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Exploring European heavy goods vehicle crashes using a three-level analysis of crash data

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Abstract: This paper addresses crashes involving heavy goods vehicles (HGV) in Europe focusing on long-haul trucks weighing 16 tons or more (16t+). The identification of the most critical scenarios and their characteristics is based on a three-level analysis: general crash statistics from CARE addressing all HGVs, results about 16t+ trucks from national crash databases and a detailed study of in-depth crash data from GIDAS, including a crash causation analysis.

Most European HGV crashes occur in clear weather, during daylight, on dry roads, outside city limits, and on non-highway roads. Three main scenarios for 16t+ trucks are characterized in-depth: (1) rear-end crashes in which the truck is the striking partner, (2) conflicts during right turn maneuvers of the truck and a cyclist riding alongside and (3) pedestrians crossing the road in front of the truck. Among truck-related crash causes, information admission failures (e.g. distraction) were the main causing factors in 72% of cases in scenario (1) while information access problems (e.g. blind spots) were present for 72% of cases in scenario (2) and 75% of cases in scenario (3).

The results provide both a global overview and sufficient depth of analysis in the most relevant cases and thereby aid safety system development.

Keywords: long-haul truck; crash scenarios; GIDAS; CARE; crash causation; European national crash data

Abbreviations

16t+ truck	Truck with a combination weight above 16t
ACAS	Accident Causation Analysis System
CARE	Community Database on Accidents on the Roads in Europe
GIDAS	German In-Depth Accident Study
HGV	Heavy Goods Vehicle (with a weight above 3.5t)
HMI	human-machine-interface
KSI	killed or severely injured
LTCCS	Large Truck Crash Causation Study (USA)
STRADA	Swedish National Crash Database
VRU	Vulnerable Road User (e.g. cyclist, pedestrian)

1. Introduction

In the year 2016, more than 1 million crashes happened on European roads, resulting in 25,651 fatalities (EC, 2018a). Although fatality numbers in crashes involving HGVs fell by almost 40% in the EU since 2007 (EC, 2018c), development and implementation of safety systems in HGVs can help to reduce this number even more. The basis for the design of these systems is a deep understanding of HGV crashes and the underlying mechanisms as well as factors influencing crash causation and outcome.

Woodroofe and Blower (2015) identified in a study of US data that rollover and head-on collisions are the main collision types for truck driver injuries, accounting for 73% of serious and fatal injuries of truck drivers. However, as shown in Zhu and Srinivasan (2011) based on data from the Large Truck Crash Causation study (LTCCS) in the US, fatally injured persons in crashes that involve heavy trucks are usually occupants of the crash opponent vehicles, and the most serious crash types in terms of the overall injury outcome are head-on collisions and collisions at intersections. An analysis of European crash data in the technical report Kockum, Örtlund, Ekfjorden and Wells (2017) indicated that HGV occupants are injured in 10-20% of HGV crashes, while the corresponding figures are 50-55% for car occupants and 30-35% for VRUs, supporting previous findings that car occupants and VRUs comprise the largest group of casualties in truck related crashes.

Vulnerable road users, lacking a protective shell around them (e.g. crumple zone, airbag), may be especially exposed in crashes with HGV involvement. Kim, Kim, Ulfarsson and Porrello (2007) correlate the involvement of a truck in the crash with a significant increase in the likelihood of a fatal injury of cyclists in the US. Lee and Abdel-Aty (2005) found in an analysis of data from Florida (USA) that the larger size of HGVs was correlated to an increased likelihood of severe injuries for pedestrians at intersections. Adminaite, Allsop and Jost (2015) describe crashes between trucks and VRUs especially problematic due to the vehicle size and difference in mass and indicate that the main reason for these crashes is the problematic field of view for truck drivers, making VRUs particularly prone to be in the blind spot and overseen by the truck driver. Seiniger, Jost and Benjamin (2015) have identified that the development of new safety systems of trucks for cyclist protection should be focused on right turning maneuvers and propose a test methodology to validate new active safety systems.

Overall, the literature review of results for crashes involving heavy trucks has revealed various limitations, especially regarding the study of crash causation. Rezapour, Wulff and Ksaibati (2018) analyzed transport data from Wyoming (USA) and conducted a violation analysis. The authors conclude that in more than 80% of all crashes involving a truck, the truck drivers are the party at fault, which emphasizes the need to introduce more safety systems into trucks. Findings based on European in-depth crash data suggest however that truck drivers are the party at fault in only 25% of cases (ETAC, 2006). The large difference in the estimates underlines the need for further study. Accident causation results are presented in Evgenikos et al. (2016) based on data collected between 2005 and 2008 in the SafetyNet project; however, safety system development may require further analysis based on more recent data and inclusion of pre-crash information (e.g. initial speed, environment conditions).

Furthermore, several studies cited above are based on data sets from North America. Wang and Wei (2016) showed in their analysis that benefits achieved by active safety systems in one country cannot easily be transferred to other countries, emphasizing the need to analyze regional data. Due to different road infrastructure designs (e.g. wider lanes) and vehicle designs (e.g. conventional cab design in North America compared to flat nose design in Europe), the representativeness of study results obtained in North America to the situation in Europe are limited. In 2008, Knight et al. identified a lack of robust European crash data especially for large trucks. Several characteristics of HGV crashes in Europe were then studied in Evgenikos et al. (2016), addressing all heavy goods vehicles (over 3.5 tons maximum permissible gross weight). However, there are significant differences in vehicle types in this category, that could range from heavy vans like a Mercedes Sprinter to long-haul truck-trailer combinations such as the Volvo FH. Different types of HGVs have different characteristics (e.g. vehicle dynamics, field of view), and a more detailed classification would be important for a more directed safety system development.

The aim of this paper is to provide descriptive statistics that are based on a comprehensive and up-to-date analysis of HGV crashes in Europe, focusing on heavy long-haul trucks with a combination weight above 16t (further referred to as 16t+ trucks). The exploratory analysis presented in this paper is planned to be followed up by explanatory methods in subsequent papers.

2. Materials and Method

The approach to identify relevant crash scenarios consists of three levels. First, data from the Community Database on Accidents on the Roads in Europe (CARE) is extracted to get a general understanding of crashes with the involvement of heavy goods vehicles (3.5t+ trucks) in Europe. As CARE contains high level data, this first level of the analysis needs to be complemented by other data sources for the identification of relevant crash scenarios.

