The Influence of Recent Legislation for Heavy Vehicles on the Risk of Underrun Collisions

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Kurzfassung

Bei Unfällen mit Lkw und deren Anhängern besteht für Pkw-Insassen ein hohes Risiko für schwere oder tödliche Verletzungen. Dies ist durch die Inkompatibilität zwischen den Kollisionsgegnern begründet: starke Massen- und Steifigkeitsunterschiede, aber auch deutlich unterschiedliche Geometrien der Fahrzeugstrukturen. Dies führt bei Zusammenstößen häufig zur Unterfahrung des Lkw- oder Anhänger-Chassis durch den Pkw, wobei dessen energieabsorbierende Karosseriebereiche und Insassenschutzeinrichtungen nur ungenügend zur Wirkung kommen. Der Vortrag stellt Ergebnisse von Sonderauswertungen der amtlichen Unfallstatistik und spezieller Unfalluntersuchungen vor. Die Gesetzgebung der letzten Jahre hat mit Einführung einer Frontunterfahrschutz-Regelung (2000/40/EG) für Lkw über 7,5 Tonnen Gesamtmasse einen wichtigen Fortschritt bei der Verbesserung der Kompatibilität bei Frontalkollisionen erzielt. Die aus den siebziger Jahren stammende Richtlinie für den Unterfahrschutz am Heck von Lkw und Anhängern wurde jüngst überarbeitet (2006/20/EG). Der Vortrag analysiert die Regelungen hinsichtlich ihrer Wirkung für den Unfallgegnerschutz. Dabei wurden Defizite in mehrerlei Hinsicht identifiziert. Einerseits lassen die technischen Anforderungen an Frontunterfahrschutzsysteme eine erhebliche Verbesserung der Kompatibilität erwarten, wie Fallbeispiele aus dem Unfallfeld und Versuche im Rahmen des EU-Projektes VC-Compat belegen, andererseits gestattet die Regelung umfassende Ausnahmen von der Ausstattungspflicht. „Geländegängige“ Nutzfahrzeuge sind davon ebenso befreit wie Lkw in der Klasse bis 7,5 Tonnen, machen aber einen erheblichen Teil der Fahrzeugflotte aus. Der Anteil der Lkw, die auch nach Einführung der Frontunterfahrschutz-Regelung ohne diese Systemen ausgerüstet sind, wurde durch Befragung der sieben größten europäischen Lkw-Hersteller und Analyse der Zulassungsstatistiken bestimmt und zeigt, dass bis zu einem Drittel der Lkw zwischen 6 und 16 Tonnen Gesamtmasse und ca. 14 % in der Gewichtsklasse darüber ohne Frontunterfahrschutz ausgeliefert werden. Anders stellt sich die Situation hinsichtlich der Anforderungen für Heckunterfahrschutzsysteme dar. Die neue Richtlinie 2006/20/EG definiert zwar gegenüber der bislang gültigen Regelung erhöhte Prüfkräfte, lässt aber dennoch keine wesentliche Verringerung

der Gefährdung erwarten. VC-Compat demonstrierte Möglichkeiten, auch das Sicherheitsniveau beim Heckaufprall gegen schwere Nutzfahrzeuge deutlich anzuheben, wobei allerdings auch Einschränkungen, die sich durch den täglichen Betrieb ergeben, insbesondere hinsichtlich der Geometrie des Unterfahrschutzes, berücksichtigt werden müssen.

Abstract

In collisions with trucks and their trailers, there is a high risk for car occupants to sustain severe or fatal injuries. Major contributing factors are the lack of compatibility between the collision opponents: large differences in mass and structural stiffness, but also significantly different geometries. In accidents with a passenger car, this often causes underrunning of the truck or trailer chassis. The energy-absorbing crash structures of the car have little effect then. Vehicle safety regulation has made great progress addressing the compatibility in frontal collisions with the introduction of an EU directive for front underrun protection (2000/40/EC) for trucks above 7.5 tons of gross vehicle weight. The regulation regarding rear underrun protection on trucks and trailers, originating from the seventies, was amended recently (2006/20/EC). However, deficits in both directives were identified. On one hand, the technical requirements for front underrun protection can be expected to enhance compatibility significantly as examples from the EU project VC-Compat and real-world accidents show. On the other hand, the regulation allows a number of exemptions from the need to install these safety components. So-called “off-road vehicles” do not fall under the requirement as well as trucks up to 7.5 tons of permissible total mass, but make up for a considerable share of vehicles in the fleet. The share of trucks which were delivered without front underrun protection after the directive went into effect was estimated from interrogation of the seven largest European truck manufacturers and analysis of registration statistics. It indicates that up to one third of trucks in the mass range between 6 and 16 tons and ca. 14 % of vehicles in the range above were not equipped with these systems in 2004. The situation is different regarding the requirements for rear underrun protection. The new Directive 2006/20/EC demands higher test loads than the previous regulation, but is still not expected to essentially reduce the danger of underrun at the truck or trailer rear end. VC-Compat determined minimum force and geometry requirements to enhance the level of protection when a passenger car impacts a heavy vehicle in a rear-end collision. Depending on the fields of operation for heavy vehicles, for instance in long distance hauling or in construction logistics, limitations to realize these improvements may exist, particularly with respect to the geometry, which should be taken into account.

