 5), with most of them having a speed limit of 50 km/h, but also 30 km/h roads and rural 80 km/h roads were found to be common. More MAIS3+ pedestrian crashes occur on road sections than on junctions (Figure 6) and in dry road surface conditions.

In January to March, May and June more MAIS3+ pedestrian crashes occur than in other months (see Figure 7). Most of the pedestrian crashes occur in the afternoon, especially between 3:00 PM and 6:00 PM (see Figure 8).

Crash scenarios
Based on the frequency tables of the variables within the linked BRON-DHD data (see Annex IIb) it was decided only to use the variables Month, Time, Crash opponent, Number of active road users, Crash type, Age, Gender, Road type, Speed limit, Junction type, Surface condition for each of the transport modes for cluster analysis. The variables Type of carriageway, Special situation, Contributing crash factors, and Contributing injury factors had missing data ranging from 50%-85%, 73%-94%, 41%-67%, and 79%-100%, respectively. We did not make a further choice beforehand in order to let the most common crash scenario's appear from the analysis.

The TwoStep Cluster analysis method (see below for further details) uses a case wise deletion approach to missing data, implying that each case with at least one missing value is automatically completely excluded from the analysis. Since the proportion of missing data, if any, in the remaining variables was only approximately 5% or less, it was decided to impute the mean of the variable if the variable was numerical, and the mode if it was nominal.

A first TwoStep Cluster analysis of the pedestrian data with 1,962 cases and the nominal variables Month, Time, CrashOpponent, CrashType, Gender, RoadType, Junction, Surface, and SpeedLimit and the interval variables ActiveRoadUsers and Age yields a 2 cluster solution with an AIC of 41,766.593 and a cluster quality labelled as just Fair. In this solution only the variables RoadType and Speedlimit have a predictor importance larger than 0.9, while the predictor importance of CrashType is only 0.18 and that of the remaining variables is even lower than that.

A second TwoStep Cluster analysis only using the variables RoadType, Speedlimit and CrashType yields a 4 cluster solution with an AIC of 1759.240 and a cluster quality labelled as Good. In this solution the variables RoadType and SpeedLimit have a predictor importance of 1.0, while the predictor importance of CrashType is almost 0.8. Unfortunately, the ratio of the largest cluster size with 1326 cases and the smallest cluster size with 92 cases in this solution is 14.4 which is quite skewed.

A third TwoStep Cluster analysis only applied to the variables RoadType and SpeedLimit which had a predictor importance of 1.0 in the previous analyses yields a 3 cluster solution with an AIC of 1663.611 and a cluster quality also labelled as Good. In this solution both variables have a perfect predictor importance of 1.0. These 3 clusters are described in Table 9 in order of cluster size.

So to summarise, analysis of main crash scenarios revealed that severe pedestrian crashes particularly occur in the following conditions:

- Pedestrian crash on a urban 50 km/h road (1355 of 1355 cases);
- Pedestrian crash on an urban 30 km/h road (280 of 368 cases);
- Pedestrian crash on a rural 80 km/h road (142 of 239 cases).

Table 9: Crash scenarios and injured body regions for the Dutch pedestrian data (BRON-DHD).

Cluster nr.	**1**	**2**	**3**	
N	1355	368	239	
Road type	Urban 1355/1355 = 100.0%	Urban 319/368 = 86.7%	Rural 239/239 = 100.0%	
Speed limit	50 km/h 1355/1355 = 100.0%	30 km/h 282/368 = 76.6%	80 km/h 142/239 = 59.4%	
Injury type				**Total**
Head	617 45.5%	137 37.2%	118 49.4%	872 44.4%
Thorax	115 8.5%	24 6.5%	17 7.1%	156 8.0%
Abdomen and pelvic contents	28 2.1%	9 2.4%	8 3.3%	45 2.3%
Spine	11 0.8%	4 1.1%	5 2.1%	20 1.0%
Upper extremities	17 1.3%	5 1.4%	5 2.1%	27 1.4%
Lower extremities	513 37.9%	174 47.3%	74 31.0%	761 38.8%
Multiple regions	54 4.0%	15 4.1%	12 5.0%	81 4.1%

Injury factors

For the pedestrian victims we first of all see that the head injuries are generally the most common type of injury (44%), closely followed by injuries to the lower extremities (38.8%), and then – but much less frequent - by injuries to the thorax (8%; see also Figure 9).

The Chi-square test for the cross-table of injury type by cluster number is significant (Chi-square = 24.900, df = 12, $p < 0.05$), indicating that for pedestrians there is a significant relationship between the variables injury type and cluster number. When inspecting the injury types in the three separate clusters, we see the following pattern:

- Injuries to the head are relatively larger in crashes on roads with higher speed limits (>30 km/h);
- Injuries to the lower extremities on the other hand are relatively larger in crashes on 30 km/h roads.

Sweden

Crash characteristics

The dataset comprises 1,034 severely injured pedestrians. Gender is fairly evenly distributed with 52% female and 48% male (Figure 2). There are 3 distinct peaks in the age distribution; around 20 years, 60 years and 80 years (Figure 3).

Pedestrian impacts with cars form the majority of cases (72%). The next largest share is when pedestrian was hit by a large vehicle, 18% (Figure 4). As expected, the proportion of crashes with two road users (pedestrian + crash opponent) is 90%.

Looking at the road type, 86% of the crashes resulting in a MAIS3+ pedestrian casualty occur in urban areas (the same as for cyclists; Figure 5). The crash occurred most frequently on a street section, 67% of cases, and at an intersection 24% of the time (Figure 6).

There is clearly a higher proportion of crashes occurring in November and December than other months of the year (Figure 7). There is also a clear rise in the crashes after mid-day, with the greatest proportion being between 3 and 6 pm (Figure 8).

Crash scenarios

A first TwoStep cluster analysis was undertaken with the nominal variables Urban Number_Road_Users Crash_opponent Location_junction Hour Month and Sex and the continuous variable Age, a total of 8 input variables. This resulted in a 3 cluster solution with an AIC of 16831.16 and a cluster quality labelled as poor. The variables Crash_opponent, and sex have a predictor importance > 0.5.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, crash_opponent and sex. This also produced a 3 cluster solution with an improved AIC of 1079.62 and a cluster quality labelled as Good. In this solution crash_opponet has predictor importance 1 and sex has a value of 0.75. The 3 clusters are described in table X along with the injury type distribution for each scenario. The total column in the injury type section refers to the injury distribution for all MAIS3+ pedestrians irrespective of cluster membership.

Cluster analysis resulted in 3 scenarios for the MAIS3+ pedestrians based upon the input variables crash_opponent and gender (those with sufficient predictor values). These are described below by the most frequently occurring value of each variable within each cluster (see also Table 10). The proportion of cluster members with the exact combination of these most frequent values is also given.

- Female pedestrians in a collision with a car (379 of 379 cases);
- Male pedestrians in a collision with a car (363 of 363 cases);
- Female pedestrians in collision with a large vehicle (87 of 194 cases)

Table 10: Crash scenarios and injured body regions for the Swedish pedestrian data (STRADA).

Cluster nr.	**1**	**2**	**3**	
N	379 (36.7%)	363 (35.1%)	292 (28.2%)	
Crash Opponent	Car (100%)	Car (100%)	Large Vehicle (63.0%)	
Gender	Female (100%)	Male (100%)	Female (53.4%)	
Injury type				**Total**
Head	23.2%	25.3%	31.2%	26.3%
Thorax	11.9%	13.5%	18.2%	14.2%
Abdomen and pelvic contents	1.1%	1.7%	1.0%	1.3%
Spine	0.5%	2.2%	2.1%	1.5%
Upper extremities	7.9%	5.0%	8.9%	7.2%
Lower extremities	43.5%	36.6%	26.7%	36.4%
Multiple regions	11.9%	15.7%	12.0%	13.3%

Injury factors

The most common body region that is severely injured in pedestrians in Sweden are the lower extremities (36%) and the head (26%). Also thorax injuries (14%) and injuries to multiple body regions are common (13%; see also Figure 9).

A chi-square test of association has been performed on the 3 x 7 contingency table generated from cluster number by injury type ($\chi 2$=33.039, *df* =12, p=0.001), however there are some cells with an expected count < 5 and so the result is not valid. Looking at the injury type within cluster, the following appears:

- Lower extremity injuries are most prevalent when the impact object is a car (both male 37% and female 44%)

- Head injuries have the highest proportion in the circumstances where the impact partner is most often a large vehicle.
- The chest injury type rate is also higher in the scenario where a pedestrian is most of the times hit by a large vehicle, compared with impacts with cars.
- Multiple injury type is most common, almost 16%, for the male pedestrians in a collision with a car.

IGLAD database

Crash characteristics

Of the 49 MAIS3+ pedestrians in the iGAD database, two third male and one third female pedestrians are severely injured in a road crash (see Figure 2). The largest numbers of injured pedestrians are among the younger elderly (55-64) (see Figure 3).

In 84% of the pedestrian crashes the first crash opponent is a car and in 10% it was a heavy vehicle. In 90% of the pedestrian crashes one other road user is involved (see Figure 4). Most of the crashes can be described by a manoeuvre (of the opponent vehicle) while going ahead (and crossing pedestrian). In the majority of cases inadequate information acquisition contributed to the crash.

Most pedestrian crashes leading to severe injury occur in urban areas (86%; see Figure 5) and on dry road surface (73%). Nearly 70% of the crashes occurred in daytime, mainly during commuter times in the morning and the (early) afternoon (see Figure 8).

Crash scenarios

A first TwoStep Cluster analysis of the pedestrian data with 49 cases and the above stated variables yields a 2 cluster solution with an AIC of 1164 and a cluster quality labelled as fair (0.3).

The second round with the variables DayNight, CrashOpponent, Manoeuvre, Gender, RoadType, CrashFactor, AgeGroup yields a 4 cluster solution with an AIC of 608 and a cluster quality labelled as good (0.5).

The third analysis yields a 4 cluster solution with an AIC of 247 and a cluster quality labelled as good (0.56) with the variables (predictor importances) are RoadType (1.0), DayNight (0.78), Manoeuvre (0.7), CrashFactor (0.05). The clusters that were found could best be summarised as follows (see Table 11):

- Daytime crashes of pedestrians in urban areas during a straight forward manoeuvre and in a situation with inadequate information acquisition (19 of 25)
- Nighttime crashes of pedestrians in urban areas during a straight forward manoeuvre and in a situation with inadequate information acquisition (8 of 9)
- Daytime crashes of pedestrians in urban areas during overtaking a stationary vehicle and in a situation with inadequate information acquisition (2 of 8)
- Daytime crashes of pedestrians in rural areas during a straight forward manoeuvre (4 of 7) and in a situation with inadequate information acquisition (1 of 7)

Injury factors

Table 11 shows the frequencies of the MAIS3+ injured body region per scenario. For the pedestrian casualties injuries of the lower extremities (41%) are most common followed by the thorax injuries (39%) and head injuries (22%) and multiple severe injuries (18%; see also Figure 9).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=14.869 df=15, p<0.461), indicating that for pedestrians there is no significant relationship between the injury type and the crash scenario.

Table 11: Crash scenarios and injured body regions for the IGLAD pedestrian data (IGLAD).

Cluster nr.	4	1	2	3	
N	25	9	8	7	
Road Type	Urban 25/25 =100%	Urban 9/9 =100%	Urban 8/8 =100%	Rural 4/7 =57.1%	
Day Night	Daytime 25/25 =100%	Nighttime 9/9 =100%	Daytime 5/8 =62.5%	Daytime 4/7 =57.1%	
Manoeuvre	Going ahead other 25/25 =100%	Going ahead other 9/9 =100%	Overtaking stationary vehicle 2/8 =25%	Going ahead other 7/7 =100%	
Crash Factor	Inadequate information acquisition 19/25 =76%	Inadequate information acquisition 8 /9 =88.9%	Inadequate information acquisition 7/8 =87.5%	Inadequate information acquisition 4/7 =57.1%	
Injury Type					**Total**
Head, Face, Neck	8/25 =32%	1/9 =11.1%	1/8 =12.5%	1/7 =14.3%	11/49 =22.4%
Thorax	4/25 =16%	0/9 =0%	1/8 =12.5%	0/7 =0%	5/49 =10.2%
Abdomen and pelvic cont.s	0/25 =0%	0/9 =0%	0/8 =0%	0/7 =0%	0/49 =0%
Spine	1/25 =4%	0/9 =0%	1/8 =12.5%	0/7 =0%	2/49 =4.1%
Upper extr.	1/25 =4%	0/9 =0%	0/8 =0%	1/7 =14.3%	2/49 =4.1%
Lower extr.	6/25 =24%	7/9 =77.8%	4/8 =50%	3/7 =42.9%	20/49 =40.8%
Whole surf. + mult. Regions	5/25 =20%	1/9 =11.1%	1/8 =12.5%	2/7 =28.6%	9/49 =18.4%

Figures

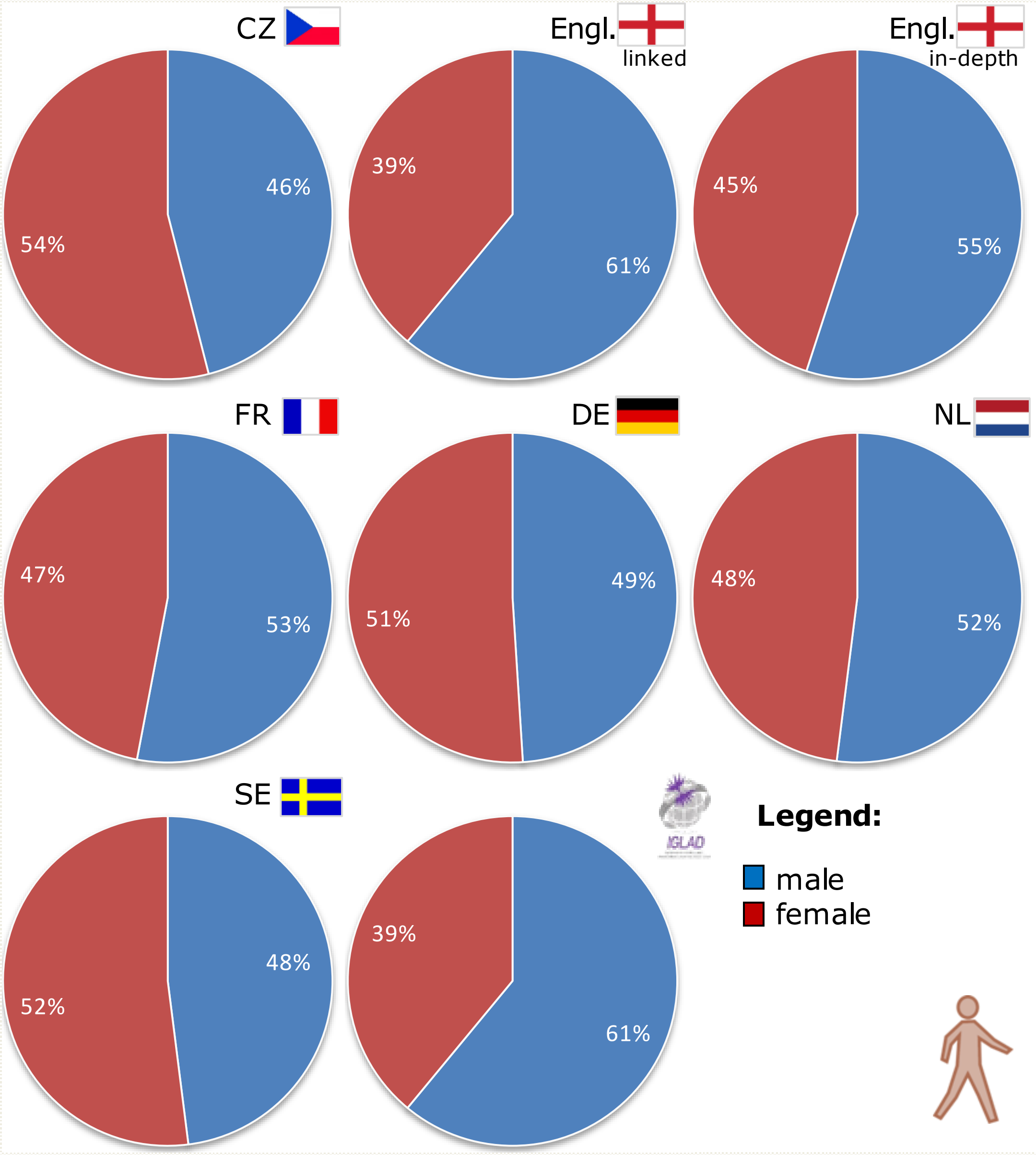

Figure 2: Gender of severely injured pedestrians in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

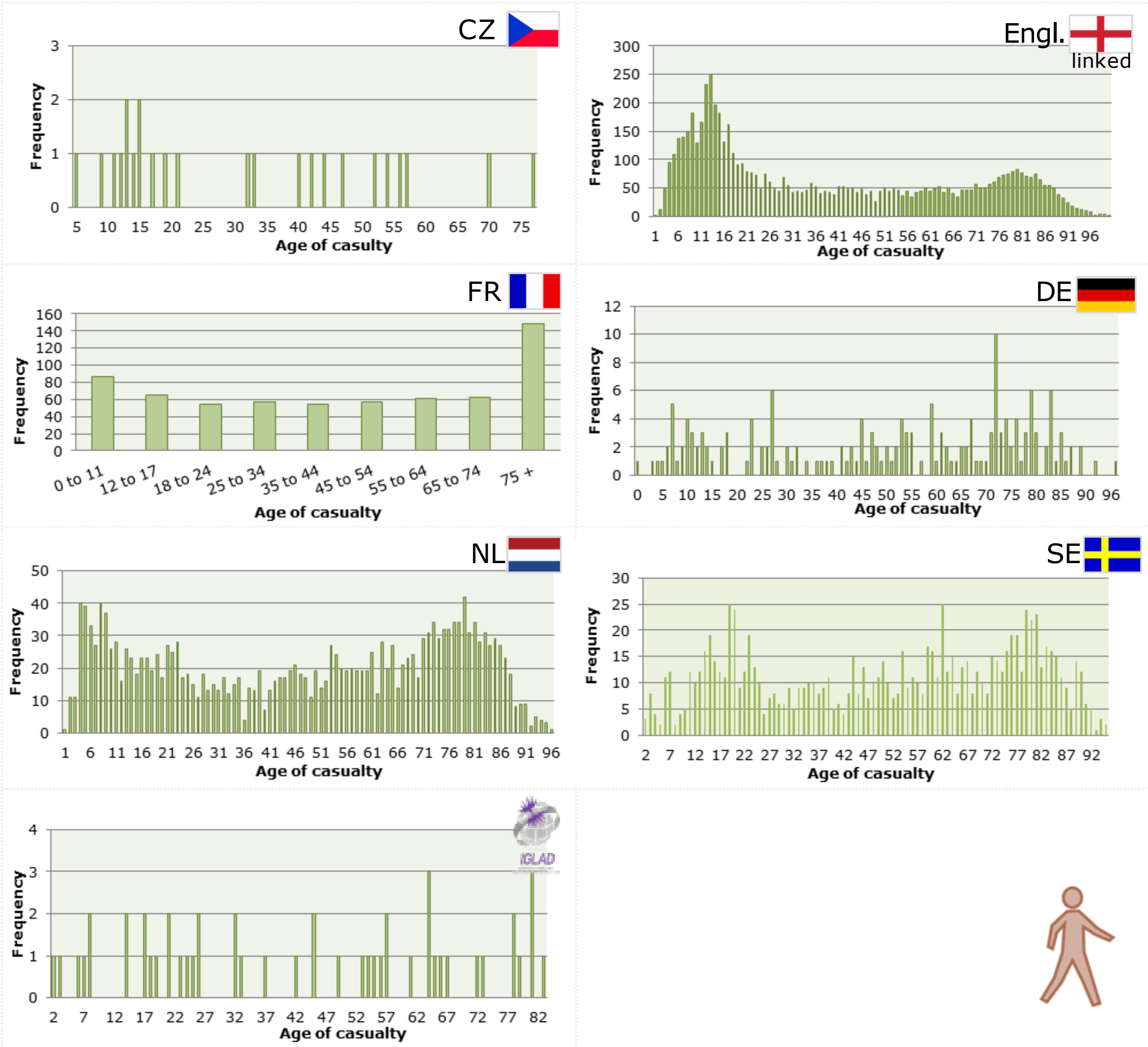

Figure 3: Age of severely injured pedestrians in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

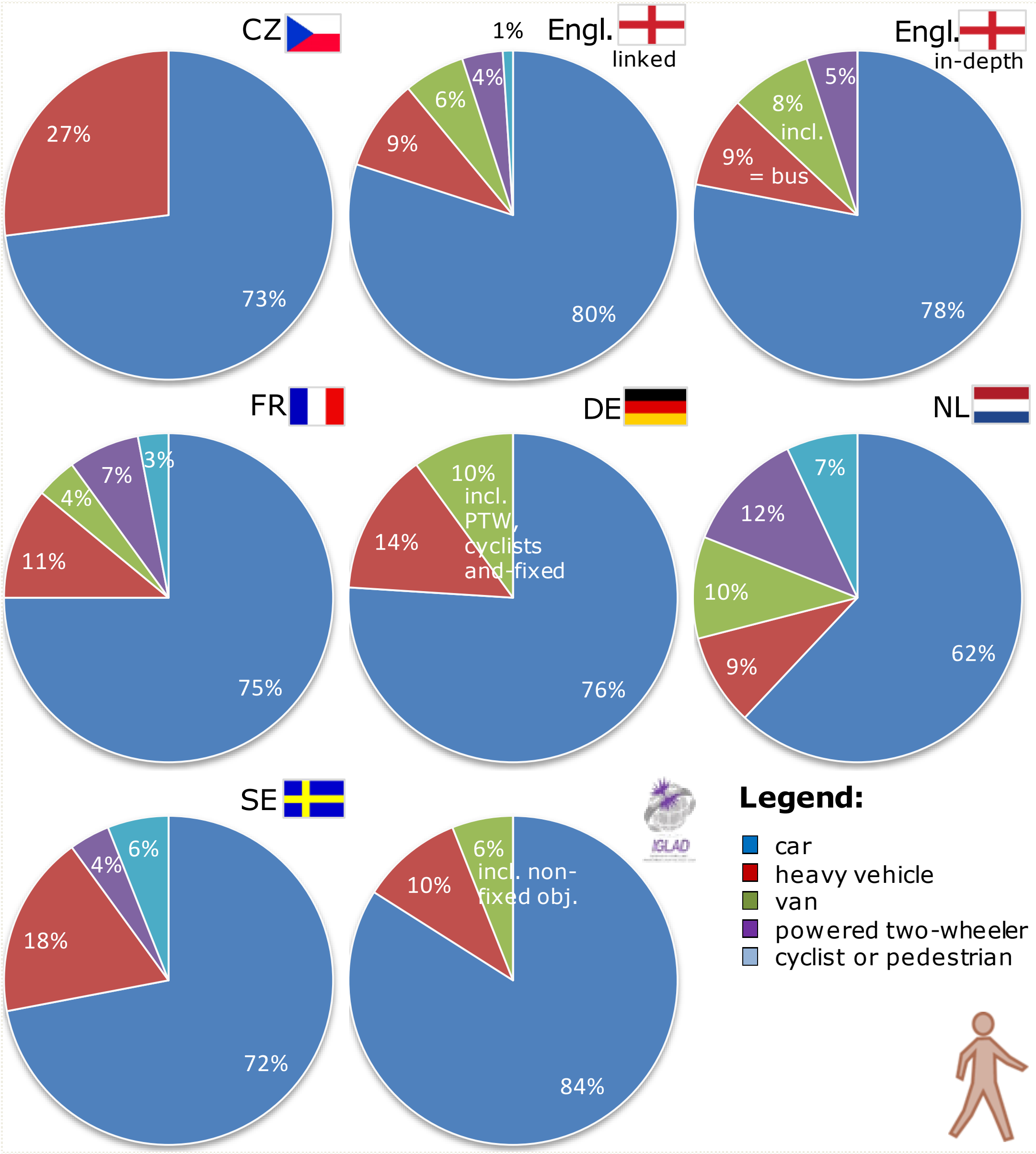

Figure 4: Most important crash opponents in crashes that lead to severely injured pedestrians in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

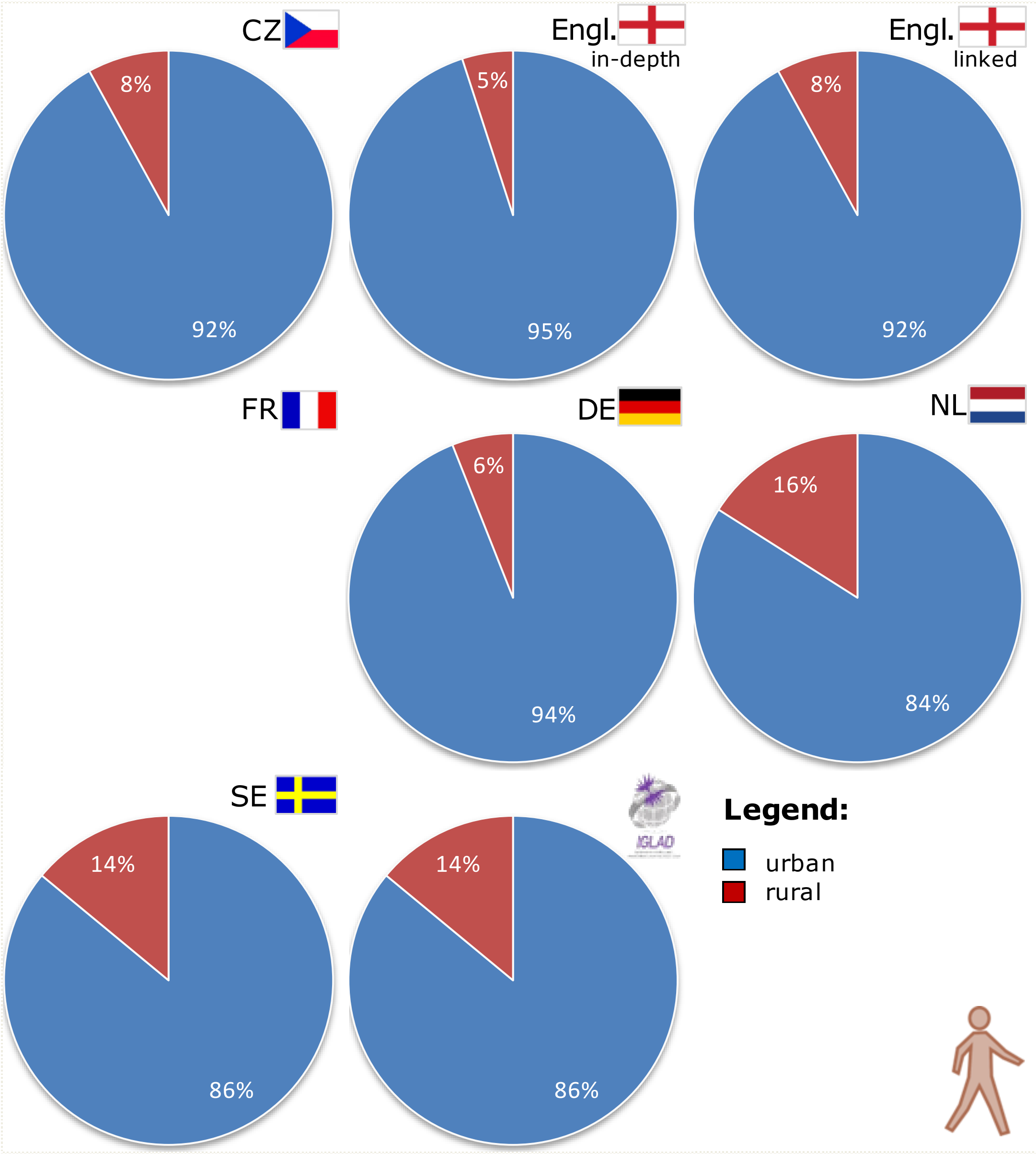

Figure 5: Main road types where crashes occur in which pedestrians get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

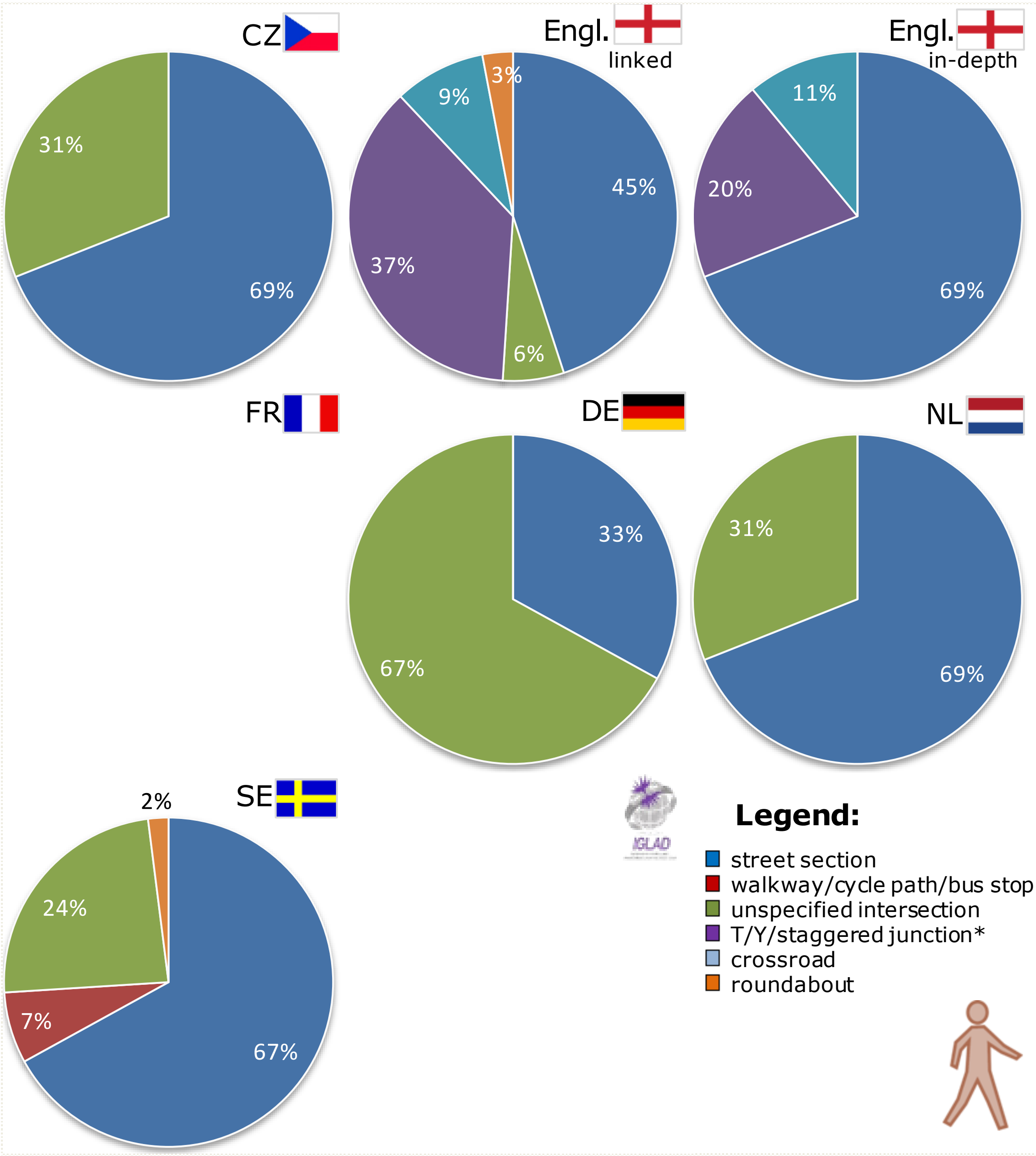

Figure 6: Road configuration where crashes occur in which pedestrians get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), and England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD) and Sweden (STRADA data). *A staggered junction is a junction were the side roads are not opposite to each other.