More detailed information can be obtained from national crash databases, which is the second level of the analysis. These usually contain more information, such as vehicle weight, that allow for a filtering of crashes to those with the involvement of a 16t+ truck. Specifically, national data from Sweden, Spain and Italy is analyzed.

The third level of analysis addresses in-depth data from the German In-Depth Accident Study (GIDAS). In-depth crash databases contain detailed crash scenario description, crash reconstruction and information about causation factors. At the same time, their sampling region and case count are substantially smaller compared to CARE or the national databases. Consequently, each of the three levels of the analysis provides information that complements results of the other two (see Figure 1) and a full picture can only be obtained by their combination.

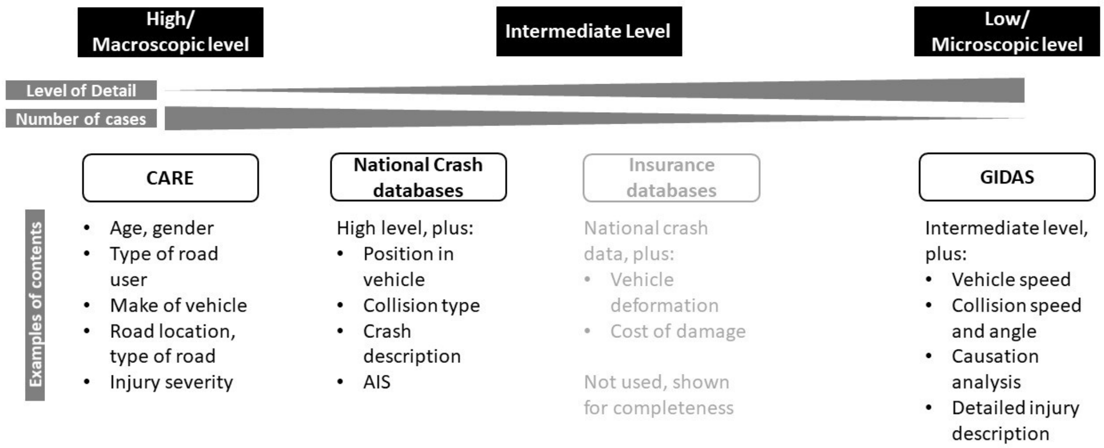

Figure 1. Overview of databases used for analysis.

The analysis addresses police-reported crash severity levels defined as follows:

Fatal crash: A crash in which at least one person was fatally injured (the person died from the crash within 30 days).

Serious crash: A crash in which at least one person was seriously injured (hospitalized for at least 24 hours), and nobody was fatally injured.

Slight crash: A crash in which at least one person was seriously injured (hospitalized for less than 24 hours or not hospitalized), and nobody was fatally or seriously injured.

Additionally, the severity level of KSI (killed or seriously injured) will be used for the analysis, which is the union of fatal and serious injuries.

2.1. CARE

As indicated above, EU crash data on an aggregated level is available in CARE. This database is used to obtain general estimates from police-reported crash data from all EU member states and additionally from Iceland, Liechtenstein, Norway and Switzerland, and the United Kingdom (EC, 2018a). The set of variables included in CARE is specified in the CaDaS glossary (EC, 2018b). As vehicle weight is not included as a variable, all results based on CARE queries will be using the general definition of HGVs, i.e. with a total weight of 3.5t or greater.

Data from 2010 to 2015 from EU28 (defined as the 28 EU countries in 2018, when the analysis was performed) was used for this analysis. Gaps in the data (e.g. years without reported data for a given country) were filled by the data value from the same country for the closest year, using data from the earlier year in case of two years that were equally close. Furthermore, for years where all crashes were coded in the category "unknown", the crashes were distributed to the available categories by interpolating the total number of crashes with the distribution from the closest year.

Police-reported injury severity levels as defined in the previous section are considered for the analysis. Italy, Finland and Estonia do not distinguish between serious and slight injuries, but rather report a generic number of injured persons. Therefore, for these countries, it was assumed that 14% of all reported non-fatal injuries were serious and 86% were slight, based on a study of Italian data that gives the large majority of cases (see the next section).

2.2. National crash databases

In the second stage of the analysis, the Swedish national crash database STRADA (Transportstyrelsen, 2019) was analyzed addressing crashes with 16t+ trucks from the years 2000 to 2016. Crashes including 16t+ trucks were also analyzed in Spanish national crash data (Dirección General de Tráfico, 2019) and Italian national crash data (Istat, 2019) using crash years 2014 to 2016, respectively 2010 to 2016.

Since Italian data does not provide a distinction between serious and slight injuries, the reported numbers of non-fatal injured persons were distributed to slight and serious injuries according to a study by the Italian road infrastructure administration (Ministero delle Infrastrutture e dei Trasporti, 2010), with 86% of the injuries being recoded as slight and the remaining 14% as serious. Additionally, Italian data did not include information about light conditions, hence the corresponding analysis will be given for the other two countries only.

To enable a comparison of basic crash types for crashes with 16t+ trucks between the three countries, the corresponding data in the Italian and Spanish databases was re-coded to the Swedish crash type classification.

2.3. GIDAS

The third level of analysis addressed in-depth crash data involving 16t+ trucks from the German In-Depth Accident Study (GIDAS). GIDAS is the largest in-depth road accident study in Germany, currently including about 30,000 crashes from the areas of Hannover and Dresden. The crash investigation teams are notified by the police and go on-scene to crashes with at least one injured person. Up to 3,000 variables are recorded per crash, including technical vehicle data, crash information, road design, active and passive safety systems, crash scene details and causes of the crash. Following the data collection, each accident is reconstructed to obtain information on crash kinematics and sequence of events. Due to a carefully defined statistical sampling process, the collected crashes are suitable for representing the German crash situation (Johannsen, Krettek, Hannawald & Schaser 2017).

The accident type catalog developed by the German insurance association GDV (see Institut für Straßenverkehr, 1998) which is also used by the police in Germany, serves as a crash classification system for this study and provides more detailed information than the crash types in the national crash databases analyzed before. There are over 200 specific crash types defined which are classified in 7 main categories. Crash types are defined in terms of the initial conflict situation of the crash (which is possibly different from the crash configuration at the time of collision).

