# Potential of heavy goods vehicle countermeasures to reduce the number of fatalities in crashes with vulnerable road users in Sweden



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*Research article*

# Potential of heavy goods vehicle countermeasures to reduce the number of fatalities in crashes with vulnerable road users in Sweden

**Tania Dukic Willstrand[1,2,3*], Kristian Holmquist[1,3], Rikard Fredriksson[4,5,3], Matteo Rizzi[4,3]**

[1]Volvo Group Trucks Technology, Sweden

[2]DuWill AB, Sweden

[3]SAFER Vehicle and Traffic Safety Centre at Chalmers, Sweden

[4]Swedish Transport Administration, Sweden

[5]Chalmers University of Technology, Sweden

[*]Corresponding author: tania.willstrand@duwill.se

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**Abstract:** Heavy Goods Vehicles (HGVs) are involved in a large share of all serious and fatal collisions. Among these, about 30% are collisions involving Vulnerable Road Users (VRUs). The aim of the present study was to evaluate the potential of Heavy Goods Vehicle countermeasures to prevent fatalities with vulnerable road users in Sweden. Both the General Safety Regulation (GSR) and coming Euro NCAP test program were taken into account. Furthermore, elaboration on existing passive HGV safety systems were used to investigate any additive benefit. The Swedish Transport Administration carry out in-depth studies of all road fatalities. All in-depth studies for the period 2015–2020 were analysed retrospectively by a consensus group of three analysts, to assess the effectiveness of 22 active and passive safety systems. For each technology, target populations and boundary conditions were defined in order to facilitate the assessment. In total, 63 fatal crashes were found, compiled of 28 pedestrians, 13 bicyclists and 22 Powered Two Wheelers (PTWs, i.e. motorcyclists and moped riders). Overall, it was found that active and passive safety technologies could prevent up to 59% (37/63) of the included fatalities. For pedestrians, the potential of improved HGV driver vision, both with a surround view system and an improved direct vision, would have the larger potential to save lives. For bicyclists where the turn-right scenario is overrepresented, the implementation of Advanced Emergency Braking in junctions and Blind Spot Information Systems had the highest potential to save lives. For passive safety systems, HGV wheel protection had a potential to save many bicyclists by preventing them from being run over. Crash scenarios involving a PTW are the most challenging to address with HGV safety systems, mostly due to high PTW speed. Nevertheless, wheel protection on the HGV could save the lives of PTW drivers, by preventing them from being overrun. The present study showed that the included active and passive safety technologies for Heavy Goods Vehicles could prevent 59% of fatalities among vulnerable road users in Sweden. The fatalities not targeted by the HGV safety technologies included in the study would need other countermeasures such as connected safety technology (e.g. V2V or V2I), infrastructure, or education.

**Keywords:** active safety system, heavy goods vehicle, passive safety system, safety performance, Vision Zero, vulnerable road user

## 1 Background

The Swedish parliament adopted Vision Zero in 1997 and has since then reduced road fatalities by approximately 60%. Sweden had in 2020 a fatality rate of 19 road fatalities per million population and year (Hurtig et al., 2023). Together with Norway, this is the lowest traffic fatality rate in the world. Vision Zero acknowledges that is in the human nature to make errors, mistakes or misjudgements and aims at aligning the crash severity with the potential to protect from bodily harm. This facilitates an environment where crashes involving safe vehicles, safe infrastructure, safe speed and safe road users won't result in fatally or severely injured individuals. Using the Vision Zero approach (Larsson & Tingvall, 2013), one would design specific road elements (roads, vehicles etc.) anticipating the speeds of vehicles and types of crashes that road users could experience.

While Heavy Goods Vehicles (HGVs; Gross Vehicle Weight Rating > 3.5 tonnes) make up 6% of vehicle mileage in Sweden (Trafikanalys, 2024), these vehicle types have been involved in 15-20% of road fatalities in the last decade (Hurtig et al., 2023). The high involvement of HGVs in fatality crashes is not restricted to Sweden. A European research project reported that HGVs were involved in 14.2% of road fatalities in 2015 even though the total involvement rate was only 4.5% of all road collisions (Schindler et al., 2018). A study of Swedish HGV crashes for the years 2012-2021 identified a total of 455 fatalities. The deceased individuals in these crashes were, in almost all cases (92%), the collision partner of the HGV (Thomson et al., 2023). Several studies examined collisions with fatal and serious injury outcomes between HGV/pedestrians and HGV/cyclists collected from polis reports and insurance company (Christie et al., 2015; Malczyk & Bende, 2019; Talbot et al., 2017). Patterns identified for HGV/cyclists' collisions occurred at junctions where the HGV was turning right or left for left-driving countries. For collisions between HGV and pedestrians, they mostly occurred during stationary and moving-off scenarios in front of the truck. Authors agreed that those scenarios occurred in complex situations which require multiple countermeasures to prevent them. It was concluded that the improvement of truck driver's visibility of the cyclists on the right side of the HGV and of the pedestrians in the near front would be a potential countermeasure.