Figure 7: Months in which pedestrians get severely injured the in the Czech Republic (CziDAS data), England (linked: STATS19-HES), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA data).

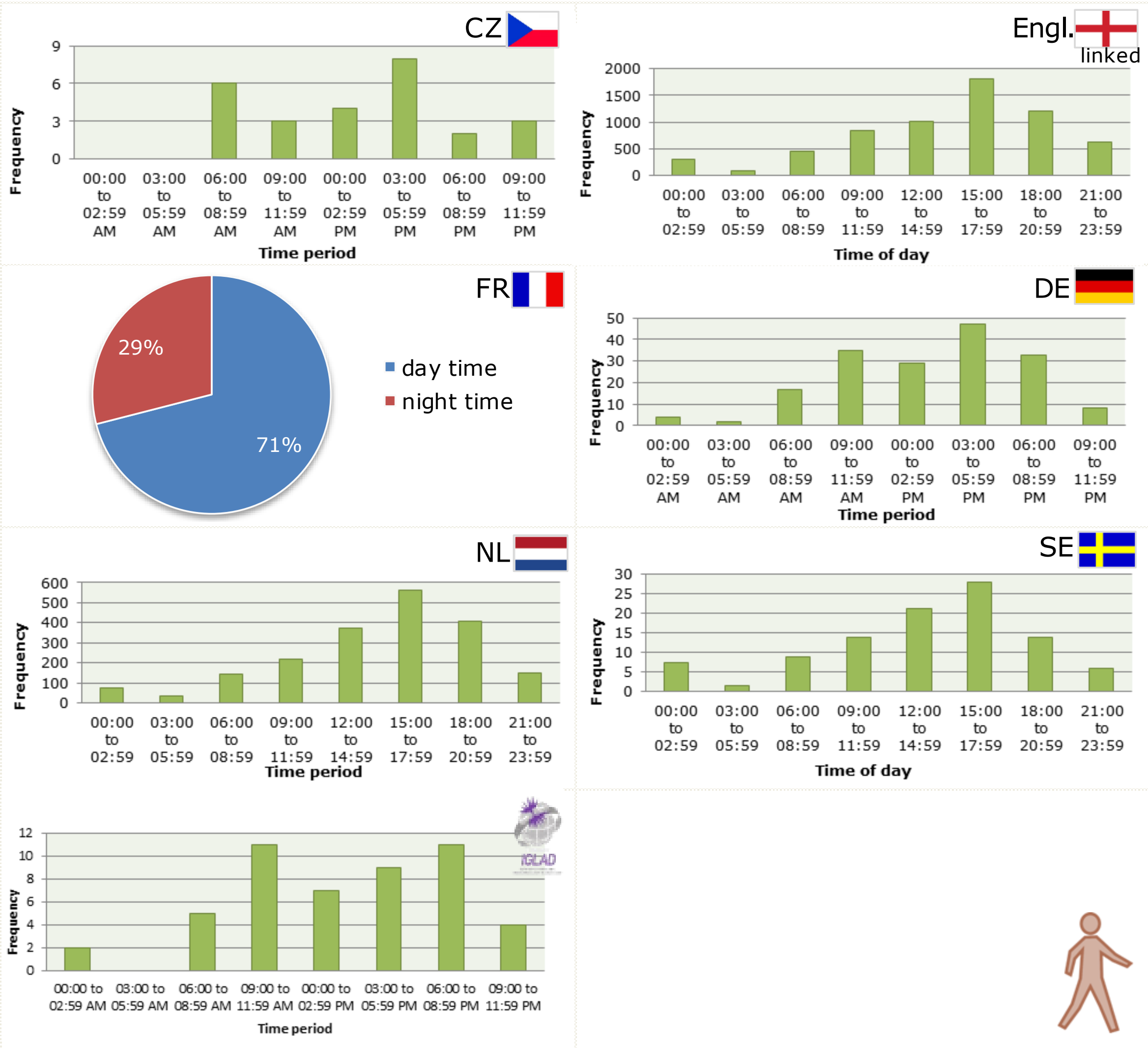

Figure 8: Time period of the day during which pedestrians get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

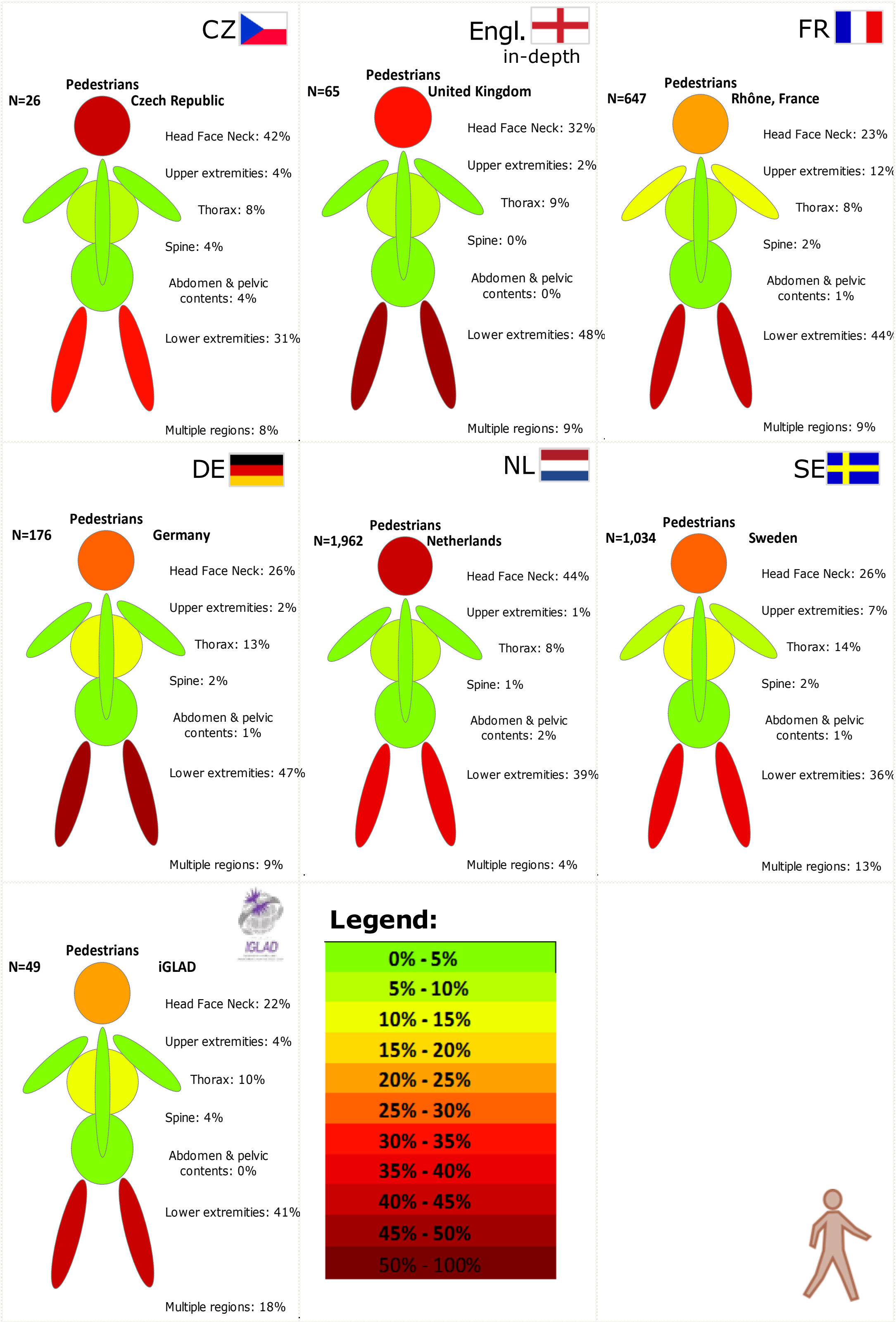

Figure 9: Overview of injured body regions of MAIS3+ pedestrians in the Czech Republic (CziDAS data), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

Bicyclists

Czech Republic

Crash characteristics

The CzIDAS cyclist data include 7 seriously injured casualties. Note the weak explanatory power due to the low number of cases.

Nearly equally shares of men and women were seriously injured as a cyclist (see Figure 10) most of them in the age 55+ (see Figure 11). In half of the crashes a car or truck was the first crash opponent (see Figure 12) and in 72% (5 cases) 2 road users were involved. All the crashes occurred in dry conditions mostly on road sections (Figure 14) and in urban areas (see Figure 13). The majority of the crashes happened in the summer months (see Figure 15) during daytime (see Figure 16).

Crash scenarios

Due to the low number of cases (n = 7), no cluster analysis was performed.

Injury factors

The most common injuries for seriously injured cyclists in the CzIDAS data are head injuries (3/7; see Table 12 and Figure 17), which occurred only in urban area accidents with a speed limit of 50 kph.

Table 12: Injured body regions for the Czech Republic bicyclist data (CziDAS).

Injury type	Total
Head, Face, Neck	3/7= 42.9%
Thorax	1/7 = 14.3%
Lower extr.	2/7= 28.6%
Whole surf. + mult. Regions	1/7= 14.3%

England

Crash characteristics

STATS19-HES - The linked STAST19-HES dataset comprises 2,012 severely injured cyclists. There are considerably more male MAIS3+ cyclists (83%) than female (17%) (Figure 10). There is a high proportion of children among the casualties (7 to 15 years; Figure 11). Pillion cyclists (two riders on a bike) are not common in this dataset, less than 1%.

The most common crash opponent is a car (68%). Combining impacts with a fixed object, a pedestrian and those with no impact partner shows impacts with no road user opponent to comprise a further 17% of the total (Figure 12). The vast majority of crashes involved two road users, defined as the number of vehicles in the crash. The proportion of ‘no impact partner’ crashes is higher than the proportion of one road user crashes since two vehicles can be involved in an crash without making impact (non-cyclist making avoidance manoeuvres etc).

For the cyclist data, just over half of the impacts are frontal, a third to the side and 10% to the rear. In over 80% of the cases, a forward manoeuvre without turning or overtaking precedes the crash.

Road type (Urban/Rural/Motorway) has been derived from the road classification and speed limit in this dataset and therefore the distribution is approximate. The indication is that the vast majority (84%) of the crashes with MAIS3+ cyclists occur in an urban environment (Figure 13). Considering any junction layout, almost 40% of the crashes occur at T/Y or staggered junctions with the next most common scenario being not at a junction, i.e. on a road section (Figure 14). The road surface was dry in almost 80% of cases.

Considering the date and time of the crash, there is a rise in the number of crashes as the weather improves into spring and this then peaks across summer (Figure 15). There is a higher frequency of crashes during mid to late afternoon (Figure 16).

Most common crash factors are:

- Failure to look properly (55%)
- Careless / reckless behaviour (19%)
- Failure to judge path / speed of other road user (19%)
- Loss of control (12%)
- Poor turn / manoeuvre (12%)

RAIDS/OTS - The combined RAIDS/OTS dataset comprises 18 severely injured car occupants of which 94% are male and just 6% (one) female (Figure 10). Age data is only available for the RAIDS data (n=2). All of the cyclists were 'drivers'. In respect of seating position, 63% are drivers, 21% front seat passengers and 16% seated in the rear.

The most common crash opponent is another car (78%) and the number of road users shows 88% of cases with two road users involved. Considering the location of the impact on the bike; the majority of cyclists resulting in MAIS3+ injury have an impact to the side (56%) followed by the front (33%). In 83% of the cases, cyclists was moving forward without turning or overtaking and was turning in the remaining 17%.

Two thirds of the crashes occur in urban areas and one third in rural (Figure 13). The speed limit is 40mile/h or less in 83% of cases. Over half of the crash occurred at a T / Y or staggered junction (56%) and 33% were only a simple road section (Figure 14). The road surface was dry in 78% of cases.

Month and time are not available in England in-depth databases for privacy protection and so daytime / night-time has been used as a substitute. 83% of the severe injury crashes occur during the daytime, with 17% at night time.

The most common factors that were found to play a role in the crash were failure to look properly (39%), careless/reckless behaviour (28%) and vision affected (22%).

Crash scenarios

STATS19-HES - A first TwoStep Cluster analysis of the Cyclist data with 2,012 cases was undertaken using the nominal variables Casualtyrole Month, Time, opponent, CrashType, Gender, Junction, Surface, Manoeuvre ActiveRoadUsers and SpeedLimit and the interval variable Age, a total of 12 input variables. This resulted in a 5 cluster solution with an AIC of 260780.4 and a cluster quality labelled as Poor.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, SpeedLimit and Surface only. A 3 cluster solution was returned with an AIC of 3563.425 and a cluster quality labelled as Good. In this solution the variables SpeedLimit and Surface both have a predictor importance = 1.0. The 3 clusters are described in Table 13 in order of cluster size. The clusters could best be summarised as:

- Bicyclists crashes at a road with a 30 mile/h speed limit under dry conditions (1208 of 1208 cases);
- Bicyclist crashes at a 30 mile/h road in wet conditions (282 of 423 cases);
- Bicyclists crashes at a 60 mile/h speed limit road in in dry conditions (192 of 381 cases).

The first two are likely to be more urban whilst the third more rural.

Failure to look properly is the most reported factor, over 50% in all clusters. Failure to judge the path or speed of another road user, loss of control and careless/reckless behaviour also feature in all clusters. Loss of control features more in the higher speed limit cluster. Poor turn or manoeuvre are reported in the 5 most frequent factors for the dry conditions clusters whereas the road condition and the cyclist clothing are reported when the road surface was wet.

Table 13: Crash scenarios for England bicyclist data (STATS19-HES).

Cluster nr.	**1**	**2**	**3**
N	1208	423	381
Speed Limit	30 mile/h (100%)	30 mile/h (70%)	60 mile/h (50%)
Surface	Dry (100%)	Wet (95%)	Dry (100%)

RAIDS/OTS - A first TwoStep Cluster analysis of the cyclist data with 18 cases was undertaken using the nominal variables DayNight, opponent, Gender, Junction, Surface, Manoeuvre, ActiveRoadUsers, roadtype, impact loaction and speed a total of 10 input variables. This resulted in a 2 cluster solution with an AIC of 237.592 and a cluster quality labelled as Fair. Roadtype, DayNight and Manoeuvre had predictor importance > 0.5 and these were entered into a further cluster analysis.

The second analysis using, the 3 input variables identified in the first, resulted in 3 cluster solution with AIC 30.14 labelled good, however only roadtype and manoeuvre have importance > 0.5. These 2 variables were included in a further cluster analysis.

The 2 input variables roadtype and manoeuvre produced a 3 cluster solution with AIC 15.82 with both manoeuvre having importance 1.0 and roadtype 0.83. The clusters are described as (see Table 14):

- Cyclists going ahead in an urban area (11 of 11 cases)
- Cyclist going ahead in rural area (4 of 4 cases)
- Cyclist turning in rural area (2 of 3 cases)

Injury factors

The Table shows the injury distribution by body region for MAIS3+ bicyclists in the RAIDS/OTS data. The lower extremities have the highest proportion (39%) in severely injured bicyclists, followed by the head (22% each) and thorax (17%; see also Figure 17).

As the RAIDS/OTS data contained too small number of cases to analyse them in a cluster analysis, the injury types could not be linked to crash scenarios. However there are some interesting qualitative observations:

- Chest injury type, (most severe of all injuries) only occurs in the urban areas and they also only occur at junction crashes.
- Half of the urban impacts resulted in the most severe injury to the lower extremity compared to 1/6 in the rural area.
- When the impact location was to the font/rear, the most severely injured body region tends to be the lower extremity (5/8), but when it is a side impact head and chest injury type feature more.

Table 14: Crash scenarios and injured body regions for England bicyclist data (RIADS & OTS).

Cluster nr.	**1**	**2**	**3**	
N	11	4	3	
Road type	Urban (100)%	Rural (100%)	Rural (67%)	
Manoeuvre	Going ahead (100%)	Going ahead (100%)	Turning (100%)	
Injury type				**Total**
Head, Face, Neck	NA	NA	NA	22.2%
Thorax	NA	NA	NA	16.7%
Abdomen and pelvic cont.s	NA	NA	NA	0.0%
Spine	NA	NA	NA	11.1%
Upper extr.	NA	NA	NA	5.6%
Lower extr.	NA	NA	NA	38.9%
Whole surf. + mult. regions	NA	NA	NA	5.6%

France, Rhône region

Crash characteristics

The bicycle data of the Rhône area contained 594 cases. The data showed that particularly male bicyclists are severely injured (78%; see Figure 10). Middle aged and younger elderly people (45 to 64 years) are dominating the number of serious pedestrian injuries (see Figure 11). By far most bicyclists get severely injured in an crash without any other road user (64%). Cars are a second most important crash opponent (19%; see Figure 12). In the Rhône area, 28% of the bicyclists wear a helmet. Most of the severe cycling crashes (ca. 75%) occur during daytime (see Figure 16).

Crash scenarios

A first TwoStep Cluster analysis of the nominal variables DayNight, FirstCrashOpponent, DemograpyAgeGroup, DemographyGender and Helmet use yields a 2 cluster solution with an AIC of 5109.749 and a cluster quality labelled as Fair. In this solution the variable Helmet use has a predictor importance of 1.0, while the predictor importance of the remaining four variables is almost zero. This means that the variable Helmet use completely dominates the cluster solution, swamping out all the other variables.

A second TwoStep Cluster analysis without variable Helmet use yields a 4 cluster solution with an AIC of 3646.925 and a cluster quality labelled as Fair. In this solution the variables DayNight, FirstCrashOpponent, DemograpyAgeGroup and DemographyGender have a predictor importance of 1.00, 0.73, 0.40 and 0.10, respectively. So we also dropped variables DemograpyAgeGroup and DemographyGender from the cluster analysis. This resulted in a solution with 4 clusters with an AIC of 565.274 and a cluster quality labelled as Good. The variables FirstCrashOpponent and DayNight in this solution have a predictor importance of 1.0 and 0.67, respectively.

The clusters that were found can best be described as follows (see Table 15):

- Bicyclist gets severely injured in an crash with no crash opponent during daylight (332 of 332 cases);
- Bicyclist gets severely injured in an crash with no crash opponent during night time (50 of 92 cases);
- Bicyclist is hit by a car during daylight (90 of 90 cases);
- Bicyclist that hits a fixed object during daylight (35 of 80 cases).

Table 15: Crash scenarios and injured body regions for the Rhône region bicyclist data (Rhône road trauma registry, France, IFSTTAR).

Cluster nr.	**4**	**1**	**2**	**3**	
N	332	92	90	80	
First crash opponent	No crash opponent 332/332 = 100.0%	No crash opponent 50/92 = 54.3%	Car 90/90 = 100.0%	Fixed object 35/80 = 43.8%	
Time of day	Day 332/332 = 100.0%	Night 92/92 = 100.0%	Day 90/90 = 100.0%	Day 80/80 = 100.0%	
Injury type					**Total**
Head+Face+Ñeck	47 15.5%	22 26.8%	22 26.8%	21 31.8%	112 21.0%
Thorax	17 5.6%	5 6.1%	15 18.3%	6 9.1%	43 8.1%
Upper extremities	139 45.7%	37 45.1%	19 23.2%	21 31.8%	216 40.4%
Lower extremities	101 33.2%	18 22.0%	26 31.7%	18 27.3%	163 30.5%

Injury factors

The lower part of the Table displays the frequencies in the cross-table of injury type by cluster number. The most common injury types of severely injured bicyclists in the Rhône area are injuries to the upper extremities (40,4%), followed by the lower extremities (30,5%) and injuries to the head, face and neck (21%; see Figure 17).

Since there are only two Face and two Neck injuries in this data set we added these four cases to the Head injuries. Moreover, there are only 14 injuries of the Abdomen and pelvic contents in this data set, only 19 Spine injuries, and only 27 multiple region injuries. We therefore dropped these injury types from the analysis because they result in 12 cells in the cross-table with expected frequencies smaller than 5. The Chi-square test for the cross-table of the remaining four categories of injury type by cluster number is very significant (Chi-square = 36.996, df = 9, p < 0.0001), indicating that for cyclists there is a significant relationship between the variables injury type and cluster number. The most important differences are:

- Injuries to the upper extremities are most common in crashes where a bicyclists get injured without a crash opponent and also common in crashes where the bicyclists hits a fixed object.
- Injuries to the lower extremities are most common in the crash scenarios where a bicyclists gets injured without impact with a crash opponent during daytime and when hit by a car.
- Injuries to the head, face and neck are most common in crashes where the bicyclists hit a fixed object (equal injury share as injuries to the upper extremities in this scenario) and also quite common when hit by a car or in an crash without crash opponent during nighttime.

Germany

Crash characteristics

In total 245 MAIS3+ bicyclist casualties were found in GIDAS and included in the analysis. About twice as much males than females got severely injured in a bicycle crash (see Figure 10). The largest numbers of injured bicyclists are found for the mid-agers starting at 35 and the young seniors (see Figure 11).

In about half of the bicycle crashes the first crash opponent is a car (111 cases). About equally often a single crash or a crash with a fixed object occur for cyclists. 8% of the crashes occur with heavy vehicles (bus, truck, rail, agricultural vehicles). In most bicycle crashes one other road user is involved, but in about 23% the crash is a single crash (see Figure 12).

Most bicycle crashes leading to severe injury occur on urban 50 or 70 km/h roads (see Figure 13). About 60% of the bicycle crashes resulting in severe injury occur at junctions (see Figure 14) and about 80% on dry road surface. 38% of the cyclists become injured in an turning crash, 58% in an crash that is characterized as going ahead round curve/other which includes also crashes of a car going ahead and a crossing cyclist. The majority of crash occur at no special location, 18 % at VRU crossings and 90% of the cases are found in not physically divided two-way traffic.

Regarding the crash factor in 75% of the cases inadequate information acquisition of one of the participants contributed to the crash and in 9 % it was speeding (probably of the opponent) and red light running (7%). Regarding the injury factors 95 % of the severely injured cyclists did not wear a helmet and the other 5% did not use the helmet properly.

During spring and summer (May and August), the highest number of bicyclists get severely injured (see Figure 15). Most crashes occur in the afternoon between 3:00 PM and 6:00 PM (see Figure 16).

Crash scenarios
A first TwoStep Cluster analysis of the cyclist data with 245 cases and the above stated variables yields a 5 cluster solution with an AIC of 6287 and a cluster quality labelled as poor (0.1). In this solution only the variables JunctionType, Location, CrashFactor, Manoevre, Gender, CrashOpponent, Time, have a predictor importance larger than 0.2.

A second TwoStep Cluster analysis with these yields a 4 cluster solution with an AIC of 3887 and a cluster quality labelled as fair (0.2). This solution suggests the removal of the variables Gender, Time, Manoevre, JunctionType.

A third TwoStep Cluster analysis yields a 4 cluster solution with an AIC of 925 and a cluster quality labelled good (0.6) with the variables (predictor importance) Location (1.0), CrashFactor (0.77), and CrashOpponent (0.67). The resulting clusters are described in Table 16 and can best be summarised as:

- Bicyclist in a single crash in a situation with inadequate information acquisition and no specific infrastructural situation (56 of 81 cases);
- Bicyclist against car in a situation with inadequate information acquisition and no specific infrastructural situation (63 of 65 cases);
- Bicyclist against a car, at a VRU crossing facility in a situation with inadequate information acquisition (10 of 61 cases);
- Bicyclist against a car in a situation where the car was speeding (6 of 38 cases).

Table 16: Crash scenarios and injured body regions for the German bicyclist data (GIDAS).

Cluster nr.	**1**	**4**	**2**	**3**	
N	81	65	61	38	
Special Situation of Location	No special Location 79/81 =97.5%	No special Location 64/65 =98.5%	VRU crossing facility 43/61 =70.5%	No special Location 38/38 =100%	
Crash Factor	Inadequate information acquisition 74/81 =91.4%	Inadequate information acquisition 65/65 =100%	Inadequate information acquisition 41/61 =67.2%	Speeding (of the car) 21/38 =55.3%	
Crash opponent	No Crash opponent 62/81 =76.5%	Car 64/65 =98.5%	Car 31/61 =50.8%	Car 16/38 =42.1%	
Injury type					**Total**
Head, Face, Neck	35/81 =43.2%	16/65 =24.6%	19/61 =31.1%	18/38 =47.4%	88/245 =35.9%
Thorax	7/81 =8.6%	15/65 =23.1%	15/61 =24.6%	7/38 =18.4%	44/245 =18%
Abdomen and pelvic cont.s	2/81 =2.5%	0/65 =0%	0/61 =0%	0/38 =0%	2/245 =0.8%
Spine	3/81 =3.7%	4/65 =6.2%	1/61 =1.6%	1/38 =2.6%	9/245 =3.7%
Upper extr.	1/81 =1.2%	2/65 =3.1%	1/61 =1.6%	1/38 =5.3%	6/245 =2.4%
Lower extr.	29/81 =35.8%	22/65 =33.8%	20/61 =32.8%	9/38 =23.7%	80/245 =32.7%
Whole surf. + mult. Regions	4/81 =4.9%	6/65 =9.2%	5/61 =8.2%	1/38 =2.6%	16/245 =6.5%

Injury factors

Table 16 shows the most common crash scenarios including the frequencies of the body regions that were MAIS3+ injured per scenario. For the cyclist casualties injuries to the head are most common (36%) followed by injuries to the lower extremities (33%) and injuries of the thorax (18%; see Figure 17).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=22.963 df=18, p<0.192), indicating that for cyclists there is no significant relationship between the injury type and the crash scenario.
Having a closer look into the injury distribution within the 4 scenarios shows: single vehicle crashes are characterized by head injuries (43%) and injuries of the lower extremities (38%). Most casualties are mid-agers (25% 45-54 years) or seniors (22% 65-74 years).

For the 245 cyclists casualties 1333 single injuries (mean of 6 injuries per casualty) were recorded of which 382 injuries (mean of 2 severe injuries per casualty) have a severity of AIS08=3 or larger. The majority of fractures were caused by the contact with the opponent car front (56/179=65.9%) or the contact with the road and environmental features (e.g. the curb) (118/179=65.9%). These causes are also the main causes for all injury types, that is 220/382=57.6% of all injuries were caused by hitting the road, 136/382=35.6% were caused by the impact to the opponent which was in most cases a car.

Netherlands

Crash characteristics

BRON-LMR - The analysis was performed on the BRON-DHD linked police data of 6,902 cases in which a bicyclist was severely injured. Somewhat more males than females get severely injured in bicycle crashes (see Figure 10). The largest numbers of injured bicyclists are among adolescents (12 to 17 years of age), middle aged and elderly people (50 to 80 years; Figure 11).

Somewhat more than half of the bicycle crashes are with a car (3,776 cases). Other common crash opponents are bicyclists, powered two wheelers, vans and trucks. Only 7% of the crashes that are registered by the police are single vehicle crashes (see Figure 12), but from the DHD traffic register we know that this share is much larger. In most bicycle crashes in the BRON-DHD database one other road user is involved. About two third of the crashes are a side-impact crash and also head-on collisions are quite common.

Most bicycle crashes leading to severe injury occur on urban 50 km/h roads (see Figure 13). About 60% of the bicycle crashes resulting in severe injury occur at junctions (see Figure 14) and about 80% on dry road surface.

During spring time and early summer (March to June) and September, the highest number of bicyclists get severely injured (see Figure 15). Most crashes occur in the afternoon between 3:00 PM and 6:00 PM (see Figure 16).

DHD traffic register - For the bicyclists, also the DHD hospital discharge was analysed since it is known that for this traffic mode there is a bias in the BRON linked to DHD statistics towards crashes including motorised vehicles, leaving single bicycle crashes largely underreported. The DHD traffic register contained 26,335 MAIS3+ injured bicyclists that were analysed.

Analysis of this data shows a nearly equal share of males and females (52% versus 48%). The DHD traffic register data show particularly large numbers of elderly bicyclists (60 years and older). According to the DHD traffic register data, only 16% of the bicyclist crashes involves a motor vehicle (see Figure 12), which means that the majority of the severe bicycle crashes is a single bicycle crash or with a non-motorised vehicle (e.g. pedestrian or another cyclist). Months with larger frequencies of serious injured bicyclists than others are May to September. Most serious bicyclist crashes occur in the afternoon.

Crash scenarios

When performing the TwoStep cluster analyses on the BRON-DHD data and the nominal variables Month, Time, Crash opponent, Crash type, Gender, Road type, Junction, Road surface, and Speed limit and the interval variables Number of active road users and Age yields a 5 cluster solution with an AIC of 157763.703 and a Cluster Quality labelled as Poor. In this solution all the variables have a predictor importance of 1.0 except for Month, Time and Gender.

A second TwoStep Cluster analysis without the latter three variables yields a 2 cluster solution with an AIC of 91786.826 and a Cluster Quality labelled as Fair. In this solution the variables Junction, Crash type, Number of active road users, Road surface and Age have a predictor importance smaller than 0.2.