The opponent involved in the most serious collision was chosen as the collision partner of the trucks for the following analysis, in order to identify the collision partner associated with the most serious injuries. If there was no most serious injury available (e.g. all people were uninjured), then the collision partner that caused the most damage to the truck was chosen. If damage was not available or visible, then the partner of the first collision was chosen.

The causes of the crashes are identified using the Accident Causation Analysis System (ACAS) methodology (Otte, Pund & Jänsch, 2009), that is based on a structured interview of the involved parties or witnesses. If no interview is possible, the information is collected from police reports or expert opinion of the accident researchers. Three main groups of causation factors are considered: vehicle-based failures (technical defects, illegal technical alterations or HMI problems), environment-based factors (road infrastructure failures, weather and other external influences) and human failures, which are further classified in 5 categories:

Information access (information was not accessible, e.g. due to blocked view, illness, darkness);

Information admission (information was in principle accessible but was not acquired, e.g. due to distraction, reduced activation due to sleepiness or drugs or wrong focus of attention);

Information evaluation (information was accessed but interpreted wrongly, e.g. the expectation was that the other one would be slower or stop);

Planning (the information was accessed correctly but the maneuver was not planned appropriately, e.g. not braking hard enough or an intentional breach of rules);

Operation (there was a problem while executing the correctly planned maneuver, e.g. mixing up brake and accelerator pedal).

Further levels of the analysis are also available, see Figure 2 for an example. If relevant, multiple causation factors can be assigned to each party involved in the crash. Participants who have not caused the crash (as deemed by the police and investigators) are not assigned with a causation factor. Because ACAS is only available from the Hannover part of the GIDAS data from the years 2008 to 2017, only a reduced number of crashes are available for the crash causation analysis.

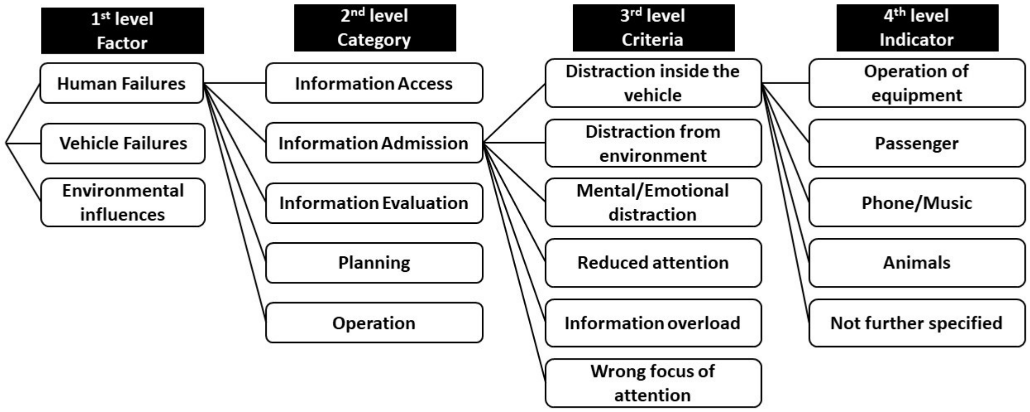

Figure 2. Example of ACAS classification in GIDAS.

3. Results

This section describes the results from all three analysis levels. For the percentages reported in this section, injuries and categorical factors that were coded as "other" or "unknown" were excluded if not indicated otherwise.

3.1. CARE

The high-level analysis based on CARE data shows that HGVs were involved in 4.5% of all crashes and 14.2% of fatal crashes in Europe, indicating an overrepresentation of HGV involvement in fatal crashes. Figure 3 gives a general characterization of crashes involving 3.5t+ trucks in Europe. This figure shows the names of the considered environmental variables, with the most frequent values specified between parentheses, and the prevalence of these values is indicated by the length of the bars. For example, for the variable "Weather" (code A-6 in CaDaS), the most common value is "Dry/clear" which is present in 81% of crashes involving HGVs in EU-28, followed by "Rain", present in 11% of crashes, and other values of the variable, present in 7% of the crashes. The results indicate that most crashes involving 3.5t+ trucks in EU-28 occur in dry/clear weather (81%), daylight (78%), on roads that are not highways (77%), on roads with a dry surface (72%) and additionally, the majority of crashes occur in rural areas (57%).

The analogous results for crashes with a serious or fatal outcome show that KSI crashes involving HGVs in EU-28 can be characterized by dry/clear weather (82%), not-highway roads (77%), daylight (73%), dry road surface (72%) and rural environment (65%). In other words, the results are similar to those for all injury crashes, but with greater percentages of rural crashes (65% vs 57%) and darkness (22% vs 18%).

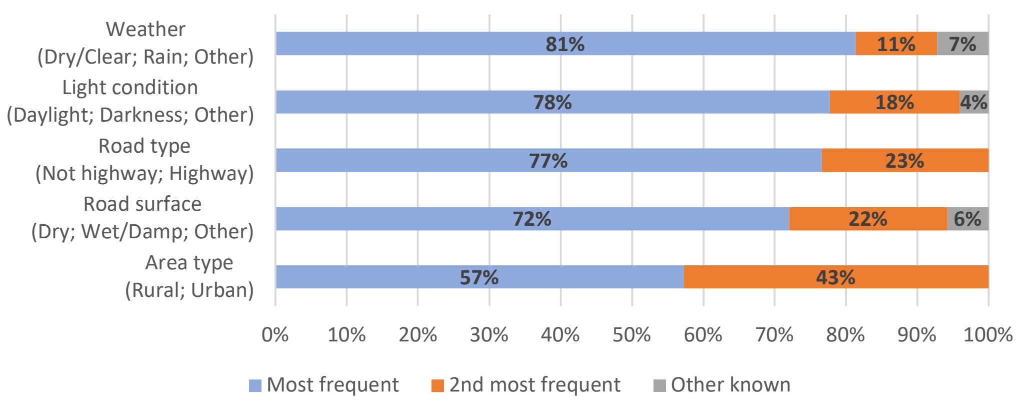

Figure 3. Characterization of crashes involving HGVs in Europe in terms of environmental variables, based on CARE.

