Safety benefit assessment for systems that protect vulnerable road users in collisions with heavy goods vehicles

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Abstract Collisions between heavy goods vehicles (HGVs) and vulnerable road users (VRUs), particularly bicyclists and pedestrians, are associated with a disproportionately high risk of severe and fatal injury. This study quantifies the potential safety benefits of vehicle-based countermeasures for HGV–VRU crashes, using a multi-regional in-depth crash analysis. Data from the German In-Depth Accident Study, China In-Depth Accident Study, Road Accident Sampling System–India, and United Kingdom Road Accident In-Depth Studies were analysed to characterise crash configurations, injury outcomes, and injury mechanisms.

A prospective safety benefit assessment was conducted for three generic countermeasures: Front Overrun Protection (FOP); Side Overrun Protection (SOP); and an Energy Absorbing Front (EAF). If a crash met the predefined boundary conditions of these systems (including impact location, collision speed, and injury causation), the corresponding injuries were assumed to be mitigated.

Across regions, HGV–VRU crashes frequently occurred at low collision speeds, yet resulted in high injury severity outcomes. FOP and SOP showed the greatest potential to reduce fatalities, particularly among bicyclists, while EAF primarily addressed serious but non-fatal injuries. A substantial share of crashes, including high-speed pedestrian impacts and blind-spot-related conflicts, remained unaddressed. These findings highlight that vehicle-based countermeasures for HGVs can deliver meaningful safety benefits.

Keywords Bicycle, Pedestrian, Crash data analysis, Heavy goods vehicle, Safety benefit assessment.

I. INTRODUCTION

Over recent decades, substantial improvements in vehicle safety have led to a reduction in injury risk for occupants of four-wheeled vehicles. In contrast, safety outcomes for vulnerable road users (VRUs), particularly pedestrians and bicyclists, have not followed the same positive trend. In recent years, the reduction in injuries among bicyclists and pedestrians has stagnated in Europe, resulting in an increasing proportion of injured road users being bicyclists and pedestrians [1]. Unlike vehicle occupants, VRUs lack a structural protective envelope and are therefore directly exposed to impact forces in the event of a collision. Consequently, their injury risk remains high, especially in mixed traffic environments where interactions with motor vehicles are frequent.

The vulnerability of pedestrians and bicyclists is further exacerbated by the growing presence of larger vehicles such as sport utility vehicles (SUVs), pickup trucks, and heavy goods vehicles (HGVs). While these vehicles may offer increased protection to their occupants, their mass, geometry, and limited direct visibility can substantially increase injury risk, as shown in [2] for crashes between SUVs and pedestrians in the US. Pedestrian protection research has historically focused on passenger cars, with comparatively limited attention given to collisions involving HGVs and buses, despite their relevance in dense urban environments and in developing regions [3]. This gap in research is particularly critical given the distinct crash characteristics and injury mechanisms associated with heavy vehicle impacts.

Although HGVs account for only a small share of total vehicle kilometres travelled, multiple studies have shown that they are disproportionately involved in crashes resulting in severe or fatal injuries [4-5]. One contributing factor is the high risk of run-over events in collisions involving heavy vehicles [6]. Beyond run-over scenarios, simulation-based studies have demonstrated that the flat-front geometry, typical for many HGVs, significantly influences pedestrian kinematics and injury risk [7-8]. Compared to the sloped front-end design of passenger cars, flat-fronted vehicles tend to induce different loading patterns, potentially increasing the severity of head,

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thoracic, and abdominal injuries.

In addition to vehicle geometry, limited direct vision and extensive blind spots around HGVs represent a major safety challenge. HGVs are disproportionately involved in serious and fatal collisions with VRUs, in part due to difficulties in detecting pedestrians and bicyclists in close proximity to the vehicle. Analyses of national crash data and physical testing of sensor systems compliant with Transport for London's Direct Vision and Safe System requirements have shown that current combinations of direct and indirect vision aids still fail to detect a substantial proportion of VRUs, particularly in nearside and front-corner blind spots [9]. These findings suggest that existing regulatory approaches and technological countermeasures may be insufficient to fully address the safety risks posed by HGVs in urban traffic.

Previous work by [10] has investigated potential countermeasures for improving VRU safety in collisions involving heavy vehicles; however, that analysis was limited to Swedish accident data. To the authors' knowledge, similar studies for other major regions, especially outside of Europe, are currently lacking. As traffic compositions, vehicle fleets, and infrastructure characteristics vary across regions, there is a need to complement these findings with data from additional countries and contexts (see also [11]). The present study aims to extend existing knowledge by incorporating accident data from multiple regions, with a particular focus on passive safety countermeasures for bicyclists and pedestrians in collisions involving HGVs.

II. METHODS

The analysis in this paper is based on data from four different in-depth crash databases. Data were analysed from the German In-Depth Accident study (GIDAS), the Road Accident Sampling System – India (RASSI), the Chinese In-Depth Accident Study (CIDAS) and the UK's Road Accident In-Depth Studies (RAIDS). The Abbreviated Injury Scale (AIS) [12] was used to classify each injury by body region according to its related severity on a 6-point scale, where 1=minor and 6=maximal, based on the different revisions available in the databases. For the purpose of this paper, HGVs have been defined as vehicles with a gross weight above 3.5t that are used for the transportation of goods, but exclude van-like vehicles such as a Mercedes Sprinter. Furthermore, VRUs have been defined as pedestrians and cyclists for this analysis. Only completed cases that are fully coded, reconstructed, and quality checked were included in the analysis.

GIDAS

GIDAS is a long-running national crash research program that collects highly detailed, on-scene and reconstructed data on police-reported road traffic crashes with injuries in selected regions of Germany. Operated since 1999 as a cooperative project of the Federal Highway Research Institute (BASt) and the Research Association for Automotive Technology (FAT), it links accident circumstances, vehicle damage, human factors, and medical injury data to support scientifically grounded improvements in vehicle safety, infrastructure design, and road safety policy. The whole database, containing 43,922 completed and reconstructed crashes from 1999 to 2024, has been queried for crashes where both a HGV and pedestrian or bicyclist have been involved.

RASSI

The RASSI database was initiated by JP Research India and is being developed by an international consortium of automobile manufacturers and suppliers. Trained crash investigators are sent to the crash scene if the crash involves at least one motorised vehicle and the accident scene is on a public road in one of the sample regions. The database includes information on the accident, vehicle, occupant, injury factors associated with each crash and also reconstruction files wherever possible [13]. The RASSI database contains a total of 7,972 crashes for the period 2014–2025. The queried sample includes the first collision event in a HGV-to-VRU crash. Bicyclists and pedestrians were filtered as VRUs. The impact location was defined based on the general area of damage.