A third TwoStep Cluster analysis also removing the latter five variables yields a 6 cluster solution with an AIC of 39466.078 and a Cluster Quality also labelled as Fair. In this solution all four remaining variables have a perfect predictor importance of 1.0. These 6 clusters are described in Table 17 in order of cluster size.

The six scenarios that appear to be most common for bicyclists that got severe injuries in the Netherlands can be described as follows (see Table 17):

- Side-impact crash during turning manoeuvre with a car as crash opponent on an urban 50 km/h road (1061 of 1682 cases);
- Head-on collision with a car on an urban 50km/h road (409 of 1424 cases);
- Side-impact crash during turning manoeuvre, with a car as crash opponent on a rural 80 km/h road (213 of 1328 cases);
- Side-impact crash during turning manoeuvre with another bicycle as crash opponent on an urban 50 km/h road (157 of 1114 cases);
- Side-impact crash during turning manoeuvre, with a car as crash opponent on an urban 30 km/h road (119 of 883 cases);
- Single vehicle-crash on an urban 50km/h road (162 of 471 cases).

Table 17: Crash scenarios and injured body regions for the Dutch bicyclist data (BRON-DHD).

Cluster nr.	**4**	**5**	**1**	**6**	**2**	**3**	
N	1682	1424	1328	1114	883	471	
Crash type	Side-impact collision turning 1061/1682 = 63.1%	Head-on collision 683/1424 = 48.0%	Side-impact collision turning 471/1328 = 35.5%	Side-impact collision turning 651/1114 =58.4%	Side-impact collision turning 281/883 = 31.8%	Single vehicle crash 35one quarter7 1 = 74.5%	
Opponent	Car 1682/1682 = 100.0%	Car 887/1424 = 62.3%	Car 708/1328 = 53.3%	Bicycle 274/1114 = 24.6%	Car 451/883 = 51.1%	No crash opponent 297/471 = 63.1%	
Road type	Urban 1682/1682 = 100.0%	Urban 1424/1424 = 100.0%	Rural 1248/1328 = 94.0.0%	Urban 1114/1114 = 100.0%	Urban 843/883 = 95.5%	Urban 290/471 = 61.6%	
Speed limit	50 km/h 1682/1682 = 100.0%	50 km/h 1424/1424 = 100.0%	80 km/h 794/1328 = 59.8%	50 km/h 1114/1114 = 100.0%	30 km/h 770/883 = 87.2%	50 km/h 299/471 = 63.5%	
Injury type							**Total**
Head, Face, Neck	861 51.2%	758 53.2%	656 49.4%	531 47.7%	477 54.0%	205 43.5%	50.5%
Thorax	190 11.3%	154 10.8%	207 15.6%	108 9.7%	82 9.3%	29 6.2%	11.2%
Abdomen and pelvic cont.s	27 1.6%	13 0.9%	36 2.7%	12 1.1%	16 2.0%	3 0.6%	1.6%
Spine	25 1.5%	19 1.3%	30 2.3%	11 1.0%	7 0.8%	13 2.8%	1.5%
Upper extr.	22 1.3%	26 1.8%	27 2.0%	27 2.4%	17 1.9%	12 2.5%	1.9%
Lower extr.	517 30.7%	424 29.8%	313 23.6%	400 35.9%	264 29.9%	206 43.7%	30.8%
Whole surface+ Mult. regions	40 2.4%	30 2.1%	59 4.4%	25 2.2%	18 2.0%	3 0.6%	2.5%

Injury factors

For the bicyclist victims we first of all see that the head and face injuries are generally the most common type of injury (51%), followed by injuries to the lower extremities (31%), and then by injuries to the thorax (11%; see Figure 17).

The Chi-square test for the cross-table of injury type by scenario is very significant (Chi-square = 177.884, *df* = 30, *p* < 0.001), indicating that for bicycles there is a significant relationship between the injury type and crash scenario.

The most remarkable differences are:

- Head injuries are the most common injury type for all crash scenarios, but somewhat less in single bicycle crashes where hip and pelvis fractures are most dominant.
- Bicyclists sustain more thorax injuries in impacts with a car, and more at roads with a higher speed limit, independent of the manoeuvre that precedes the crash.
- Injuries to the lower extremities are particularly common in single-bicycle crashes and in crashes with another bicycle.

Sweden

Crash characteristics

The dataset comprises 1,044 severely injured cyclists of which 58% are male and 42% female (Figure 10). There are distinct peaks in the age distribution for children around 14 years old, and adults in their mid-fifties (Figure 11). Only 3 of the 1,044 cyclists are coded as being a rear passenger.

Bicycle to car impacts are the most common crash scenario (61%). The next largest share is for the single vehicle crashes (17%; Figure 12). This is supported by the number of road users which shows 16% of cases with just the cyclist involved (81% with 2 road users).

Looking at the road type, 86% of the crashes resulting in a MAIS3+ cyclist occur in urban areas (Figure 13). The crash occurred at an intersection (junction) in 44% of cases, and on a road section 35% of the time. In 17% of the cases the data is coded as a walkway or cycle lane (Figure 14).

The month with the highest proportion of crashes is August with generally more crashes occurring May – October than over the winter months (Figure 15). The vast majority of crash occur between 6am and 6pm, with the greatest proportion being between 3 and 6 pm (Figure 16).

Crash scenarios

A first TwoStep cluster analysis was undertaken with the nominal variables Urban Number_Road_Users Crash_opponent Location_junction Hour Month and Sex and the continuous variable Age, a total of 8 input variables. This resulted in a 5 cluster solution with an AIC of 16694.34 and a cluster quality labelled as Fair. The variables Crash_opponent, Number_road_users and Location_junction have a predictor importance > 0.5.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, Number_road_users, Crash_opponent and location_junction. This produced a 5 cluster solution with an improved AIC of 2270.110 and a cluster quality labelled as Good. In this solution the 3 input variables all have predictor importance > 0.7. Removing Number_Road_Users, lowest predictor importance, produced a 3 cluster solution but with an increased AIC.

Thus, the second solution was chosen. The 5 clusters are described in Table 18 along with the injury type distribution for each scenario. They can be summarised as follows (see Table 23):

- Cyclist to car crashes at intersections with 2 road users (329 of 329 cases);
- Cyclist to car crashes on a street section with 2 road users (198 of 201 cases);
- Crashes with only the cyclist involved (single vehicle)* on a street section, one road user (72 of 194 cases);
- Cyclist to car impacts on a walkway or cycle path involving 2 road users (30 of 172 cases);
- Crashes involving the cyclist and predominantly a large vehicle, at intersections with 2 road users (51 of 148 cases).

Table 18: Crash scenarios and injured body regions for the Swedish bicyclist data (STRADA).

Cluster nr.	1	3	4	2	5	
N	329 (31.5%)	201 (19.3%)	194 (18.6%)	172 (16.5%)	148 (14.2%)	
Crash Opponent	Car (100%)	Car (98.5%)	Single Vehicle (76.8%)	Car (42.4%)	Large Vehicle (51.4%)	
Junction/ road section	Intersection (100%)	Street Section (100%)	Street Section (51%)	Walkway / Cycle path (71.5%)	Intersection (59.5%)	
Number road users	2 (100%)	2 (100%)	1 (86.6%)	2 (100%)	2 (100%)	
Injury type						**Total**
Head, Face, Neck	34.3%	39.3%	51.5%	34.3%	31.8%	38.1%
Thorax	17.6%	17.4%	10.8%	18.0%	10.1%	15.3%
Abdomen and pelvic cont.s	1.2%	1.5%	2.1%	0.6%	0.7%	1.2%
Spine	3.0%	3.0%	5.7%	4.1%	2.0%	3.5%
Upper extr.	6.1%	2.0%	8.8%	6.4%	10.8%	6.5%
Lower extr.	28.0%	24.4%	17.5%	31.4%	30.4%	26.2%
Whole surf. + mult. regions	9.7%	12.4%	3.6%	5.2%	14.2%	9.0%

Injury factors

Bicyclists in Sweden appear to sustain most severe injuries to the head (38%), followed by the lower extremities (26%) and the thorax (15%; see also Figure 17). A chi-square test of association has been performed on the 5 x 7 contingency table generated from cluster number by injury type ($\chi 2=63.837$, *df* $=24$, $p<0.001$), however there are some cells with an expected count < 5 and so the result is not valid. A further chi-square was performed looking at overall injury severity between the clusters. A visual examination of the cross-tabulation shows that:

- Head injuries have the highest proportion across all scenarios with the highest being in single bicycle crashes
- Cyclists that are hit by a heavy vehicle, have the highest rate of multiple region injuries.

IGLAD database

Crash characteristics

In total 17 MAIS3+ cyclist casualties were found in IGLAD database and were included in the analysis. The number of casualties is very low and must not be considered as representative.

Two third of the MAIS3+ cyclists are male (see Figure 10). Due to the low number of casualties no particular age group can be identified (see Figure 11). In two third of the crashes the crash opponent is a car and in 80% two road users were involved (see Figure 12). The cyclists were hurt mainly in crashes that were preceded by a turning manoeuvre (35%) or going straight (41%). The most important contributing crash factor was inadequate information acquisition (88%). In nearly 90% the road conditions were dry and crashes occurred between 9:00 AM and 8:00 PM (see Figure 16).

Table 19: Crash scenarios and injured body regions for the IGLAD bicyclist data (IGLAD).

Cluster nr.	1	2	
N	14	3	
Active Road Users	2 14/14 =100%	1 3/3 =100%	
Crash Opponent	Car 10/14 =71%	No opponent 3/3 =100%	
Crash Factor	Inadequate information acquisition 14/14 =100%	Inadequate information acquisition 1/3 =33%	
Manoeuvre	turning 6/14 =43%	Going ahead other 2/3 =67%	
Injury Type			**Total**
Head, Face, Neck	5/14 =35.7%	2/3 =66.7%	7/17 =41.2%
Thorax	3/14 =21.4%	0/3 =0%	3/17 =17.6%
Abdomen and pelvic cont.s	0/14 =0%	0/3 =0%	0/17 =0%
Spine	1/14 =7.1%	0/3 =0%	1/17 =5.9%
Upper extr.	0/14 =0%	0/3 =0%	0/17 =0%
Lower extr.	3/14 =21.4%	1/3 =33.3%	4/17 =23.5%
Whole surf. + mult. Regions	2/14 =14.3%	0/3 =0%	2/17 =11.8%

Crash scenarios

A first TwoStep Cluster analysis of the cyclist data with 17 cases and the above stated variables yields a 2 cluster solution with an AIC of 286 and a cluster quality labelled as fair (0.3). The model suggests the removal of the variables Gender, Surface, Age, RoadType (predictor importance <0.2).

A second TwoStep Cluster analysis of the cyclist data with Time, CrashOpponent, ActiveRoadUsers, Manoevre, CrashFactor yields a 2 cluster solution with an AIC of 208 and a cluster quality labelled as quite fair (0.5).

A third TwoStep Cluster analysis of the cyclist data with CrashOpponent, ActiveRoadUsers, Manoevre, CrashFactor yields a 2 cluster solution with an AIC of 105 and a cluster quality labelled as good (0.6). The variables (predictor importances) are AcvtiveRoadUsers (1.0), CrashOpponent (0.61), CrashFactor (0.52) and Manoevre (0.27). The clusters that were found can best be summarized as follows (see Table 19):

- Bicyclist against a car while turning in a situation with to inadequate data acquisition (5 of 14)
- Single bicyclist crash while going ahead (2 of 3) in a situation with inadequate data acquisition (2 of 3).

Injury factors
Table 19 shows the frequencies of the MAIS3+ injured body regions per scenario. For the cyclist casualties head injuries are most common (41%) followed by injuries of the lower extremities (24%) and the thorax (18%; see also Figure 17).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=2.009 df=4, p<0.734), indicating that for cyclists there is no significant relationship between the injury type and the crash scenario.

Figures

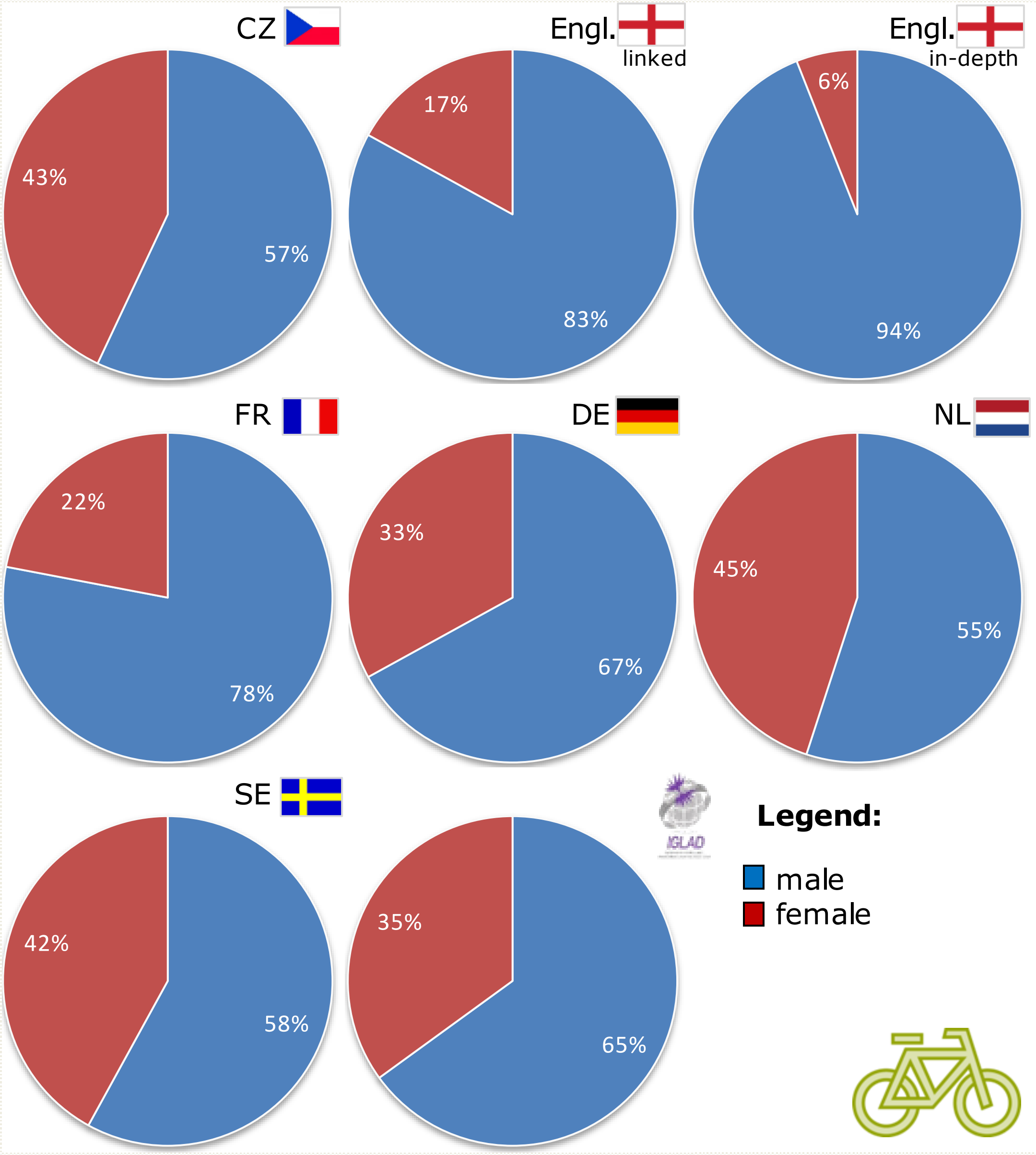

Figure 10: Gender of severely injured bicyclists in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

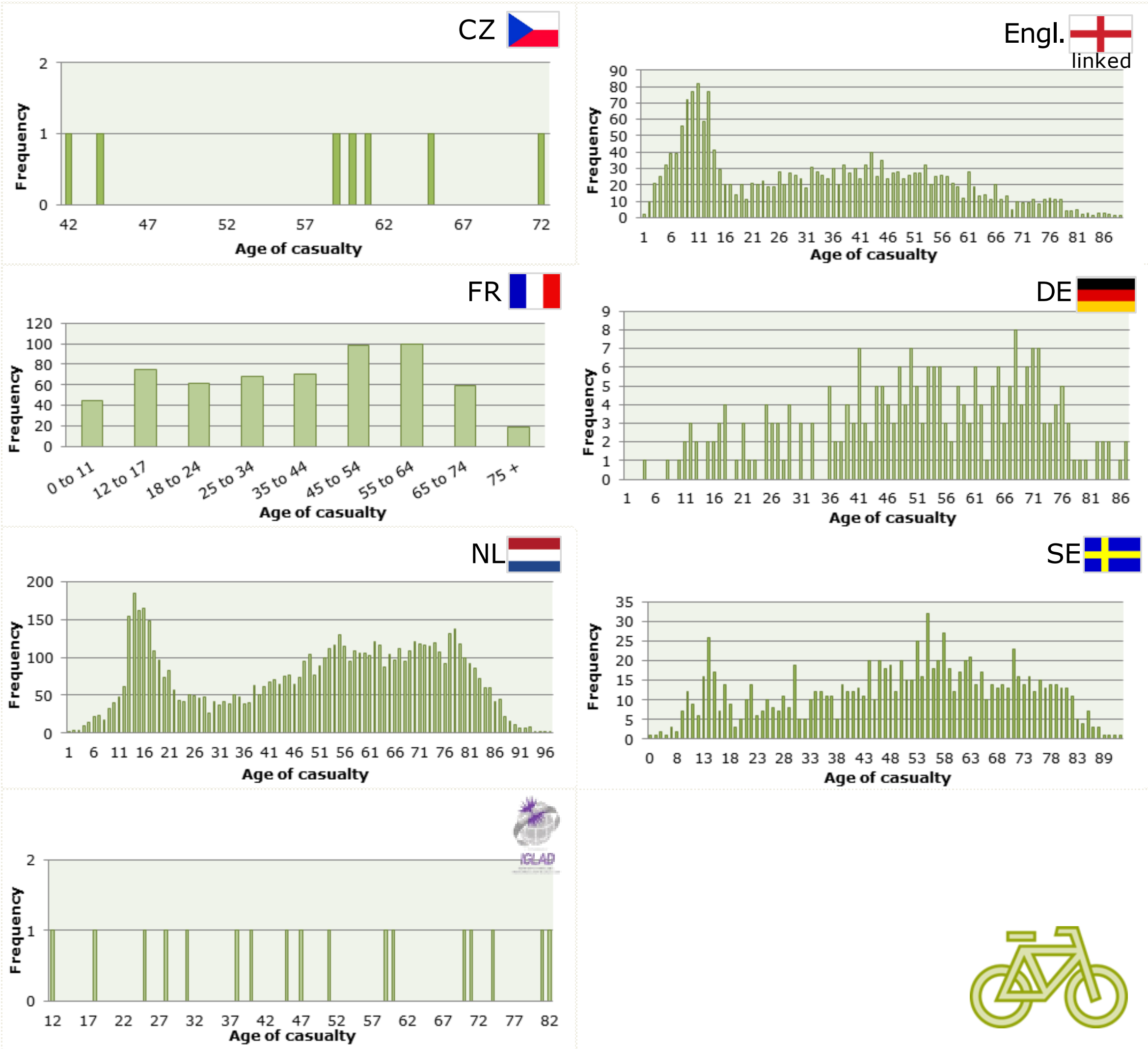

Figure 11: Age of severely injured bicyclists in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

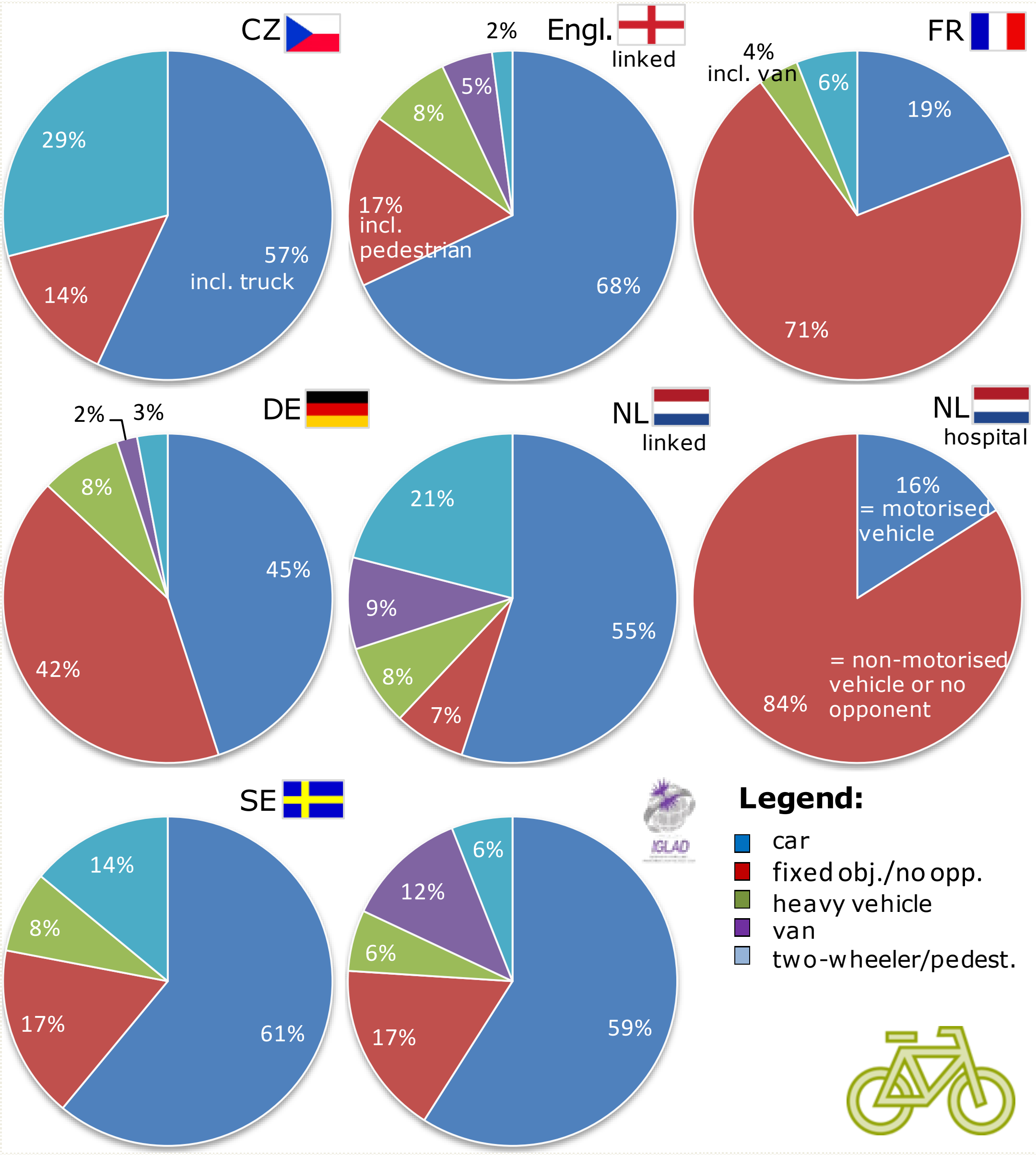

Figure 12: Most important crash opponents in crashes that lead to severely injured bicyclists in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), the Netherlands (DHD hospital discharge), Sweden (STRADA data), and the European sample from the IGLAD database.

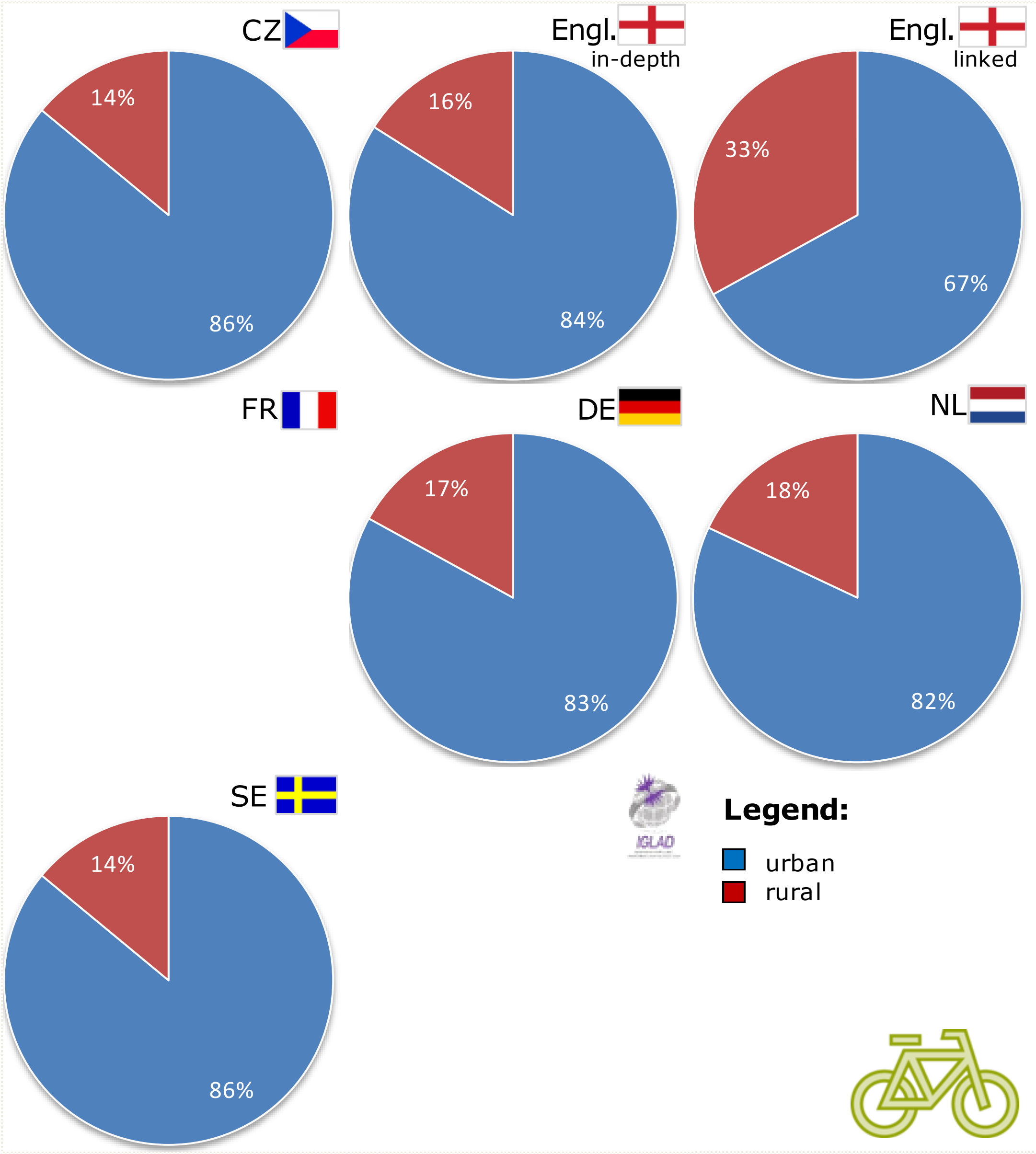

Figure 13: Main road types where crashes occur in which bicyclists get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA data).

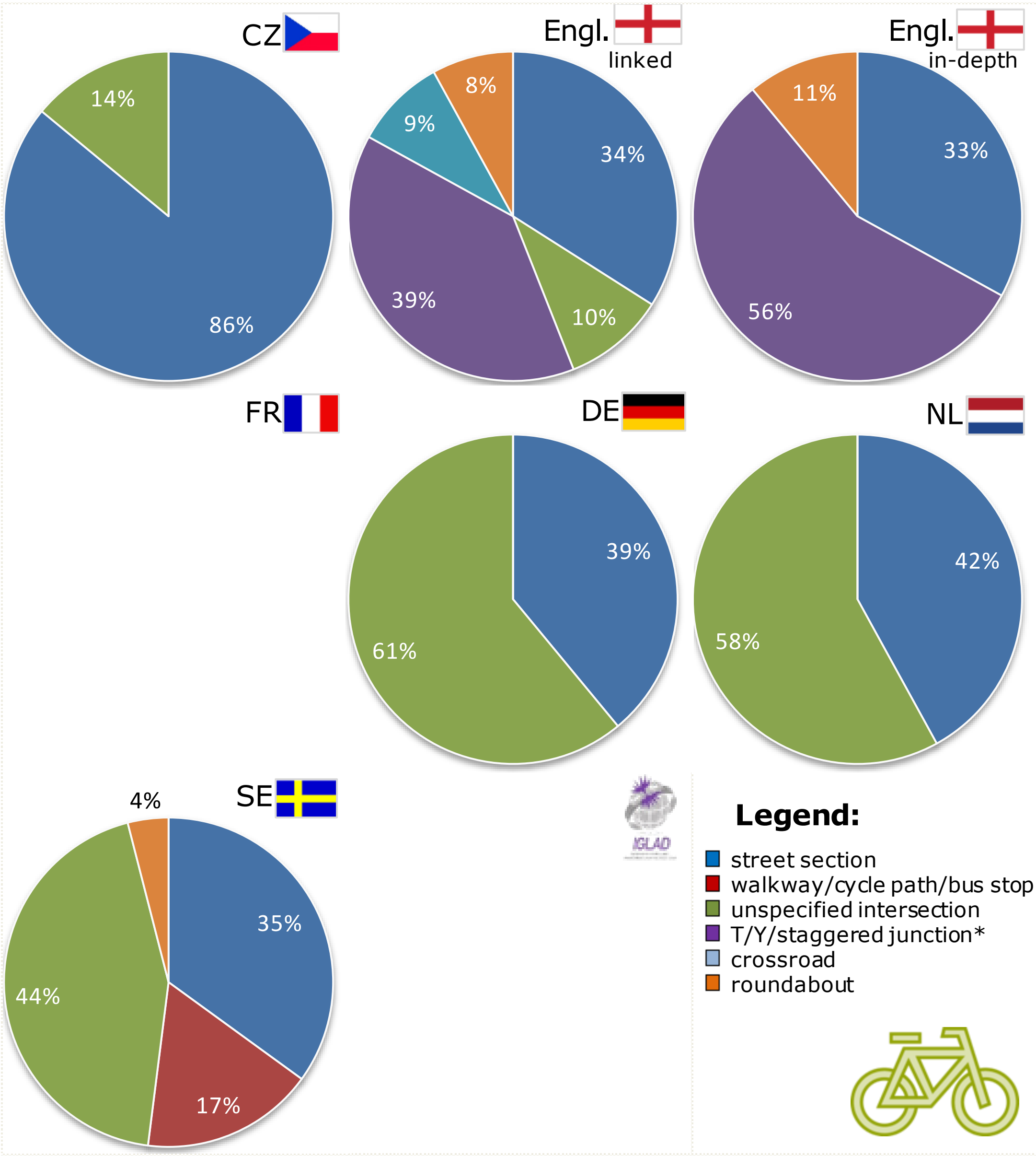

Figure 14: Road configuration where crashes occur in which bicyclists get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), and England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD) and Sweden (STRADA data). *A staggered junction is a junction were the side roads are not opposite to each other.