After having focused on passenger car safety to a great extent, regulators have acknowledged this road safety issue. The General Safety Regulation (GSR) update includes several areas relevant for HGV, including e.g. speed assistance systems, Advanced Emergency Braking for Vulnerable Road Users (VRUs) in 2028 for new registrations and driver distraction in 2026 (GSR, 2019, 2021). Further, the European consumer test programme, Euro NCAP, has published a road map (EuroNCAP, 2023) detailing plans to launch consumer tests of heavy commercial vehicles in three phases starting in year 2024. In the first phase, active safety countermeasures will be evaluated since it is believed to be most feasible to introduce on a short-term. Mid-term, year 2027, driver attention assessment is planned, including driver monitoring of distraction and drowsiness. Longer-term, in year 2030, assessment of passive safety for HGV occupants and compatibility with other motor vehicles and vulnerable road users are planned.

While the road map is already quite detailed on an overall level, the specific test scenarios and their respective scoring still need to be decided. In order to support that process, further crash analysis is very valuable, to understand these scenarios in detail, as well as how potential countermeasures can be effective. As a first step, the present study focusses on fatalities among VRUs in collision with an HGV.

## 2 Aim

The aim of the study was to evaluate existing and future HGV countermeasures with respect to their potential efficiency to save lives among VRUs (i.e. GSR and coming Euro NCAP for HGV). As vehicles are part of the transport systems, the safe system approach is adopted here. Thus, HGV safety systems were prioritised to study their potential to avoid fatalities, which can be a prevented collision or mitigation of injury severity. The results will be used for understanding the potential of the included countermeasures and what the contribution to reduced fatalities in the transport system these may have.

## 3 Method

### 3.1 Material

The Swedish Transport Administration (STA) has been collecting in-depth studies of all fatal crashes in Sweden since 1997. This database was used to analyse all fatal crashes between an HGV and a vulnerable road user (VRU) in Sweden from 2015 to 2020. The database was accessible with an approval from the administration and confidentiality agreement was signed between partners. A VRU is defined as a pedestrian, a bicyclist or a PTW rider (Powered Two Wheeler, i.e. motorcyclists or moped riders). In total, 63 fatal crashes were included in the present study (Table 1).

**Table 1** Number of fatal crashes per year and per VRU type in Sweden 2015–2020

| Year | Pedestrians | Bicyclists | PTW | TOTAL |
|---|---|---|---|---|
| 2015 | 3 | 4 | 4 | 11 |
| 2016 | 3 | 3 | 4 | 10 |
| 2017 | 5 | 2 | 4 | 11 |
| 2018 | 8 | 3 | 5 | 16 |
| 2019 | 6 | 1 | 3 | 10 |
| 2020 | 3 | 0 | 2 | 5 |
| TOTAL | 28 | 13 | 22 | 63 |

The in-depth database includes information from the police, emergency rescue service, medical journals from hospital, witness reports and STA traffic investigator analyses. The investigators from STA work systematically by means of crash scene investigation, vehicles inspections, weather and lighting conditions at the time of the crash. These parameters are combined with witness statements to identify preventative measures, which mainly are infrastructural due to the responsibilities of the STA. In the current study, the sample included all fatalities except one case, where the HGV was not actively involved in the crash, i.e. a motorcycle crashed into a passenger car, lost control, and the motorcycle ran under the HGV. The distribution of fatalities with respect to VRU types is shown in Table 1.

