Cost Analysis: Current and Improved
Truck and Trailer Underrun Protection

VC-Compat Workshop
Eindhoven, The Netherlands

Axel Malczyk
German Insurance Assoc., Accident Research

October 18, 2006
Overview

• Cost of current and improved underrun protection

• Determination of front underrun protection equipment rates in trucks

• Considerations on current legislation regarding underrun protection
Need for Effective Front and Rear Underrun Protection on Heavy Vehicles

No front underrun protection (FUP) regulation until end of 2003 (Directive 2000/40/EC going into effect)

Rear underrun protection (RUP) regulation (Direct. 70/221/EEC) from early 70’s
Estimated Costs of Front Underrun Protection

- Data from truck manufacturers among VC-Compat partners
- Cost data per vehicle from three manufacturers, for development and production preparation from two manufacturers
- Development and preparation cost estimations apply to one truck-model line, each (e.g., light, medium and heavy duty class)

<table>
<thead>
<tr>
<th>type of FUPD or improv. measure</th>
<th>min. cost per vehicle</th>
<th>max. cost per vehicle</th>
<th>min. developm. &amp; prep. cost</th>
<th>max. developm. &amp; prep. cost</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;rigid&quot; FUPD</td>
<td>120 … 200 €</td>
<td>250 … 300 €</td>
<td>1.0 mill. €</td>
<td>3.0 mill. €</td>
<td>costs per vehic. are variable costs only</td>
</tr>
<tr>
<td>energy-absorbing FUPD</td>
<td>+100 €</td>
<td>+100 … +200 €</td>
<td>+1.0…+2.0 mill. €</td>
<td>+3.0 mill. €</td>
<td>costs per vehic. are variable costs only</td>
</tr>
</tbody>
</table>
Costs of Rear Underrun Protection

Two manufacturers of truck bodywork interviewed

Manufacturer #1 (F.X. Meiller, Germany)
  - primarily vehicles for construction logistics
  - ca. 10,000 tipper bodies annually
  - market share of ca. 70 % in Germany
  - production of roll-off tippers and skip handlers

Manufacturer #2
  - primarily transport logistics vehicles
  - ca. 21,000 „rolling units“ incl. (semi-) trailers annually
  - 2nd largest German (23 % market share) and European manufacturer
Costs of Rear Underrun Protection

- Cost information from truck manufacturers among VC-Compat partners and bodywork/trailer manufacturers (e.g., spare part prices)
- Large spread of costs due to variety of designs for different purposes

- **RUPD rigid type**
  - (ca. 100 – 200 €)

- **RUPD folding type**
  - (ca. 800 – 1600 €)

- **RUPD sliding type**
  - (ca. 1900 – 4600 €)
Costs of Improved Rear Underrun Protection

Special questionnaire for bodywork / trailer manufacturers on influence of raised requirements or RUPD improvement measures, respectively:

- Improve resistance (200 kN in two points, each)
- Improve resistance under angled impact (ca. 10°)
- Increase size of cross member profile (to a height of 200 mm)
- Reduce distance to rear of vehicle (flush with rear contour)
- Reduce ground clearance (to 400 mm from road surface)

With key descriptors:

- Add-on cost
- Additional weight
- Others like feasibility, variety of variants, …
## Costs of Improved Rear Underrun Protection

### Example of questionnaire

<table>
<thead>
<tr>
<th>Improve resistance (200 kN in two points, each)</th>
<th>influence on ...</th>
<th>cost per vehicle</th>
<th>mass</th>
<th>feasibility / constr. effort</th>
<th>variety of variants</th>
<th>obstruction of other functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>larger profile, material of higher strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>remarks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- More than +100 €; more than +30 kg $\uparrow$ presumably strong influence
- +21 to +100 €; +11 to +30 kg $\rightarrow$ presumably slight influence
- 0 to +20 €; 0 to +10 kg $\rightarrow$ presumably no influence
## Costs of Improved Rear Underrun Protection

\( \text{M#1} = \text{Bodywork/trailer manufacturer for construction logistics} \)

\( \text{M#2} = \text{Bodywork/trailer manufacturer for transport logistics} \)

<table>
<thead>
<tr>
<th>Constructive Improvement</th>
<th>Added cost</th>
<th>Added mass</th>
<th>Feasibility, constr. effort</th>
<th>Obstruction for other functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve impact resistance</td>
<td>( \text{M#1} \rightarrow \text{M#2} \uparrow )</td>
<td>( \text{M#1} \rightarrow \text{M#2} \uparrow )</td>
<td>( \text{M#1} \uparrow \text{M#2} \uparrow )</td>
<td>40 daN max. operat. force for folding RUP</td>
</tr>
<tr>
<td>Improve under angled impact</td>
<td>( \text{M#1} \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \uparrow \text{M#2} \rightarrow )</td>
<td>Interferes w. rear-mnt. parts on constr. vehic.</td>
</tr>
<tr>
<td>Higher cross member</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>Interferes in folded-up position w. tipper body</td>
</tr>
<tr>
<td>Reduce distance to rear</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \ n.p. \rightarrow \text{M#2} \rightarrow )</td>
<td>Interferes in folded-up position w. tipper body</td>
</tr>
<tr>
<td>Reduce ground clearance</td>
<td>( \text{M#1} \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \rightarrow \text{M#2} \rightarrow )</td>
<td>( \text{M#1} \uparrow \text{M#2} \rightarrow )</td>
<td>Limits off-road capab., may require fold. RUP</td>
</tr>
</tbody>
</table>

\( \rightarrow \) = probably no influence, added cost +0 to +20 €, added mass +0 to +10 kg

\( \uparrow \) = probably slight influence, added cost +21 to +100 €, added mass +11 to +30 kg

\( \text{n.p.} \) = not possible to realize
Folding and Extending RUPS

in transport logistics (e.g., Ro/Ro traffic)

in construction logistics

Source: F.X. Meiller
Summary of Cost of Improved Underrun Protect.