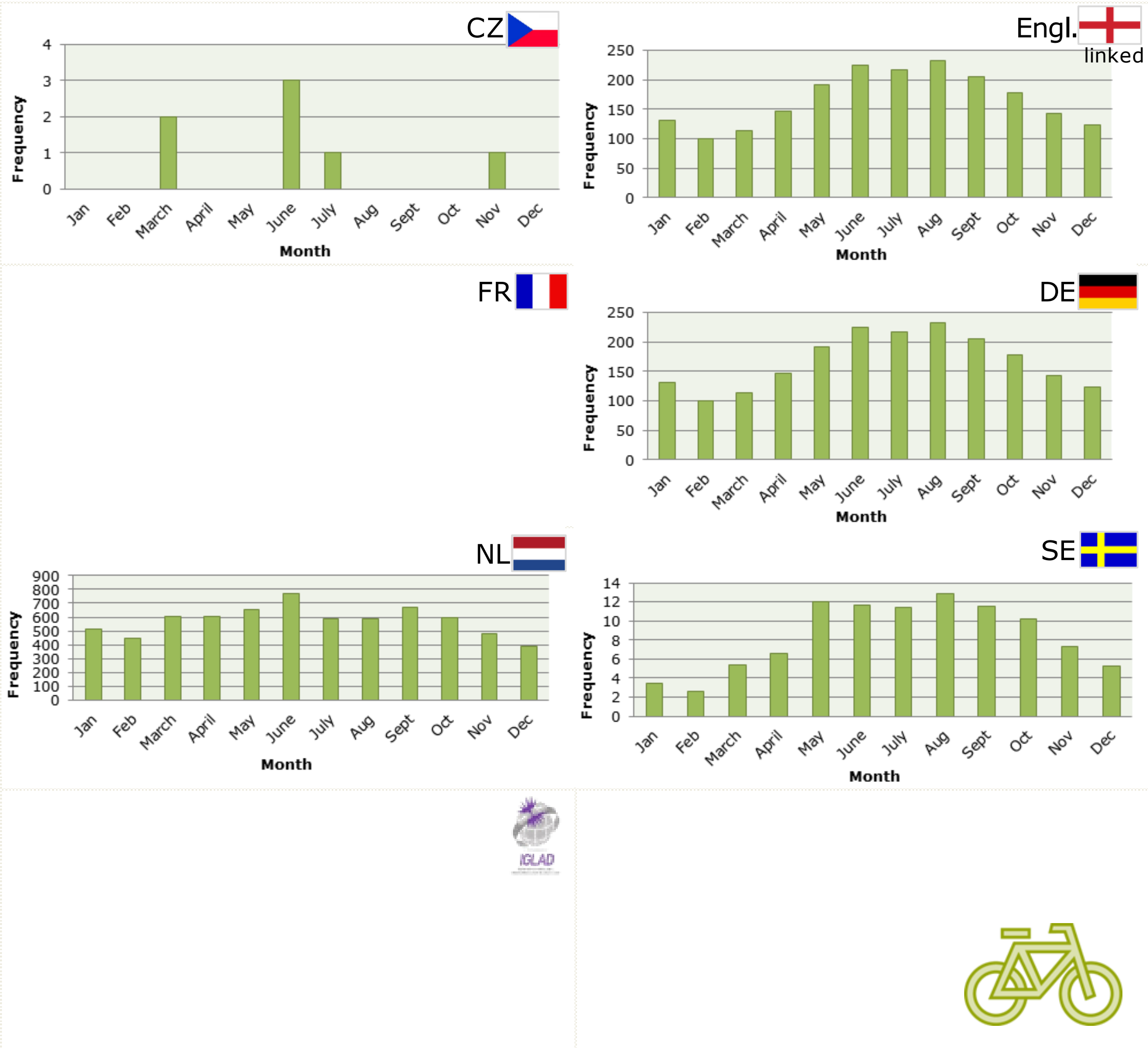

Figure 15: Months in which bicyclists get severely injured the in the Czech Republic (CziDAS data), England (linked: STATS19-HES), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA data).

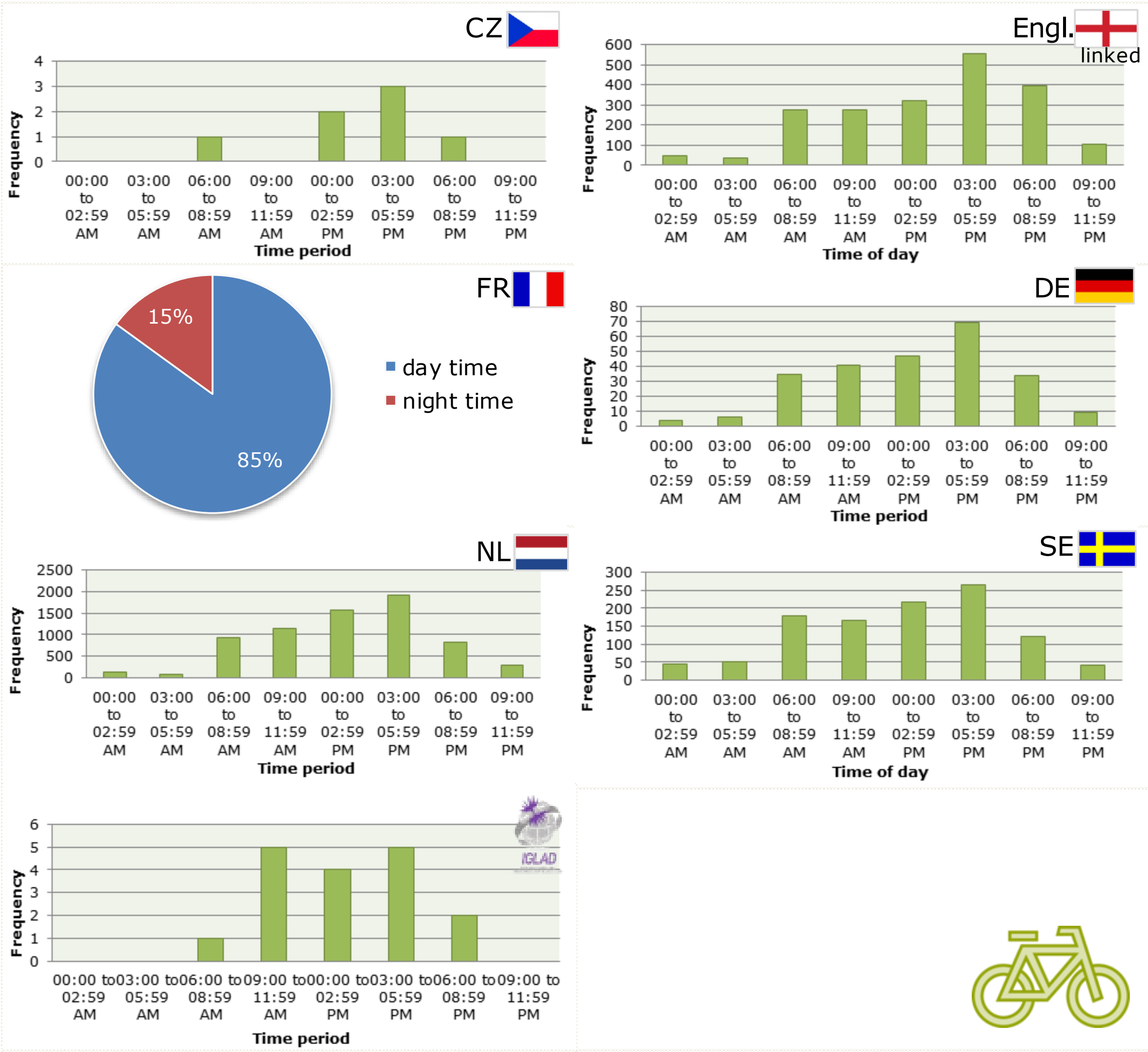

Figure 16: Time period of the day during which bicyclists get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

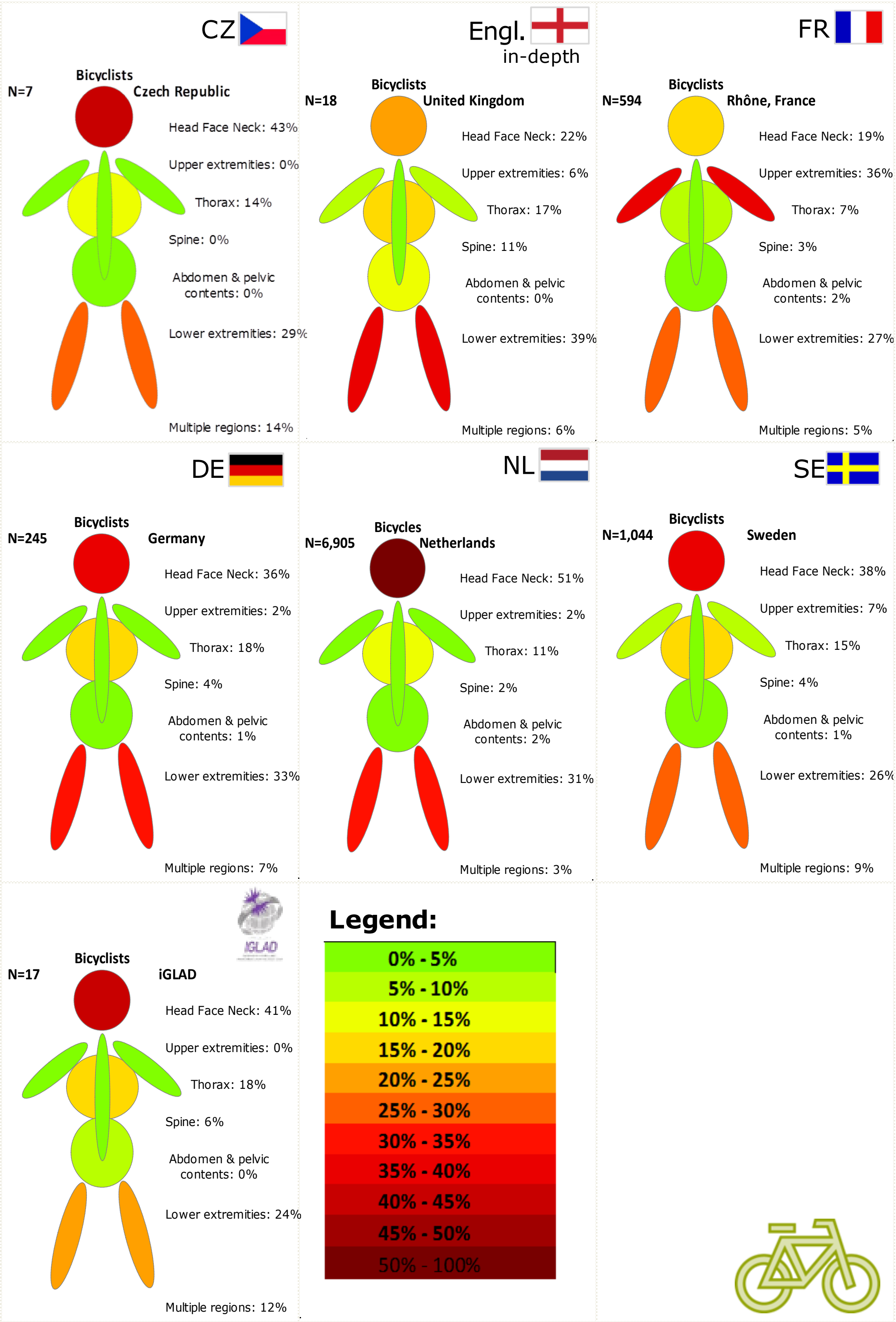

Figure 17: Overview of injured body regions of MAIS3+ bicyclists in the Czech Republic (CziDAS data), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

Motorcyclists

Czech Republic

Crash characteristics

The CzIDAS PTW data include 33 seriously injured casualties. The group includes 1 moped, 3 PTW of unknown type and 29 motorcyclists, thus, the groups are merged into one.

¾ of the seriously injured PTW riders were male (see Figure 18) and 91% were the driver of the vehicle. The most prominent group of injured PTW riders is found in the young(er) drivers (17-34 years; see Figure 19).

In 21% of the crashes only one road user was involved, in 43 one other road user was involved and in 36% three or more road users were involved. In nearly equal shares the PTW rider's first crash opponent was a car or a fixed object/ single crash (see Figure 20).

In 37% of the cases, the PTW riders were injured in an crash that was characterized as a turning crash. In each 27% of the cases the manoeuvre was going ahead round curve or going ahead other. In 43% of cases the contributing crash factor was inadequate information acquisition of one of the crash participants in 21% one of the drivers was under influence. In each 15% of the cases speeding or tailgating contributed to the crash.

Two third of the crashes occurred on road sections (see Figure 22) and nearly half of the PTW rider were injured in urban areas (see Figure 21). 36% of the casualties were injured on rural roads with a speed limit of 80 or 90 km/h. The crashes happened mostly in not physically divided two-way traffic (94%) and in the majority of cases in no special location (85%).

The majority of crashes occurred under dry conditions (88%) in the morning and early afternoon (see Figure 24). Most crashes occurred during the summer months (July-September; see Figure 24).

Crash scenarios

A first TwoStep Cluster analysis of the pedestrian data with 26 cases and the above stated variables yields a 2 cluster solution with an AIC of 1 403 and a cluster quality labelled as fair (0.3). The next iteration was done with the variables Month, CrashOpponent, Manoeuvre, RoadType, SpeedLimitJunctionType, CrashFactor.

The second round yields a 2 cluster solution with an AIC of 572 and a cluster quality labelled as fair (0.4).

The third round yields a 3 cluster solution with an AIC of 223 and a cluster quality labelled as good (0.5). The variables (predictor importance) are Manoeuvre (1.0), JunctionType (0.91), RoadType (0.74), SpeedLimit (0.61). This cluster result (see Table 20) can best be summarised as:

- PTW on rural road section with a speed limit of 90 kph going straight (9 of 19); This are mainly single vehicle crashes (63%);
- PTW at urban junction with a speed limit of 50 kph in turning manoeuvre (7 of 14). In this scenario, the crash opponent is mainly a car (64%).

Table 20: Crash scenarios and injured body regions for the Czech Republic powered two wheeler data (CziDAS).

Cluster nr.	1	2	
N	19	14	
Manoeuvre	Going ahead other 9/19 =47.4%	turning 11/14 =78.6%	
Junction Type	Road section 18/19 =94.7%	crossroad 10/14 =71.4%	
Crash opponent	rural 15/19 =78.9%	urban 12/14 =85.7%	
Crash Factor	90 km/h 11/19 =57.9%	50 km/h 13/14 =92.9%	
Injury type			**Total**
Head, Face, Neck	4/19 =21.1%	2/14 =14.3%	6/33= 18.2%
Thorax	2/19 =10.5%	1/14 =7.1%	3/33= 9.1%
Abdomen and pelvic contents	1/19 =5.3%	0/14 =0%	1/33= 3.0%
Spine	4/19 =21.1%	0/14 =0%	4/33= 12.1%
Upper extr.	0/19 =%	0/14 =0%	0/33 =0%
Lower extr.	4/19 =21.1%	9/14 =64.3%	13/33= 39.4%
Whole surf. + mult. regions	4/19 =21.1%	2/14 =14.3%	6/33 =18.2%

Injury factors
Most PTW serious injuries were found on the lower extremities (39%), followed by the head and multiple regions (18%; see Figure 25).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square =8.016, df =5, $p<0.155$), indicating that for PTW rider there is no significant relationship between the injury type and the crash scenario.

England

Crash characteristics
STATS19-HES - The STAST19-HES linked dataset comprises 5,424 severely injured motorcyclists. The vast majority of these, 95%, are male (Figure 18). Those aged 17 and 18 occur most frequently in the data, with another small peak at age 40 (Figure 19) with the mean age being 33 (SD 13). Of the MAIS3+ non-fatal motorcyclists, 95% are drivers and 5% passengers.

The most common crash opponent is another car (59%). Combining impacts with a fixed object (17%) and those with no impact partner (12%) shows impacts with no road user opponent to comprise 39% of the total (Figure 20). Two thirds of the crashes resulting in MAIS3+ motorcyclist involved two road users, with a little of 20% involving just the motorcyclist. In ¾ of cases the location of the impact on the motorcycle is to the front with a further 21% to the side. In over 80% of the cases, the motorcycle is moving forward without turning or overtaking.

Road type (Urban/Rural/Motorway) has been derived from the road classification and speed limit in this dataset and therefore the distribution is approximate. It is suggested that 60% of the crashes with MAIS3+ car motorcyclists occur in an urban environment, 38% in rural areas and just 2% on motorways (Figure 21). Looking at any junction layout, almost 40% of the crashes occur on a road section (no junction). Crashes at T/Y or staggered junctions are almost as frequent 35% (Figure 22). The road surface was dry in 81% of cases.

There is a rise in the frequency of crashes during the summer months, peaking in August (Figure 23) and there is a higher frequency of crashes from mid-afternoon though to 9pm (Figure 24

The most common crash factors are;

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

RAIDS/OTS - The combined RAIDS/OTS dataset comprises 67 severely injured motorcyclists. The vast majority are male (91%) (Figure 18). Age data is only available for the RAIDS data (n=16) – in this small sample there is an even distribution casualties across all ages. The casualty was the driver 97% of the time.

The most common crash opponent is another car (61%). The next most frequent opponent is a fixed object, 21% (Figure 20). Unlike car impacts where the majority of fixed object impacts are trees and road side furniture, for motorcyclists these tend to be kerb strikes resulting in sliding across the ground. Looking at the number of road users, this supports the crash opponent result; 27% have one road user which equates to the fixed and no impact within the crash opponent. In 57% of cases there were two road users. Whilst the majority of impacts are frontal (46%), there are a high proportion classified at skidding (27%) – this varies from the national data and is explained by the coding options in the different data sets. In over ¾ of cases the motorcycle was simply going forwards, and in a further 15% there was a manoeuvre that involved moving out of lane.

Considering the road type (Urban/Rural/Motorway) there is an even split of urban and rural crashes (Figure 21). This is also reflected in the speed limit distribution where a combination of 30 and 40 mile/h account for 55% of the crashes. The road layout shows that almost half of the crashes resulting in severe motorcycle crashes occurred at a T or staggered junction with almost as many occurring on a simple road section (see Figure 22). The road surface was dry in almost ¾ of cases.

Considering the lighting conditions, ¾ of the crashes occurred during the daytime.

The most common crash factors that were found are:

- Careless / reckless behaviour (43%);
- Speed as a factor (34%);
- Vision affected (34%);
- Poor turn or manoeuvre (31%);
- Loss of control (25%).

Crash scenarios

STAST19-HES - A first TwoStep Cluster analysis of the Motorcylist data with 5,424 cases was undertaken using the nominal variables Casualtyrole Month, Time, opponent, CrashType, Gender, Junction, Surface, Manoeuvre ActiveRoadUsers and SpeedLimit and the interval variable Age, a total of 12 input variables. This resulted in a 2 cluster solution with an AIC of 134371.8 and a cluster quality labelled as Fair.

A second TwoStep Cluster analysis used the 4 input variables from the first with a predictor importance > 0.5 (Opponent, Manouevre, Junction and ActiveRoadUsers). A 2 cluster solution was returned with an AIC of 41653.7 and a cluster quality labelled as Fair. In this solution Opponent and ActiveRoadUsers have predictor importance of 1, Manoeuvre 0.46 and Junction 0.42.

Removing the latter 2 variables produces a 4 cluster solution based upon the two variables opponent and ActiveRoadUsers. This has an AIC of 7437.2 and Good cluster quality. This solution (see Table 21) can be described as:

- Motorcyclists crashes with a car (2775 of 2775 cases);
- Motorcyclist crashes with a fixed object (789 of 1207 cases);
- Motorcyclist crashes with a van (237 of 834 cases);
- Motorcyclist crashes with a car and at least one other road user is involved as well (339 of 608 cases).

When the crash involves in main an impact with another road user the same five factors are most common: failure to look, judgement of other vehicles path/speed, speeding/inappropriate speed, careless/reckless behaviour, poor turn or manoeuvre. However, in impacts with fixed object, loss of control is the most dominant crash factor, and the driver being under the influence of drugs or alcohol also features.

Table 21: Crash scenarios for England motorcyclist data (STATS19-HES).

Cluster nr.	1	4	3	2
N	2747	1207	862	608
Number Active Road Users	2 (100%)	1 (100%)	2 (100%)	3 (79%)
Opponent	Car (100%)	Fixed Object (69%)	Van (28%)	Car (67%)

RAIDS/OTS- A first TwoStep Cluster analysis of the Motorcyclist data with 67 cases was undertaken using the nominal variables DayNight, opponent, Gender, Junction, Surface, Manoeuvre, ActiveRoadUsers, roadtype and speed a total of 9 input variables. This resulted in a 5 cluster solution with an AIC of 877.63 and a cluster quality labelled as Fair.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5 (Roadtype speed opponent and surface). In this case a 2 cluster solution was returned with an AIC of 354.88 and labelled good. Just 2 of the input variables had predictor importance > 05, RoadType and speed.

These latter two were entered into a final analysis which produce a 2 cluster solution (Good, AIC 124.41) categorised as Urban crash, mostly 30 mile/h rural crashes, mostly 60 mile/h. The details are shown in Table 22 and can best be summarised as:

- Motorcyclists crashes on an urban road where the speed limit is typically 30mile/h (27 of 34 cases);
- Motorcyclist crashes on a rural road with a typical speed limit of 60mile/h (20 of 33 cases).

When the motorcyclist accidents are split into these two clusters, whilst there are many factors in common, there are some indications that the contributory factors differ: Crashes inside urban areas features failure to look unlike the rural accidents, whereas loss of control and swerving are more common in in the scenario with rural crashes.

Table 22: Crash scenarios and injured body regions for England motorcyclist data (RIADS & OTS).

Cluster nr.	1	2	
N	34	33	
Road type	Urban 34/34 = 100%	Rural 33/33 = 100%	
Speed limit	30 mile/h 27/34 = 79%	60 mile/h 20/33 = 61%	
Injury type			**Total**
Head, Face, Neck	14.7%	9.1%	11.9%
Thorax	26.5%	30.3%	28.4%
Spine	2.9%	0	1.5%
Upper extr.	5.9%	18.2%	11.9%
Lower extr.	44.1%	24.2%	34.3%
Whole surf. + mult. Regions	5.9%	18.2%	11.9%

Injury factors
There is a clear high proportion of injuries to the upper extremities for motorcyclists, followed by those to the chest (see Table 22 and Figure 25).

There was not a significant association between cluster membership and body region ($\chi2$=.345, df=1, p=.557). Both of the scenarios, urban and rural, show chest and lower extremity injury type as being common. Lower extremity type is the most frequent in urban areas (44.1%) followed by the chest (26.5%). For rural areas, the chest proportion is 30.3% and the lower extremity 24.2%. Both Upper extremity and multiple injury types seem associated more with rural areas than with urban areas.

France, Rhône region

Crash characteristics
Of the 1429 severely injured PTW cases of the Rhône region, most of them appeared to be male (92%; see Figure 18) and young (18 to 24 years of age; see Figure 19). The most common crash opponent for motorcyclists are cars (51%) but also crashes with no crash opponent are common (30%; see Figure 20). In the Rhône area, 91% of the severely injured motorcyclist wear a helmet. Most crashes happen during daytime (72%; see Figure 24).

Crash scenarios
A first TwoStep Cluster analysis of the PTW data and the nominal variables DayNight, FirstCrashOpponentOpponent, DemographyAgeGroup, DemographyGender, and Helmet yields a 4 cluster solution with an AIC of 8831.963 and a Cluster Quality labelled as Fair. In this solution the variable DayNight has a predictor importance of 1.0 while the predictor importances of the variables FirstCrashOpponentOpponent, DemographyAgeGroup, DemographyGender, and Helmet are 0.62, 0.08, 0.57 and 0.60, respectively.

A second TwoStep Cluster analysis without the variable DemographyAgeGroup yields a 4 cluster solution with an AIC of 3476.346 and a Cluster Quality labelled as Good. In this solution the variables DayNight, FirstCrashOpponentOpponent, DemographyGender.

The clusters that were found could best be described as (see Table 23):

- Male motorcyclist wearing a helmet hit by a car during daylight (437 of 437 cases);
- Male motorcyclist wearing a helmet crashing with no crash opponent during daylight (262 of 416 cases);
- Male motorcyclist wearing a helmet hit by a car during night time (180 of 328 cases);
- Female motorcyclist not wearing a helmet hit by a car during daylight (3 of 248 cases).

Table 23: Crash scenarios and injured body regions for the Rhône region motorcyclist data (Rhône road trauma registry, France, IFSTTAR).

Cluster nr.	1	2	3	4	
N	437	416	328	248	
Time of day	Day 437/437 = 100.0%	Day 416/416 = 100.0%	Night 328/328 = 100.0%	Day 171/248 = 69.0%	
First crash opponent	Car 437/437 = 100.0%	No crash opponent 262/416 = 63.0%	Car 180/328 = 54.9%	Car 112/248 = 45.2%	
Helmet use	Yes 437/437 = 100.0%	Yes 416/416 = 100.0%	Yes 328/328 = 100.0%	No 132/248 = 53.2%	
Gender victim	Male 437/437 = 100.0%	Male 416/416 = 100.0%	Male 328/328 = 100.0%	Female 126/248= 50.8%	
Injury type					**Total**
Head+ Face + Neck	24 5.5%	29 7.0%	28 8.5%	42 16.9%	123 8.6%
Thorax	74 16.9%	69 16.6%	59 18.0%	31 12.5%	233 16.3%
Abdomen and pelvic contents	17 3.9%	14 3.4%	15 4.6%	7 2.8%	53 3.7%
Spine	7 1.6%	11 2.6%	8 2.4%	3 1.2%	29 2.0%
Upper extremities	83 19.0%	101 24.3%	56 17.1%	41 16.5%	281 19.7%
Lower extremities	177 40.5%	155 37.3%	118 36.0%	98 39.5%	548 38.3%
Whole surface + Multiple regions	55 12.6%	37 8.9%	44 13.4%	26 10.5%	162 11.3%

Injury factors

In the lower part of the Table we have also added the frequencies in the cross-table of variables injury type and cluster number. Since there is only one face injury in this data set we added this to the Head injuries. The proportions in the lower half of the Table are column proportions; adding them over injury type these proportions therefore all add up to 100%. For the powered two-wheeler victims we first of all see that injuries to the lower extremities are generally the most common type of injury (38%), followed by injuries to the upper extremities (20%), injuries to the thorax (16%), and then by injuries to multiple regions (11%; see also Figure 25).

The Chi-square test for the cross-table of injury type by cluster number is very significant (Chi-square = 45.11, df = 18, $p < 0.001$), indicating that for PTWs there is a significant relationship between the variables injury type and cluster number. When inspecting the injury types in the four separate clusters, we see the following differences:

- Injuries to the head and face are relatively larger in daytime PTW crashes of females who are hit by a car;

- Upper extremities are relatively larger in males crashing without a crash opponent by daytime;
- Thorax, abdomen and pelvic spine content injuries are more common in males crashing.

Germany

Crash characteristics

The 173 cases of severely injured motorcyclists showed that 96% of them are male (Figure 18) and the age profile shows two peaks, one for the young drivers and one for the middle aged centred around 50 (Figure 19). The majority of casualties (95%) were the driver of the motorcycle.

In 43% of the crashes in which motorcyclists get severely injured the first crash opponent is a car. About 51% of the crashes are either single without an opponent (e.g. hitting the road) or are a crash with a (non-) fixed object. Vans or heavy vehicles are other common crash opponents (see Figure 20). In one third of the cases are single vehicle crashes, in nearly two third of the cases one other road user is involved. Nearly 60% of the severely injured motorcyclists get in injured in a head-on collision followed by single vehicle crashes and side impact.

Half of the motorcyclists crashes occur in urban areas, but also crashes on rural roads are very common (43%; Figure 21). Two third of the motor rider crashes occur on road sections (Figure 22) and in 88% of the cases the road was dry.

The majority of severe motorcyclist crashes occur in the motorcycle season (April to September; see Figure 23), mostly by daylight (80%), especially in the early and later afternoon (00:00 PM till 6:00 PM; Figure 24).

Crash scenarios

A first TwoStep Cluster analysis of the motorcyclist data with 173 cases and the above stated variables yields a 3 cluster solution with an AIC of 7079 and a cluster quality labelled as poor (0.1).

A second TwoStep Cluster analysis with the variables CrashOpponent, CrashType Manoeuvre, JunctionType, CrashFactor, ActiveRoadUsers yields a 2 cluster solution with an AIC of 1940 and a cluster quality labelled as fair (0.4).

A third TwoStep Cluster analysis yields a 2 cluster solution with an AIC of 783 and a cluster quality labelled still as good (0.5) with the variables (predictor importance) ActiveRoadUsers (1.0), CrashOpponent (0.24), and CrashFactor (0.23). The clusters can be summarised as follows (see Table 24):

- Motorcycle in a single vehicle crash while speeding (55 of 112).
- Motorcycle hit by a car in a situation with inadequate information acquisition (25 of 61).

Injury factors

Table 24 shows the most common crash scenarios including the frequencies of the AIS body region injury type per scenario. For the motorcycle casualties the injuries of the lower extremities are most common (45%) followed by thorax injuries (29%) and multiple region injuries and head injuries (each 9%; see also Figure 25).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=5.939 df=5, $p<0.312$), indicating that for motorcyclists there is no significant relationship between the injury type and the crash scenario.

Having a closer look into the injury distribution within the two scenarios, there are indications that:

- The single vehicle crashes show a higher share of thorax injuries compared to the crashes with another participant involved. However, the share of injuries of the lower extremities is lower;
- Abdomen and pelvic injuries are more common for single motorcyclist crashes.

Table 24: Crash scenarios and injured body regions for the German motorcyclist data (GIDAS).