### 3.2 Analysis

Fatal crashes were studied from a system perspective where the potential of each safety countermeasure was determined retrospectively by analyzing the entire time frame for each crash leading to fatalities. This method is in accordance with previous studies performed with similar data sets (Kullgren et al., 2019; Stigson, 2009; Strandroth, 2015; Strandroth et al., 2012). The analysis was carried in a consensus group consisting of a minimum of three persons, with expertise in active safety, passive safety, human factors and crash investigations. Each crash from the in-depth database samples was analyzed. The first step was to go through the reconstruction of the crash, using all available data, so that all members of the consensus group had a common understanding of the course of events. The second step was to discuss and reach consensus on whether each relevant countermeasure could have prevented the crash altogether or prevented the fatal injuries. To facilitate the process and provide a framework for discussion, target populations had been previously set for each included countermeasure, i.e. setting boundary conditions for any given countermeasure to be effective. The analysis yielded a 'yes' if there was consensus in the analysis group that the countermeasure would have prevented the fatality, based on the stated boundary conditions for each countermeasure.

### 3.3 Countermeasures

The countermeasures used in the present study are summarised in Table 2, and a complete list is available in Appendix A. The countermeasures had a potential effect to prevent the crash, or to mitigate it to prevent fatal outcome, in a crash between an HGV and a VRU. The countermeasures could either be already on the market or to be implemented in the future. In total, 22 active and passive safety systems were defined and selected for their potential to save lives. For each countermeasure, a target population and boundary conditions were defined. A target population is a definition of relevant scenarios where the countermeasures is supposed to trigger and to perform. Boundary conditions represent the limitations in terms of speed, angle, environment, or type of road users where the countermeasures can function. The boundaries are used as pass/fail for each countermeasure.

## 4 Results

### 4.1 Crash pattern per VRU types

The distribution of all 63 fatalities is summarised into categories in Table 3 using crash patterns. The collisions between pedestrian and HGV occurred in moving-off scenarios and when the pedestrian crossed the HGV path in the front. Moving-off collision occurred most often when the pedestrian crossed the road at a zebra-crossing equipped with traffic lights (seven collisions at zebra-crossing, nine total moving-

**Table 2** Safety system countermeasures included in the study

| Active safety systems | Passive safety systems |
|---|---|
| AEB front to rear (PTW only) | Frontal Underrun Protection (FUP)—extended |
| AEB pedestrian/bicyclist | Passive VRU protection—sharp edges and projections (UNECE R-61) |
| AEB junction | Passive VRU protection—energy absorbing front |
| AEB reversing | Rear Underrun Protection (RUP)—extended |
| HGV Alcohol lock | Side Underrun Protection (SUP)—current legislation (UNECE R-73) |
| Brake assist | Side Underrun Protection (SUP)—extended |
| Blind Spot Information System (BSIS) | VRU airbag—reduces direct impact injuries to front |
| Direct Vision | Wheel protection—prevents run-over |
| HGV Intelligent Speed Adaptation | |
| Moving-Off Information System (MOIS) | |
| Reversing safety | |
| Surround view | |

off). Here, the pedestrian started crossing the road and before reaching the other side, the traffic light turned green, and the HGV started moving-off. The HGV speed was lower than 10 km/h and the pedestrians lower than 5 km/h.

The collisions between HGV and a bicyclist often occurred when the HGV was turning right and crossed the bicyclist's path on its right-hand side. Both vehicles were coming from the same direction. The speed of the HGV was lower than 20 km/h when turning and the bicyclists had an estimated speed lower than 20 km/h. In all cases, the HGV driver was not aware of the VRU presence on its path. The bicyclists seemed to have misunderstood that the HGV was turning in front of them and did not brake to avoid the collision. The bicyclists were overran by one or several wheels of the HGV.

For powered two wheelers, collisions occurred when the HGV was turning left and the PTW was coming from the opposite direction leading to a frontal collision. The HGV speed was estimated to be around 20 km/h since it was turning and the PTW was often reaching a speed above 90 km/h. The PTW was often speeding in these situations creating a risk.

### 4.2 Analysis of the potentials of countermeasures

The potential effects of the countermeasures are summarised in Table 4. Overall, the active and passive safety technologies were assessed to have a potential to save 32 and 28 lives, respectively. For bicyclists, and to some extent for pedestrians, an overlap was observed between active and passive systems. This means that in some cases, both active and passive safety technologies were of equal potential to prevent a fatal outcome. However, for PTW crashes, a more distinct effect was observed where more lives could be saved by implementing both active and passive systems. In total, by introducing active safety technology on HGV, a potential of saving 51% of the lives was observed respectively 44% for passive systems. In total, by combining HGV active and passive safety technologies, the total share of lives saved end up at 59% (37/63) in the current sample.