CIDAS

CIDAS is a national crash investigation program initiated in 2011 by the China Automotive Technology and Research Center (CATARC) to collect detailed, in-depth data on real-world road traffic accidents in China. It links accident scene information, vehicle damage, and injury outcomes to support automotive safety research, regulatory development, and consumer testing such as C-NCAP, with a strong focus on both active and passive safety systems. It collects roughly 900 injury-related crashes per year across 10 cities in China. Investigation teams operate 24/7, responding with police to any crash involving an injured person and at least one four-wheeled vehicle. The whole database, containing 10,427 completed and reconstructed crashes from 2011 to 2025, has been queried for crashes where both a HGV and pedestrian or bicyclist have been involved.

RAIDS

The RAIDS database is a national research program led by the Department for Transport, that collects detailed, anonymised data on how road crashes occur and how injuries are sustained. It combines on-scene crash investigations with retrospective vehicle and hospital-based analyses to link collision circumstances, vehicle damage, and injury outcomes, supporting vehicle safety, road design, and policy development rather than liability assessment. All 2,777 crashes that were collected between 2013 and 2025, were made available for our analysis, and crashes involving at least one HGV and pedestrian or bicyclist were extracted. The mapping of RAIDS crash types can be found in the Appendix (Table AI). Due to the low number of cases, the RAIDS data has not been used in the safety benefit assessment. However, the general statistics include results from RAIDS, but should be regarded as indicators and used carefully.

Safety Benefit Assessment

In addition to a better understanding of how crashes between HGVs and pedestrians and bicyclists occur, the focus of this study was to investigate how these crashes could be addressed through vehicle-based protective safety systems. The safety benefit assessment was performed through a prospective analysis of potential countermeasures, similar to the study by [10], by applying these to the current crashes we see in the different databases. If a crash falls within the boundary conditions we have defined below, it is assumed that the system would mitigate the injuries recorded in this crash. The analysis did not factor in the presence of personal protective equipment, as their presence rate is typically low and their absence presents a worst-case scenario. Furthermore, the systems only address injuries caused by the vehicle parts specified for each system – if for example a fatal injury occurs from secondary ground impact, this case would not be considered as avoided by the system.

The conditions for the different interventions to protect bicyclists and pedestrians were defined as follows:

1. Front Overrun Protection (FOP): collision speed of the HGV is less than or equal to 30 km/h, with the principal direction of force between 10 o’clock and 2 o’clock at the front of the HGV. The system addresses cases where the VRU contacted the undercarriage or any of the tyres of the HGV (i.e. run-over cases).
2. Side Overrun Protection (SOP): collision speed of the HGV is less than or equal to 30 km/h, with the principal direction of force between 1 o’clock and 4 o’clock or 8 o’clock and 11 o’clock at the left or right side of the HGV. The system addresses cases where the VRU contacted the undercarriage or any of the tyres of the HGV (i.e. run-over cases).
3. Energy Absorbing Front (EAF): collision speed of the HGV is less than or equal to 40 km/h, with the principal direction of force between 11 o’clock and 1 o’clock at the front of the HGV. The system addresses cases where the VRU hit the front structure of the HGV (including the windscreen), and sustained injuries to either head, face, neck, thorax, abdomen, spine, or upper extremities.

For our study, we have explicitly chosen the terms above, different from the commonly used terms Front and Side Underrun Protection System (FUPS and SUPS), to highlight that these are different systems with different goals. FUPS and SUPS are specifically designed to support the interaction with other vehicles (such as passenger cars), and there are no requirements for VRU protection. While in reality, these two systems and ideas can work together, we do not believe that this is a given fact, and hence have decided to use these more descriptive names, highlighting that we are investigating systems specifically aiming at the protection of bicyclists and pedestrians.

III. RESULTS

In total, the databases cover 560 crashes between HGVs and bicyclists, and 704 crashes between HGVs and pedestrians. Table I provides a more detailed overview of the number of cases available in the different databases. For ease of reading, only the bicyclist and pedestrian will be referred to throughout the remaining paper, but all results shown are from crashes with HGV involvement.

TABLE I
OVERVIEW OF RESULTS FROM DATABASES

Number of	GIDAS		RASSI		CIDAS		RAIDS	
	Bicyclist	Pedestrian	Bicyclist	Pedestrian	Bicyclist	Pedestrian	Bicyclist	Pedestrian
crashes	413	195	41	211	94	290	12	8
HGVs	413	205	41	211	94	290	12	9
VRUs	423	209	43	211	94	290	12	8
Fatally injured	17	30	35	175	52	167	9	3
Seriously injured	129	94	6	29	20	50	3	5

General crash statistics

Across all databases, crashes typically occur in good weather conditions on dry roads. The bicyclists involved typically do not wear a helmet (0% in CIDAS and 5% in RASSI). While GIDAS and RAIDS show a higher helmet-wearing rate, just below 20% and 25%, respectively, this is still below the estimated population average in Germany [14] and the UK [15].

CIDAS and RASSI exhibited substantially higher fatality rates than GIDAS and RAIDS, particularly in rural areas. For RASSI and CIDAS, fatality rates are beyond 50% (around 84% for RASSI and 58% for CIDAS), while GIDAS and RAIDS show a more commonly expected distribution (4–14% fatalities, 30–45% serious injuries, and remaining majority of VRUs sustain slight injuries).

In GIDAS, bicyclist crashes predominantly happen in urban areas (see Fig. 1). In RASSI and RAIDS, urban crashes also dominate, but rural crashes have a higher share. In CIDAS, the share between urban and rural areas is almost equal. Pedestrian crashes show a similar trend, whereas CIDAS is even more notable now with a higher share of rural crashes than urban ones, accounting for two-thirds of cases. Notably, rural crashes also include pedestrian crashes on motorways, a location where pedestrians theoretically should not be present, but sometimes are as construction workers, occupants that have left broken down vehicles or drunk drivers stopping and exiting their vehicle.