1. Introduction

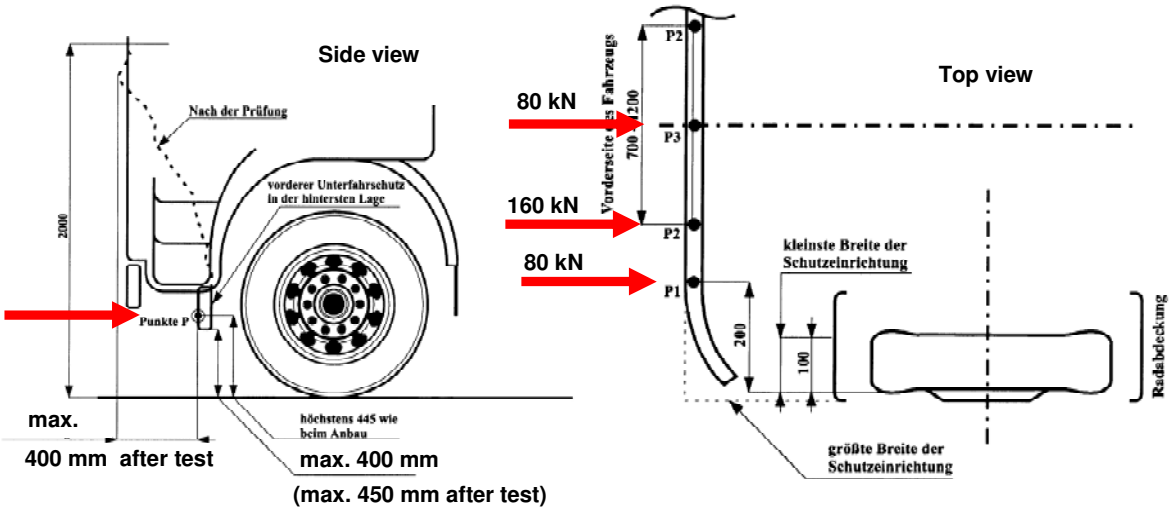
The passive safety of passenger cars has seen dramatic improvements over the last years due to the efforts in structural and interior safety. However, these achievements show their benefit primarily in car-to-car and car-to-object collisions. When collisions between very unlike opponents like heavy vehicles, particularly trucks and their trailers, and passenger cars occur crash compatibility remains a big concern. German 2003 accident statistics registered 38,085 traffic accidents with personal damage and involvement of goods vehicles (including van-style vehicles). 71 % of these involved one other collision opponent, the majority being passenger cars. 492 car occupants lost their lives in these accidents. 448 incidents with at least one fatality were categorized as the kind of accident in which the goods vehicle collides with an oncoming vehicle. 395 of these accidents occurred on rural roads.

In addition to the large differences in masses between the colliding vehicles, the structural stiffnesses and – most of all – their geometries are often incompatible. In consequence, the car's crash structure and restraint systems for the occupants often cannot work properly, resulting in large vehicle deformation, sometimes with late or no triggering of restraint components like airbags and seat belt pretensioners at all. Often, these particular problems in compatibility can be attributed to so-called underrun of the truck or trailer which describes that the strong vehicle portions of the truck and car body miss each other due to lacking alignment in the vertical, causing the car body to slide under the truck chassis or bodywork. This greatly increases the risk of the passenger compartment impacting the truck superstructure directly and suffering severe deformations with an increased risk for severe or fatal injury of the car occupants.

Efforts to introduce technical measures on heavy vehicles to benefit the weaker crash opponent were suggested already in the 70's and 80's [2], but for decades only a regulation describing a rear underrun protection requirement existed (Directive 70/221/EEC) [3]. This regulation was introduced in the seventies and remained largely unchanged until 2006. Side underrun protection devices are also mandated for most trucks and trailer (Directive 89/297/EEC), but are intended only to prevent pedestrians and cyclist from getting in front of the rear axles of the vehicle where they are exposed to the danger of becoming over-rolled by a wheel. The required strength of side underrun protection devices is therefore low and cannot be expected to provide significant resistance against an impacting passenger car.

2. Front underrun protection of trucks

It was only in 2003 that a regulation describing the requirements against frontal underrun of a truck came into effect (Directive 2000/40/EC), also as a result of the previous work of EEVC Working Group WG 14 [4]. It requires that trucks intended for on-road use and above a total permissible mass – or gross vehicle weight GVW – over 7.5 tons have a front underrun protection device (FUPD) or system (FUPS). This device is usually mounted to the chassis directly under the front bumper to catch an oncoming car early during the collision and engage its energy absorbing structure properly. Most of these devices are designed as assemblies of a crossbeam being connected rigidly to the main chassis, but a few systems are engineered to provide additional energy absorption. The regulation requires that a minimum ground clearance is observed for the FUP and that a maximum deflection of 400 mm's is not exceeded when static loads are applied in five points on the front of the system (Fig. 1). Directive 2000/40/EC demands front underrun protection in principal also for N_2 vehicles over 3.5 tons and up to 7.5 tons of permissible mass. However, no strength requirements are stated for these vehicles, but only the 400 mm ground clearance requirement exists.