**Table 4** Number of potential lives saved by implementing countermeasures on HGV by VRU types

| Systems | Pedestrians | Bicyclists | PTWs |
|---|---|---|---|
| Active safety | 19 | 11 | 2 |
| Passive safety | 14 | 10 | 4 |
| Active and passive | 20 | 11 | 6 |

For each VRU type, a specific analysis was performed to identify what countermeasures within active and passive safety systems had the largest potential to save lives. For pedestrians, the potential of improved vision, both with a surround view system and an improved direct vision, have the larger potential to save lives (Table 5). Advanced Emergency Braking (AEB) was also found to be beneficial to save a significant number of lives. For bicyclists, where the HGV turn-right scenario was overrepresented, the implementation of AEB junction and Blind Spot Information System (BSIS) have the highest potential to save lives. Direct vision was also a countermeasure that can contribute to the detection of bicyclists for the HGV drivers.

**Table 3** Distribution of fatalities per crash category and VRU types in Sweden (2015–2020)

| Crash category | Pedestrians (n = 28) | Bicyclists (n = 13) | PTW (n = 22) |
|---|---|---|---|
| HGV turning off right | 3 | 9 | 1 |
| HGV turning off left | 0 | 1 | 8 |
| Moving-off | 9 | 0 | 0 |
| Oncoming | 0 | 0 | 7 |
| Overtaking | 0 | 0 | 2 |
| Reversing | 5 | 0 | 0 |
| VRU crosses HGV path | 7 | 3 | 1 |
| Others | 4 | 0 | 3 |

**Table 5** Potential share of lives saved per countermeasure for each VRU types

| Countermeasures | Pedestrians (n = 28) | Bicyclists (n = 13) | PTWs (n = 22) |
|---|---|---|---|
| **Active safety systems** | | | |
| Direct vision | 43% | 46% | 0% |
| Surround view | 50% | 15% | 0% |
| AEB pedestrian/bicyclist | 36% | 31% | 0% |
| Moving-Off Information System (MOIS) | 32% | 15% | 0% |
| AEB junction | 18% | 85% | 0% |
| Blind Spot Information System (BSIS) | 18% | 85% | 9% |
| AEB reversing | 11% | 0% | 0% |
| Reversing safety | 0% | 0% | 0% |
| Brake assist | 0% | 0% | 0% |
| HGV Alcohol lock | 0% | 0% | 0% |
| HGV Intelligent Speed Adaptation | 0% | 0% | 0% |
| AEB front to rear (PTW only) | n/a | n/a | 0% |
| **Passive safety systems** | | | |
| Wheel protection – Prevent run-over | 14% | 54% | 18% |
| Side Underrun Protection (SUP)—extended | 7% | 46% | 14% |
| Front Underrun Protection (FUP)—extended | 21% | 31% | 0% |
| Rear Underrun Protection (RUP)—extended | 11% | 0% | 0% |
| Side Underrun Protection (SUP)—current legislation (R-73) | 0% | 0% | 0% |
| Passive VRU protection—sharp edges and projections, current legislation (R-61) | 0% | 0% | 0% |
| Passive VRU protection—energy absorbing front | 0% | 0% | 0% |
| VRU airbag | 0% | 0% | 0% |

For passive safety systems, HGV wheel protection had a potential to save many bicyclists, by preventing them to be overrun by the HGV. Crash scenarios involving a PTW in collision with an HGV were the most challenging to address with active safety systems mostly due to high PTW speed. Wheel or Extended Side Underrun protection on the HGV could save four PTW riders lives by preventing them to enter under the HGV and be overrun.

### 4.3 Residual analysis

In total, it was estimated that 26 lives (41%) could not be saved by implementing the included active and passive safety systems on the HGV (Table 6). The size of the residual was VRU dependent. The largest challenge for HGV safety system was to address collision with PTW mainly due to motorcycle speed which are out of boundaries for the assessed technology. Bicyclist residual was limited to two cases in the present sample. The first, where the HGV was travelling at a high speed while the bicyclist was hidden from view, then suddenly crossing the road. In the second case the bicyclist hits a slow-moving HGV, falls, and hits his/her head on the pavement.