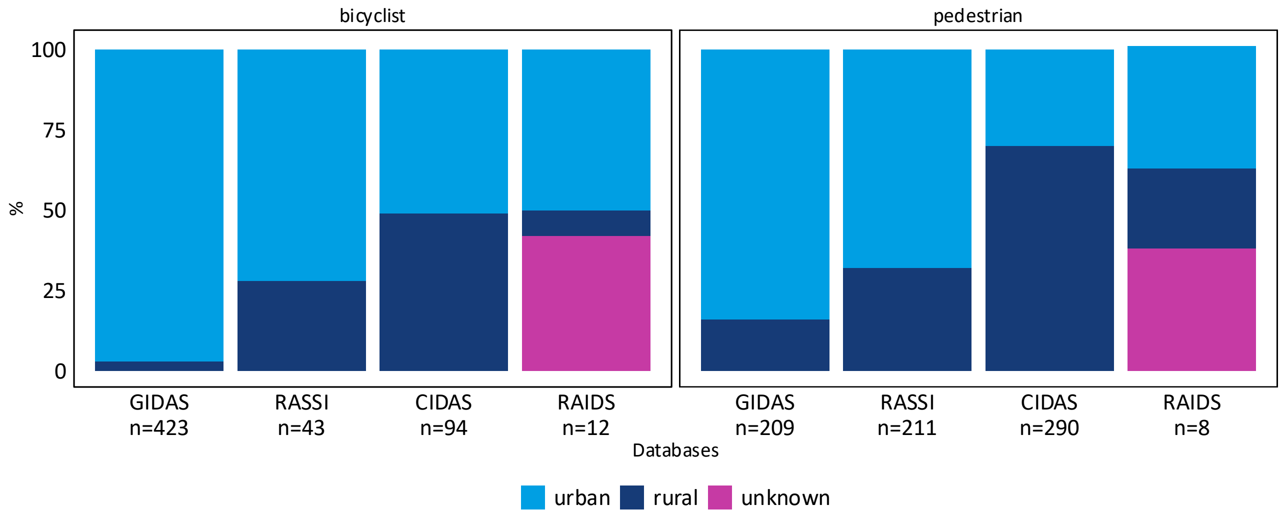

Fig. 1. Crash location distribution for bicyclists and pedestrians involved in a crash with a HGV in the different databases (*left:* bicyclist, *right:* pedestrian).

Crash configurations show larger differences between countries and VRUs (see Fig. 2). Both in GIDAS and CIDAS, bicyclist crashes typically occur at intersections, often involving a turning manoeuvre of the HGV or a bicyclist crossing in front of the HGV. In India, and to a lesser extent in RAIDS, bicyclist crashes more commonly occur when both parties are moving along in the carriageway. Pedestrian crashes typically occur away from intersections, where pedestrians cross in front of a moving or standing HGV, the latter then accelerating from a standstill and impacting the pedestrian.

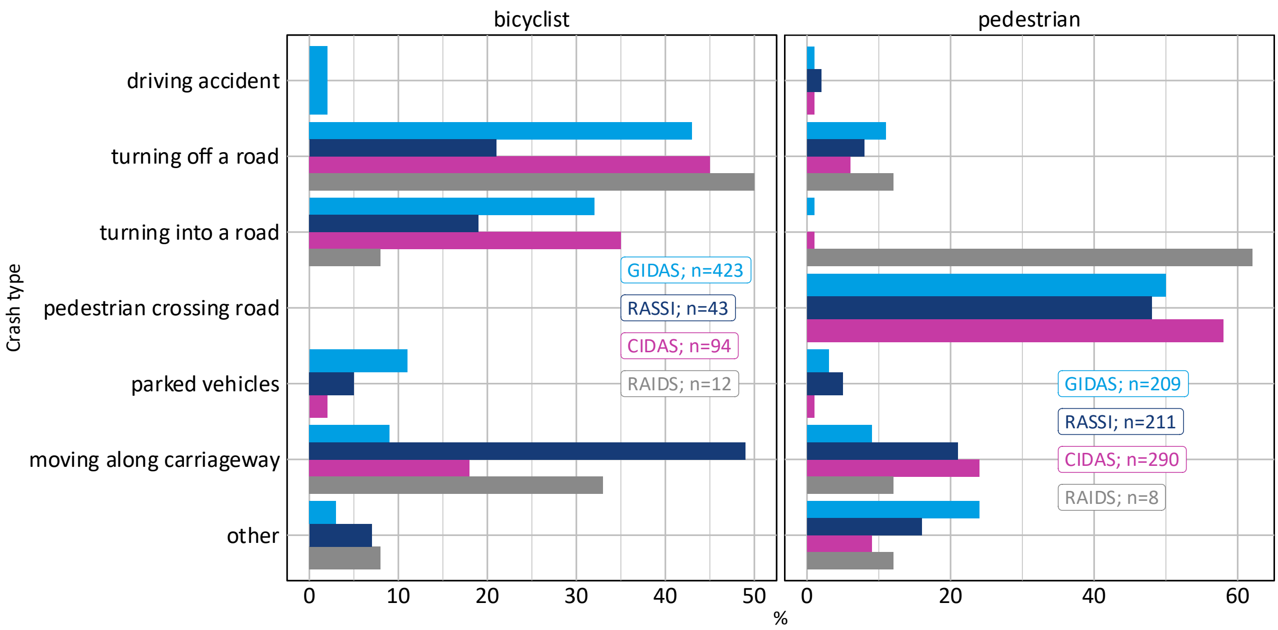

Fig. 2. Crash type distribution for bicyclists and pedestrians involved in a crash with a HGV in the different databases, from the perspective of the HGV (*left:* bicyclist, *right:* pedestrian).

Across the different databases, crashes happen predominantly during daytime, with GIDAS typically showing the highest share of daylight crashes (see Fig. 3). There are, however, notable differences between the two VRUs; pedestrian crashes have a much higher share of night-time crashes, up to around 50% for RASSI.