Static test loads in points, seperately applied:

P1, P3: 80 kN or 50% of permissible mass (GVW)

P2: 160 kN or 100% of permissible mass (GVW)

Fig. 1: Strength requirements for FUP according to Directive 2000/40/EC

Still, the need was found to conduct further research both for potential optimisation of front underrun protection and improvement of the regulation and for determining the deficiencies in a rear-underrun situation and enhancement of the protection systems. Much of this work was carried out in the course of the research project VC-Compat (Vehicle Crash Compatibility) which was commissioned and co-financed by the European Commission under contract no. GRD2-2001-50083-SI2.346753 and ran from March 2003 until November 2006 [5]. The project consortium was divided into two groups, with the “Car-to-Truck Leg” conducting research into the problems of front and rear underrun and developing proposals for countermeasures as well as for future legislation in this field. Members of the Car-to-Truck Leg consisted of TNO (The Netherlands), DAF Trucks (The Netherlands), Renault Trucks (France), UTAC (France), INSIA (Spain), TRL (United Kingdom), Scania (Sweden), Volvo Trucks (Sweden), DaimlerChrysler (Germany), Bundesanstalt für Straßenwesen BASt (Germany) and Unfallforschung der Versicherer GDV (Germany).

Full-scale crash tests proved that modern passenger cars would be able to withstand impact forces in a 75 kph offset collision with a truck that is equipped with legal front underrun protection. The passenger compartment remained stable, restraint systems were fired in time and occupant loadings remained within acceptable limits (Fig. 2 – 5). However, there is indication that passenger cars that feature multiple load paths have an advantage over cars with single load paths.

Currently, the possibilities to assess the benefit of FUP from accident statistics are limited since it is only demanded for vehicles registered by the end of 2003 and after. The number of vehicles registered in the period of time after this date represents only a small portion of the current fleet. A few truck manufacturers had offered these safety systems before the regulation went into effect, but only a very small number was ordered by truck buyers. However, cases in which FUP-equipped trucks were involved in frontal collisions give rise to the assumption that these devices work well also in real-world accidents. As an example, figures 6 and 7 show the damage of a sports car that collided head-on and with full overlap with a semi-trailer tractor. The distributed deformation on the front of the passenger car and the stable occupant compartment indicates that its crash structures were engaged as intended. The driver sustained injuries, but survived.