Additional analysis was performed identifying that people injured in HGV crashes in EU-28 are mainly car occupants (55%), followed by HGV occupants (21%), vulnerable road users (16%) and other road users (8%). The distribution of injured road users by road user type and age is provided in Table 1 below, showing that the largest group of injured people in HGV crashes are car occupants and HGV occupants between 25 and 64 years. This age group is especially prevalent for HGV occupants, as 85% of all injured HGV occupants and 86% of all KSI HGV occupants are in this group. Notably, the percentage of young (<25 years) and old (>64 years) VRUs is much higher among KSI road users than for all injury levels. The gender distribution, provided in Figure 4 below, indicates that males are more frequently injured in crashes with HGV involvement than females, with males having a total share of 65% of all injuries and 71% of KSI injuries. The gender distribution is close to equal for injured car occupants and very skewed towards males for injured HGV occupants (92% of whom are males).

Table 1. Joint distribution of age and road user group for people injured in crashes with HGV involvement in EU-28, separately for all injury levels and fatally or seriously injured (KSI) people, rounded values, based on CARE.

		<18	**18-24**	**25-64**	**>64**	**TOTAL**
All injured road users	HGV occupant	0%	2%	18%	1%	21%
	Car occupant	4%	9%	36%	6%	55%
	VRU	2%	2%	9%	3%	16%
	Other	1%	1%	5%	1%	8%
	TOTAL (n=462,107)	7%	14%	69%	10%	100%
KSI road users	HGV occupant	0%	2%	17%	1%	20%
	Car occupant	3%	8%	30%	8%	48%
	VRU	3%	3%	14%	6%	25%
	Other	1%	1%	5%	1%	8%
	TOTAL (n=109,825)	6%	13%	66%	16%	100%

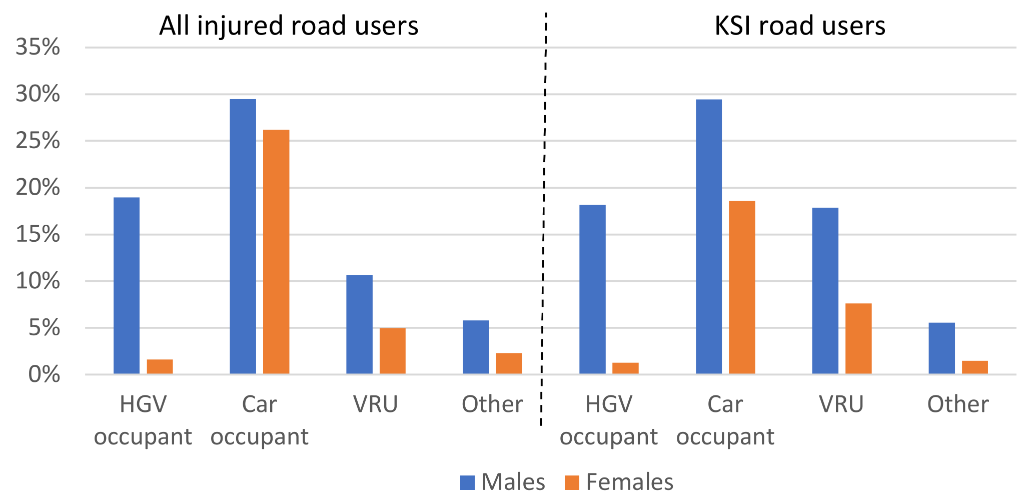

Figure 4. Joint distribution of gender and road user group for people injured in crashes with HGV involvement in EU-28, separately for all injury levels and for KSI road users, based on CARE.

3.2. National crash databases

The databases in Sweden, Spain and Italy for the analyzed years as specified in the Methods section contained 7069, 5232 and 27008 crashes with 16t+ trucks respectively out of which 1569, 1246 and 5237 were KSI. For weather and light conditions, the national crash statistics for 16t+ trucks from the analyzed countries (Sweden, Spain, Italy) generally follow the trends observed for 3.5t+ trucks in CARE: crashes occurred mostly in dry/clear weather conditions

(SWE 77%, ESP 88%, ITA 76%) and in daylight (SWE 73%, ESP 74%, ITA n.a.). Bigger differences between countries (and towards CARE) can be observed for surface conditions, where most crashes with 16t+ trucks occur with dry surfaces (SWE 51%, ESP 83%, ITA 81%), on non-highway roads (SWE 81%, ESP 54%, ITA 69%) and in rural areas (SWE 60%, ESP 87%, ITA 66%).

Crash type distributions can be compared across countries after re-coding as described in the materials and method section, see Figure 5. The figure shows the importance of rear-end crashes among all injury crashes and a greater prevalence of VRU crashes and meeting/overtaking crashes among KSI crashes compared to their shares among all crashes, indicating more serious injury outcomes in these crash types.

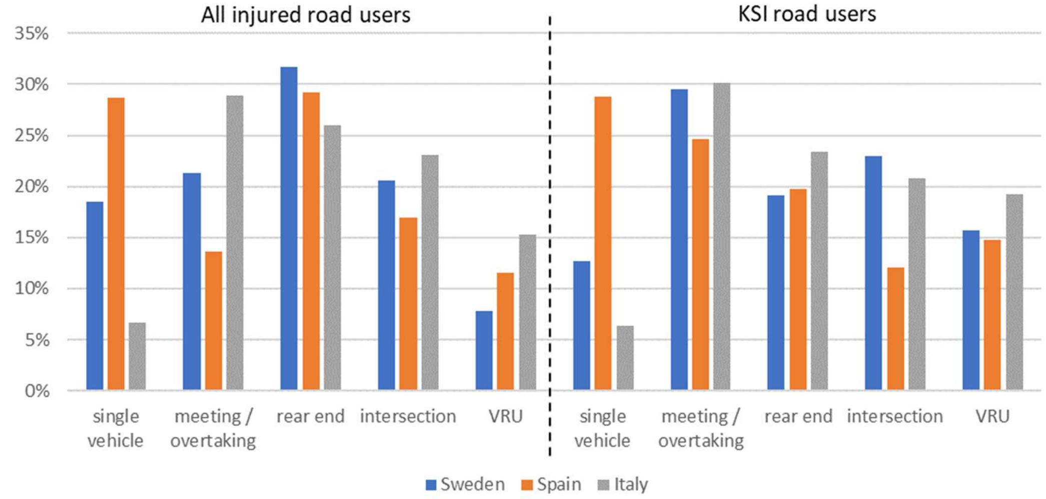

Figure 5. Joint distribution of countries and crash scenarios for people injured in crashes with HGV involvement in EU-28, separately for all injury levels and for KSI road users, based on the respective national crash databases.