**Table 6** Residuals per VRU types

| VRU type | Residual |
|---|---|
| Pedestrians (n = 28) | 8 (29%) |
| Bicyclists (n = 13) | 2 (15%) |
| PTW (n = 22) | 16 (73%) |

The pedestrian residual contained one case of a pedestrian crossing on dark high-speed road, and one crash where the HGV was reversing into a loading dock and a pedestrian tried to rapidly move in through the loading dock in between trailer and HGV. The remaining six pedestrians in the residual were fatally injured during high-speed collisions on highway, where the pedestrian previously was a passenger car driver, which had exited their vehicle due to breakdown.

## 5 Discussion

The aim of the study is to evaluate existing and future safety systems on HGV regarding their potential efficiency to save lives among VRUs. In total, 63 fatal crashes were studied from a system perspective by retrospectively analyzing the entire time frame leading to fatalities. The majority of the fatalities are pedestrians, followed by PTW riders and bicyclists. Crash pattern for each VRU type is specific, namely, moving-off scenarios for pedestrians, frontal collision and HGV turning left for PTW, and HGV turning right for bicyclists. Active safety systems were found to potentially address the majority of those scenarios. Patterns identified and countermeasures regarding improved truck drivers' vision of VRU on the right side of the truck and in the near front area are also find in the present study (Christie et al., 2015; Malczyk & Bende, 2019; Talbot et al., 2017). More specifically, we could identify a large potential to save pedestrians lives with MOIS and direct vision and bicyclists lives with AEB junction and BSIS. Passive safety systems have also a large potential. This study especially showed the need for protecting pedestrians and bicyclists from being run over by the heavy goods vehicle. The flat vertical design of the front is likely to contribute to this compared to a passenger car where a pedestrian or bicyclist typically lands on the hood and travels with the vehicle during part of the crash decreasing the risk of sliding down under the vehicle. This study also showed the need to further develop designs to prevent bicyclists from under-running the side of the heavy goods vehicle. The current regulatory side protection (UNECE R73) was evaluated to understand if the severe outcome in a crash was mainly due to the existing exceptions in the regulation (tractors for semi-trailers and special purpose vehicles), or failure to follow regulation, or if additional countermeasures were needed to modify the outcome in the crashes, which was found to be a potential candidate in the extended side protection countermeasure (UN/ECE, 2011). Similarly, VRU protection (as regulated by UNECE R61) was included to keep the consensus group aware of any illicit HGV modifications, which potentially could have made the crash more severe (UN/ECE, 1984). However, no indications of such modifications were identified. Although this study did not show potential effect for passive pedestrian protection (energy absorption), this could partly be due to the limited sample size of the study. Also, this could be hidden by the fact that many were over-ridden by the HGV which creates more severe injuries. If this is solved, the passive pedestrian protection issue may very well rise to the surface. Furthermore, both active and passive systems were found to complement each other, adding robustness or redundancy in a crash. Although it is often difficult for active safety systems to reach full avoidance, they can often reduce impact speeds down to levels where it is easier to protect with passive safety systems. Speed was found to not be an issue neither for HGV nor for pedestrians and bicyclists. However, speed was found to be a major contributor in PTW crashes where the high speed of the motorcycle was considered outside of effective boundaries for the safety systems included. Driving under the influence of alcohol for HGV drivers was not found to be a relevant factor in the studied crashes, as no drivers tested positive for alcohol.

The safe system approach, where all parts of the transport system are integrated, is needed to prevent all crashes and injuries, i.e. HGV systems, PTW systems, VRU systems, infrastructure, connected systems, etc. However, as a first step, the focus was to evaluate the potential of HGV countermeasures. The list of countermeasures was designed based on current and potential future HGV safety systems relevant to all or individually targeted VRU groups but not brand specific. The safety systems included here are not conclusive, but a selection based on potential effect of present or coming systems. In addition, some of the passive safety systems are custom variants of existing countermeasures where no specific limitations for actual implementation possibilities are proposed, but rather a system included to identify an area of improvement, e.g. the different extended underrun protection systems and wheel protection. Regarding the effect of the systems included, independently the level of automation, all systems were considered to have a 100% effectiveness where the boundary conditions were met, which means that adverse weather conditions and possible misusage or behavioral adaptation where not included. Thus, it is likely that warnings are less effective than automatic vehicle-induced interventions since warnings may be neglected or misunderstood by the driver.

The countermeasure definitions and boundaries are simplified and loosely based on system descriptions in the European GSR and in the coming HGV protocol for Euro NCAP testing. The functionality interpretations are set at a low stringency level to allow for hypothesis testing against the data available in the STA database. In many cases, there is no information on travel speed for the HGV, and for the VRU no speed is available at all. The speed estimation of VRU was based on the findings in Wisch et al. (2013), and the expertise from the consensus group.