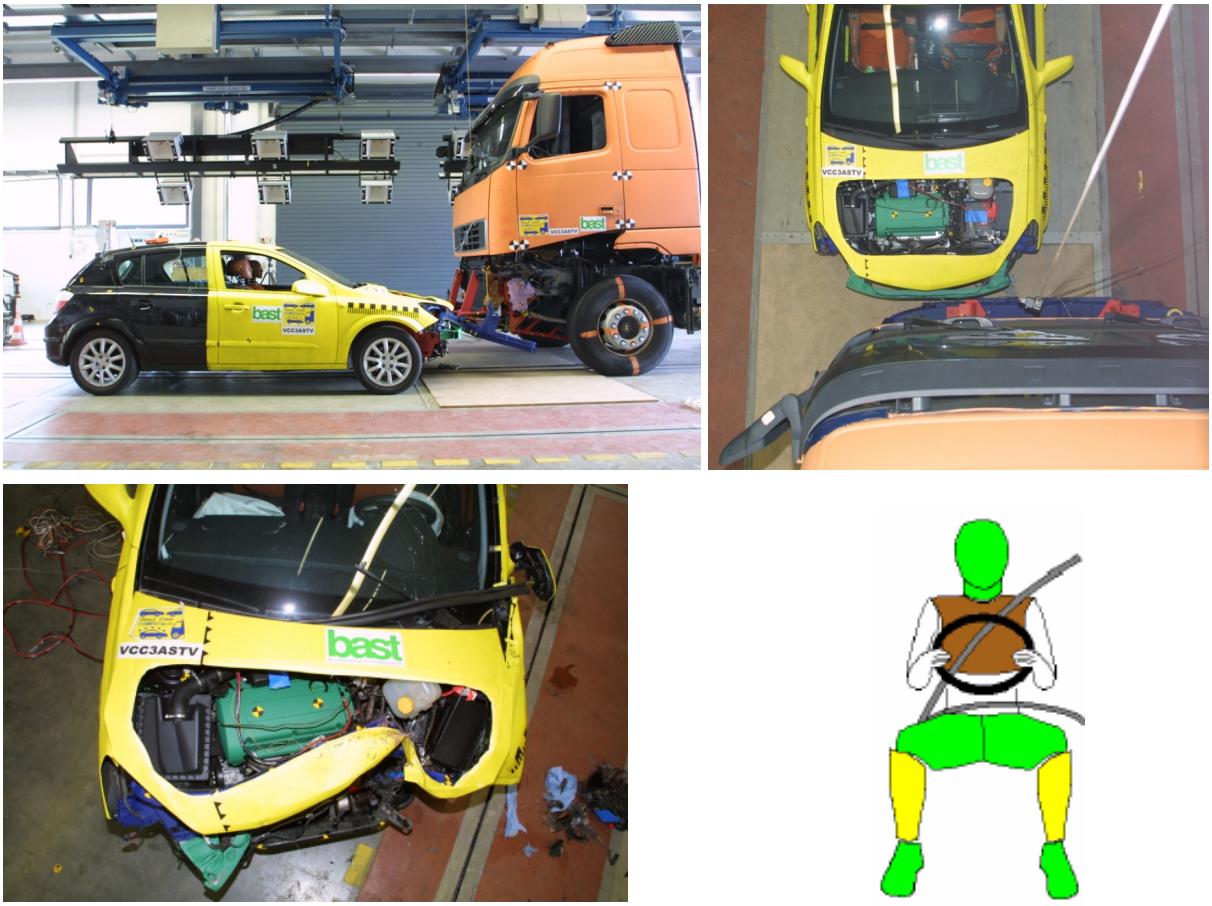


Fig. 2 - 5: Crash test with car at 75 kph into stationary truck with front underrun protection system (special rigid design for test purpose) and driver biomechanical loading applying EuroNCAP injury assessment reference values (source: VC-Compat, BASt)

Fig. 6, 7: Frontal collision between passenger car and truck with front underrun protection (source: Kreispressewart Friedrich W. Thies, Hameln)

3.1 Fitment rate of front underrun protection

Directive 2000/40/EC allows some exemptions from the FUP requirement. Where the installation of a FUPS or FUPD interferes with the purpose of the vehicle it does not need to have front underrun protection. More important, heavy vehicles that classify as “off-road” vehicles according to Directive 70/156/EEC [3] are also exempt from the FUP requirement. An overview of the criteria for an off-road vehicle is given in Table 1. Vehicles of class N_2 and N_3 [6] that fall into this category are designated as belonging to class N_2G and N_3G, respectively. A closer look at the criteria reveals that these are not difficult to fulfill. Presence of all-wheel drive is one possibility, but not a necessity. If, for instance, at least half of the wheels are driven, allowing to climb a gradient of a least 25 % and the vehicle has a differential lock it qualifies also.

Table 1: Conditions for provision of front underrun protection acc. to Directive 2000/40/EC (ECE-R93, respect.) and rear underrun protection acc. to 70/221/EEC (ECE-R58, respect.)

Front Underrun Protection System (FUPS) (ECE-R93)						**Rear Underrun Protection System (RUPS) (ECE-R58)**
FUPS is mandatory	**FUPS is not mandatory**					
		Vehicles, such that their use is incompatible with the provisions of front underrun protection				
N_2 vehicles with a GVW over 3.5 t up to and including 7.5 t (fulfillment of ground clearance of 400 mm for the FUPS is sufficient)	Off-Road Vehicles (Directive 70/156/EEC)	N_2 Vehicles	either if the wheels are designed to be driven simultaneously, including vehicles where the drive to one axle can be disengaged	or	at least one front and at least one rear axle are designed to be driven simultaneously, including vehicles where the drive to one axle can be disengaged and there is at least one differential locking mechanism or at least one mechanism having a similar effect and they can climb a 25 % gradient calculated for a solo vehicle	All vehicles of categories N_2, N_3, O_3 and O_4 which has not been so designed and/or equipped that its component parts can be regarded as totally or partially fulfilling the function of the RUPD
N_2 vehicles with a GVW over 7.5 t up to and including 12 t N_3 vehicles		N_3 Vehicles	either if the wheels are designed to be driven simultaneously, including vehicles where the drive to one axle can be disengaged	or	at least half the wheels are driven and there is at least one differential locking mechanism or at least one mechanism having a similar effect and they can climb a 25 % gradient calculated for a solo vehicle at least four of the following six requirements are satisfied: the approach angle must be at least 25° the departure angle must be at least 25° the ramp angle must be at least 25° the ground clearance under the front axle must be at least 250 mm the ground clearance between the axles must be at least 300 mm the ground clearance under the rear axle must be at least 250 mm	

From the truck industry it is reported that customers would sometimes configure their new trucks deliberately such that they qualify as “off-road vehicles” and thus avoid the need for installation of front underrun protection. For instance, a differential lock would be ordered extra or the rear underrun protection device moved closer to the rear wheel than necessary, thus increasing the departure angle, in order to fulfill the “off-road” criteria. Therefore, one of the objectives of this study was to estimate the actual equipment rate of trucks after Directive 2000/40/EC became mandatory. The results support a better prediction of the benefit of this regulation as the presence or lack of a FUPS or FUPD will have direct impact on the conditions under which frontal collisions between passenger cars and trucks occur.