Notable differences between the crash type results for the analyzed three counties include the high proportion of single vehicle crashes in Spain (especially for KSI crashes) while the proportion of meeting/overtaking crashes among all injury crashes and the intersection crashes among KSI crashes is smaller in Spain compared to Italy and Sweden.

3.3. GIDAS

The general analysis of GIDAS cases from the years 2000-2017 including 1,091 16t+ trucks in total revealed that the majority of crashes happened during daytime (75%) and that most crashes occurred outside city limits (59%) and on motorways (42%). Most trucks had an accident outside of junctions, either on a straight stretch of road (55%) or in a curve (9%). Crashes at junctions (11%) or crossings (20%) were less frequent.

For an analysis of the type of road user as crash opponent, 165 cases with unknown accident type or unknown collision partner as well as single vehicle crashes were discarded. A summary of the types of collision partners of 16t+ trucks and crash type frequencies can be found in Table 2, showing that 16t+ trucks are mostly involved in crashes with cars (44.6%), the majority of them occurring due to a conflict in longitudinal traffic (in 55.9% of truck-to-car cases, see Figure 6). Of these crashes, 35.7% occurred due to a rear-end collision (in which the truck was the striking vehicle in 54% of cases) and 23.9% occurred due to a lane-change maneuver (in which the truck changed lane in 63% of cases).

Table 2. Categories of accident types for 16t+ trucks with different types of road users as crash opponents, based on GIDAS.

Categories based on initial conflict	Cars	Commercial Vehicles	Bicycles	Pedestrian	Powered Two-Wheeler	*TOTAL*
1 Driving accident	39	12	3	0	3	*57*
2 Turning off accident	44	11	50	10	10	*125*
3 Crossing/entering accident	81	15	30	0	7	*133*
4 Pedestrian crossing road	1	0	0	34	0	*35*
5 Accident with parked vehicle	20	8	4	2	3	*37*
6 Accident in longitudinal traffic	272	192	8	2	14	*488*
7 Other accident types	30	12	1	8	0	*51*
TOTAL	*487*	*250*	*96*	*56*	*37*	*926*

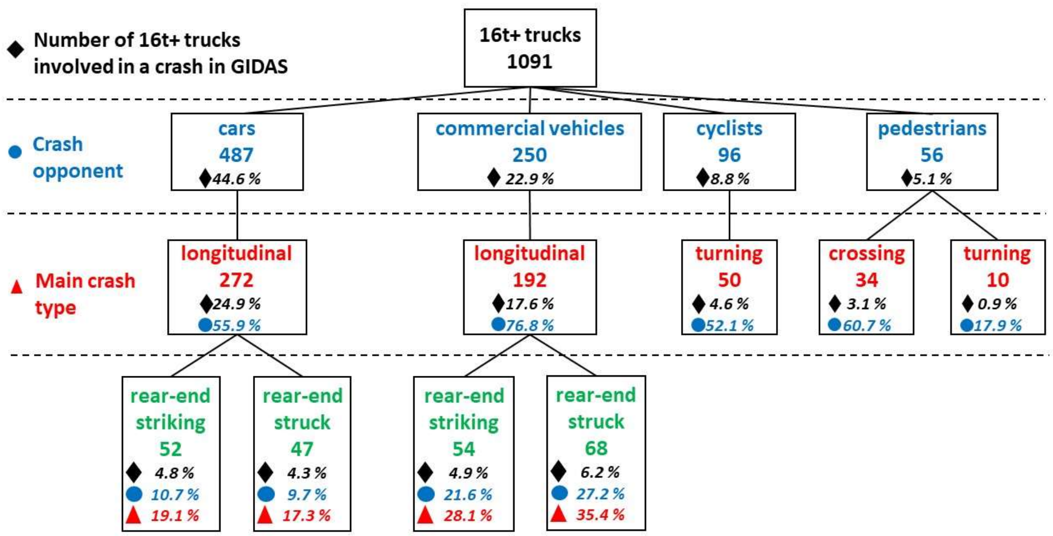

Figure 6. Most common crash types from GIDAS (case count and percentages per category); less frequent crash types are omitted for readability.

Commercial vehicles (Buses and HGVs) are the second most frequent crash opponents of 16t+ trucks (22.9%). Accidents in longitudinal traffic are again the most frequent types (76.8%, corresponding to 17.6% of all cases). In 28.1% of longitudinal cases, the 16t+ truck is the striking vehicle in a rear-end collision, and in 35.4% the struck vehicle; crashes between two 16t+ trucks are only counted in the rear-end striking category to avoid double-counting. In contrast to accidents with cars, lane change accidents rarely occurred between a heavy truck and another commercial vehicle.

Among the vulnerable road users, cyclists have the highest share as crash opponents for 16t+ trucks. The most common specific

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accident type with 44.8% is when a truck turns right and has a conflict with a cyclist travelling alongside in the same direction mostly on a bicycle path on the right side of the road.

Conflicts between 16t+ trucks and pedestrians were found in 5.1% of all cases. The most frequent category among those crashes is when a pedestrian enters the road to cut across perpendicular to the direction of travel of the truck in 60.7% of cases. The second most frequent category of crashes with pedestrians is when the truck turned off the main road and had a conflict with a pedestrian walking on the sidewalk (17.9%).

Crashes of 16t+ trucks with powered two wheelers were not as common as with other road users (3.4% of cases). These cases were mostly from the accident type categories of "turning off accidents" or "accidents in longitudinal traffic" and are not further investigated due to the low amount of cases.

Based on the most common accident types and results from CARE and national crash databases, three crash scenarios for 16t+ trucks were established as most relevant to further investigate in a more detailed crash analysis.

Scenario 1: rear end crashes with cars and commercial vehicles as collision partners. Due to the focus on preventability of the crash, only cases where the 16t+ truck is the striking vehicle are considered for further analysis.

Scenario 2: conflicts between a truck that is turning right and a cyclist that is travelling alongside with the intention to go straight.

Scenario 3: conflicts between pedestrians crossing the road and trucks.

These scenarios address the three different road user types, with scenario 1 as the overall most frequent one and scenarios 2 and 3 as the most frequent crash scenarios with VRUs as the crash opponent. Focus on VRU crashes is motivated by the high crash severity outcome in these crashes indicated by previous literature results detailed in the introduction as well as Figure 5 and is in line with the EC objective number 7 on improved protection for cyclists and pedestrians (EC, 2010).