Cluster nr.	2	1	
N	112	61	
Active Road Users	2 road users 110/112 =98.2%	Single crash 51/61 =83.6%	
CrashOpponent	car 67/112 =59.8%	No crash opponent 39/61 =63.9%	
Crash Factor	Inadequate information acquisition 86/112 =76.8%	Speeding 41/61 =67.2%	
Injury Type			**Total**
Head, Face, Neck	11/112 =9.8%	5/61 =8.2%	16/173= 9.2%
Thorax	31/112 =27.7%	19/61 =31.1%	50/173= 28.9%
Abdomen and pelvic cont.s	1/112 =0.9%	4/61 =6.6%	5/173 = 2.9%
Spine	3/112 =2.7%	3/61 =4.9%	6/173= 3.5%
Upper extr.	2/112 =1.8%	0/61 =0%	2/173= 1.2%
Lower extr.	52/112 =46.4%	25/61 =32.5%	77/173 = 44.5%
Whole surf. + mult. Regions	12/112 =10.7%	5/61 =8.2%	17/173 = 9.8%

For the 173 motorcycle casualties 1068 single injuries (mean of 6 injuries per casualty) were recorded of which 287 injuries (mean of 2 severe injuries per casualty) have a severity of AIS08=3 or larger. The majority of fractures were caused by the contact with the opponent (41/142=28.9%) or the contact with the road and environmental features (e.g. the curb) (72/142=50.7%). These causes are also the main causes for all injury types, that is 160/287=55.7% of all injuries were caused by hitting the road, 76/287=26.5% were caused by the impact to opponent and 18/287=6.3% of the injuries were caused by contact with the own motorcycle.

Netherlands

Crash characteristics

The 2,365 cases of severely injured motorcyclists showed that more than 90% of them is male (Figure 18) and mostly aged between 22 and 50 years of age (Figure 19).

Half of the crashes in which motorcyclists get severely injured are with a car and about one third is a single vehicle crash. Vans or heavy vehicles are other common crash opponents (see Figure 20). In two third of the cases, one other road user is involved but also more than one other road user is common.

Most motorcyclists get severely injured in a head-on collision (42%) or a side-impact collision (34%). The majority of the motorcyclists crashes occur on rural roads (45%), but also crashes on urban roads are very common (40%; Figure 21). Nearly 60% of the motor rider crashes occur on road sections and 40% at junctions (Figure 22) and in nearly 90% of the cases the road is not wet or slippery.

The majority of severe motorcyclist crashes occur in the warmer months April to September (Figure 23), mostly by daylight, especially in the early and later afternoon (00:00 PM - 6:00 PM; Figure 24).

Crash scenarios

A first TwoStep Cluster analysis of the moped data with 2365 cases from the linked BRON-DHD data and the nominal variables Month, Time, opponent, CrashType, Gender, RoadType, Junction, Surface, and SpeedLimit and the interval variables ActiveRoadUsers and Age yields a 5 cluster solution with an AIC of 51928.339 and a cluster quality labelled as Poor. In this solution the variables Month, Time, Gender, Age, Surface and Junction have a predictor importance lower than 0.7.

A second TwoStep Cluster analysis without the latter five variables yields a 3 cluster solution with an AIC of 21241.282 and a cluster quality labelled as Fair. In this solution only the variables opponent, CrashType, RoadType and SpeedLimit have a predictor importance higher than 0.9; the predictor importance of ActiveRoadUers is lower than 0.3.

A third TwoStep Cluster analysis only applied to the four variables opponent, CrashType, RoadType and SpeedLimit yields a 3 cluster solution with an AIC of 19987.028 and a cluster quality also labelled as Fair. In this solution all four remaining variables have a predictor importance higher than 0.9. These 3 clusters are described in Table 25 in order of cluster size and can best be summarised as follows:

- Side-impact crash during turning manoeuvre with another car as crash opponent on an urban 50 km/h road (116 of 953 cases);
- Side-impact crash during turning manoeuvre with another car as crash opponent on a rural 80 km/h road (154 of 714 cases);
- Collision with a fixed object on a rural 80 km/h road (127 of 698 cases).

Injury factors

In the lower part of the Table are the frequencies in the cross-table of variables injury type and cluster number for this data set. For the motorcycle victims we first of all see that the injuries to the lower extremities are generally the most common type of injury (38%), followed by injuries to the thorax (24%), and then by injuries to the head (16%; see also Figure 25).

The Chi-square test for the cross-table of injury type by cluster number is very significant (Chi-square = 70.391, *df* = 12, $p < 0.001$), indicating that for motorcycles there is a significant relationship between the variables injury type and cluster number. When inspecting the injury types in the three separate clusters, we see that the relation between injury type and cluster type for motorcycles is mainly due to the fact that:

- injuries to the thorax are relatively larger in collisions with a fixed object;
- injuries to the lower extremities and injuries to multiple body regions are relatively larger in motorcyclist that are hit by a car, both on rural 80 km/h and urban 50 km/h roads.

Table 25: Crash scenarios and injured body regions for the Dutch motorcyclist data (BRON-DHD).

Cluster nr.	2	1	3	
N	953	714	698	
Crash type	Side-impact collision turning 239/953 = 25.1%	Collision with a fixed object 430/714 = 60.2%	Side-impact collision turning 222/698 = 31.8%	
Opponent	Car 666/953 = 69.9%	Fixed object 399/714 = 55.9%	Car 549/698 = 78.7%	
Road type	Rural 719/953 = 75.4%	Rural 335/714 = 46.9%	Urban 698/698 = 100.0%	
Speed limit	80 km/h 627/953 = 65.8%	80 km/h 261/714 = 36.6%	50 km/h 600/698 = 86.0%	
Injury type				**Totaal**
Head	136 14.3%	137 19.2%	110 15.8%	383 16.2%
Thorax	202 21.2%	224 31.4%	145 20.8%	571 24.1%
Abdomen and pelvic contents	45 4.7%	46 6.4%	48 6.9%	139 5.9%
Spine	29 3.0%	32 4.5%	23 3.3%	84 3.6%
Upper extremities	31 3.3%	25 3.5%	33 4.7%	89 3.8%
Lower extremities	413 43.3%	213 29.8%	283 40.5%	909 38.4%
Multiple regions	97 10.2%	37 5.2%	56 8.0%	190 8.0%

Sweden

Crash characteristics

Within the STRADA data selected, there are 1,157 severely injured motorcyclists of which the vast majority (91%) are male (Figure 18). There are a couple of peaks in the age distribution, firstly in the age distribution for motorcyclists in their early 20's and then for those between the age of 45-55 (Figure 19). In respect of seating position, 95% are the motorcycle driver, with the remaining 5% passenger.

Single vehicle impact is the most common crash scenario (43%). Impacts with a car are next most common accounting for 40% of the crashes (Figure 20). Considering the number of road users, 50% of cases with have a single road user. A further 46% involve 2 road users.

Considering road type, 55% of the crashes occur in a rural environment, 39% in urban areas and 7% on motorways (Figure 21). The most frequent speed limit is 50 km/h (37%) followed by 70 km/h (34%). Looking at any junction layout, the data is primarily distinguished by either 'intersection' or 'road section'. Around two third (65%) of crashes occur on a road section (no junction; Figure 22).

There is a clear rise in the number of motorcycle crashes across the summer months (Figure 23). There is a rise in the proportion of crash occurring in the afternoon into the early evening, with the greatest proportion being between 3 and 6 pm (Figure 24).

Crash scenarios
A first TwoStep cluster analysis was undertaken with the nominal variables Urban Number_Road_Users Crash_opponent Location_junction Hour Month Role and Sex and the continuous variables SpeedLimit and Age, a total of 10 input variables.
This resulted in a 2 cluster solution with an AIC of 20812.91 and a cluster quality labelled as Fair. Only the variables Crash_opponent and Number_road_users have a predictor importance > 0.5.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, Number_road_users and Crash_opponent. This produced another 2 cluster solution with an improved AIC of 2347.48 and a cluster quality labelled as Good. In this solution the variable Number_road_users has importance 1.0 and crash_opponent 0.58. The 2 clusters are described in Table 26 and can best be summarised as:

- 1 road user in a single vehicle crash* (451 of 621 cases);
- 2 road users where the opponent was a car (393 of 536 cases).

Table 26: Crash scenarios and injured body regions for the Swedish motorcyclist data (STRADA).

Cluster nr.	2	1	
N	621 (53.7)%	536 (46.3%)	
Number Road Users	1 (92.9%)	2 (100%)	
Crash Opponent	Single Vehicle (73.9%)	Car (73.3%)	
Injury Type			**Total**
Head, Face, Neck	9.7%	9.7%	9.6%
Thorax	37.7%	27.8%	33.1%
Abdomen and pelvic cont.s	5.2%	4.9%	5.0%
Spine	7.1%	3.0%	5.2%
Upper extr.	3.5%	6.9%	5.1%
Lower extr.	22.7%	33.6%	27.7%
Whole surf. + mult. Regions	14.2%	14.2%	14.1%

Injury factors
The table of injury type by body region shows that the chest is the most common injury type (38%), followed by the head (22%; see also Figure 25).

A chi-square test of association has been performed on the 2 x 7 contingency table generated from cluster number by injury type ($\chi 2=36.505$, *df* =6, p<0.001) which shows that an association exists between injury type and crash scenario as defined by the 2 clusters. Visual inspection of the table shows the following most prominent differences:

- Injuries to the thorax are dominant in single vehicle crashes;
- Injuries to the lower extremities are dominant in crashes where the motorcyclist is hit by a car.

IGLAD database

Crash characteristics

The 49 cases of severely injured motorcyclists showed that 92%of them are male (Figure 18) and mostly aged between 22 and 34 years of age (Figure 19). 94% of the casualties were the rider of the vehicle. The motorcycles were mainly 5-10 years old.

In 61% of the crashes in which motorcyclists get severely injured the first crash opponent is a car, in 29% of the cases it was a fixed object or no crash opponent (Figure 20). However, in 80% of the cases one other participant was involved and in 14% of the cases, the crash included only the motorcyclist and no other active traffic participants. Most crashes were preceded by a (U-) turning manoeuvre (63%) or by going straight or rounding a curve (27%).

Half of the motorcyclists crashes occur in urban areas, but also crashes on rural roads are very common (43%; Figure 21). In 90% of the cases the road is not wet or slippery. In 63% of the cases inadequate information acquisition contributed to the crash, but also speeding & red light running, as well as tailgaiting and wrong way driving are common contributing factors.

The majority of severe motorcyclist crashes occur by daylight, especially in the early and later afternoon (3:00 PM till 6:00 PM; Figure 24).

Crash scenarios

A first TwoStep Cluster analysis of the cyclist data with 49 motorcyclist cases and the above stated variables yields a 4 cluster solution with an AIC of 1595 and a cluster quality labelled as poor (0.2). The model suggests the removal of the variables Role, Manoevre, VehicleAge.

A second TwoStep Cluster analysis of the cyclist data with CrashOpponent, Manoeuvre, RoadType, ActiveRoadUsers, CrashFactor and AgeGroup yields a 3 cluster solution with an AIC of 671 and a cluster quality labelled as poor (0.2).

A third TwoStep Cluster analysis yields a 4 cluster solution with an AIC of 342 and a cluster quality labelled as good (0.6). The variables (predictor importances) are RoadType (1.0), CrashFactor (0.49), AcvtiveRoadUsers (0.38), and Manoeuvre (0.27). The four clusters that have been found can be described according to the following major characteristics (see Table 27):

- Motorcyclist crashes with another traffic participant on an urban road in a situation with inadequate information acquisition and preceded by a turning manoeuvre (12 of 17).
- Motorcyclist crashes with another traffic participant on an rural road in a situation with inadequate information acquisition and preceded by a turning manoeuvre (9 of 17).
- Motorcyclist crashes with another traffic participant on an urban road while speeding and going straight (1 of 11).
- Motorcyclist in a single vehicle crash on a motorway preceded by wrong way driving and a turning manoeuvre (2 of 4).

Injury factors

Table 27 shows the frequencies of the MAIS3+ injured body regions per scenario. For the motorcyclist casualties injuries of the lower extremities (45%) are most common followed by thorax injuries (18%) and injuries to the head (16%; see also Figure 25).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=20.205 df=15, p<0.164), indicating that for motorcyclists there is no significant relationship between the injury type and the crash scenario. A closer look into the injury distribution provides indications that in motorway crashes, particularly head injuries and multiple injuries are common.

Table 27: Crash scenarios and injured body regions for the IGLAD motorcyclist data (IGLAD).

Cluster nr.	**3**	**2**	**4**	**1**	
N	17	17	11	4	
Road type	Urban 17/17 =100%	Rural 17/17 =100%	Urban 7/11 =%	Motorway 4/4 =100%	
Crash Factor	Inadequate information acquisition 15/17 =88.2%	Inadequate information acquisition 13/17 =76.5%	Speeding 5/11 =45.5%	Wrong-way driving 4/4 =100%	
Active Road Users	2 17/17 =100%	2 17/17 =100%	2 6/11 =63.6%	1 3/4 =75%	
Manoeuvre	turning 13/17 =76.5%	turning 10/17 =58.8%	going ahead other 6/11 =63.6%	turning 2/4 =50%	
Injury type					**Total**
Head, Face, Neck	3/17 =17.6%	1/17 =5.9%	1/11 =9.1%	3/4 =75%	8/49 =16.3%
Thorax	5/17 =29.4%	2/17 =11.8%	2/11 =18.2%	0/4 =0%	9/49 =18.4%
Abdomen and pelvic cont.s	0/17 =0%	1/17 =5.9%	0/11 =0%	0/4 =0%	1/49 =2%
Spine	0/17 =0%	1/17 =5.9%	1/11 =9.1%	0/4 =0%	2/49 =4.1%
Upper extr.	0/17 =0%	0/17 =0%	0/11 =0%	0/4 =0%	0/49 =0%
Lower extr.	8/17 =47.1%	8/17 =47.1%	6/11 =54.5%	0/4 =0%	22/49 =44.9%
Whole surf. + mult. regions	1/17 =5.9%	4/17 =23.5%	1/11 =9.1%	1/4 =%	7/49 =14.3%

Figures

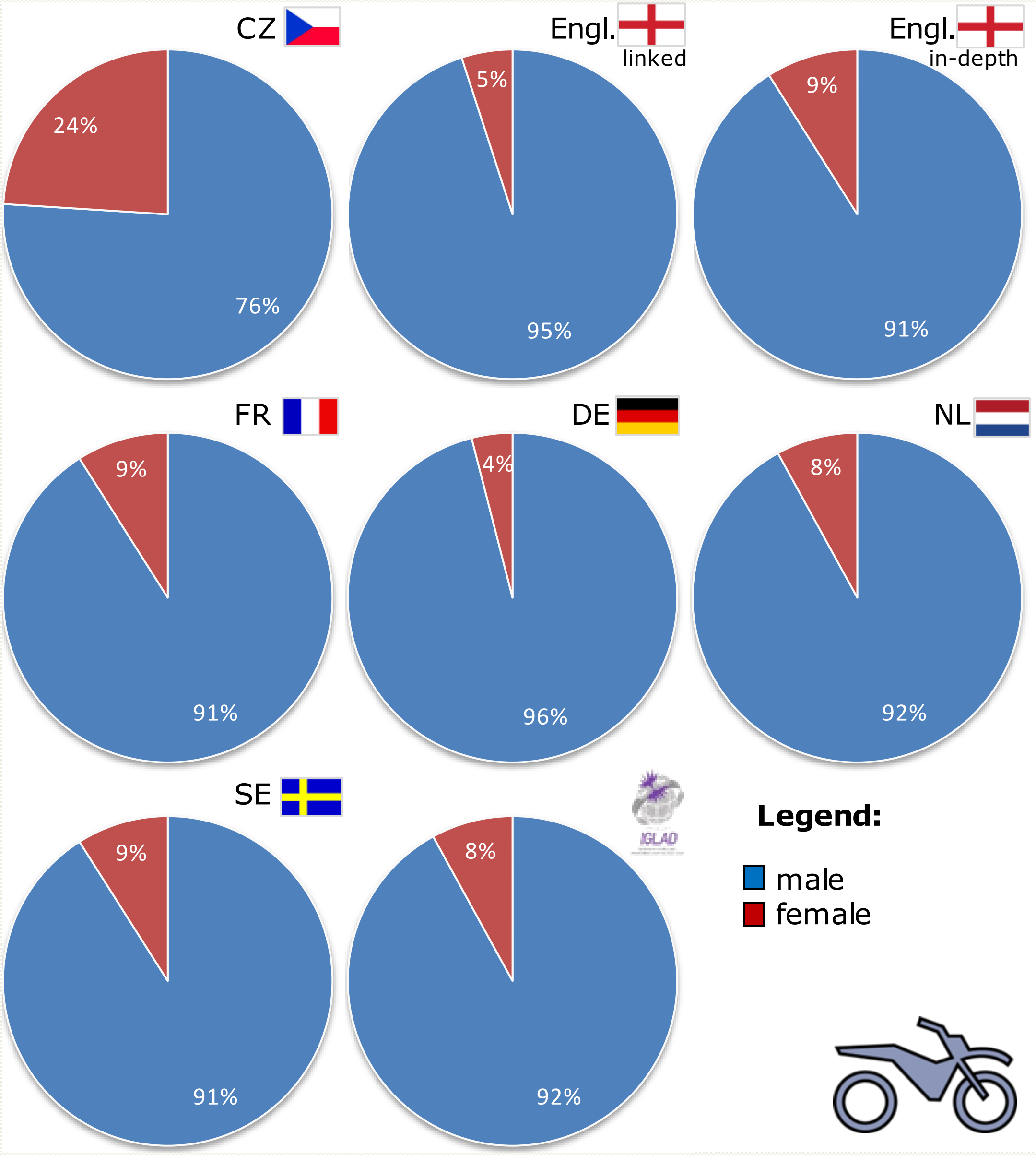

Figure 18: Gender of severely injured motorcyclists (powered two-wheelers for databases with *) in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France*, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from the IGLAD database *.

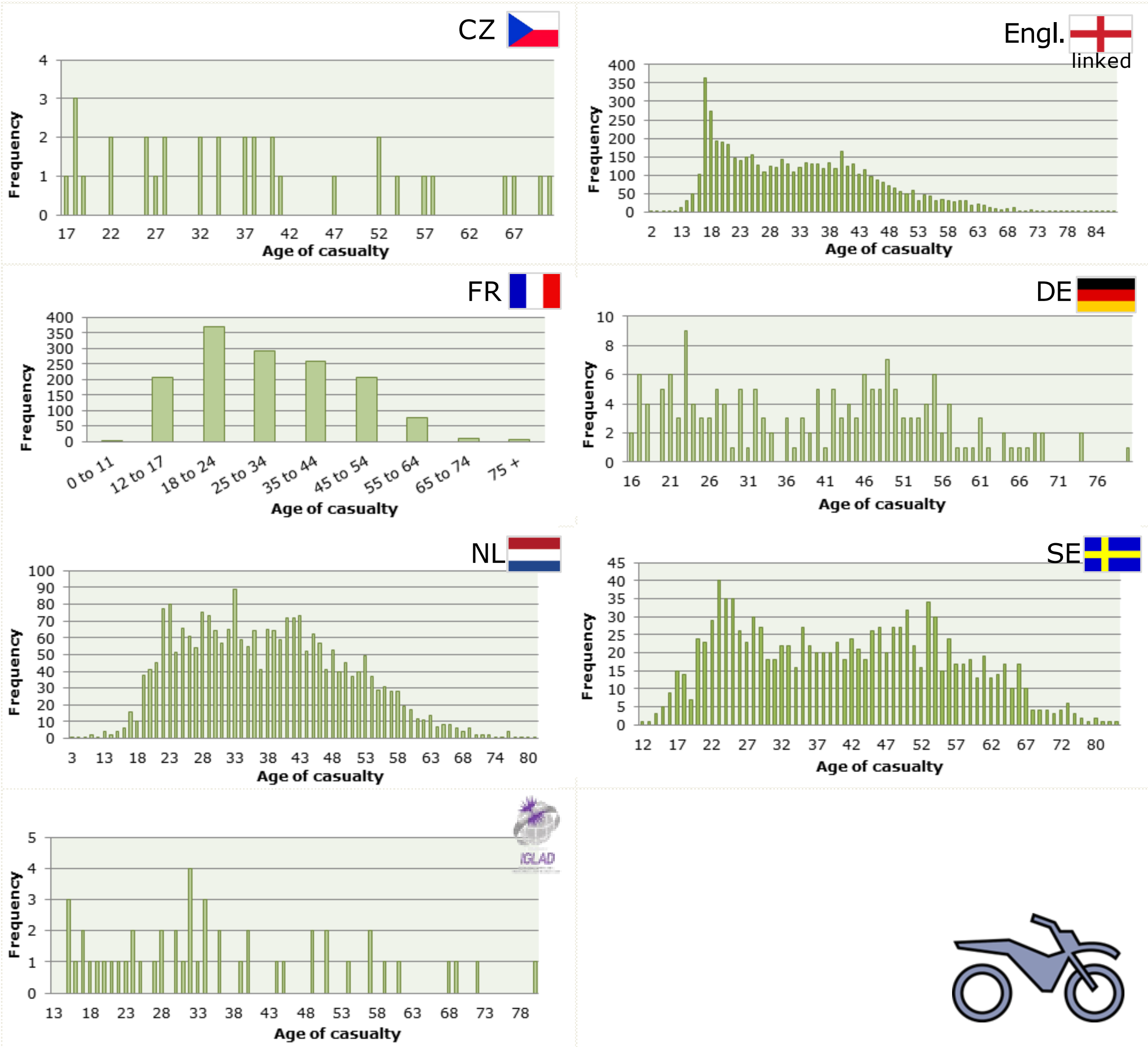

Figure 19: Age of severely injured motorcyclists (powered two-wheelers for databases with *) in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), France*, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from the IGLAD database *.

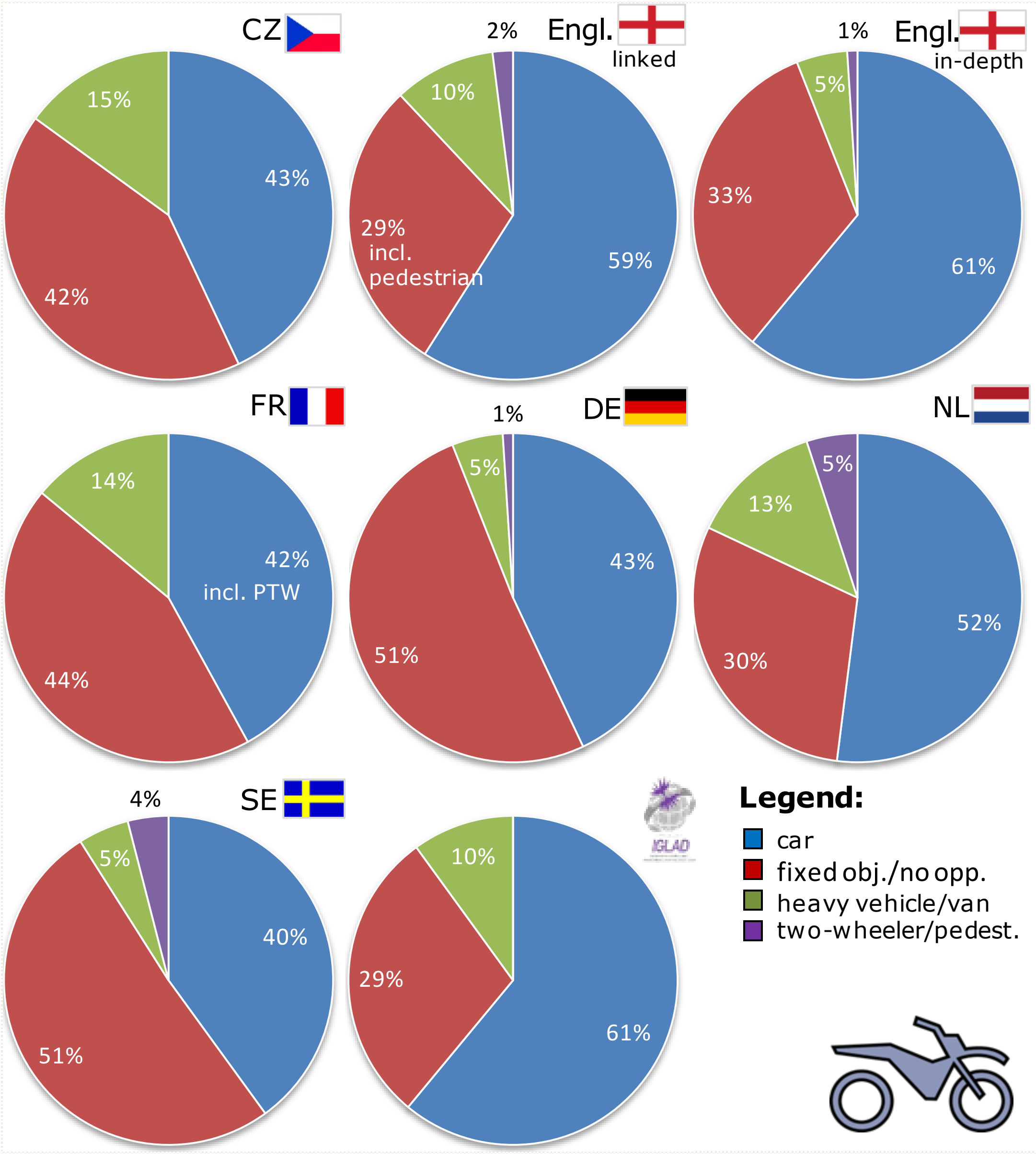

Figure 20: Most important crash opponents in crashes that lead to severely injured motorcyclists (powered two-wheelers for databases with *) in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France*, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from the IGLAD database*.

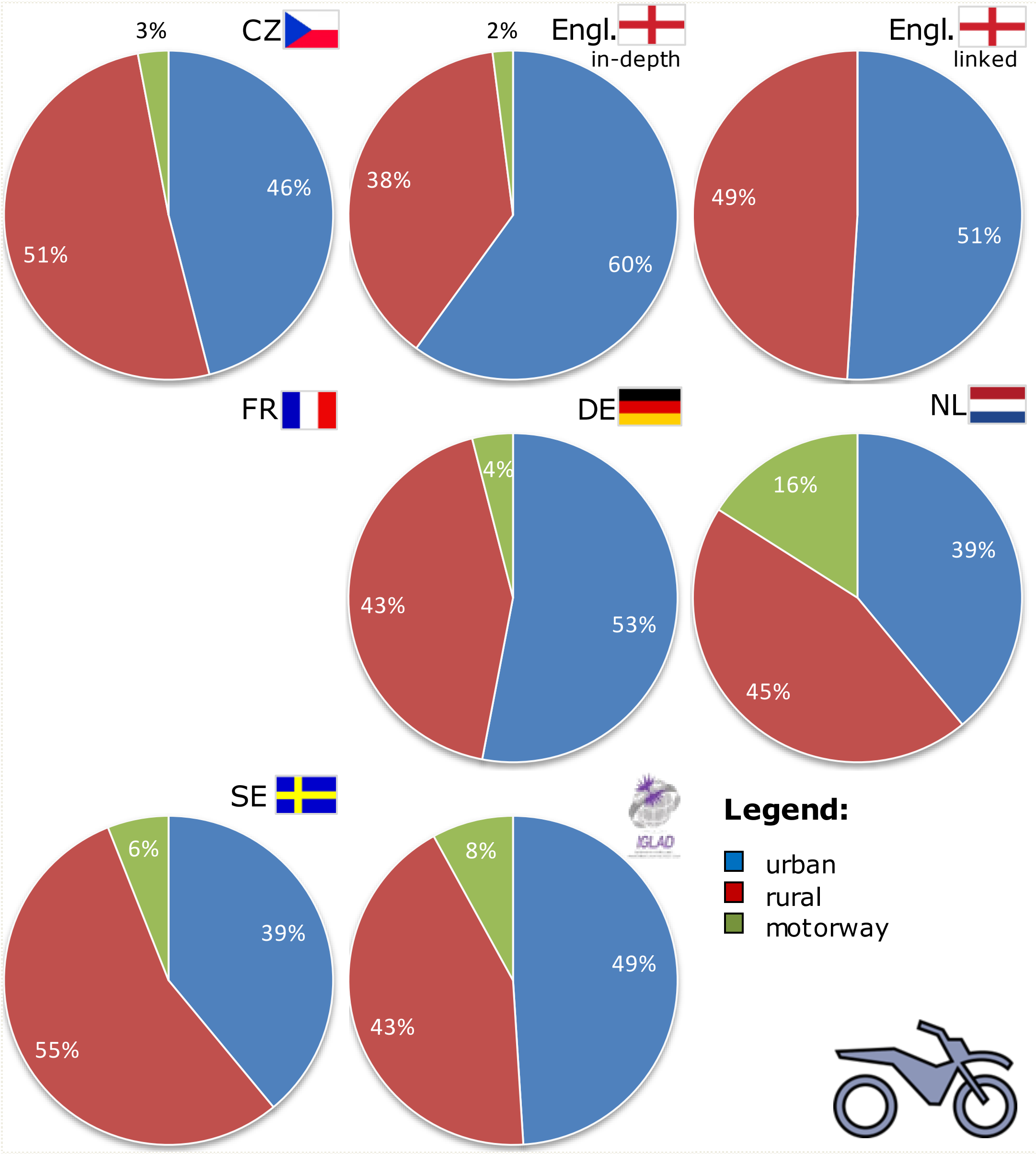

Figure 21: Main road types where crashes occur in which motorcyclists (powered two-wheelers for databases with *) get severely injured in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from the IGLAD database*.