3.2 Methodology for determining FUP equipment rate

Although a separate designation of off-road vehicles among N_2 and N_3 vehicles exists (designated as N_2G and N_3G) it is currently not possible to identify them immediately in national registration statistics in the EU or its member states. Instead, European heavy vehicle manufacturers were contacted with a questionnaire and requested to provide figures of their vehicles sold in Germany and in Europe and the percentage of FUP equipment on these. 2004 was chosen as the reference year because it represents the first year where Directive 2000/40/EC was fully in effect. All major manufacturers responded, both those being represented in VC-Compat (DaimlerChrysler, DAF, Scania, Volvo, Renault) and MAN and Iveco. These seven manufacturers cover almost the entire European market of trucks above 7.5 tons of permissible mass with the exception of small and niche market manufacturers. Depending on the country, they occupy between 90% and 100% of the truck markets from 6 to 15.9 tons (except Ireland and Spain). For trucks of 16 tons and above their market shares are even higher (Tables 3 and 4). However, it was not possible to estimate the portion of FUP-equipped trucks in the EU directly because the sales figures provided by the manufacturers differed regarding the referenced regions in Europe, e.g. some were related to EU-15, others to all of Europe. Therefore, it was first necessary to determine the market share for each manufacturer in a region as large as possible. For this purpose, an artificial “whole market” was defined for the study. It consisted of 13 EU countries including Switzerland for which registration figures as well as individual market shares of the seven truck makes were available. The annual catalogue on trucks and buses “Lastauto Omnibus Katalog” [7] provides statistics on truck sales in the market segments of 6 tons to 15.9 tons and 16 tons and over for most European countries.

Table 3: Market shares of manufacturers for trucks 6.0 – 15.9 tons of permissible mass for selected European countries (source: Lastauto Omnibus Katalog 2006 [7])

Trucks 6.0 - 15.9 tons GVW, 2004 new registrations

	DAF	Iveco	MAN	D/C	Renault	Volvo	Asian	others	Total Europ. OEMs
Belgium	13,5	19,0	11,3	30,5	10,4	11,2	2,5	1,6	95,9
Denmark	1,4	37,7	24,2	19,8	3,8	9,8	3,0	0,3	96,7
Germany	2,2	21,7	23,6	49,7	2,1	0,6	0,0	0,1	99,9
France	3,1	22,9	4,7	18,9	46,2	3,0	1,2	0,0	98,8
UK	28,6	31,2	12,1	16,1	5,2	1,7	0,0	5,1	94,9
Ireland	19,1	23,4	10,8	18,5	5,4	2,1	19,3	1,4	79,3
Italy	3,0	62,5	2,5	11,6	11,0	2,3	6,3	0,8	92,9
Netherlands	24,8	16,7	11,8	30,6	8,5	7,5	0,0	0,1	99,9
Austria	3,2	14,0	35,2	39,1	4,6	3,3	0,4	0,2	99,4
Poland	7,3	31,0	18,6	16,1	22,1	4,9	0,0	0,0	100,0
Sweden	0,0	14,1	1,3	35,6	5,1	43,9	0,0	0,0	100,0
Switzerland	4,6	26,4	10,9	36,5	10,2	9,9	0,3	1,2	98,5
Spain	5,3	32,0	8,7	13,6	25,4	2,0	12,6	0,4	87,0

Table 4: Market share of manufacturers for trucks of 16 tons of permissible mass and over for selected European countries (source: Lastauto Omnibus Katalog 2006 [7])

Trucks over 16.0 tons GVW, 2004 new registrations

	DAF	Iveco	MAN	D/C	Renault	Scania	Volvo	others	Total Europ. OEMs
Belgium	19,7	3,7	15,3	11,9	8,5	15,2	24,6	1,1	98,9
Denmark	9,5	4,5	17,0	10,8	2,8	26,3	29,1	0,0	100,0
Germany	8,1	6,9	28,4	39,2	1,8	7,1	8,5	0,0	100,0
France	12,5	8,9	6,8	14,6	35,6	8,8	12,3	0,5	99,5
UK	23,0	5,7	7,5	16,6	4,8	17,2	16,4	8,8	91,2
Ireland	24,7	4,6	4,4	6,8	2,6	21,5	22,0	13,4	86,6
Italy	7,7	35,5	8,3	13,3	8,8	12,9	10,4	3,1	96,9
Netherlands	33,0	2,1	9,9	10,8	3,0	19,2	19,3	2,7	97,3
Austria	10,2	7,3	40,0	14,4	3,3	12,0	12,8	0,0	100,0
Poland	14,6	3,9	17,6	14,4	13,2	16,7	18,8	0,8	99,2
Sweden	1,2	0,0	1,6	5,7	0,0	45,2	46,2	0,1	99,9
Switzerland	4,1	9,5	16,2	26,6	4,4	16,1	20,0	3,1	96,9
Spain	9,8	18,1	13,3	14,5	17,5	11,0	14,8	1,0	99,0

For each manufacturer, the percentage of vehicles sold in 2004 that were fit with front underrun protection and the percentage of those which were not is known from the provided data. Together with the manufacturers' data about the rate of FUP equipment in this year, the proportion of trucks with and without front underrun protection according to Directive 2000/40/EC that were newly registered in 2004 on the "whole market" can be determined (Fig. 8). This proportion is presumed to be valid also for the EU. As noted above, the permissible mass categories defined by ECE-R13 or Directive 71/320/EEC, respectively, do

not coincide entirely with the mass classes for which sales statistics were available (from 6.0 to 15.9 tons and 16 tons and over). However, the number of vehicle registrations in the segment from 12 to 15.9 tons is small compared to the areas where the categories overlap. Therefore, the percentage of vehicles with and without FUP registered in 2004 in the two segments of 6 to 15.9 tons and over 16 tons can be regarded as a realistic estimate.