Scenario 1: Rear-end crashes, 16t+ truck as striking vehicle

In the first scenario, including 106 cases in the GIDAS database (11.4% of all cases), the median travelling speed of the trucks at conflict initiation was 50km/h, with 25% of the trucks travelling at speeds above 80km/h (see the box plot in Figure 7). The initial speeds of the struck vehicles were substantially lower at the initiation of the conflict (median: 20km/h). Collision speeds were lower than the initial travelling speeds for both vehicles, with most collision opponents standing at the time of collision.

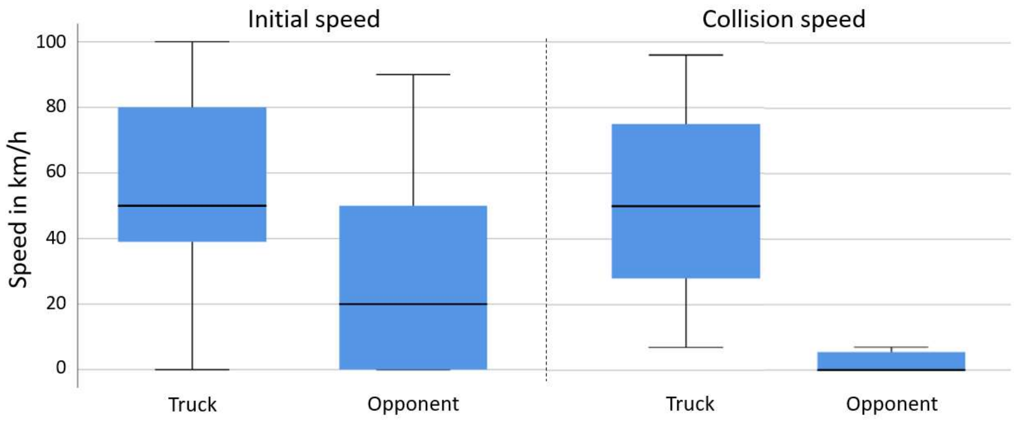

Figure 7. Scenario 1, initial and collision speeds of truck and collision partners in rear end crashes, based on GIDAS.

For this scenario, 60 cases are available with ACAS coding in the GIDAS database (see Figure 8) of which 57 were assigned a human failure, one case included a vehicle failure (brakes) and in 2 cases, the truck had not caused the crash. 75% of human failure cases and thereby 72% of scenario cases were from the category of information admission. These were mostly not further specified as the drivers of the trucks often could not be interviewed or did not remember the crash due to its severity. Less frequent human failure categories were information access problems (8.8%), information evaluation failures (8.8%) and planning failures (10.5%).

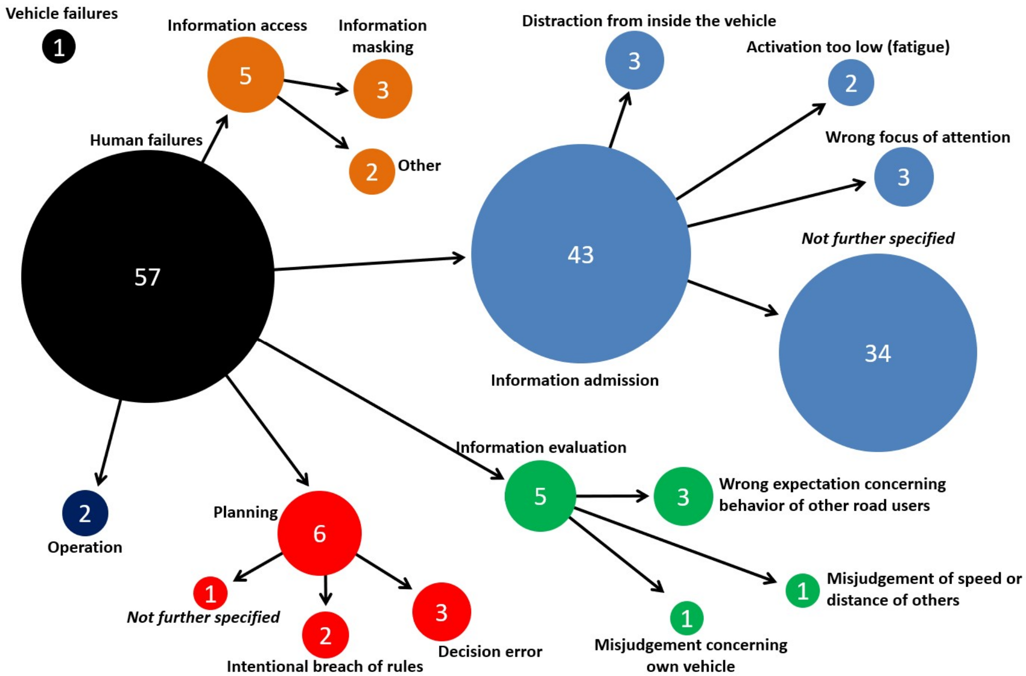

Figure 8. ACAS analysis of truck drivers in scenario 1 (rear-end striking crashes).

Scenario 2: Right-turn conflicts with cyclists

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The second scenario includes right turning trucks that had a conflict with a cyclist travelling along the initial direction of the truck in 43 cases (4% of all cases with 16t+ trucks in GIDAS). The conflicts occurred at lower collision speeds of the truck compared with scenario 1, with a median of 13km/h (see Figure 9). No reliable speed data is available for the cyclist.

The collision angle between cyclist and truck describes the angle between the motion vectors of the truck and cyclist at the point of the collision. It was found to be between 0° and 60° in most cases with a peak at 30° (see Figure 10). In 75% of the cases, the cyclist collided with the side of the truck in the range of 2m from the front of the truck, see Figure 11. Only 4 contact points were further away from the front than 5m (i.e. behind the cabin and further towards the trailer/rear axle of the truck).

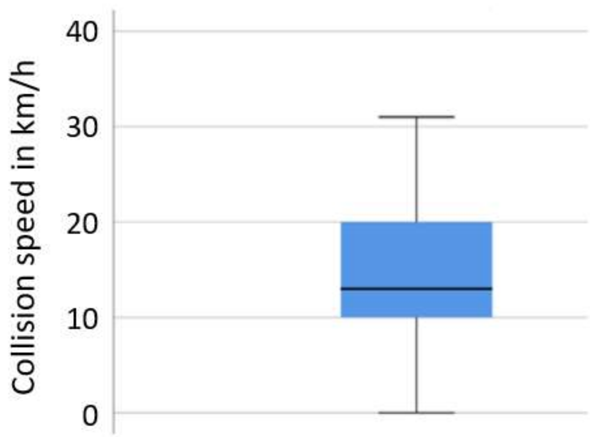

Figure 9. Scenario 2, collision speed of truck in right turn crashes, based on GIDAS.