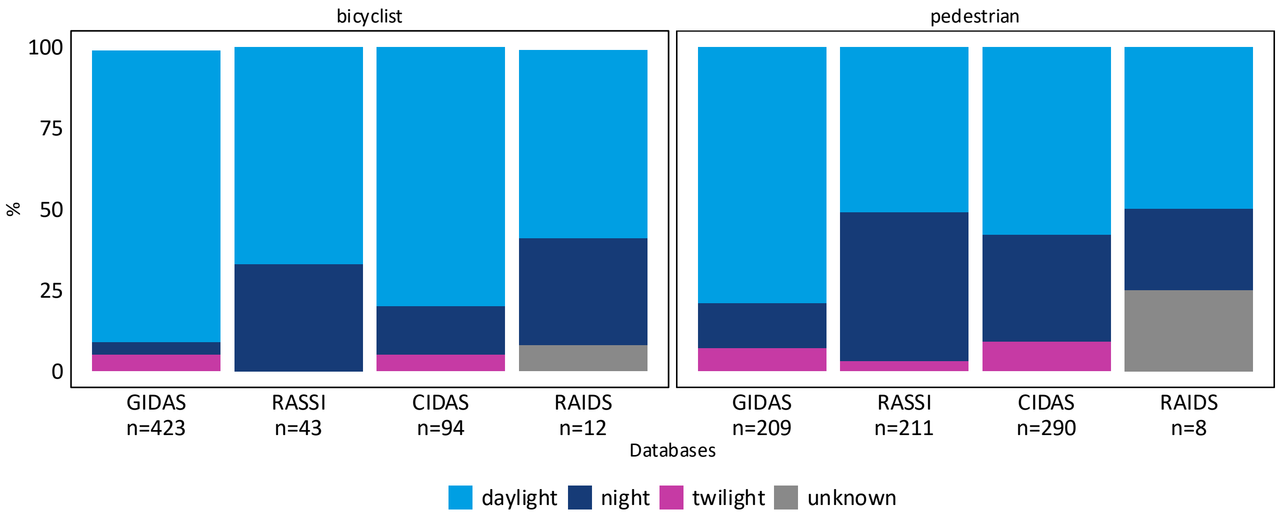

Fig. 3. Time of day distribution for bicyclists and pedestrians involved in a crash with a HGV in the different databases (*left:* bicyclist, *right:* pedestrian).

The HGVs involved in the crashes are often newer models, typically around five years old (see Fig. 4). The vehicle age distribution is quite similar across databases and throughout the years where crashes were collected. Initial speeds (i.e. speeds before the conflict with the VRU arises) for the HGV are typically quite low in bicyclist crashes (see Fig. 5). In GIDAS, up to 30% of cases have an initial speed of 0 km/h, i.e. HGVs start from a standstill, e.g. at a red traffic light – very much in line with the crash configurations shown previously. Impact speeds (i.e. the speed shown on the speedometer when the HGV and VRU "make contact") are typically a bit higher than the initial speeds (see Fig. 6), again as a result of the typical crash configurations observed. For pedestrians, both initial and collision speeds are generally higher than those for bicyclists, in line with the crash configurations observed and crashes typically happening further away from intersections, resulting in higher travelling speeds for the HGVs. It was observed that collision speeds are an important factor for the occurrence of run-overs, with lower collision speeds leading more often to run-overs of the pedestrians.

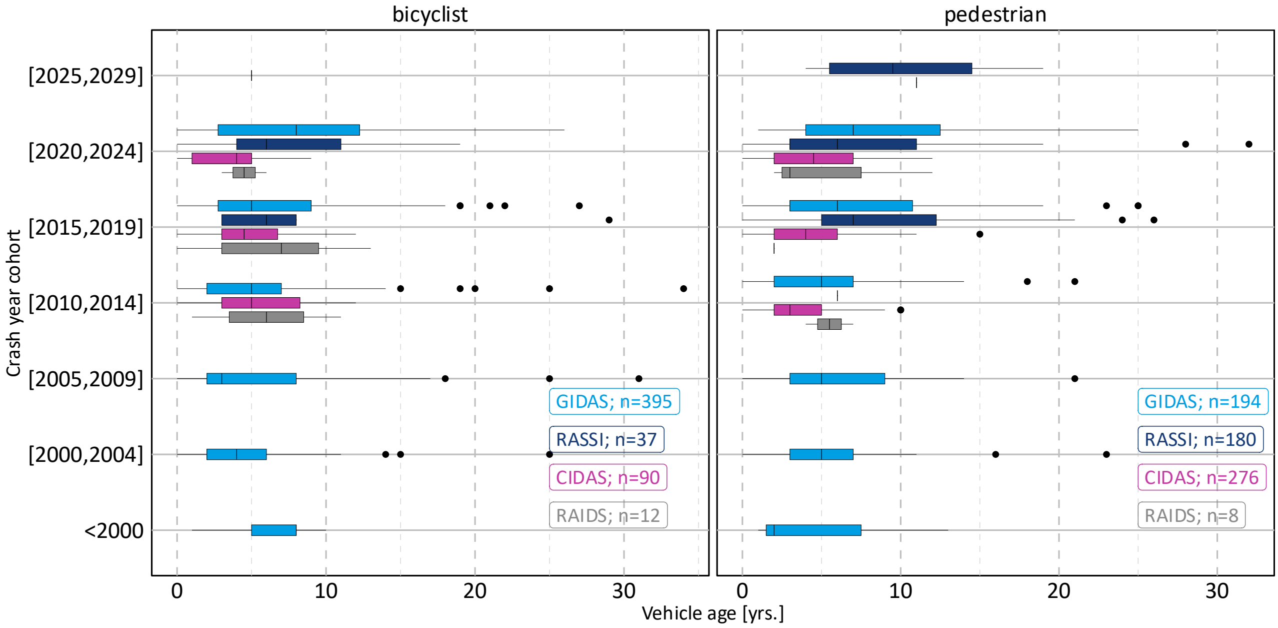

Fig. 4. HGV age distribution across different crash years for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

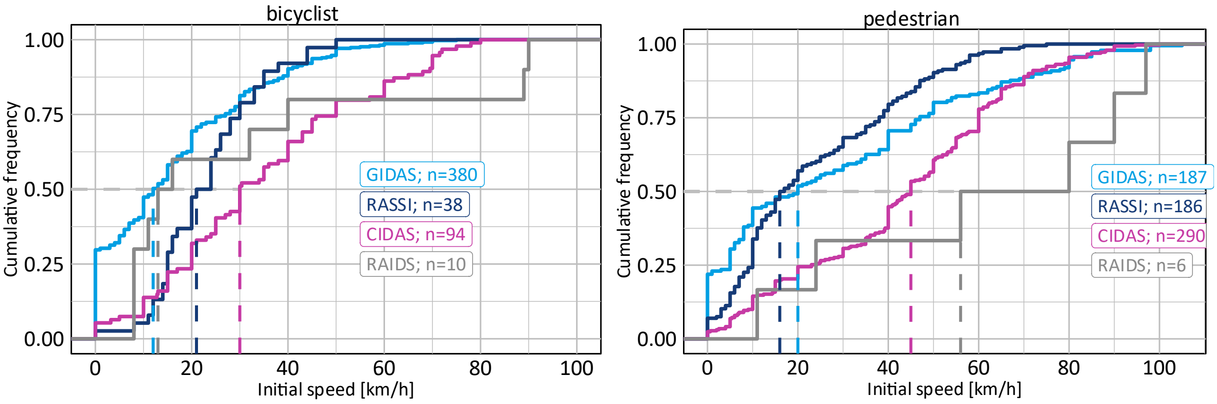

Fig. 5. Initial HGV speed distribution for bicyclist and pedestrian crashes in the different databases (*left:* bicycle, *right:* pedestrian).