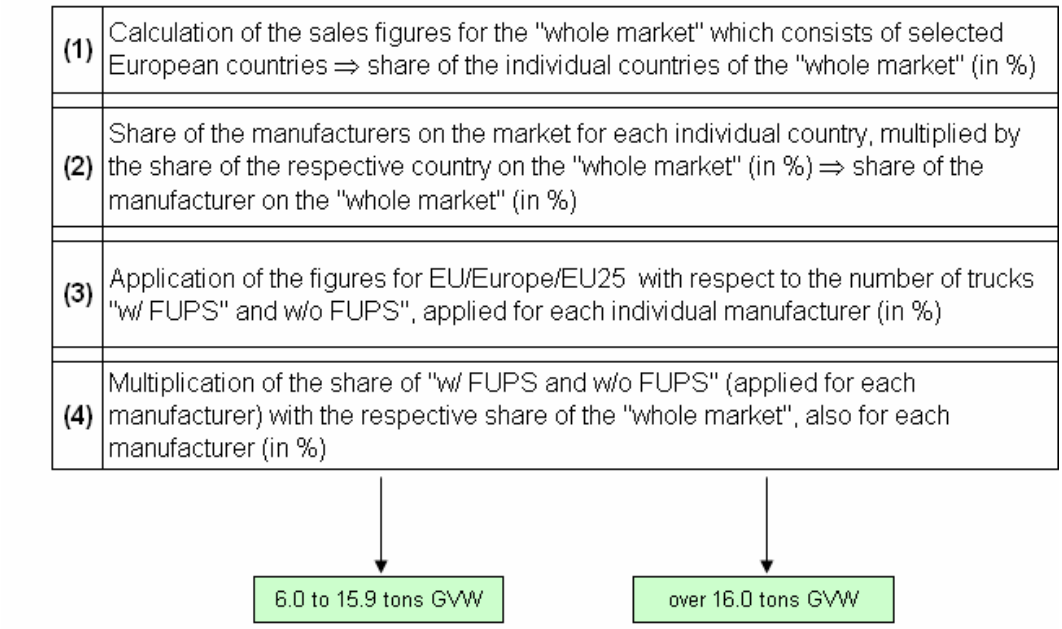


Figure 8: Methodology for estimating the share of trucks equipped and not equipped with front underrun protection for the “whole market”

3.3 Results of FUP equipment rate estimation

The resulting estimate indicates that in the medium duty truck segment from 6.0 tons to ca. 16 tons 33.4% of the newly registered vehicles were not fit with front underrun protection in 2004. The exact split between trucks up to 7.5 tons for which front underrun protection is not required and trucks above 7.5 tons is not known. However, where this discrimination was available it suggests that they account for a large percentage of non-equipped trucks in this mass range. Also, the national statistics for some countries, for instance Germany and UK show a large number of newly registered trucks in the range between 7.0 and 7.5 tons of permissible mass (15082 in Germany [8] and 12511 in the UK [9], in 2004). The reasons why front underrun protection is omitted in a percentage of trucks above 7.5 tons are not known, but presumably a significant number of vehicles in this mass category operate under off-road

conditions (construction logistics, road maintenance, fire trucks etc.) or are at least prepared for it, thus being exempt from the requirement of front underrun protection. This assumption is backed by the fact that the percentage of vehicles not being equipped with FUP is significantly higher among manufacturers that are strong in the off-road segment compared to those who have their strength rather in the on-road segment. In the mass category of 16 tons and over, 14.1% of the trucks do not feature a FUP system or device. This class of heavy trucks is dominated by long-distance haulers and other types of trucks that are intended for on-road operation. Nevertheless, approximately one in seven vehicles will probably not have front underrun protection. Taking into account the proportion of the two permissible vehicle mass categories on the entire market of trucks over 6.0 tons a 78 % FUP equipment rate can be estimated.

The actual risks for trucks with or without front underrun protection to become involved in a frontal impact are currently not known. The exposure of a truck to this kind of collision is influenced by several factors, for instance the time a truck spends on paved roads as well as the type of public road it uses predominantly, and will presumably differ for typical on-road or off-road vehicles. Trucks without front underrun protection (for construction logistics or as specialty trucks) are presumably less frequently present on roads due to lower annual mileage compared to long-haul vehicles. On the other hand, they probably drive rather on rural roads than on motorways with divided lanes, thus being at higher risk of a front-to-front collision with a car. Notwithstanding these parameters, there remains a significant danger that in front-to-front collisions between cars and trucks no front underrun protection system will be present to improve the compatibility between both vehicles.