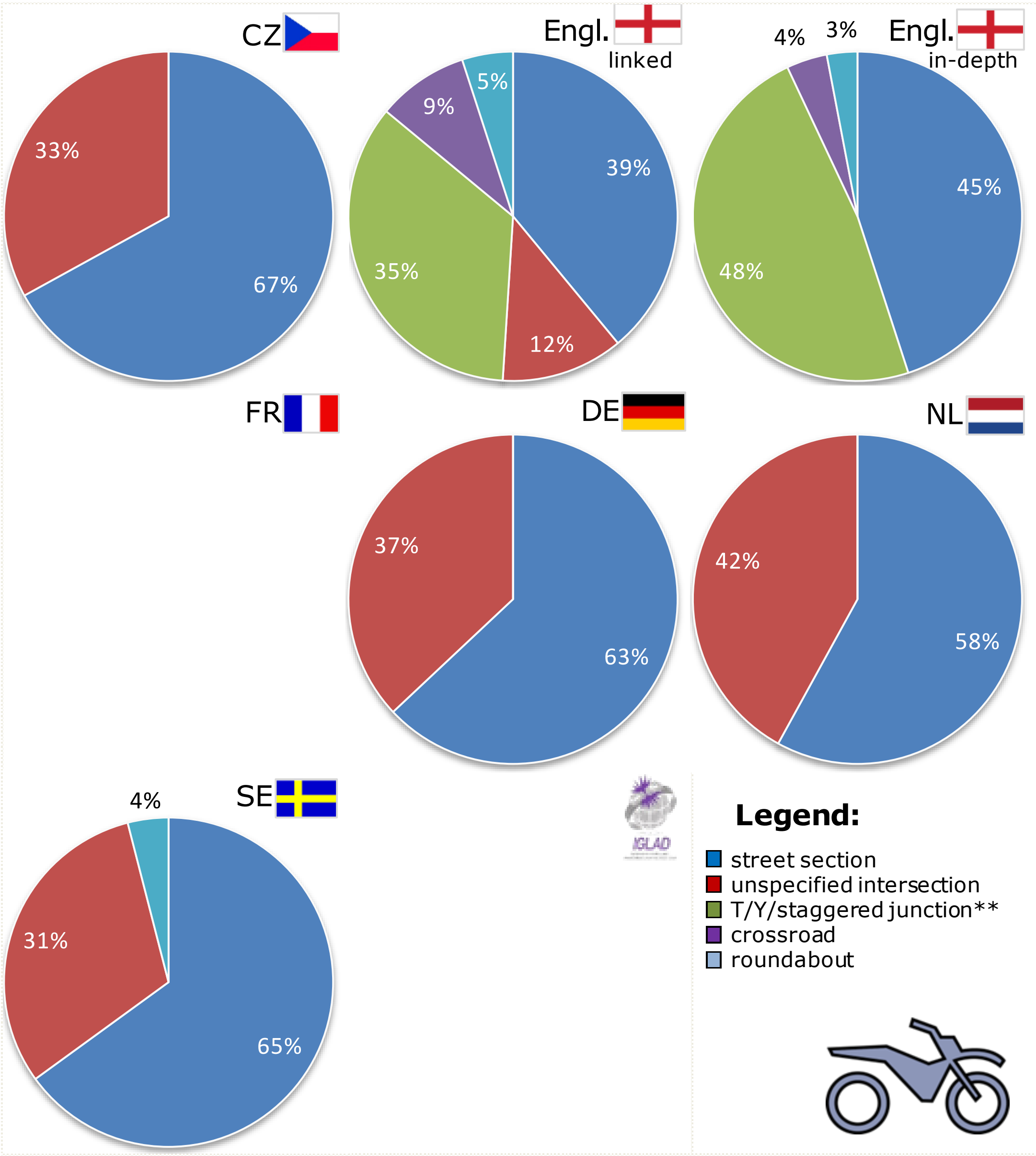

Figure 22: Road configuration where crashes occur in which motorcyclists (powered two-wheelers for databases with *) get severely injured in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA). **A staggered junction is a junction were the side roads are not opposite to each other.

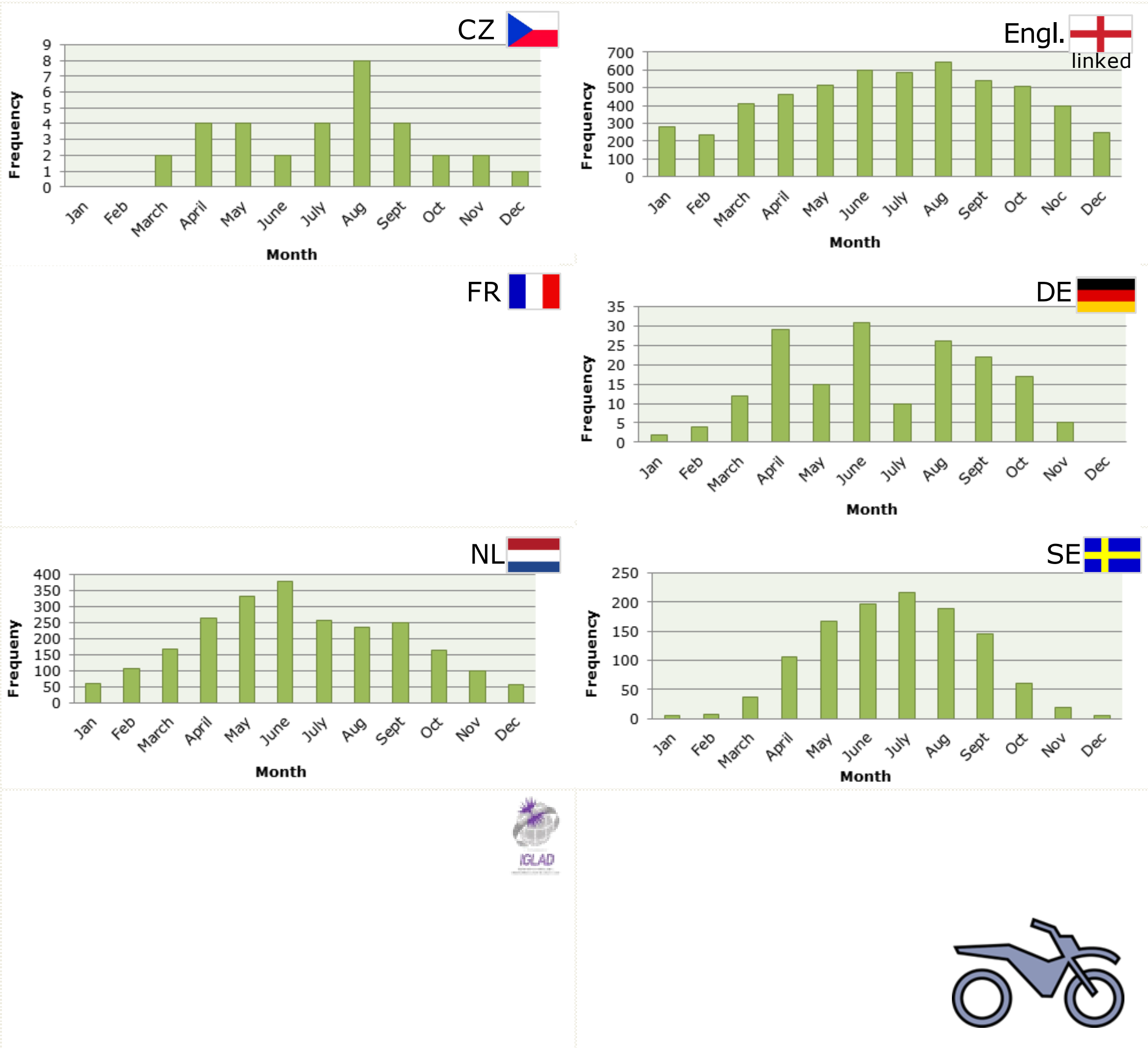

Figure 23: Months in which motorcyclists (powered two-wheelers for databases with *) get severely injured in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA).

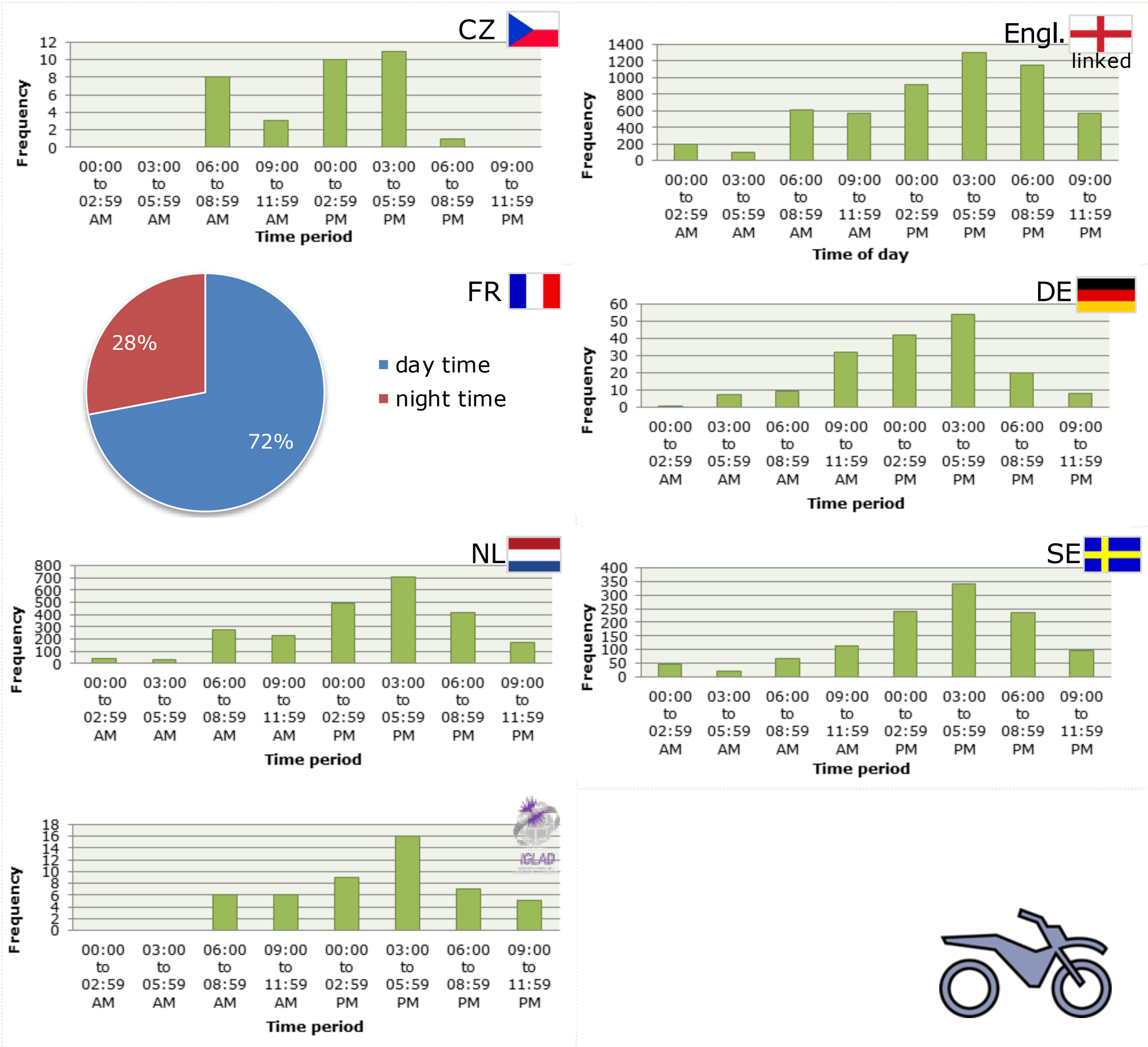

Figure 24: Time period of the day during which motorcyclists (powered two-wheelers for databases with *) get severely injured in the Czech Republic* (CziDAS data), England (linked: STATS19-HES), France*, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA) and the European sample from the IGLAD database*.

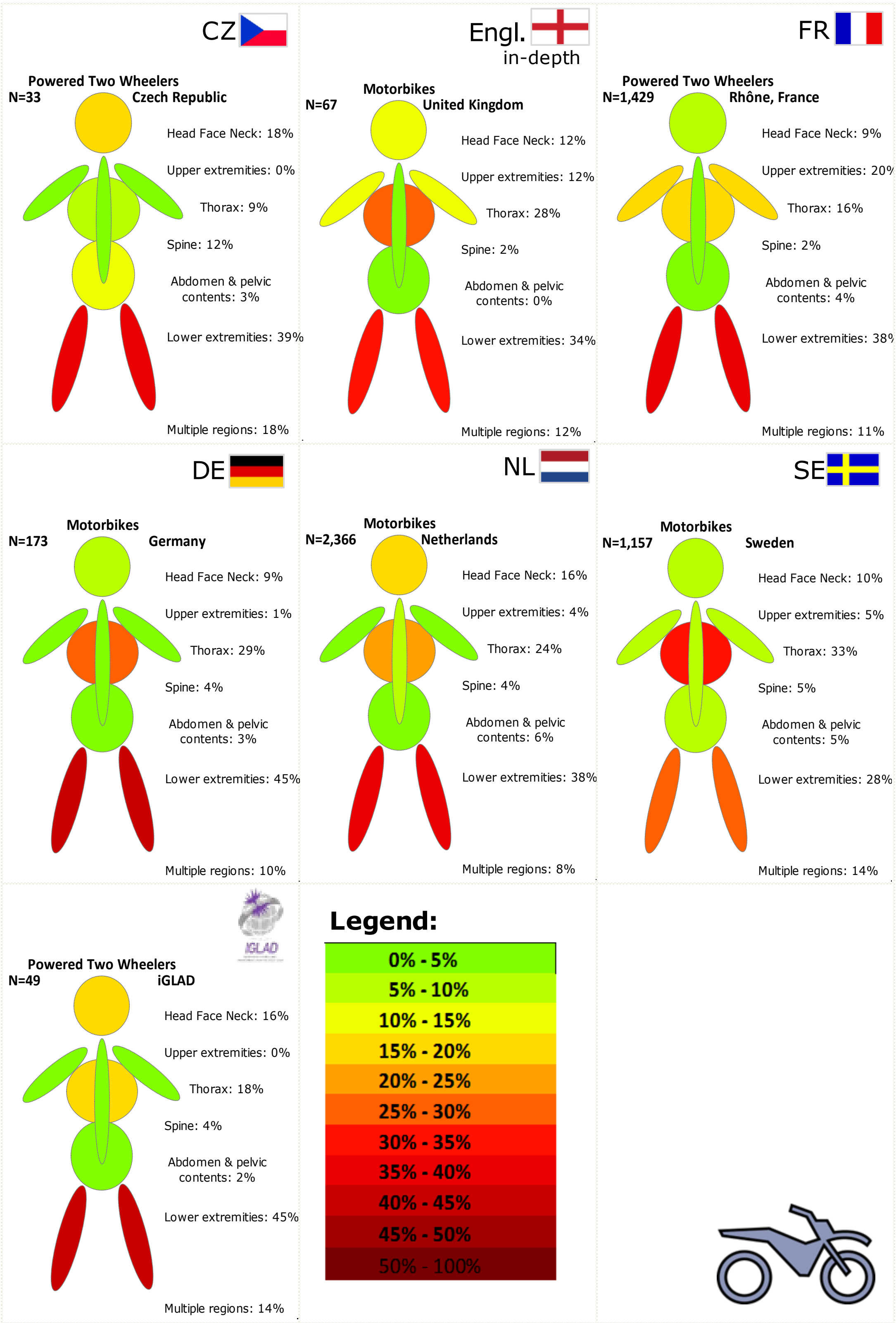

Figure 25: Overview of injured body regions of MAIS3+ motorcyclists (powered two-wheelers for databases with *) in the Czech Republic* (CziDAS data), England (in-depth: RAIDS/OTS), France*, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden, (STRADA), and the European sample from the IGLAD database*.

Car occupants

Czech Republic

Crash characteristics

The CzIDAS car occupant data include 64 seriously injured casualties. two third of the severely injured car occupants were male (see Figure 26), particularly youngsters (Figure 27) and two third were the driver of the car (see Figure 28).

In half of the cases a car was the first crash opponent, in 14% of the cases it was a heavy vehicle and 38% of the cases were a crash with an object as first crash opponent or no crash opponent (see Figure 29). In 22% of the cases only one road user was involved, 34% were crashes with 2 road users and in 44% 3 or more road user were involved.

The majority of car occupants was injured on rural roads (see Figure 30) with a speed limit of 90 km/h (66%) and the crashes occurred mainly on road sections (72%; see Figure 31) and in dry conditions (70%). In 92% of the cases the crashes occurred in not physically divided two-way traffic and with no special location (89%).

Two third of the crashes were head-on collisions, 25% side impact collisions. 26% of the car occupants got injured in an crash that was characterized by the manoeuvre of going ahead round curve (39% going ahead other) and 30% got injured in a (U-) turning crash.

69% of the crashes happened during the day, most of them in the forenoon and the early afternoon during 6am-3 pm (see Figure 33).

Crash scenarios

A first TwoStep Cluster analysis of the car occupant data with 64 cases and the above stated variables yields a 3 cluster solution with an AIC of 2324 and a cluster quality labelled as poor. The next iteration was done with the variables Month Time,, CrashOpponent, ActiveRoadUsers, Manoeuvre, RoadType, CarriageWay, SpeedLimit, JunctionType, and CrashFactor.

The second round yields a 4 cluster solution with an AIC of 1603 and a cluster quality labelled as fair.

The third round yields a 4 cluster solution with an AIC of 452 and a cluster quality labelled as fair. The variables (predictor importances) are ActiveRoadUsers (1.0), CrashOpponent (0.93), Manoeuvre (0.64) and JunctionType (0.62). The results of this analysis (see Table 28) can best be summarised as:

- Car crashes with fixed object while going rounding a curve at a road section (6 of 23);
- Car crashes with another car and one other road user while going straight at a road section (7 of 19);
- Car crashes with another car and two other road user while turning at a crossroad (5 of 13);
- Car crashes with a truck and another road user while turning at a road section (3 of 9).

Table 28: Crash scenarios and injured body regions for the Czech Republic car occupant data (CziDAS).

Cluster nr.	**1**	**3**	**4**	**2**	
N	23	19	13	9	
Active Road user	1 14/23 =60.9%	2 15/19 =78.9%	4 5/13 =38.5%	3 8/9 =88.9%	
Crash opponent	Fixed object 19/23 =82.6%	Car 16/19 =84.2%	Car 13/13 =100%	Truck 5/9 =55.6%	
Manoeuvre	Going ahead round bend 12/23 =52.2%	Going ahead other /19 =68.4%	turning 13/13 =100%	turning 4/9 =44.4%	
Junction Type	Road section 21/23 =91.3%	Road section 19/19 =100%	crossroad 13/13 =100%	Road section 6/9 =66.7%	
Injury type					**Total**
Head, Face, Neck	4/23 =17.3%	4/19 =21%	4/13 =30.8%	1/9 =11.1%	13/64 = 20.3%
Thorax	8/23 =34.8%	6/19 =31.6%	5/13 =38.5%	1/9 =11.1%	20/64 31.3%
Abdomen and pelvic contents	2/23 =8.7%	2/19 =10.5%	0/13 =0%	0/9 =0%	4/64 6.3%
Spine	1/23 =4.3%	0/19 =0%	0/13 =0%	0/9 =0%	1/64 1.6%
Upper extr.	0/23 =0%	0/19 =0%	1/13 =7.7%	1/9 =11.1%	2/64 3.1%
Lower extr.	4/23 =17.4%	5/19 =26.3%	2/13 =15.4%	6/9 =66.7%	17/64 26.6%
Whole surf. + mult. regions	4/23 =17.4%	2/19 =10.5%	1/13 =7.7%	0/9 =0%	7/64 10.9%

Injury factors

The most prominent injuries in the CzIDAs car occupant data are thorax injuries (31%) followed by injuries of the lower extremities (27%; see also Figure 34).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square =19.382, df =18, p<0.369), indicating that for car occupants there is no significant relationship between the injury type and the crash scenario. Looking closer at the data, the following indications can be found:

- Crashes with a truck lead mainly to injuries of the lower extremities and less to the head than in other scenarios;
- Multiple region injuries most common in crashes with a fixed object, here also abdomen, pelvic injuries and injuries of the spine are found (not in the other scenarios);
- Upper extremities are injured only in turning accidents.

England

Crash characteristics

STATS19-HES - The STATS19 HES linked dataset comprises 9,413 severely injured car occupants. Considering the gender just over two third of them are male slightly under one third female (Figure 26). Adolescents (18 to 24 years) appear to be the most dominant age group among MAIS3+ injured car occupants (Figure 27) with the mean age being 35 (SD 20). In respect of seating position, 70% are drivers (see Figure 28), 18% front seat passengers and 12% seated in the rear.

The most common crash opponent is another car (45%; Figure 29). Combining impacts with a fixed object (35%) and those with no impact partner (8%) shows impacts with no road user opponent to comprise 43% of the total (Figure 29). These results are supported when considering the number of active road users in the crash where almost half involve 2 road users and a third only involve the car. This data set records the location of the impact on the car; the majority of crashes resulting in MAIS3+ injury have an impact to the front of the vehicle (66%) followed by the side (29%). In 83% of the cases, the car is moving forward without turning or overtaking.

Road type (Urban/Rural/Motorway) has been derived from the road classification and speed limit in this dataset and therefore the distribution is approximate. The indication is that over half (56%) of the crashes with MAIS3+ car occupants occur in an rural environment, 40% in urban areas and just 5% on motorways (Figure 30). Looking at any junction layout, a third of the crashes occur on a road section (no junction). Of the remaining, crashes at T/Y or staggered junctions are most prevalent (Figure 31). The road surface was dry in 56% of cases.

Considering the date and time of the crash, the prevalence is highest in the winter months, October to December (Figure 32) and there is a higher frequency of crashes from mid-afternoon though till Midnight (Figure 33).

The most common crash factors that have been found in the STATS19-HES are;
- Loss of control (40%)
- Speeding and/or inappropriate speed (35%)
- Careless / reckless behaviour (23%)
- Driver under the influence (drugs/alcohol) (18%)
- Failed to look properly (17%)
- Road condition (wet/icy/poor surface; 14%).

RAIDS-OTS - The combined RAIDS/OTS dataset comprises 148 severely injured car occupants of which 63% are male and 37% female (Figure 26). Age data is only available for the RAIDS data (n=30); in this sample there are more occupants under the age of 35 than over. In respect of seating position, 63% are drivers (see Figure 28), 21% front seat passengers and 16% seated in the rear.

The most common crash opponent according to this dataset is another car (45%). However, combining impacts with a fixed object (35%) and those with no impact partner (4%) shows impacts with no road user opponent to comprise just a slightly smaller proportion (Figure 29). The number of road users shows 39% of cases with just the single car involved. A further 46% involve 2 road users. Considering the location of the impact on the car; the majority of crashes resulting in MAIS3+ injury have an impact to the front of the vehicle (56%) followed by the side (38%). In 86% of the cases, the car is moving forward without turning or overtaking.

Considering Road type (Urban/Rural/Motorway) the indication is that over half (53%) of the crashes with MAIS3+ car occupants occur in a rural environment, a third in urban areas and 14% on motorways (Figure 30). Around 60% of crashes occur where the speed limit is 60mile/h or greater, a further 25% are where the limit is 30mile/h or lower. Looking at any junction layout, a 70% of the crashes occur on a road section (no junction). Of the remaining, crashes at T/Y or staggered junctions are most prevalent, 18%, and 8% are at cross roads. The road surface was dry in 55% of cases (Figure 31).

Month and time are not available in English in-depth data for privacy protection and so daytime/night-time has been used as a substitute. 60% of the severe injury crashes occur during the daytime, with 40% at night time.

The RAIDS/OTS data gave also some starting points to say somewhat more about the causes of crashes. The factors that were found to be most common in crashes where car occupants get severely injured are:

- Loss of control (58%);
- Speed – either in excess of speed limit or too fast for the conditions (56%);
- Careless / reckless behaviour (49%).

Other contributing factors that were found: drivers in the crash were distracted in 16% of cases and under the influence of drugs or alcohol in 17% of cases. Failure to look properly (17%), failure to judge another road users path or speed (15%) and aggressive driving (16%) are other common factors. Road design was mentioned in almost 12% of cases.

Crash scenarios

STATS19-HES - A first TwoStep Cluster analysis of the car data with 9413 cases in the STATS19-HES database was undertaken using the nominal variables CasualtyRole Month, Time, opponent, CrashType, Gender, Junction, Surface, Manoeuvre ActiveRoadUsers and SpeedLimit and the interval variable Age, a total of 12 input variables. This resulted in a 2 cluster solution with an AIC of 260780.4 and a cluster quality labelled as Poor.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, opponent, ActiveRoadUsers, Time and Manoeuvre. Again a 2 cluster solution was returned with an AIC of 105134.6 and a cluster quality labelled as Fair. In this solution the variables opponent, ActiveRoadUsers and Time have a predictor importance > 1.0.

A third TwoStep Cluster analysis only using the latter three variables yields a 2 cluster solution with an AIC of 83239.131 and a cluster quality labelled as Good. In this solution Opponent and ActiverRoadUsers have a predictor importance of 1.0 and Time has 0.61. The 2 clusters are described in Table 29 in order of cluster size and can best be summarised as:

- car to car crashes, with two active road users (3259/6021) most frequently occurring during the rush hour period (5-6pm; 245 of 6021 cases);
- Single vehicle crashes in to a fixed object (2995/3392) occurring most frequently at night (11pm to midnight; 256 of 3392 cases).

Table 29: Crash scenarios for England car occupant data (STATS19-HES)

Cluster nr.	1	2
N	6021	3392
Opponent	Car (69.9%)	Fixed Object (87.5%)
ActiveRoadUsers	2 (76.1%)	1 (99.6%)
Time	5:00 PM (7.5%)	11:00 PM (8.5%)

Loss of control and speeding/inappropriate speed remain the most commonly reported factors in both clusters, however there is evidence for a higher proportion of crashes with these factors when the car impacts with a fixed object. Alcohol or drugs feature in car to fixed object crashes, but not so much in car to car impacts, whereas failure to look and/or judge another road users path or speed are more associated with car to car impacts. The road condition is also reported more in car to fixed object crashes than for car to car impacts.

RAIDS/OTS - Also a cluster analysis of the RAIDS/OTS data split the data into two common scenarios based upon two input variables CrashOpponent and ActiveRoadUsers. The first (62% of severe car occupant casualties) is defined by car to car crashes, with two active road users. The second (38% of casualties) comprises single vehicle crashes in to a fixed object. These two clusters support the picture produced for the national English data which shows very similar distributions of these two variables.

A first TwoStep Cluster analysis of the car data with 148 cases was undertaken using the nominal variables CasulaltyRole DayNight, CrashOpponent, CrashType, Gender, Junction, Surface, Manoeuvre ActiveRoadUsers, area and SpeedLimit a total of 11 input variables. Age was not included due to non-availability in OTS. This resulted in a 2 cluster solution with an AIC of 2784.06 and a cluster quality labelled as Poor.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, ActiveRoadUsers and CrashOpponent. Again a 2 cluster solution was returned this time with an improved AIC of 350.66 and a cluster quality labelled as Good. In this solution the variable opponent has importance 0.7 and opponent 1,0. The 2 clusters are described in Table 30 and can best be summarised as:

- Car to car crash with two active road users involved (46 of 91 cases);
- Car crash with a fixed object and only one active road user involved (48 of 57 cases).

Whilst loss of control and speed are the most frequent for both clusters, they occur more frequently in crash scenarios where a car hits a fixed object than in car to car crashes. The car to fixed object crashes feature driver under the influence and poor manoeuvre, whereas those car to car crashes cluster features errors of judgement such as failing to look properly and misjudging the path or speed of another vehicle.

Table 30: Crash scenarios and injured body regions for England car occupant data (RIADS & OTS).

Cluster nr.	**1**	**2**	
N	91	57	
Crash opponent	Car 64/91 = 70%	Fixed object 48/57 = 84%	
Number of active road users	Two road users 68/91 = 75%	One road user 57/57 = 100%	
Injury type			**Total**
Head, Face, Neck	*17.6%*	*21.1%*	*18.9%*
Thorax	*26.4%*	*28.1%*	*27.0%*
Abdomen and pelvic cont.s	*3.3%*	*0%*	*2.0%*
Spine	*4.4%*	*10.5%*	*6.8%*
Upper extr.	*9.9%*	*5.3%*	*8.1%*
Lower extr.	*23.1%*	*14.0%*	*19.6%*
Whole surface+ Mult. Regions	*15.4%*	*21.1%*	*17.6%*

Injury factors

The Table shows the injury distribution by body region for MAIS3+ car occupants in the OTS/RAIDS data. Firstly, considering injuries of all severities, the chest is most often injured (60%), followed by the lower extremity (59%) and the head (55%). When just severe injury outcome is considered for each body region, the chest has the highest proportion (43%) followed by arms (28%) and the head (24%; see also Figure

34). About 11% of the severely injured car occupants did not wear a seat-belt, but seat-belt wearing is unknown for 45%.

A chi-square test of association has been performed on the 2 x 7 contingency table generated from cluster number by injury type ($\chi 2=7.118$, *df* =6, p=.301) however some cells in the table have expected count < 5 and so the test is not valid. A further chi-square test to test for an association between MAIS and cluster membership ($\chi 2=1.338$, *df* =2, p=.512) was also not valid.

Looking in more detail at the injury type within each cluster, chest injury type is the most common in both scenarios, (26.4% car to car, 2 road users and 28.1% Car to fixed object, one road user). Injury type head, Spine and multiple have higher proportions in the car to fixed object scenario, with extremities, both upper and lower having higher proportions in the car to car scenario.

France, Rhône region

Crash characteristics

From the French Rhône region, data of 781 severely injured car occupant showed that about two third of them is male (see Figure 26). Adolescents (18 to 24 years) appear to be the most dominant age group among MAIS3+ injured car occupants (Figure 27). According to the Rhône database, 80% of the severely injured car occupants has used a seat belt but in only 30% of the crashes, an airbag was used.

Crashes with another car are most common (42%), followed by single vehicle crashes and crashes with a fixed object (Figure 29). Somewhat more car crashes happen during daytime than during the night (Figure 33).

Crash scenarios

A first TwoStep Cluster analysis of the completed car data with 781 cases and the nominal variables DayNight, FirstCrashOpponentOpponent, DemographyAgeGroup, DemographyGender, Seatbelt use and Airbag use yields a 2 cluster solution with an AIC of 8227.363 and a Cluster Quality labelled as Fair. In this solution the variable DemographyGender has a predictor importance of 1.0 while the predictor importances of the remaining variables are all almost zero. This means that the variable DemographyGender completely dominates the cluster solution, swamping out all the other variables.

A second TwoStep Cluster analysis without the variable DemographyGender yields a 2 cluster solution with an AIC of 7041.746 and a Cluster Quality also labelled as Fair. This solution is dominated by the variable DayNight which has a predictor importance of 1.0 while the predictor importances of the other variables are all smaller than 0.30.