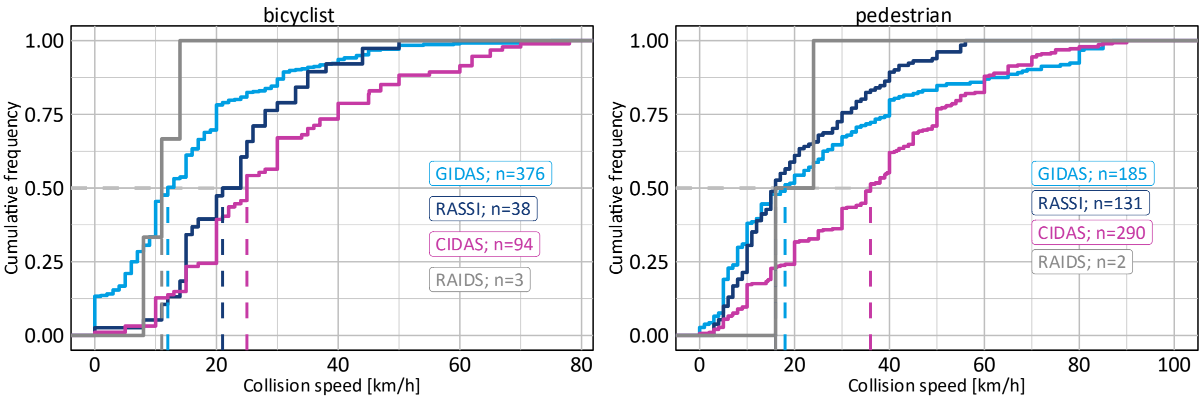

Fig. 6. Collision speed distribution for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

The initial contact points are shown in Fig. 7 and were only available in GIDAS and CIDAS. In collisions at the front of the HGV, initial contact points are spread across the whole front, but there is a tendency towards the right edge, in line with the typical crash configurations observed. Along the longitudinal axis, most impacts are within the first 4 m of the vehicle, i.e. around the cab and before the second axle.

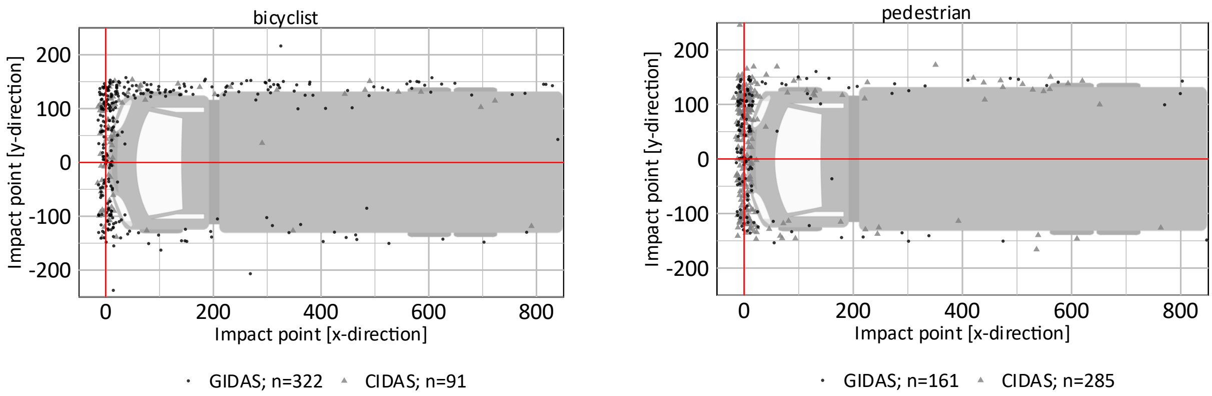

Fig. 7. Impact point distribution for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian; Impact points are scaled to a truck of 900 cm length and 280 cm width. Points that are beyond the length of the truck are not shown in the Figure. The underlying HGV sketch is for visualisation only and might not reflect the actual HGV type).

From the perspective of the HGV, the principal direction of force is typically from 12 o'clock to 2 o'clock (see Fig. 8). Notably, there are also impacts from 6 o'clock, which in the case of pedestrians are often due to reversing HGVs, and in the case of bicyclists, riders who rode into the back of a (often stationary) HGV.

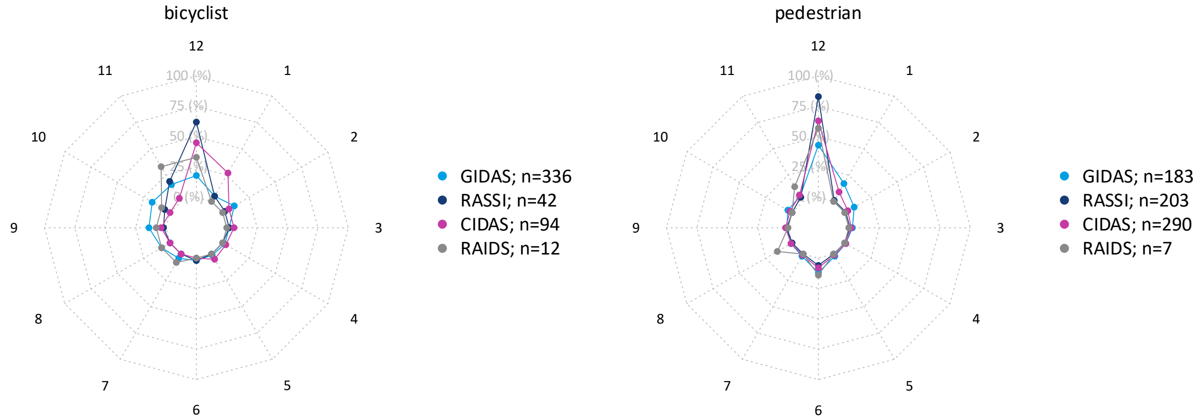

Fig. 8. Principle direction of force distribution for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

Severity outcomes in HGV–VRU crashes show large differences between the databases (please see Discussion, below, for further details on this). Typically, head and thorax injuries dominate AIS2+ injuries across databases and VRUs (see Fig. 9). AIS2+ injuries are most commonly caused by contact with the wheels or ground, but there is a wide variety between the databases (e.g. tyres account for roughly 10% of AIS2+ injuries in GIDAS, while it goes up to 80% in RASSI). For pedestrian crashes, the HGV front is also a major injury source (see Fig. 10). The corresponding figures for AIS1+ injuries can be found in the Appendix (Fig. A1 and Fig. A2).