4. Future improvements of FUP regulation

In light of this, it should be discussed whether the exemptions from the necessity of a FUPS or FUPD leave currently too much room for omitting such protection. Undoubtedly, vehicles that operate under severe off-road conditions would be at disadvantage if the current geometrical requirements for front underrun protection were applied. Adopting the directive's strength requirement, but modifying the geometrical specifications due to the need for higher ground clearance and approach angle could be a way to enhance compatibility also for these types of trucks. It would respect the situation of vehicles operating in rough terrain and still improve the current situation of excluding them from the need for underun protection. In Japan, where similar problems of crash compatibility with off-road trucks are being discussed, the Japan Automobile Research Institute (JARI) proposed to extent the principal

FUP requirement also to these types of trucks, but relaxing the ground clearance criterion to provide sufficient off-road capabilities [10]. Alternatively, a stricter definition of “off-road vehicles” in Directive 70/156/EEC would help to enforce fitment of FUPS and FUPD on vehicles that currently use the “off-road” clause to avoid installation of these devices not for operational, but for cost and weight reasons. Furthermore, lowering the permissible mass threshold of 7.5 tons could be taken into consideration. These typical distribution trucks constitute a significant portion of all trucks in several EU countries, but are not subject to FUP strength requirements. Nevertheless, they pose a high risk for car occupants in frontal collisions, too, due to their typical truck chassis construction and resulting deficiencies in crash compatibility.

5. Rear underrun protection of heavy vehicles

For more than thirty years, the regulation demanding rear underun protection devices on trucks and trailers had remained unchanged in essence (Directive 70/221/EEC). The performance standards set by this directive often demonstrate to be insufficient in real-world accidents. In many rear-end crashes the protection devices become either bent away or torn off the longitudinal frame of the truck or trailer without significant energy absorption when being impacted by a car (Fig. 9, 10). In result, the smaller vehicles underrun the truck, often up to the A-pillar and windscreen area and beyond which can cause severe injuries to the front passengers due to massive structural damage in the area of the occupant compartment or direct contact with the truck superstructure.

Fig. 9, 10: Severe underrun with fatal outcome, rear underrun protection device torn off (source: Freiwillige Feuerwehr Friedberg)

VC-Compat determined from its research work minimum requirements for improved protection for the majority of such accidents which include doubling the test forces on the RUP, lowering the maximum ground clearance to 450 mm's and increasing the crossbar height to at least 200 mm's. An offset crash test conducted by VC-Compat with a modern passenger car into a trailer equipped with prototype reinforced RUP device at 56 kph demonstrated significantly better structural interaction as well as sufficient impact resistance and proper triggering of the car's restraint system. The measured loadings for the driver and passenger dummy were uncritical accordingly.

Fig. 11, 12: Driver and passenger side view of car impacting prototype RUP device at 56 kph (source: VC-Compat, TRL)

The regulation for rear underrun protection was amended recently with Directive 2006/20/EC replacing the 70/221/EEC. Changes in the new regulation pertain primarily doubling the test forces in test points P1 and P3 as they were prescribed in the previous directive (Fig. 13). However, this small improvement is far away from the requirements formulated by VC-Compat and is not expected to enhance the protective function of these devices significantly. Another shortcoming of the old regulation has not been changed either. The static forces that have to be applied in the test are dependent on the permissible vehicle mass and are cut off at a maximum value for trucks and trailers of 20 tons and over (Fig. 14). In practice, this means that a RUPD for a 7.5 ton truck needs to fulfill considerably lower strength requirements than one for a 20 ton truck. As devices designed for heavy trucks have shown to be insufficient in many rear-end accidents, the same has to be feared for trucks in the medium

mass range, especially when they feature divided FUPD designs which are common in conjunction with hydraulic loading platforms.