A third TwoStep Cluster analysis only applied to the FirstCrashOpponentOpponent, DemographyAgeGroup, Seatbelt use and Airbag use results in a 4 cluster solution with an AIC of 5122.018 and a Cluster Quality also labelled as Fair. In this solution the variables FirstCrashOpponentOpponent, DemographyAgeGroup, Seatbelt use and Airbag use have predictor importances of 0.50, 0.06, 1.00 and 0.95, respectively. Finally removing variable DemographyAgeGroup from the analysis we obtain a 4 cluster solution with an AIC of 1820.769 and a Cluster Quality labelled as Good. In this solution the variables FirstCrashOpponentOpponent, Seatbelt use and Airbag use have predictor importances of 0.54, 1.00 and 0.88, respectively.

The following clusters were found and between brackets the number of cases that exactly have the combination of characteristics described (Table 31):

- Car crashes with no crash opponent in a crash without an airbag used but the driver wearing a seat-belt (82 of the 231 cases; 59 cases are against fixed objects);
- Car with airbag hit by a another car while the driver is wearing a seatbelt (70 of the 213 cases);
- Car without an airbag hit by another car while the driver is wearing a seatbelt (134 of the 186 cases);
- Car crashes with no crash opponent or with a fixed object in a car with no airbag and the driver not wearing a seatbelt (30 of the 151 cases with no crash opponent, 31 cases with fixed object).

Table 31: Crash scenarios and injured body regions for the Rhône region car occupant data (Rhône road trauma registry, France, IFSTTAR).

Cluster nr.	**2**	**3**	**4**	**1**	
N	231	213	186	151	
Seatbelt use	Yes 231/231 = 100.0%	Yes 213/213 = 100.0%	Yes 186/186 = 100.0%	No 151/151 = 100.0%	
Airbag use	No 226/231 = 97.8%	Yes 213/213 = 100.0%	No 186/186 = 100.0%	No 134/151 = 88.7%	
First crash opponent	No crash opponent 82/231 =35.5%	Car 97/213 = 45.5%	Car 186/186 = 100.0%	No crash opponent 50/151 = 33.1%	
Injury type					**Total**
Head+ Face+ Neck	39 16.9%	32 15.0%	25 13.4%	45 29.8%	141 18.1%
Thorax	56 24.2%	56 26.3%	62 33.3%	33 21.9%	207 26.5%
Abdomen and pelvic contents	12 5.2%	8 3.8%	6 3.2%	9 6.0%	35 4.5%
Spine	24 10.4%	16 7.5%	8 4.3%	11 7.3%	59 7.6%
Upper extremities	45 19.5%	36 16.9%	31 16.7%	9 6.0%	121 15.5%
Lower extremities	31 13.4%	28 13.1%	23 12.4%	24 15.9%	106 13.6%
Whole surface + multiple regions	24 10.4%	37 17.4%	31 16.7%	20 13.2%	112 14.3%

Injury factors

In the lower part of the Table we have also added the frequencies in the cross-table of variables injury type and cluster number. Since there is only one face injury in this data set we added this case to the Head injuries. The proportions in the lower half of Table 4 are column proportions; adding them over injury type these proportions therefore all add up to 100%. For the car victims we first of all see that injuries to the thorax are generally the most frequently in car occupants (27), followed by injuries to the head and face (18%), injuries to the upper extremities (16%), and then by injuries to multiple regions (14%) and to the lower extremities (14%; see also Figure 34).

The Chi-square test for the cross-table of injury type by cluster number is very significant (Chi-square = 44.14, $df = 18$, $p < 0.001$), indicating that for cars there is a significant relationship between the variable injury type and the clusters obtained in the TwoStep Cluster analysis. Inspecting the distribution of the injury types over the four separate clusters, we see the following most important differences:

- Injuries to the head and face occur more often in crashes without an opponent and no use of a seatbelt and airbag;
- Injuries to the thorax occur more often in crashes with other cars when a seatbelt but no airbag is used;
- The Abdomen and pelvic contents are more often injured in single vehicle crashes;
- The number of injuries to the spine in crashes without an opponent using a seatbelt but not an airbag is smaller than in the other three clusters;
- The number of injuries to the upper extremities in crashes without an opponent and with neither seatbelt nor airbag use is smaller than in the other three clusters.

Germany

Crash characteristics

The 309 cases of severely injured car occupants in GIDAS showed that about two third of them is male and one third female (Figure 26). Younger drivers (18 to 24 years) appear to be the most dominant age group among MAIS3+ injured car occupants (Figure 27). Nearly two third of the car occupants that get severely injured is involved as a driver and nearly one third as a passenger (see Figure 28).

Crashes without any other road user are most common (50%), followed by cars as the second most important crash opponent (34%; Figure 29). Also car crashes with a van or heavy vehicle are common. About 40% of the car crashes are single crashes and 50% involve one other active road user. Furthermore, nearly two third of the MAIS3+ car crashes is a head-on crash, with side-impact collisions as important second crash type. 47% of the crashes are characterized by the manoeuvre of going ahead other, 24% going ahead round curve and 18% of the car occupants got injured in a turning crash.

Somewhat more than half of the crashes in which car occupants get severely injured are on rural roads and about one third on urban roads (see Figure 30). About 80% of the crash occur on road sections and 20% on junctions (Figure 31). In about two third of the cases, the road is dry; in the other one third of the cases, the road was wet or slippery. 75% of the crashes occur in not physically divided two-way traffic, 24% on physically divided roadways. For the majority of cases (89%) the crash happened at no special location. Concerning crash factors in nearly equal shares inadequate information acquisition or speeding contributed to the crash. In 10% a fatigued driver (casualty or opponent) caused the crash.

Most car occupants get severely injured in Winter (November- February) or in the summer months July and August (Figure 32). Most injuries occur in the middle of the day noon to 6:00 PM (Figure 33).

Crash scenarios

A first TwoStep Cluster analysis of the car occupant data with 309 cases and the variables as stated above leaving out yields a 4 cluster solution with an AIC of 12 110 and a cluster quality labelled as poor (0.1). In this solution only the variables Manoeuvre, RoadType, JunctionType, CarriageWay, Crash opponent, CrashFactor, CrashType, ActiveRoadUsers and Location have a predictor importance larger than 0.2.

A second TwoStep Cluster analysis with the left variables yields a 4 cluster solution with an AIC of 3840 and a cluster quality labelled as just fair (0.2).

A third TwoStep Cluster analysis different combinations of the former variables were tested and the best solution with a 5 cluster solution with an AIC of 874 and a cluster quality labelled as good (0.6) was achieved. In this solution the variables (predictor importances) are RoadType (1.0), Manoeuvre (0.82), JunctionType (0.53) and CarriageWay (0.34). The most common clusters are (see Table 32):

- Cars going ahead on rural road sections where the traffic is not physically divided (71 of the 71 cases);
- Cars going ahead round a curve on rural road sections where the traffic is not physically divided (53 of the 65 cases);
- Cars going ahead on an urban road sections where the traffic is not physically divided (28 of the 65 cases);
- Cars in a turning manoeuvre on an urban crossroads where the traffic is not physically divided (29 of the 63 cases);
- Cars going ahead on motorways, which have physical divided road directions (28 of the 45 cases).

Table 32: Crash scenarios and injured body regions for the German car occupant data (GIDAS).

Cluster nr.	5	2	4	3	1	
N	71	65	65	63	45	
Road Type	Rural 71/71 =100%	Urban 47/65 =72.3%	Rural 65/65 =100%	Urban 63/63 =100%	Motorway 4one quarter5 =91.1%	
Manoeuvre	Going ahead other 71/71 =100%	Turning 55/65 =84.6%	Going ahead round curve 53/65 =81.5%	Going ahead other 39/63 =61.9%	Going ahead other 28/45 =62.2%	
Junction Type	Road section 71/71 =100%	Crossroad 48/65 =73.8%	Road section 65/65 =100%	Road section 62/63 =98.4%	Road section 45/45 =100%	
Carriage Way	Two-way traffic not divided 71/71 =100%	Two-way traffic not divided 45/65 =69.2%	Two-way traffic not divided 65/65 =100%	Two-way traffic not divided 51/63 =81%	Physically divided roadway 45/45 =100%	
Injury Type						**Total**
Head, Face, Neck	7/71 =9.9%	7/65 =10.8%	15/65 =23.1%	7/63 =11.1%	12/45 =26.7%	48/309 =15.5%
Thorax	28/71 =39.4%	31/65 =47.7%	22/65 =33.8%	29/63 =46%	11/45 =24.4%	121/309 =39.2%
Abdomen and pelvic cont.s	4/71 =5.6%	4/65 =6.2%	1/65 =1.5%	3/63 =4.8%	4/45 =8.9%	16/309 =5.2%
Spine	3/71 =4.2%	7/65 =10.8%	5/65 =7.7%	4/63 =6.3%	4/45 =8.9%	23/309 =7.4%
Upper extr.	1/71 =1.4%	2/65 =3.1%	0/65 =0%	1/63 =1.6%	1/45 =2.2%	5/309 =1.6%
Lower extr.	14/71 =19.7%	9/65 =13.8%	15/65 =23.1%	13/63 =20.6%	3/45 =6.7%	54/309 =17.5%
Whole surf. + mult. regions	14/71 =19.7%	5/65 =7.7%	7/65 =10.8%	6/63 =9.5%	10/45 =22.2%	42/309 =13.6%

Injury factors

Table 32 shows the most common crash scenarios including the frequencies of the MAIS3+ injured body regions per scenario. For the car occupant casualties the thorax injuries are most common (39%) followed by injuries of the lower extremities (18%), the head (16%) and multiple regions (14%; see also Figure 34).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=33.825 df=24, p<0.088), indicating that for car occupants there is no significant relationship between the injury type and the crash scenario. However, a closer look into the injury distribution reveals a tendency that crashes on motorways show a lowest share in injuries of the thorax and the lower extremities but the highest share in head injurie, injuries of the abdomen and multiple region injuries. Crashes on rural roads show the highest share of young drivers: 40.8% and 33.8%, respectively and also the highest share of single crashes (38.5%) or crashes with a fixed object (40.8%).

For the 309 car occupant casualties 1931 single injuries were recorded (mean of about 6 injuries per casualty) of which 574 injuries (mean of 2 injuries per casualty) have a severity of AIS08=3 or larger. The majority of fractures were caused by the contact with the internal of the own car. 15% of the injuries were inflicted by the seatbelt, mainly causing rip fractures and organ injuries. 4% of the injuries were caused by a whiplash, 11% by contact with the control panel and 15% by contact with the steering wheel.

Netherlands

Crash characteristics

Data of 7,438 severely injured car occupants revealed that about two third of them is male and one third female (Figure 26). Adolescents (18 to 24 years) appear to be the dominant age group among MAIS3+ injured car occupants (Figure 27). Nearly ¾ of the car occupants that get severely injured is involved as a driver and nearly ¼ as a passenger (see Figure 28).

Crashes without any other road user are most common (44%), followed by cars as the second most important crash opponent (Figure 29). Also car crashes with a van or heavy vehicle are common in MAIS3+ car crashes. About one third of the car crashes involve on other active road user, but also two or more other active road users are common. Furthermore, nearly two third of the MAIS3+ car crashes are head-on crashes, with side-impact collisions as important second crash type.

Somewhat more than half of the crashes in which car occupants get severely injured are on rural roads, more than ¼ on urban roads and one fifth on motorways (see Figure 30). About 70% of the crashes occur on road sections and 30% on junctions (Figure 31). In two third of the cases, the road is dry; in the other one third of the cases, the road was wet or slippery.

Most car occupants get severely injured in January-February and May-June (Figure 32). Most injuries occur in the afternoon, but also in the evening and morning (6:00 AM to 9:00 AM) are common (Figure 33).

Crash scenarios

A first TwoStep Cluster analysis of the car data from BRON-DHD with 7,438 cases and the nominal variables Month, Time, opponent, CrashType, Gender, RoadType, Junction, Surface, and SpeedLimit and the interval variables ActiveRoadUsers and Age yields a 4 cluster solution with an AIC of 176738.016 and a cluster quality labelled as

Poor. Only the variables opponent, CrashType, RoadType, Junction, and SpeedLimit have a predictor importance of 1.0.

A second TwoStep Cluster analysis only using the latter five variables yields a 3 cluster solution with an AIC of 70880.198 and a cluster quality labelled as Fair. In this solution only the variables opponent, CrashType, RoadType, and SpeedLimit have a predictor importance of 1.0.

A third TwoStep Cluster analysis only using the latter four variables yields a 6 cluster solution with an AIC of 44,875.352 and a cluster quality labelled as Fair. In this solution all four variables have a predictor importance of 1.0. These 6 clusters are described in Table 33 in order of cluster size and between brackets the number of crash scenarios that exactly fit to the combination of characteristics that is the most common in each of the clusters.

Table 33: Crash scenarios and injured body regions for the Dutch car occupant data (BRON-DHD).

Cluster nr.	**6**	**1**	**5**	**4**	**2**	**3**	
N	1,666	1,621	1,577	1,047	775	752	
Crash type	Side-impact collision turning 543/1666 = 32.6%	Collision fixed object 1620/1621 = 99.9%	Head-on collision 633/1577 = 40.1%	Rear-end collision 426/1047 = 40.7%	Collision fixed object 448/775 = 57.8%	Collision fixed object 752/752 = 99.3%	
Opponent	Car 991/1666 = 59.5%	Fixed object 1619/1621 = 99.9%	Car 986/1577 = 62.5%	Car 627/1047 = 59.9%	Fixed object 410/775 = 52.9%	Fixed object 751/752 = 99.9%	
Road type	Urban 1302/1666 = 78.2%	Rural 1621/1621 = 100.0%	Rural 1577/1577 = 100.0%	Motorway 983/1047 = 93.9%	Motorway 538/775 = 69.4%	Urban 752/752 = 100%	
Speed limit	50 km/h 1150/1666 = 69.0%	80 km/h 1308/1621 = 80.7%	80 km/h 1569/1577 = 99.5%	120 km/h 328/1047 = 31.3%	120 km/h 336/775 = 43.4%	50 km/h 631/752 = 83.9%	
Injury type							**Total**
Head, Face, Neck	473 25.5%	512 31.6%	402 25.5%	312 29.8%	252 32.5%	230 30.6%	2181 29.3%
Thorax	419 25.2%	381 23.5%	433 27.5%	311 29.7%	229 29.5%	186 24.7%	1959 26.3%
Abdomen and pelvic cont.s	76 4.6%	89 5.5%	94 6.0%	47 4.5%	38 4.9%	38 5.1%	382 5.1%
Spine	68 4.1%	46 2.8%	56 3.6%	58 5.5%	53 6.8%	22 2.9%	303 4.1%
Upper extr.	34 2.0%	18 1.1%	26 1.6%	15 1.4%	22 2.8%	16 2.1%	131 1.8%
Lower extr.	518 31.1%	430 26.5%	436 27.6%	225 21.5%	131 16.9%	208 27.7%	1948 26.2%
Whole surface+ Mult. regions	78 4.7%	145 8.9%	130 8.2%	79 7.5%	50 6.5%	52 6.9%	534 7.2%

The combination of factors via TwoStep Cluster analysis revealed the following six most common scenarios (see Table 33):

- Side-impact crash during turning manoeuvre with another car as crash opponent on an urban 50 km/h road (233 of the 1,666 cases);
- Collision with a fixed object on a rural 80 km/h road (1,306 of the 1,621 cases);
- Head-on collision with a car on a rural 80km/h road (444 of the 1,577 cases);
- Rear-end collision with another car on a 120 km/h motorway (102 of the 1,047 cases);
- Collision with a fixed object on a 120 km/h motorway (239 of the 775 cases);
- Collision with a fixed object on an urban 50 km/h road (625 of the 752 cases).

Injury factors
Since there are only two face injuries and one neck injury in this data set we added these to the Head injuries and because there are only eight Whole surface area injuries in this data set we added them to the Multiple region injuries. For the car victims we first of all see that head injuries are generally the most common type of injury (29%), closely followed by injuries to the thorax (26%), and by injuries to the lower extremities (26%; Table 33 and Figure 34).

The Chi-square test for the cross-table of injury type by cluster number is very significant (Chi-square = 150.923, df = 30, $p < 0.001$), indicating that for cars there is a significant relationship between injury type and cluster.

When inspecting the injury types in the six separate clusters, we see that the relation between injury type and cluster type is mainly due to the fact that:
- Injuries to the lower extremities are relatively much larger in the cases in car to car side impacts on a 50 km/h road (31.1%) while being much smaller in the cases where a car hits a fixed object on a motorway (16.9%).
- Moreover, injuries to multiple body regions are relatively larger in crashes where a car hits a fixed object on a 80 km/h road (8.9%) while being much smaller in car side-impact crashes on 50 km/h roads (4.7%).
- Injuries to the spine are less common when a car hits a fixed object on 50 km/h or 80 km/h roads than in other crash types and are most common in rear-end collisions on motorways.

Sweden

Crash characteristics
The dataset comprises 3,291 severely injured car occupants of which 65% are male and 35% female (Figure 26). There is a peak in the age distribution for young adults aged 18-25 (Figure 27). In respect of seating position, 70% are drivers (see Figure 28) with the remaining 30% passengers of whom 11% are confirmed in the front and 7% in the rear.

Car to car impacts are the single most common crash scenario (37%). Impacts either with a single vehicle involved or into a fixed object account for 45% of the crashes (Figure 29). This is supported by the number of road users which shows 46% of cases with just the single car involved. A further 45% involve 2 road users.

Almost two thirds of the crashes occur in a rural environment, a quarter in urban areas and 15% on Motorways (Figure 30). The most frequent speed limit is 70 km/h and almost 80% of crashes occur at this speed limit or greater. Looking at any junction layout, the data is primarily distinguished by either 'intersection' or 'road section'. Over 3.4 (77%) crashes occur on a road section (no junction; Figure 31).

The months with the highest proportion of crashes are July and November. On the whole the latter 6 months of the year have more crashes per month than those between January to June (Figure 32). There is a rise in the proportion of crash occurring in the afternoon, with the greatest proportion being between 3 and 6 pm (Figure 33).

Crash scenarios
A first TwoStep cluster analysis was undertaken with the nominal variables Urban Number_Road_Users Crash_opponent Location_junction Hour Month Role and Sex and the continuous variables SpeedLimit and Age, a total of 10 input variables.
This resulted in a 2 cluster solution with an AIC of 70807.98 and a cluster quality labelled as Fair. Only the variables Crash_opponent and Number_road_users have a predictor importance > 0.5.

A second TwoStep Cluster analysis used input variables from the first with a predictor importance > 0.5, Number_road_users and Crash_opponent. This produced a 5 cluster solution with an improved AIC of 2328,62 and a cluster quality labelled as Good. In this solution the variable crash_opponent has importance 1.0 and so does Number_road_users. The 5 clusters are described in Table 34 and can be summarised as follows:

- Car hit by another car (all of the 946 cases)
- Car in single vehicle crash[19] (all of the 945 cases)
- Car hit by a heavy vehicle (367 of the 544 cases)
- Car that crashes with a fixed object (all of the 473 cases)
- Car hit by another car and with at least one other traffic participant involved (192 of the 383 cases)

Table 34: Crash scenarios and injured body regions for the Swedish car occupant data (STRADA).

Cluster nr.	1	4	2	5	3	
N	946 (28.7%)	945 (28.7%)	544 (16.5%)	473 (14.4%)	383 (11.6%)	
Crash Opponent	Car (100%)	Single Vehicle (100%)	Large Vehicle (67.3%)	Fixed Object (100%)	Car (67.1%)	
ActiveRoadUsers	2 (100%)	1 (100%)	2 (100%)	1 (100%)	3+ (75.5%)	
Injury Type						**Total**
Head, Neck, Face	157 16.6%	229 24.2%	148 27.2%	91 19.2%	82 21.4%	21.5%
Thorax	367 38.8%	321 34%	178 32.7%	157 33.2%	118 30.8%	34.7%
Abdomen and pelvic contents	41 4.3%	24 2.5%	16 2.9%	22 4.7%	19 5.0%	3.7%
Spine	62 6.6%	113 12%	40 7.4%	57 12.1%	39 10.2%	9.5%
Upper Extremities	40 4.2%	35 3.7%	12 2.2%	10 2.1%	9 2.3%	3.2%
Lower Extremities	165 17.4%	100 10.6%	70 12.9%	82 17.3%	64 16.7%	14.6%
Whole surface and multiple regions	114 12.1%	123 13.0%	80 14.7%	54 11.4%	52 13.6%	12.9%

Injury factors
The Table shows the injury distribution by body region for MAIS3+ car occupants in the STRADA data. Due to the low number of face and neck injuries, these are combined with the head. Similarly, the whole surface is combined with multiple

[19] defined as accidents with no crash opponent recorded but with a crash code indicating a single vehicle accident.

regions (see Table 34 and Figure 34). The chest shows the highest proportion followed by the head and then the lower extremity.

A chi-square test of association has been performed on the 5 x 7 contingency table generated from cluster number by injury type ($\chi2=90.821$, *df* =24, p<0.001) which shows that an association exists between injury type and crash scenario as defined by the 5 clusters. A visual examination of the cross-tabulation shows that:

- Chest injuries have the highest proportion across all scenarios (30-38%) with the highest being in the scenario where a car is hit by another car.
- The most striking differences are for the head where the scenario of car hit by another car results in a lower proportion of injury to the head with the highest proportion when the impact is to a large vehicle and single vehicle crashes.
- Lower extremity injury is higher in the scenarios where a car is hit by at least one other car or where the car hits a fixed object.

IGLAD database

Crash characteristics

The 113 cases of severely injured car occupants showed that about 60% of them is male and 40% female (Figure 26). Most MAIS3+ injured car occupants are in the age of 18 to 44 (Figure 27). Sixty percent of the car occupants that get severely injured are involved as a driver (see Figure 28). The vehicle in which the victim was driving was mainly 1 to 10 years old.

Crashes with a car as first crash opponent are most common (56%), followed by single vehicle crashes and crashes with a fixed object (31%) and heavy vehicles (13%; Figure 29). About 26% of the car crashes are single crashes and 65% involve one other active road user. Furthermore, 77% of the MAIS3+ car crashes is a head-on crash, with side-impact collisions as important second crash type (19%). The majority of crashes are preceded by going straight or rounding a curve (78%). Also turning crashes are common (17%). Important crash factors are inadequate information acquisition (32%), speeding (26%), and a driver being under influence/fatigued/medically impaired (13%) or wrong-way driving (12%).

Somewhat more than half of the crashes in which car occupants get severely injured are on urban roads (see Figure 30). In about 65% of the cases, the road is dry. Most injuries occur from noon to 6:00 PM (Figure 33).

Crash scenarios

A first TwoStep Cluster analysis of the car occupant data with 113 cases and the above stated variables yields a 2 cluster solution with an AIC of 4987 and a cluster quality labelled as poor (0.2).

A second TwoStep Cluster analysis of the car occupant data with Role, Time, DayNight, CrashOpponent, Manoevre, RoadType, CrashFactor, AgeGroup, ActiveRoadUsers yields a 3 cluster solution with an AIC of 2651 and a cluster quality labelled as fair (0.2).

A third TwoStep Cluster analysis yields a 3 cluster solution with an AIC of 1252 and a cluster quality labelled as good (0.5). The variables (predictor importances) are AcvtiveRoadUsers (1.0), CrashOpponent (0.76), DayNight (0.71),Time (0.27) and Manoeuvre (0.14). The three clusters that have been found can be described according to the following major characteristics (see Table 35):

- Car occupant in a crash with another car during daytime while going straight (18 of 54)

- Single car crash hitting an object during daytime while driving round a bend (6 of 33).
- Car occupant in a crash with another car during night time while rounding a curve (7 of 26).

Table 35: Crash scenarios and injured body regions for the IGLAD car occupant data (IGLAD).

Cluster nr.	**3**	**2**	**1**	
N	54	33	26	
Active Road Users	2 47/54 =87%	1 33/33 =100%	2 26/26 =100%	
Crash Opponent	Car 42/54 =77.8%	Fixed object 25/33 =75.8%	Car 21/26 =80.8%	
DayNight	Day 54/54 =100%	Day 20/33 =60.6%	Night 26/26 =100%	
Manoeuvre	Going ahead other 26/54 =48.1%	Going ahead round a bend 18/33 =54.5%	Going ahead round a bend 12/26 =46.2%	
Injury Type				**Total**
Head, Face, Neck	7/54 =13%	6/33 =18.2%	4/26 =15.4%	17/113 =15%
Thorax	15/54 =27.8%	13/33 =39.4%	9/26 =34.6%	37/113 =32.7%
Abdomen and pelvic cont.s	2/54 =3.7%	1/33 =3%	1/26 =3.8%	4/113 =3.5%
Spine	2/54 =3.7%	2/33 =6.1%	1/26 =3.8%	5/113 =4.4%
Upper extr.	1/54 =1.9%	1/33 =3%	0/26 =0%	2/113 =1.8%
Lower extr.	10/54 =18.5%	3/33 =9.1%	6/26 =23.1%	19/113 =16.8%
Whole surf. + mult. Regions	17/54 =31.5%	7/33 =21.2%	5/26 =19.2%	29/113 =25.7%

Injury factors

Table 35 shows the frequencies of the MAIS3+ injured body regions per scenario. For the car occupant casualties injuries of the thorax (33%) are most common followed by multiple injuries (26%; see also Figure 34).

The Chi-square test for the cross table of injury type by scenario is not significant (Chi-square=5.587 df=12, p<0.935), indicating that for car occupants there is no significant relationship between the injury type and the crash scenario.

Further analyses of the scenarios showed that in scenario 1, speeding (46%) and inadequate information acquisition (33%) play an important role. In scenario 2 speeding (31%) and wrong way driving (31%) are important contributing factors and in scenario 3, inadequate information acquisition (48%) is important.

Figures

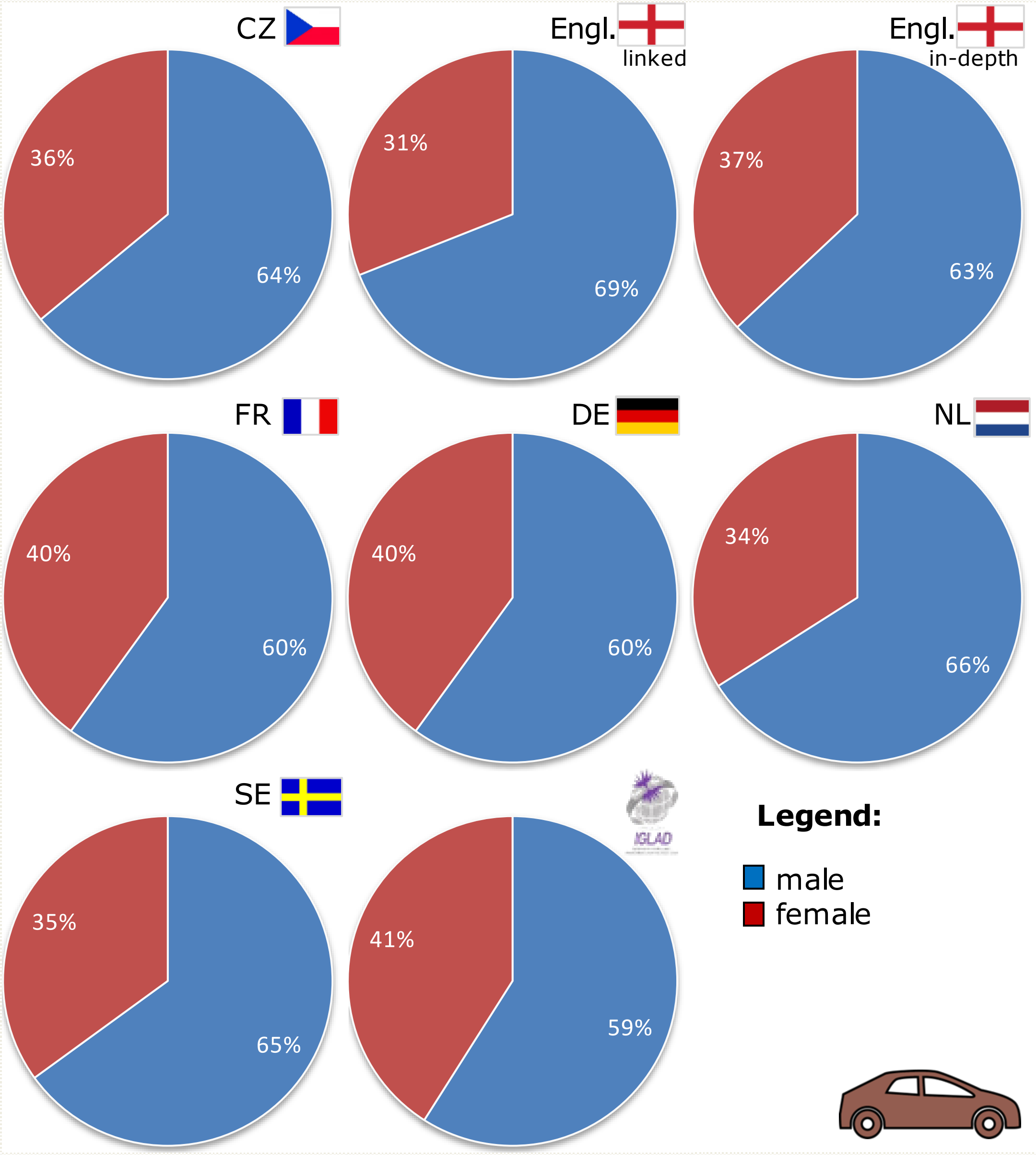

Figure 26: Gender of severely injured car occupants in the Czech Republic (CziDAS data), England (STATS19-HES), England (RAIDS/OTS), France , Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