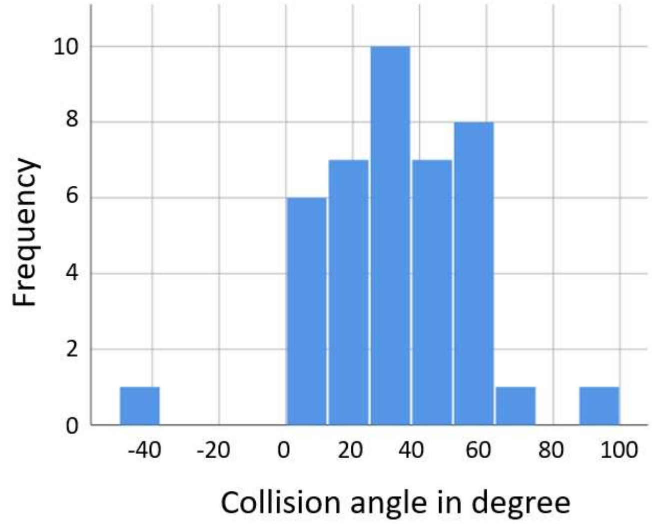

Figure 10. Scenario 2, collision angles between truck and cyclist in right turn crashes, based on GIDAS.

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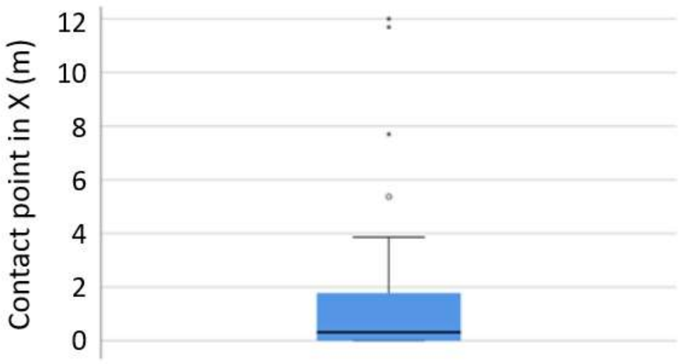
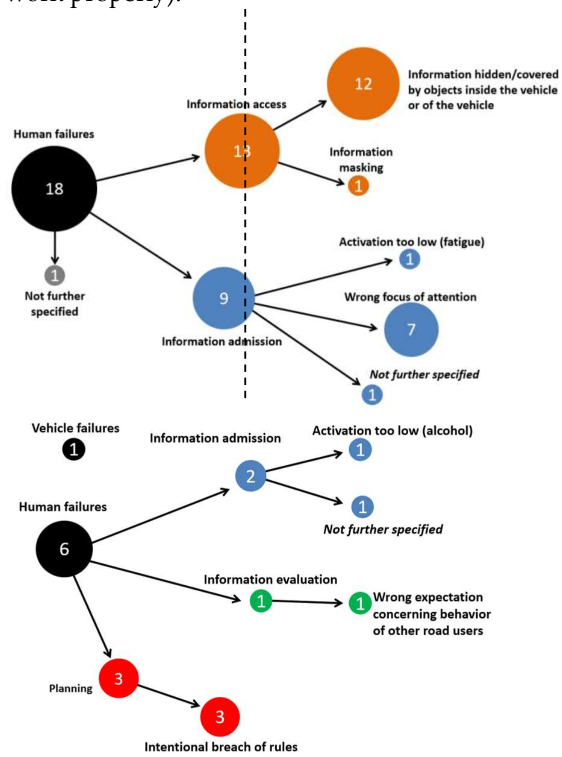


Figure 11. Scenario 2, contact point of cyclist with truck in x-direction from the front of the truck, based on GIDAS.

For this scenario, 18 drivers of 16t+ trucks were assigned with causation factors, which were all from the group of human failures, see Figure 12, left. 72% of these cases included information access problems - here mostly that the relevant information (i.e. the cyclist) was hidden by bodywork of the truck (e.g. the driver's cabin). For 39% of the 18 truck drivers, a wrong focus of attention such as a missed reassuring view (information admission failures) was reported.

Cyclists are less often identified to have caused crashes in scenario 2 compared to the truck drivers (see Figure 12, right), with 6 cases where the cyclist was assigned a human failure (out of which 50% were an intentional breach of rules such as an irregular use of roadway) and one case with a vehicle failure (brakes did not work properly).

(a



(b)

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Figure 12. ACAS analysis of truck drivers (a) and cyclist (b) for Scenario 2 (right turn crashes).

Scenario 3: Conflicts with crossing pedestrians

In the third scenario, including 34 cases (3% of all analyzed GIDAS cases), the pedestrian was overrun by a part of the truck in 16 cases (which leads to more serious or fatal injuries). In 10 out of the 16 cases, the truck was initially standing (e.g. at a traffic light) and the pedestrian crossed the road directly in front of the truck when the truck started to accelerate. Thus, the collision speeds here were under 10km/h in most cases (see Figure 13). In the remaining cases where the pedestrians were not overrun, the truck had a considerably higher average collision speed at 23km/h (in 25% of cases above 40km/h).

The speed at the initiation of the conflict for the cases where the pedestrian was not overrun were similar to the collision speed (see Figure 13), suggesting little or no braking happened in many cases.

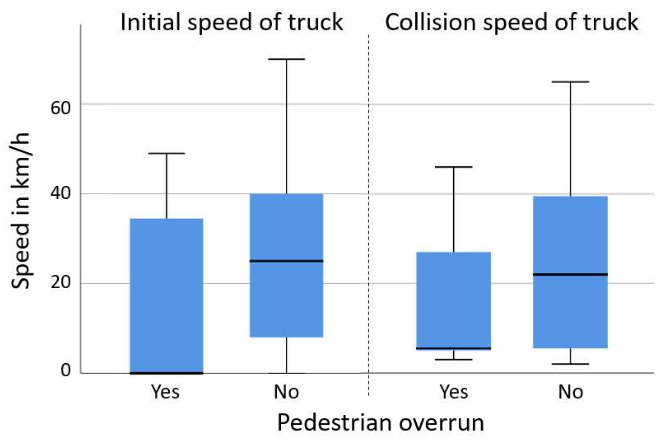

Figure 13. Scenario 3, initial speeds of truck in pedestrian crossing crashes, based on GIDAS.