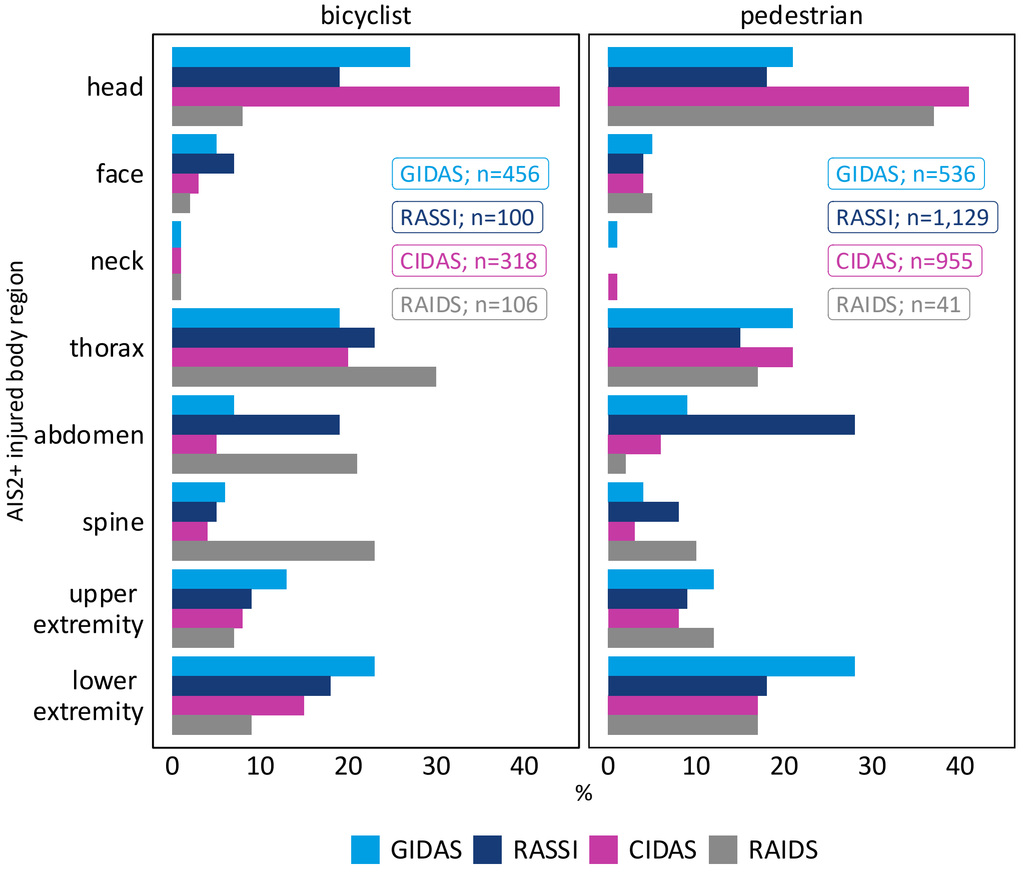

Fig. 9. Injured body region distribution for AIS2+ injuries for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

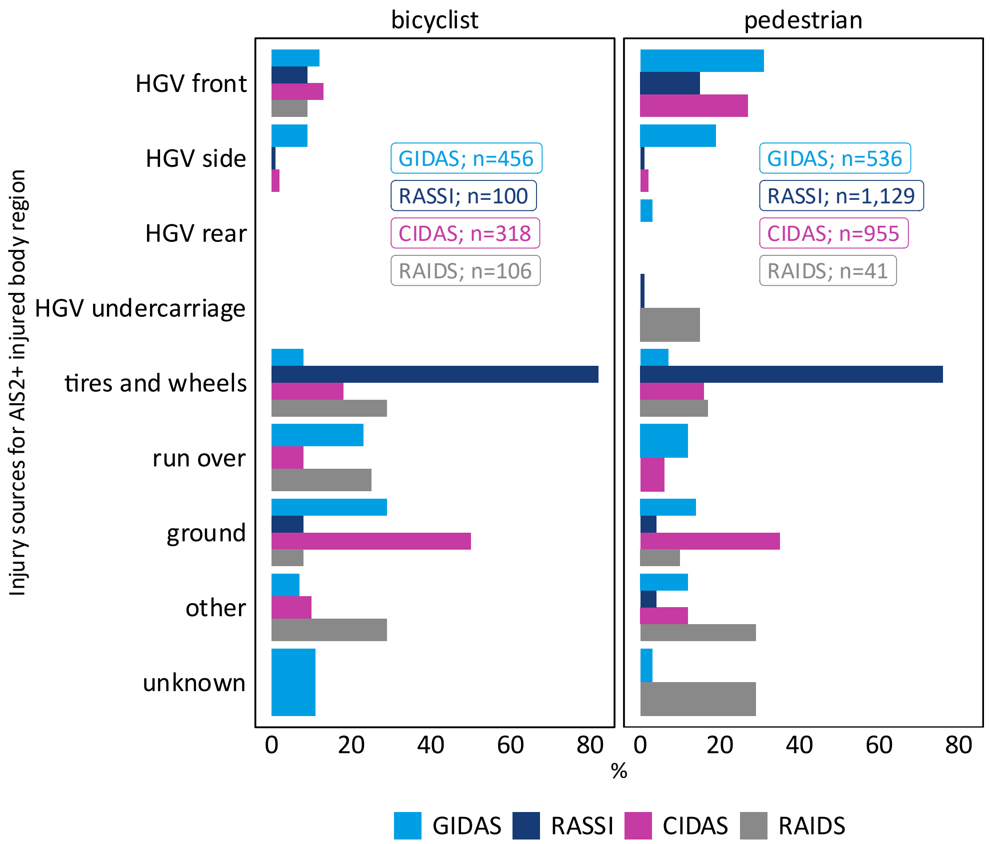

Fig. 10. Injury-causing part distribution for AIS2+ injuries for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

Safety benefit assessment

Table II and Table III provide an overview of the results from the safety benefit assessment for the different databases and safety systems considered in this study, excluding RAIDS data due to the low number of cases available in the database.

The FOP system has shown great potential for avoiding bicyclist and pedestrian fatalities across the different regions. It ranges from 18% of bicyclist fatalities in GIDAS that could be avoided up to 29% in CIDAS and RASSI. For seriously injured bicyclists, its effectiveness is lower, at 0%, 5% and 15% for RASSI, GIDAS and CIDAS, respectively.

The SOP showed large potential in GIDAS, addressing 53% of bicyclist fatalities, while results for RASSI (14%) and CIDAS (19%) are lower but also important. For seriously injured bicyclists, percentages are again lower, even down to 0% for RASSI.