The potential for saving lives of active and passive systems on HGV seems to be promising in the light of the present results. However, to get closer to the halving of fatalities by 2030 and Vision Zero, there will be a need to implement other types of countermeasures such as infrastructure, systems on PTW or on bicycle. As emphasized by previous research, collisions between HGV and VRU are complex and require a multiple approach to prevent then (Talbot et al., 2017). Moreover, education and enforcement of legislation were not included in the present study, but they already have a documented effect in PTW crashes (Forsman et al., 2021). In PTW scenarios, there is a large potential for saving lives with coming connected safety systems. The future systems will support both the PTW riders and the HGV drivers to increase their awareness and perception that a vehicle, not visible, will soon be in a collision angle and preventive actions need to be taken such as decrease speed or stay in your lane until the approaching vehicle has passed. In the present study, seven fatalities could have been prevented by connected safety systems, giving an overall theoretical reduction of 70% of fatalities.

Utilizing the Safe System approach and having a holistic mindset to manage HGV crashes, the available safety technologies need to be deployed to a broad extent to save the maximum number of lives. The penetration rate of safety technology is limited in Europe. With an average age of trucks of 14.2 years in the EU (ACEA, 2023), a broad effect of safety systems will not be a reality before many years. The upcoming regulations in Europe, as well as the introduction of consumer rating tests, will most likely contribute to increase the penetration of safety systems on the market and will accelerate the decrease of fatalities in traffic. Additional in-depth studies in other regions of the world where data is available and studies including light and severe injuries are urgently needed to deliver relevant data for several stakeholders to act on the situation to reach the goal of halving fatalities by 2030 worldwide.

## 6 Conclusions

Based on the study results, the following could be concluded:

- Countermeasures regarding improved truck drivers' vision of Vulnerable Road Users (VRUs) on the right side of the truck and in the near front area are found to be effective to save lives.
- Large potential to save pedestrians lives was found with Moving Off Information Systems (MOIS) and direct vision.
- Large potential to save bicyclists lives was found with Advanced Emergency Braking system (AEB) junction and Blind Spot Information System (BSIS).
- There is a need for protecting pedestrians and bicyclists from being run over by the wheels of a heavy goods vehicle.
- Both active and passive systems were found to complement each other, adding robustness or redundancy in a crash.
- Upcoming regulations in Europe, as well as the introduction of consumer rating tests, will most likely contribute to increase the penetration of safety systems on the market and will accelerate the decrease of fatalities in traffic.

## CRediT contribution statement

**Tania Dukic Willstrand:** Conceptualization, Formal analysis, Methodology, Writing—original draft, Writing—review & editing. **Kristian Holmquist:** Formal analysis, Writing—review & editing. **Rikard Fredriksson:** Methodology, Writing—review & editing. **Matteo Rizzi:** Conceptualization, Formal analysis, Methodology, Writing—review & editing.

## Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Availability of data

All data supporting the article could be accessible through application at the Swedish Transport Administration.

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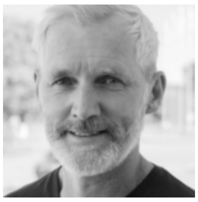
## About the authors

**Tania Dukic Willstrand** works within the field of traffic safety and sustainable transport with her own consulting company DuWill. She has a PhD from Chalmers University in Human Factors Engineering and she has been working with Human factors research and traffic safety for the last 20 years. Lately, she has focused on traffic safety as a tool to contribute to the global sustainable development goals, help organisation to measure their traffic safety footprint and to find countermeasures to decrease their impact.

**Kristian Holmquist** is a traffic safety researcher at the Accident Research Team at Volvo Group Trucks Technology, Gothenburg, Sweden. He has a Ph.D. in Machine and Vehicle systems from Chalmers University of Technology. Kristian has been working within injury biomechanics and traffic safety since 2003. His high interest topics are within traffic safety related to heavy goods vehicles.



**Rikard Fredriksson** is a Senior Advisor in Vehicle safety at the Swedish Transport Administration. He has a PhD in car pedestrian protection from Karolinska Institute and holds a position as Adjunct Professor at Chalmers University of Technology. He is also a board member of Euro NCAP. Rikard has been working with vehicle safety, biomechanics and crash analysis since 1995, first at Autoliv Research and then Apple Special Projects Group before joining the Swedish Transport Administration (Trafikverket) in 2019. His research interest is broadly vehicle safety with special interests in vulnerable road users, driver impairment, crash analysis, safety system effectiveness, commercial vehicles and vehicle automation.