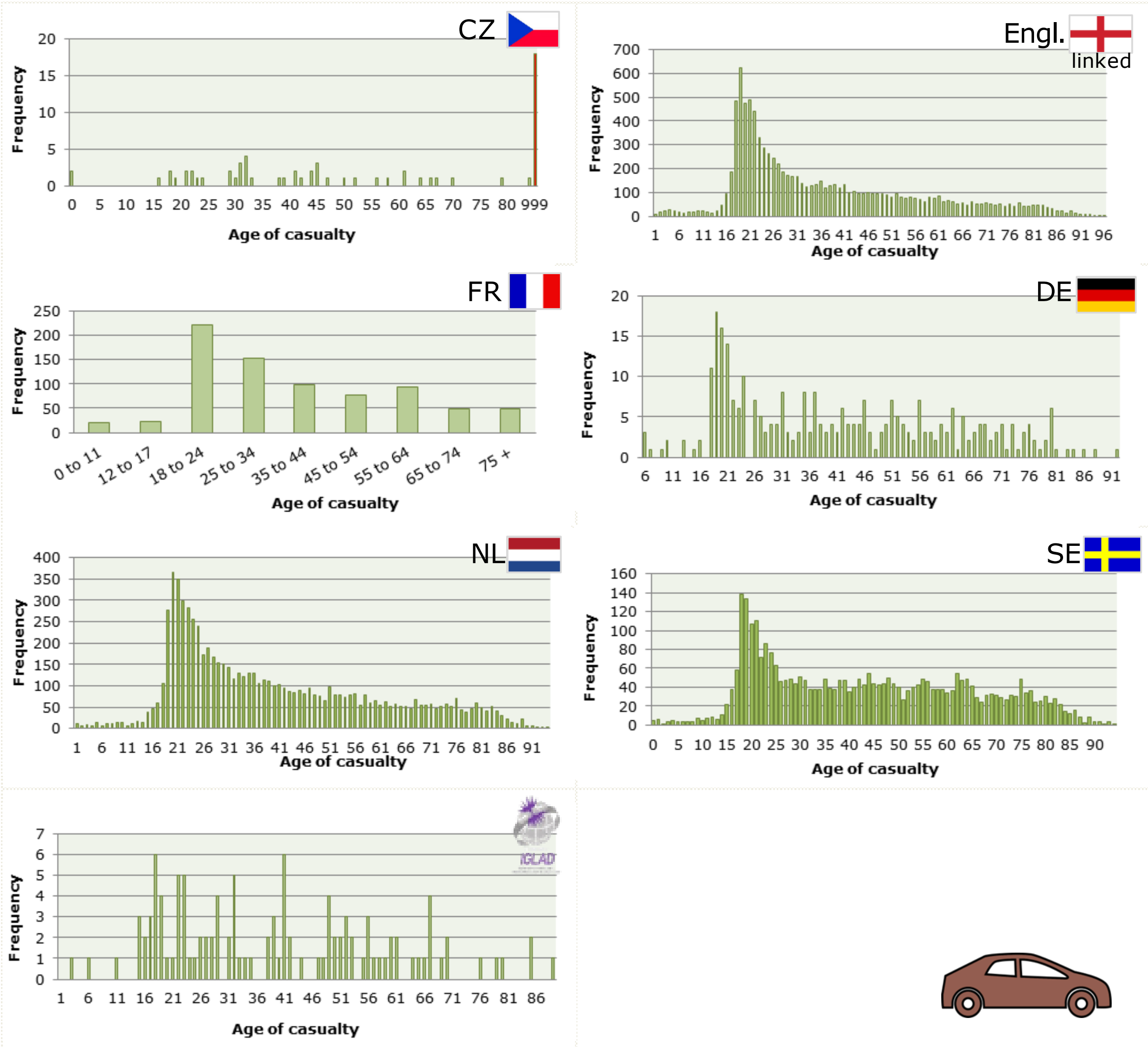

Figure 27: Age of severely injured car occupants in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

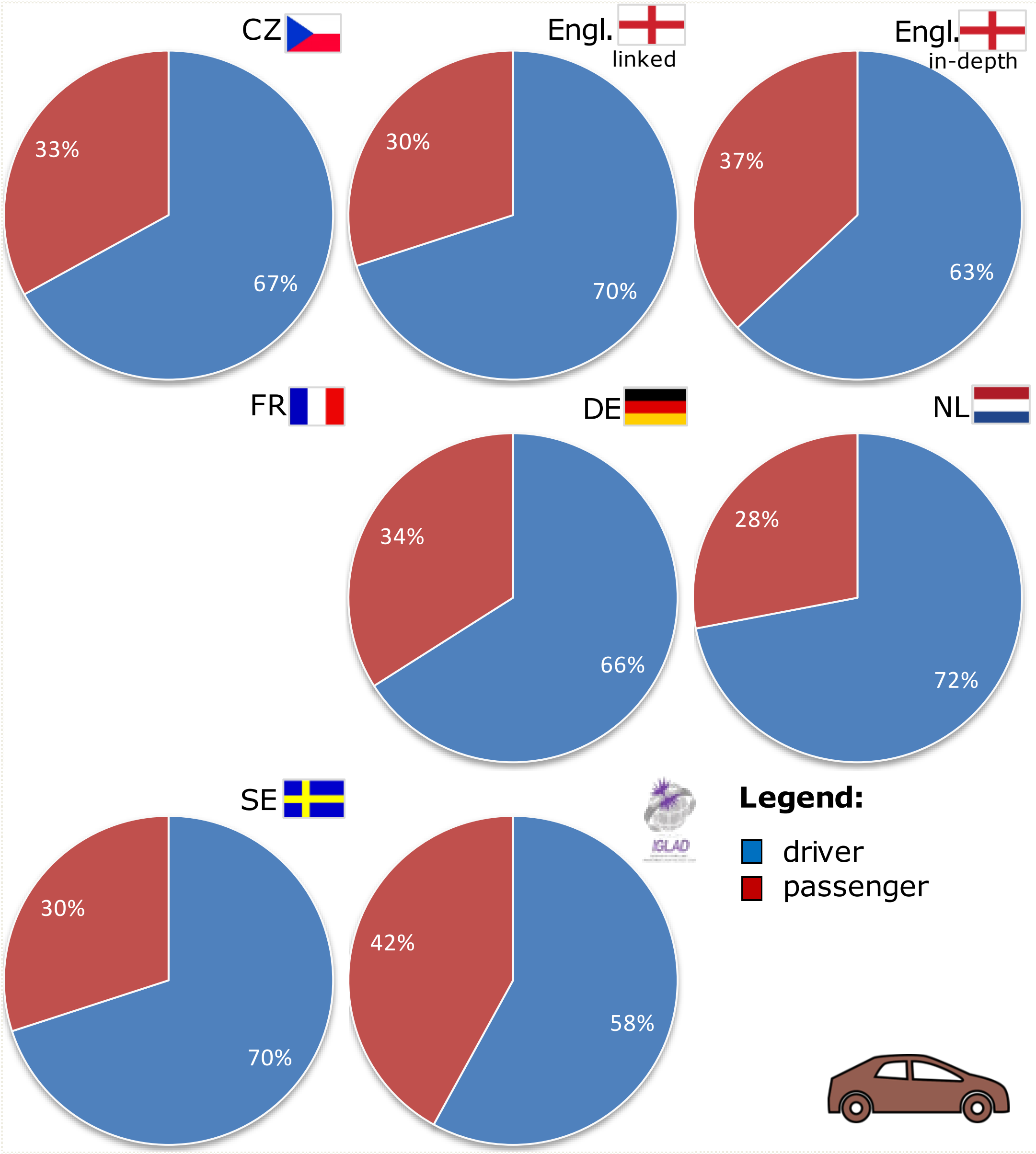

Figure 28: Role of severely injured car occupants in the Czech Republic (CziDAS data), England (STATS19-HES), England (RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

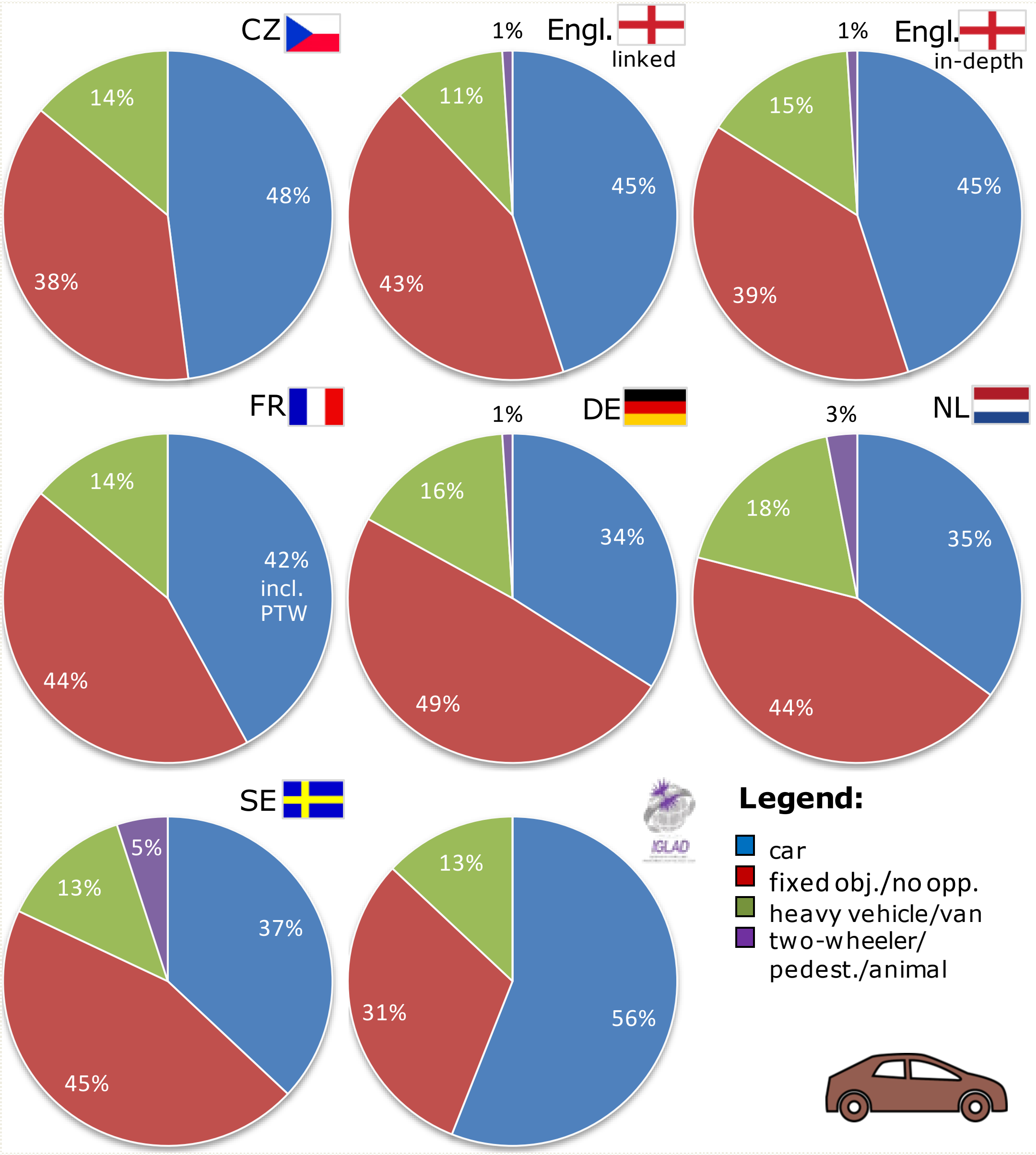

Figure 29: Most important crash opponents in crashes that lead to severely injured car occupants in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

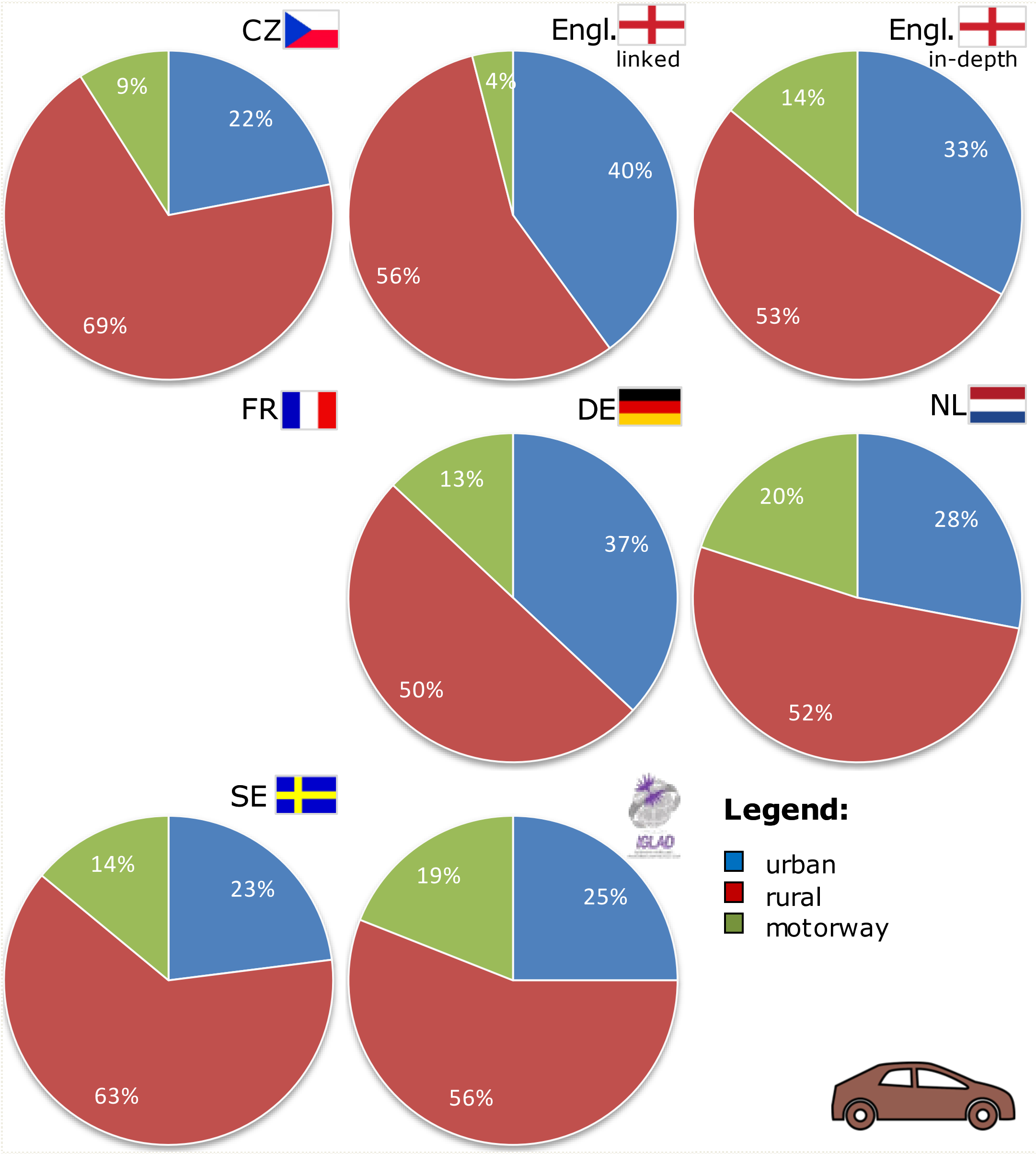

Figure 30: Main road types where crashes occur in which car occupants get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

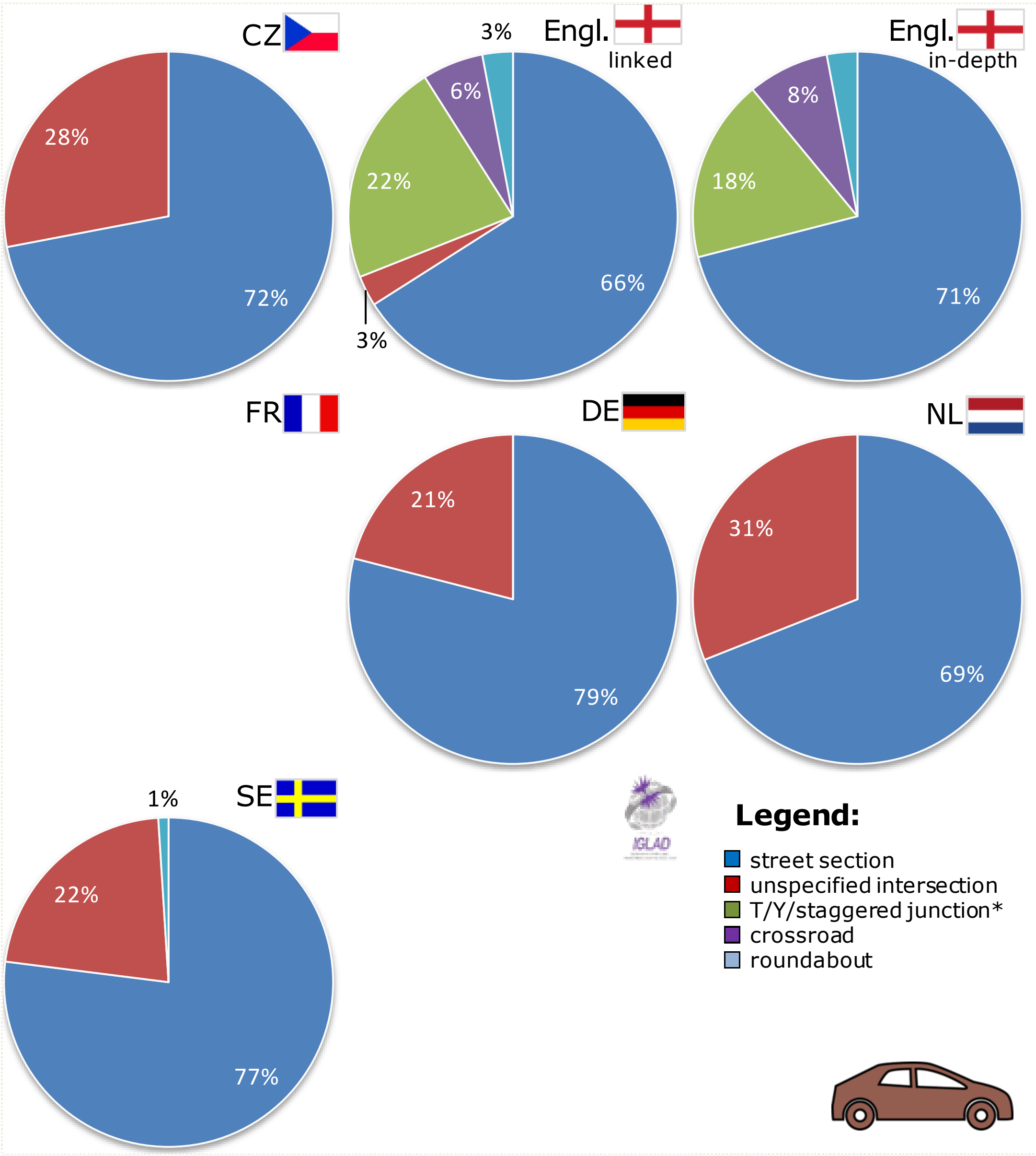

Figure 31: Road configuration where crashes occur in which car occupants get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), and England (in-depth: RAIDS/OTS), Germany (GIDAS data), the Netherlands (BRON-DHD) and Sweden (STRADA data). *A staggered junction is a junction were the side roads are not opposite to each other.

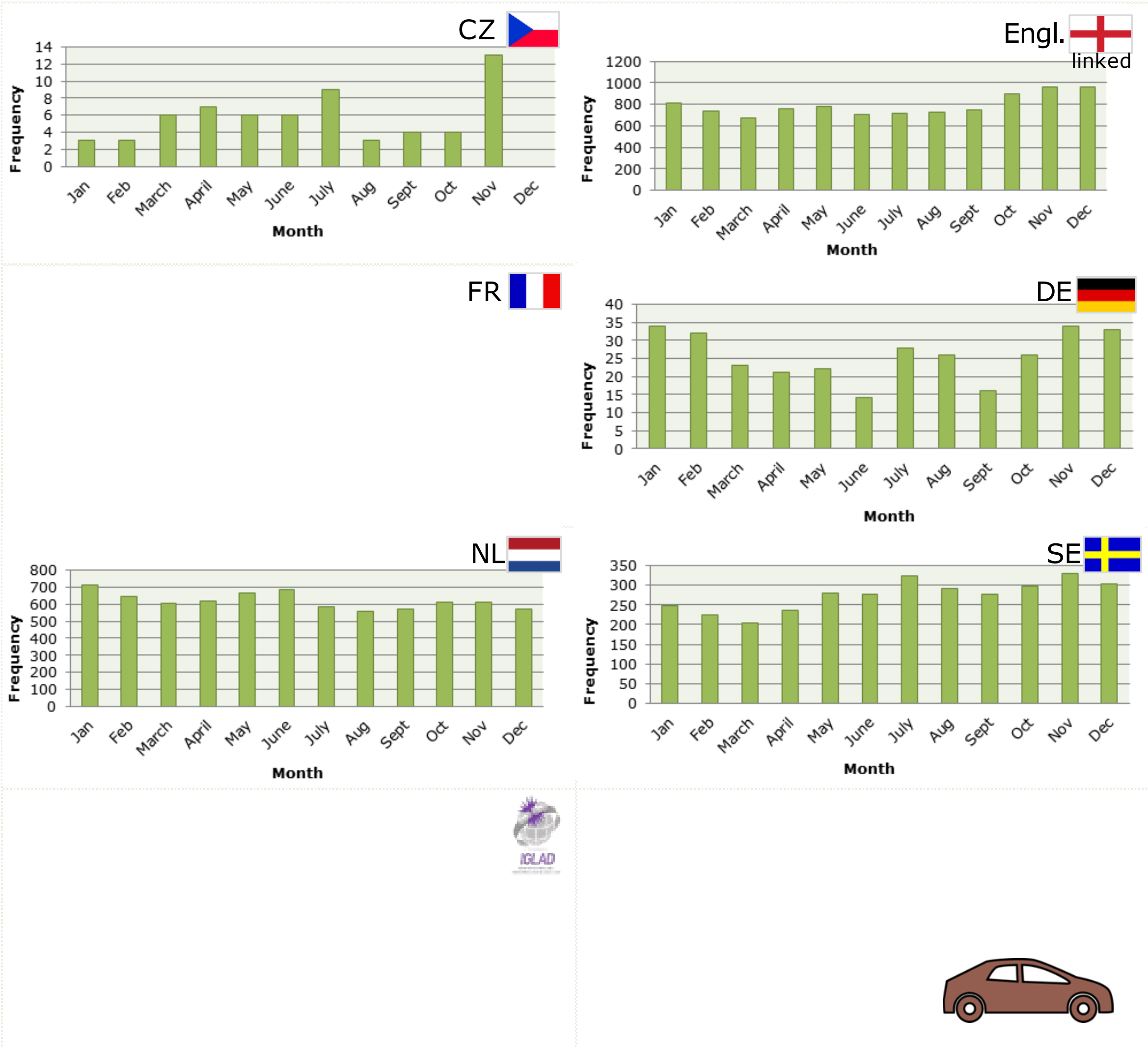

Figure 32: Months in which car occupants get severely injured the in the Czech Republic (CziDAS data), England (linked: STATS19-HES), Germany (GIDAS data), the Netherlands (BRON-DHD), and Sweden (STRADA data).

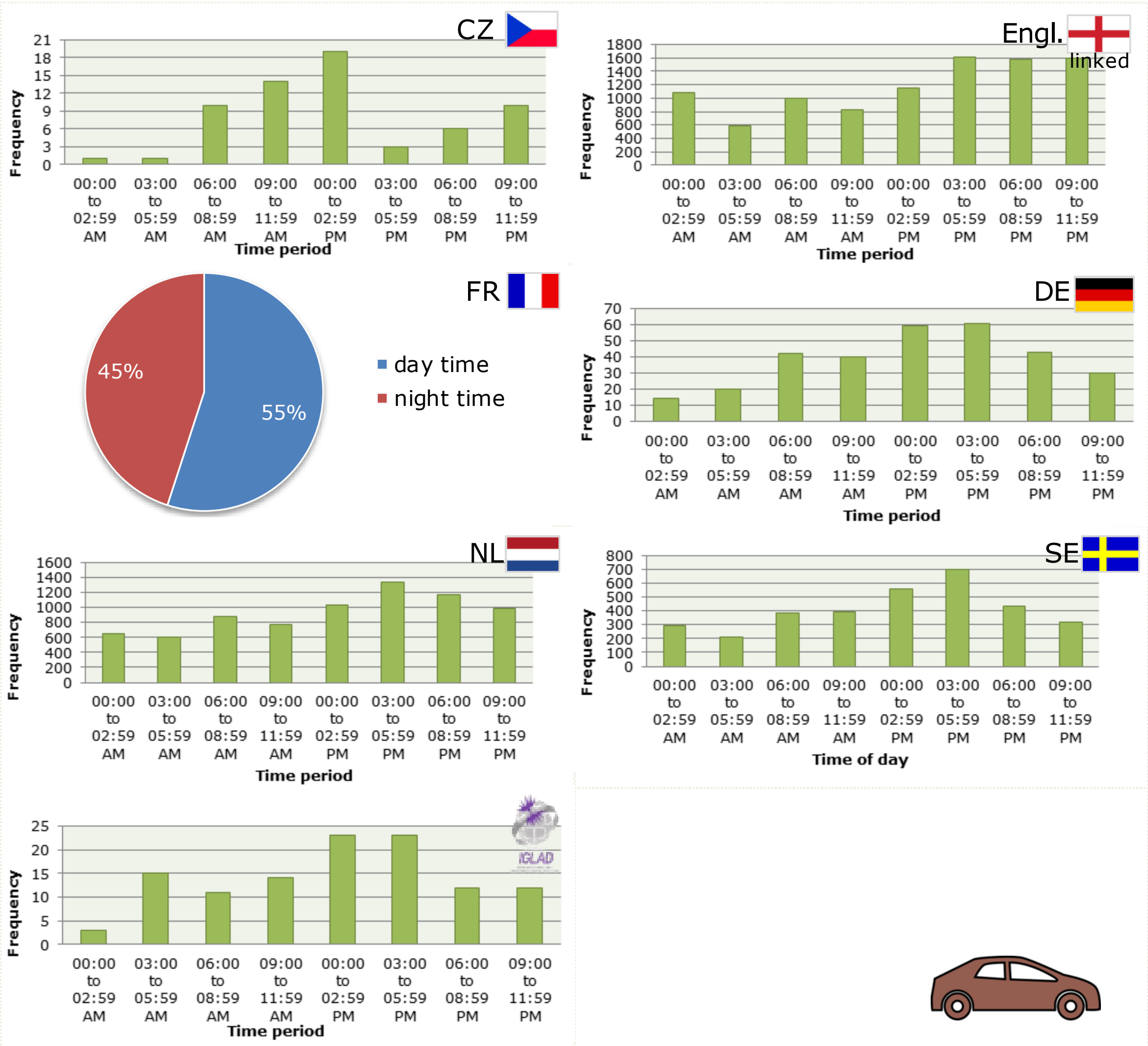

Figure 33: Time period of the day during which car occupants get severely injured in the Czech Republic (CziDAS data), England (linked: STATS19-HES), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

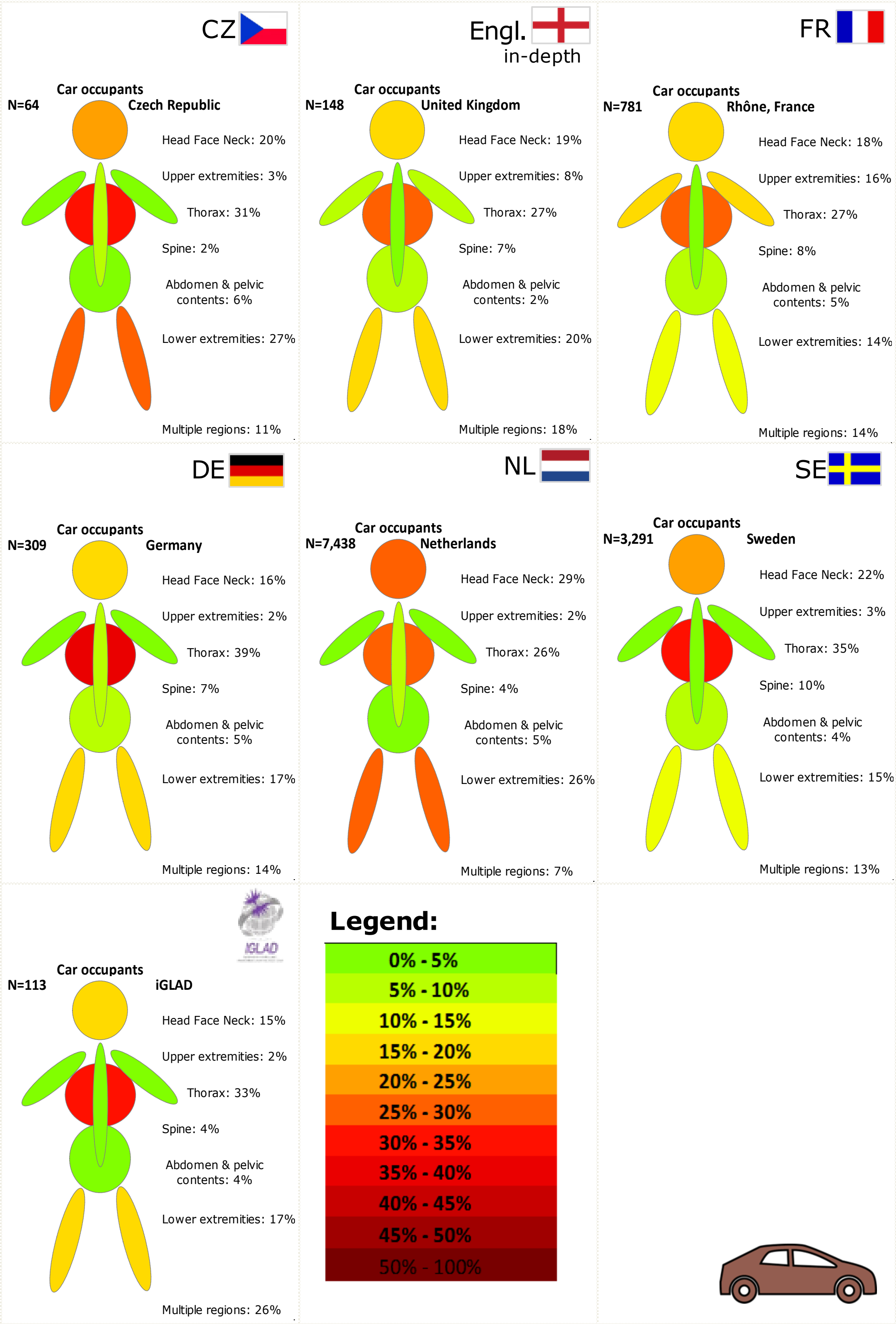

Figure 34: Overview of injured body regions of MAIS3+ car occupants in the Czech Republic (CziDAS data), England (in-depth: RAIDS/OTS), France, Rhône region (Rhône trauma register data), Germany (GIDAS data), the Netherlands (BRON-DHD), Sweden (STRADA data), and the European sample from the IGLAD database.

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