For this scenario, 4 truck drivers and 6 pedestrians were assigned with a human failure code in ACAS (no vehicle or environmental failure was present). 3 of the 4 cases for truck drivers (75%) included information access problems - here mostly that the relevant information (i.e. the presence of movement of the pedestrian) was hidden by bodywork of the truck (e.g. the driver's cabin), see Figure 14, left. These cases resulted in the pedestrian being overrun by the truck, whereas in the one case left where the pedestrian was not overrun, the truck driver had a wrong focus of attention. There are 6 cases with human failures of the pedestrian (see Figure 14, right), out of which 50% are from the information admission. Out of these 6 cases, there was only one case where the pedestrian was not overrun, and it fell into the category "activation too low".

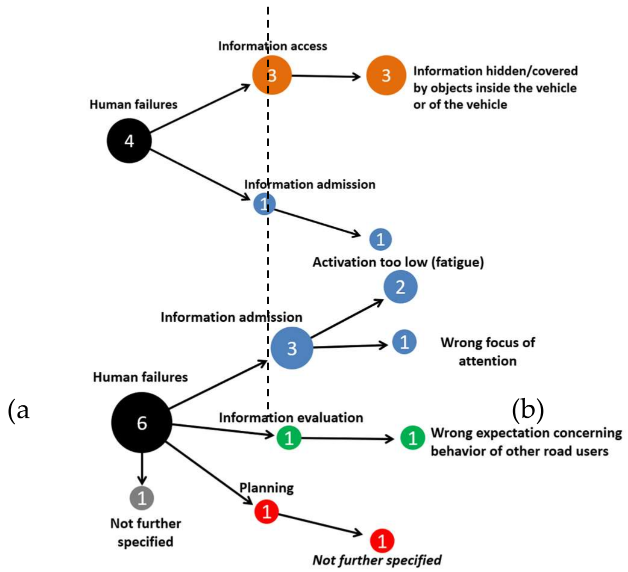

Figure 14. ACAS analysis of truck drivers (a) and pedestrians (b) in scenario 3 (pedestrian crossing crashes).

4. Discussion

Overall, this study provides an up to date three-level analysis of crashes that involve heavy trucks in Europe, widening the scope of previous studies. Differences seen between the data from CARE, national databases and GIDAS can result from (a) the existence of local differences (e.g. there are more days with rain in Sweden compared to Spain, resulting in a higher exposure to rainy weather conditions in Sweden) or (b) different filter criteria (i.e. weight restriction to above 3.5t for CARE and 16t for national databases and GIDAS). As only three national databases were available for analysis, no definite conclusions can be drawn, but a reasonable assumption is that the differences are a result of the combination of both factors. To which extent each factor is involved will be part of future research of the authors.

Further uncertainties are introduced by the coding scheme. Different countries are using different coding schemes, e.g. for crash types.

For this analysis of national crash data, crash types have been re-coded to a common scheme, following the Swedish crash type categorization. There are however crash types that are difficult to re-code, and even at the point of data collection, police officers might have difficulties to categorize the crash. Indicators for the difficulty can be seen in single vehicle crashes where, by definition only truck occupants should be injured, but also car occupant and VRU injuries are sometimes reported.

The results obtained in the crash data analysis at hand are similar to the findings of previous studies in the US, such as Zhu and Srinivasan (2011) who identified collisions in longitudinal traffic and collisions at intersections as the most common crash types.

Developers can use the detailed scenario characterizations to improve their systems by focusing on the most relevant crash situations and achieve the highest benefits. In particular, the results from this work are the basis for the further development of active and passive safety systems for heavy, long-haul trucks within the EU H2020 project AEROFLEX. In addition, the results of this work aim to improve the safety of heavy trucks by providing the data input necessary to develop test protocols.

5. Conclusion

This study provides a deeper understanding of crashes involving 16t+ trucks on European roads by a comprehensive data analysis conducted simultaneously on three levels and an investigation of crash causation. Most crashes occur in dry and clear weather conditions (76%-88%, depending on region), during daylight conditions (73%-78%), on dry roads (51%-83%), outside city limits (57%-87%) and on non-highway roads (54%-81%). All three analysis levels show the same trends regarding these variables, but small differences exist. The reasons for these differences could range from local effects (e.g. weather, driving behavior, vehicle types) to filter criteria in each database (e.g. weight or size restrictions).

As a result of the three-stage analysis, three scenarios were identified that should be addressed by future research and safety systems: (1) rear-end crashes with other vehicles in which the truck is the striking partner, (2) conflicts during right turn maneuvers between the truck and a cyclist travelling alongside with the intention to go straight, and (3) pedestrians crossing the road perpendicular to the direction of travel of the truck. These three scenarios were studied in detail in the GIDAS database, leading to the following conclusions:

(1) In rear-end striking crashes, the average speed of the truck at conflict onset is about 50km/h and by the time of the collision, it is reduced to about 30km/h, whereas the struck vehicle is typically standing at impact. In 95% of cases, human failures were identified as the causing factor (with information admission identified as the most common category, prevalent in 72% of truck-related causes).

(2) During the right turn maneuvers, the average collision speed of the truck is about 13km/h and the impact happens at an angle of 33 degrees on average, with the impact point within the first 2m along the length of the truck (i.e. around the area of the passenger-side door). In this scenario, problems with information access (e.g. blind spots) were identified in 72% of cases for the truck drivers, and in 27% of all crashes the cyclist was identified as the party at fault.

(3) In the pedestrian crossing scenario, initial truck speeds are generally low (< 5km/h) for cases where the pedestrian is overrun by the truck. Such a case often results from situations when pedestrians cross the road in front of a waiting truck and are not perceived by the truck driver when starting to accelerate. Collision speeds are higher (>20km/h) when the pedestrians are not overrun. Overall, problems with information access were identified as the main causing factor in 75% of cases for truck drivers. Even though the speeds in the VRU related scenarios are generally low, the

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outcomes are serious, especially when the VRUs are overrun by the truck.

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