**Matteo Rizzi** has a long experience of working with road safety related research and analysis. He currently works as a road safety analyst at the Swedish Transport Administration. He has worked with crash investigation, road safety analysis and assessment of safety countermeasures. He has previously worked as a researcher at the insurance company Folksam and as a road safety analyst at Vectura. Matteo has a PhD from Chalmers University of Technology, where his research focused on motorcycle safety.

## A List of countermeasures included in the study with their targeted population and boundaries

| Countermeasure name | Target population and boundaries |
|---|---|
| **Active safety systems HGV** | |
| AEB front to rear | Rear-end crashes involving PTW (HGV < 60 km/h; PTW < 50 km/h) |
| AEB junction | Crashes when HGV cross VRU path, same or opposite direction (HGV speed < 20 km/h; pedestrian < 5 km/h; bicycle < 15 km/h; PTW < 60 km/h) |
| AEB reversing | Reversing crashes low-speed, VRU behind the HGV, VRU moving or falling behind the HGV (HGV < 8 km/h; pedestrian < 5 km/h; bicyclist < 15 km/h) |
| HGV Alcohol lock | HGV driver under the influence of alcohol; prevents HGV driver to drive under the influence of alcohol |
| Brake assist | HGV driver apply insufficient brake pedal force to avoid collision |
| Blind Spot Information System (BSIS) | Crashes during lane change collision, side by side, HGV/VRU in same direction (HGV < 90 km/h; PTW < 100 km/h; pedestrian < 5 km/h; bicyclist < 20 km/h). |
| Direct vision | Collision with pedestrians and bicyclists in the front/side of the HGVs' cab; VRU within 4.5 m farside, 0.6 m nearside, 2 m to the front; VRU is visible from the drivers' field of view |
| HGV Intelligent Speed Adaptation | Accidents due to speeding; crashes where the VRU would have survive within the speed limit |
| Moving-Off Information System (MOIS) | HGV moving-off crashes, same target population and boundaries as AEB pedestrian/bicyclist |
| Reversing safety | Reversing crashes low-speed, VRU behind the HGV |
| Surround view | VRU close to HGV not detected; VRU hits in the blind spot area on the left or right side of the HGV at low speed; VRU hits in the front of the HGV at low speed; VRU hits within the length of the HGV at low speed; rear area is not included |
| **Passive safety systems HGV** | |
| Front Underrun Protection (FUP)—extended | Prevents VRU to enter undercarriage area in the front, frontal accidents or moving-off (HGV < 20 km/h, HGV driver alerted to stop within < 40 m) |
| Passive VRU protection—sharp edges and projections | Prevents VRU from catching on external surface of HGV (sharp edges or protruding parts causing injuries); collision VRU and front/side of HGV cab (UNECE R-61, 1984) |
| Passive VRU protection—energy absorbing front | Reduces injuries in direct impact of VRU to the HGV front; VRU injured on the head and/or upper body; impact location below windshield area; impact is the cause of death (relative speed VRU/HGV < 40 km/h) |
| Rear Underrun Protection (RUP)—extended | Prevents VRU to enter undercarriage area from the rear, while reversing or catching-up accidents (relative speed VRU/HGV < 40 km/h) |
| Side Underrun Protection (SUP)—current legislation | Prevents VRU including vehicle to enter undercarriage area from the side of the HGV; collision VRU/HGV turning or crossing path of VRU; horizontal force < 1 kN (UNECE R-73, 2011) |
| Side Underrun Protection (SUP)—extended | Prevents VRU including vehicle to enter undercarriage area from the side of the HGV; collision VRU/HGV turning or crossing path of VRU. Extended protection to prevent VRU in undercarriage area of HGV and Trailer from side (relative speed VRU/HGV < 40 km/h) |
| VRU airbag | Reduces injuries in direct impact of VRU to HGV front; VRU injured on the head and/or upper body; VRU in contact with windshield; impact is the cause of death (relative speed VRU/HGV < 40 km/h) |
| Wheel protection (run-over prevention) | Prevents override risk for VRU by one or several wheels (forward and rearward travel direction); excluding HGV front axle (HGV < 20 km/h) |