Combining FOP and SOP systems can address a large share of bicyclist fatalities, from 43% in India up to 71% in Germany, and between 16% of pedestrian fatalities in China up to 33% in Germany.

The EAF has shown potential for avoiding fatal injuries (between 0% and 15%), but shows higher potential for avoiding serious injuries (between 0% and 32%).

Effectiveness results for serious injuries are different from the ones observed for fatal injuries, suggesting that other injury mechanisms are at play and other interventions might be needed to address them.

TABLE II
SAFETY BENEFIT ASSESSMENT RESULTS FOR FATAL INJURIES

	GIDAS		RASSI		CIDAS	
Safety System	Bicyclist	Pedestrian	Bicyclist	Pedestrian	Bicyclist	Pedestrian
FOP	18%	30%	29%	20%	29%	12%
SOP	53%	3%	14%	3%	19%	4%
EAF	0%	10%	14%	14%	15%	17%

TABLE III
SAFETY BENEFIT ASSESSMENT RESULTS FOR SERIOUS INJURIES

	GIDAS		RASSI		CIDAS	
Safety System	Bicyclist	Pedestrian	Bicyclist	Pedestrian	Bicyclist	Pedestrian
FOP	5%	7%	0%	10%	15%	8%
SOP	8%	2%	0%	0%	10%	12%
EAF	9%	16%	0%	10%	25%	32%

IV. DISCUSSION

Representativeness

RASSI and CIDAS show significantly higher fatality rates than GIDAS and RAIDS. One plausible explanation is that their large populations increase the exposure of VRUs to hazardous traffic environments. Moreover, rural regions in China and India tend to have more intensive human activity and mixed traffic conditions compared to rural Germany. At the same time, there are differences between the databases, both in what and how data are collected, that can also bias the results observed, especially when it comes to statistical analysis. For example, the large difference in fatality rates between the regions is mostly likely also influenced by inclusion bias (i.e. which crashes the investigations teams are notified of and collect), and not necessarily an indicator that general fatality rates in these types of crashes are close to 5% in Germany and 85% in India.

In line with typical crash constellations, observed collision speeds, especially with bicyclists, are typically low, much lower than is often observed in collisions with cars. Nonetheless, injury outcomes are severe across all regions analysed, indicating that collision speeds are not a good predictor for injury severity in these crashes. Within these HGV and VRU crashes, the large differences in the estimated safety benefits indicate that different injury mechanisms might be at play. While a combination of FOP and SOP could address up to 71% of bicyclist fatalities in Germany, it seems to address only 13% of seriously injured bicyclists.

Limitations

The results shown in this paper are based on absolute numbers from the different databases. That means, for example, that no conclusions about risk can be drawn from the presented numbers. More crashes happening during the day does not mean that it is riskier for bicyclists during the day. In order to talk about risk, exposure data need to be included in the analysis, but these data are not readily available.

This is study used a simplistic, rule-based method to estimate the effectiveness, and does not account for any confounding factors which would need further research. Furthermore, the safety systems used in this study are only of theoretical nature and follow some reasonable boundary conditions, which have also been used previously (e.g. [10]). Real systems, depending on their design and specifications, can show different outcomes.

It should also be noted that infrastructure design plays an important role. Countries such as India often lack fundamental infrastructure (e.g. continuous footpaths, protected cycle tracks, facilities that physically separate vulnerable users from motorized traffic). These contextual differences can significantly influence crash occurrence and injury outcomes, but data on infrastructure design (e.g. presence of bicycle lanes) is not consistently present throughout the different databases used in our study, and hence could not be analysed in this study.

The analysis focussed on bicyclists and pedestrians as VRUs – but motorcyclists are also a vulnerable road user group. Previous research [5-6] indicated that crash constellations and injury patterns were quite similar between bicyclists and pedestrians, but different for motorcyclists. This study has therefore focussed on bicyclists and pedestrians, but future research should also investigate crashes with motorcyclists.

Remaining crashes that need further investigation in the future

In this section, we want to provide a couple of example cases that were not addressed by the systems and need further investigation in future studies.

While helmets showed little effect when it came to run-over crashes, they would have very well protected those bicyclists who did not end up under the HGV (who are still the majority), but who were deflected away from the HGV and sustained injuries from ground contacts. Some of these injuries could have been avoided by wearing a helmet. Indeed, the low helmet-wearing rate across all databases is alarming.

In particular for pedestrians, high-speed cases are still a major concern. A lot of the remaining cases involve collisions with pedestrians on highways and rural areas, quite often in the dark, where HGVs travel well in excess of 50 km/h. On highways, these are often areas where pedestrians are unexpected (and not supposed to be), and involve constructions workers or occupants of broken-down vehicles – but also drunk persons who cross a highway in the middle of night. But surprisingly, we could also see that crashes at the lower speed spectrum could still result in fatalities. This is particularly the case when HGVs are manoeuvring in tight spaces, where pedestrians can get trapped. In some cases, even just a small push from a manoeurving HGV, that leads to a fall of a pedestrian, can have deadly consequences, especially for older age groups. We have also observed cases where the initial contact is at slow speed and pedestrians are deflected away from the HGV (which is the best situation to avoid run-overs), but subsequently have a (unprotected) head impact to the ground or kerb, resulting in serious or fatal injuries.

For both VRU groups, blind spots around the HGV seem to remain a significant problem. Even seemingly aware drivers had difficulties in detecting pedestrians who crossed right in front of the HGV or bicyclists who approached during slow-speed manoeuvres.

V. CONCLUSION

This study provides a multi-regional, in-depth analysis of collisions between HGVs and VRUs, highlighting substantial differences in crash characteristics, injury outcomes, and potential safety benefits across Germany, the UK, China, and India. Despite generally low collision speeds – particularly in bicyclist crashes – injury severity remains high, underscoring that vehicle mass, front-end geometry, run-over mechanisms, and limited direct vision play a more decisive role than speed alone in determining outcomes. The consistently high proportion of severe and fatal injuries, especially in CIDAS and RASSI, reinforces the critical safety challenge posed by HGV–VRU interactions in mixed traffic environments.

The prospective safety benefit assessment indicates that passive vehicle-based countermeasures can meaningfully reduce VRU injuries, but their effectiveness is highly mechanism-dependent. Front and side overrun protection show the greatest potential for preventing fatalities, particularly among bicyclists, while energy-absorbing front structures mainly address serious but non-fatal injuries. However, a substantial share of crashes – especially high-speed rural pedestrian impacts, blind-spot-related conflicts, and secondary ground-impact injuries – remain outside the scope of these measures. This demonstrates that passive safety systems play an important role in protecting VRUs, but cannot address all situations alone and should be complemented by improved direct vision, active sensing, infrastructure measures, and behavioural interventions.