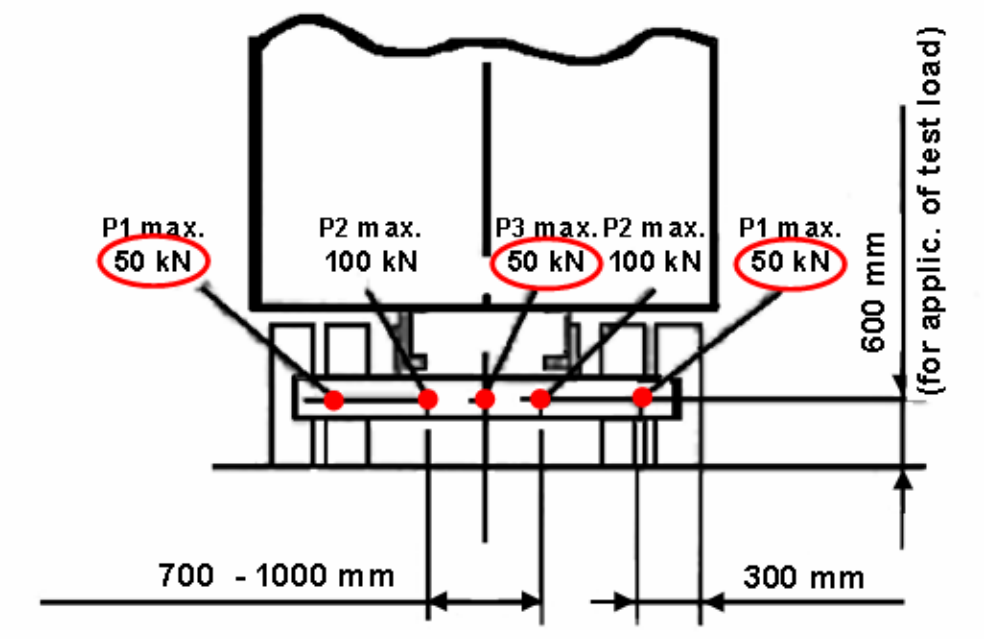


Fig. 13: Static test loads according to Directive 2006/20/EC

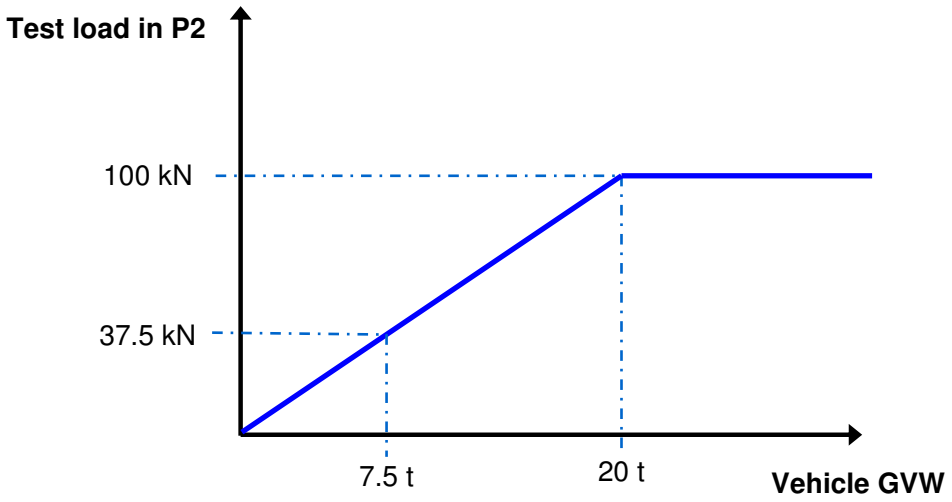


Fig. 14: Dependency of RUP device test loads on total permissible vehicle mass

While improving the strength of the rear underrun protection systems constitutes no technical challenge, but will increase the weight of the device, stricter geometrical requirements may pose a problem to some trailer designs. Longer rear overhangs may require folding RUP devices to avoid that the trailer end touches the ground when entering ferry boat ramps or loading docks (Fig. 15). Also, construction logistics vehicles feature articulating RUP designs to prevent their interference with a tipping body. Increased RUP strength would make larger and heavier structures necessary which are harder to handle (i.e., to lift) by the truck driver.

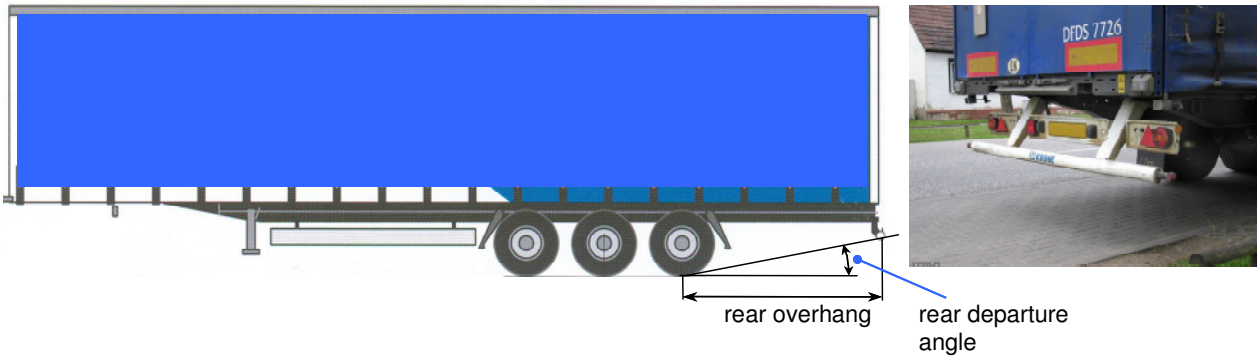


Fig. 15: Geometrical restrictions for rear underrun protection devices (source: Krone, modified) and folding RUPD for Ro/Ro traffic

6. Summary and Conclusions

Although smaller in number than car-to-car collisions accidents between heavy vehicles and passenger cars remain a significant contributing factor for causing severe or fatal car occupant injuries. Due to the large mass differences between these crash opponents passive safety measures on cars are of limited effect which makes passive safety measures on trucks even more important. The safety level in frontal collisions was greatly improved by the introduction of a legal front underrun protection requirement for medium and heavy trucks. Regulatory solutions to include off-road vehicles should be considered, perhaps with some modifications to account for their special needs in rough terrain operation. The requirements for rear underrun protection devices as set out in Directive 70/221/EEC as well as its successor 2006/200/EC are not sufficient to protect passenger cars from underrunning trucks or trailers even at moderate impact speeds. A revision of the regulation for this kind of opponent protection is needed. Notwithstanding the enhanced safety for crash opponents effective underrun protection devices have a positive effect also for the company operating a truck: even if truck occupants are rarely seriously injured in crashes with passenger cars and

underrun protection devices are sometimes perceived as a cost and weight burden in road transport they can minimize the economic impact for the hauling company by helping to prevent damage to wheel suspension, steering system and other expensive parts which may otherwise make the truck inoperable for a long time.

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8. References

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