Overall, the findings support a system-level approach to HGV safety that combines region-specific evidence, targeted passive countermeasures, and broader Safe System strategies to achieve meaningful reductions in VRU fatalities and serious injuries.

VI. ACKNOWLEDGEMENTS

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VIII. APPENDIX

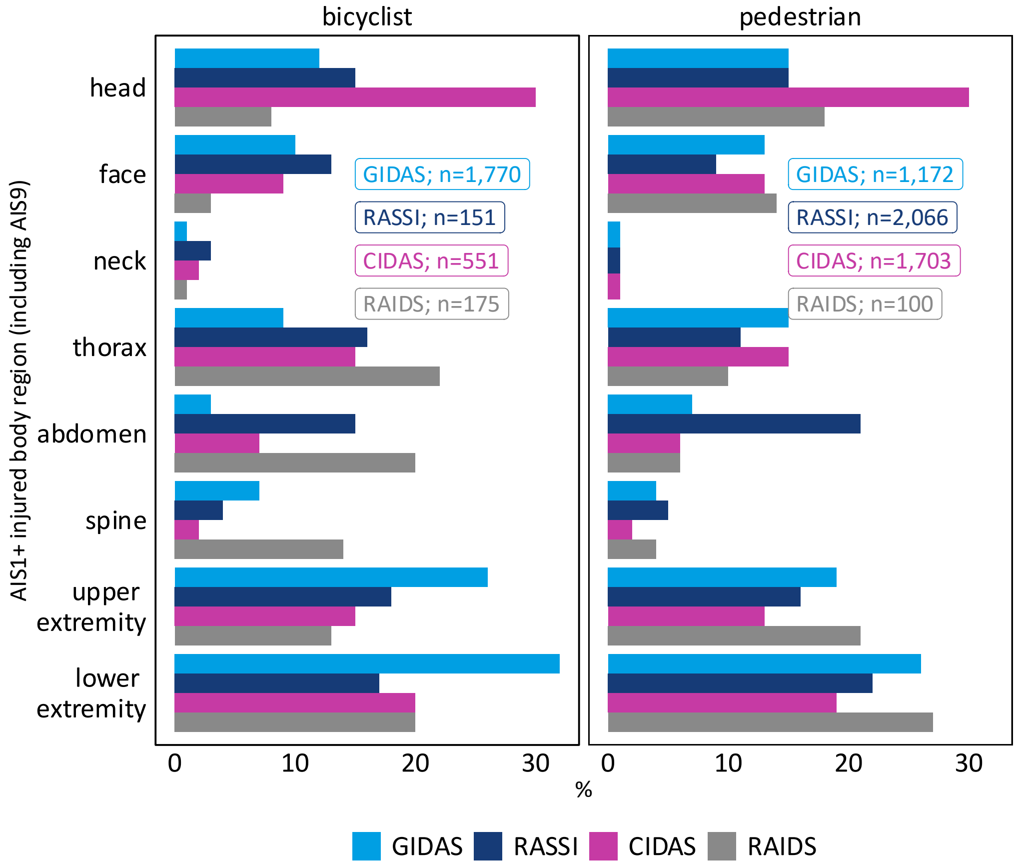

Fig. A1. Injured body region distribution for AIS1+ injuries for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

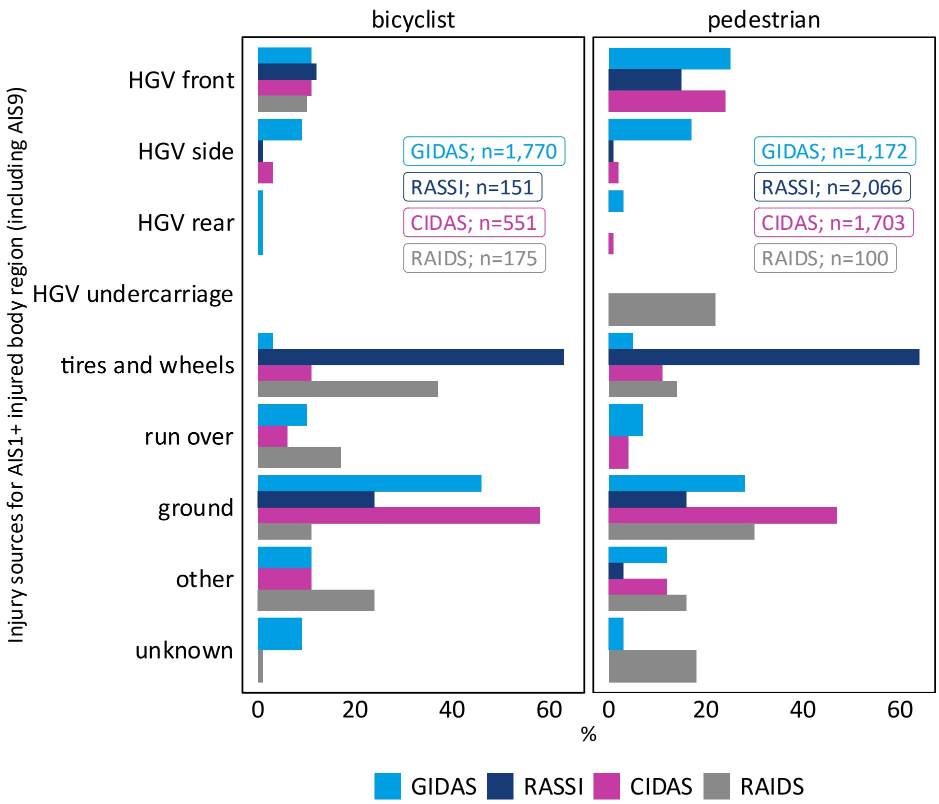

Fig. A2. Injury-causing part distribution for AIS1+ injuries for bicyclists and pedestrians involved in a crash with a HGV in different databases (*left:* bicyclist, *right:* pedestrian).

TABLE AI
CRASH TYPE MAPPING FOR RAIDS

Crash type RAIDS	Crash type category manuscript
G2	Turning off a road
G3	Turning off a road
G5	Turning off a road
N3	Turning off a road
G6	Turning off a road
J1	Turning into a road
N1	Turning into a road
N2	Turning into a road
A3	Moving along carriageway
F1	Moving along carriageway
P1	Moving along carriageway
OT	Other