Cost of energy-absorbing front underrun protection

- Energy-absorbing FUPD adds ca. +100 to +200 € to cost of “rigid” FUPD (120 to 300 €) (cost per vehicle)
- Development of e.a. FUPD adds ca. +1.0 million to +3.0 million € to costs for “rigid” FUPD (one-time cost per model line)

Cost of improved rear underrun protection

- Generally, improvements for better RUPD performance feasible, but some difficult, esp. on construction vehicles with folding RUPD (higher cross member, reduced distance to rear)
- Higher RUPD strength, also for angled impact, possible at moderate cost and mass increase (mostly for less than +100 € and +30 kg)
- Reduced RUPD ground clearance also possible, but may require folding device also for road transport (semi-) trailers (ca. +250 €)
Static test loads in points, separately applied:

P1, P3: 80 kN or 50% of permissible mass (GVW)
P2: 160 kN or 100% of permissible mass (GVW)
FUP Requirements and Exemptions

FUP fitment is required for:

• $N_2$ vehicles with a GVW $> 3.5$ t and $\leq 7.5$ t
  (only FUPS ground clearance $\leq 400$ mm required, no strength requirem.)

• $N_2$ vehicles with a GVW $> 7.5$ t

• $N_3$ vehicles (i.e., with a GVW $> 12$ t)

FUP fitment is not required for:

• “Vehicles, such that their use is incompatible with the provisions of front underrun protection”

• $N_2$ and $N_3$ vehicles that qualify as „off-road vehicles“ ($N_2G$ and $N_3G$) acc. to Directive 70/156/EEC
FUP Fitment Exemptions

N₂ vehicles qualify as „off-road“ (N₂G) acc. to Directive 70/156/EEC if:

- all wheels can be driven simultaneously or
- at least half the wheels are driven and
- at least one differential locking mechanism or similar and
- can climb 25 % gradient (solo vehicle)
FUP Fitment Exemptions

N\textsubscript{3} vehicles qualify as „off-road“ (N\textsubscript{3}G) acc. to Directive 70/156/EEC if:

- all wheels can be driven simultaneously
- at least half the wheels are driven
- at least one differential locking mechanism or similar
- can climb 25\% gradient (solo vehicle)

\textit{at least four of the following six requirements are satisfied:}

- approach, ramp and departure angle ≥ 25°
- ground clearance under front and rear axle ≥ 250 mm
- ground clearance between the axles ≥ 300 mm
Determination of FUP Equipment Rate in EU

- Collect 2004 truck sales figures from 7 major European manufact.

<table>
<thead>
<tr>
<th>2004 truck sales</th>
<th>region</th>
<th>trucks ≤ 12 tons GVW with FUPS</th>
<th>trucks ≤ 12 tons GVW w/o. FUPS</th>
<th>trucks &gt; 12 tons GVW with FUPS</th>
<th>trucks &gt; 12 tons GVW w/o. FUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volvo</td>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>all EU*</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

* if „all EU“ figures not available, please provide „all Europe“ figures

- For selected European countries: Determine 2004 truck registration figures and market share of truck makes

Example

<table>
<thead>
<tr>
<th>Trucks over 16.0 tons GVW, 2004 new registrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAF</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>Denmark</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>France</td>
</tr>
<tr>
<td>UK</td>
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<tr>
<td>Ireland</td>
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<tr>
<td>Italy</td>
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<tr>
<td>Netherlands</td>
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<tr>
<td>Austria</td>
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<tr>
<td>Poland</td>
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<tr>
<td>Sweden</td>
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<tr>
<td>Switzerland</td>
</tr>
<tr>
<td>Spain</td>
</tr>
</tbody>
</table>
## Determination of FUP Equipment Rate in EU

1. Calculation of sales figures for "whole market", which consist of pre-selected European countries ⇒ share of individual countries of "whole market" (in %)

2. Share of manufacturers of market for each individual country, multiplied by share of respective country of "whole market" (in %) ⇒ Share of manufacturer of "whole market" (in %)

3. Application of figures for EU/Europe/EU25 with respect to number of trucks "with FUPS" and w./o FUPS", applied for each individual manufacturer (in %)

4. Multiplication of share for "with FUPS" and "w./o FUPS" (applied for each manufacturer) with respective share of "whole market", also for each manufacturer (in %)

<table>
<thead>
<tr>
<th>GVW Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0 to 15.9 t GVW</td>
</tr>
<tr>
<td>over 16.0 t GVW</td>
</tr>
</tbody>
</table>
Determination of FUP Equipment Rate in EU

Results:

- for category 6 – 15.9 t GVW *
  - trucks equipped with FUPS = 60.7 %
  - trucks without FUPS = 33.4 %

- for category ≥ 16 t GVW
  - trucks equipped with FUPS = 83.6 %
  - trucks without FUPS = 14.1 %

Note:

* segment of trucks 6 – 7.5 t GVW (no FUPS strength requirement) included
no information for remaining 5.9 % and 2.3 %, respectively, due to share of other manufacturers without available data
New registrations for trucks with 7.001 – 7.5 t GVW in 2004 (no FUP strength requirement):

- in UK: 12511 trucks*
- in Germany: 15082 trucks**
- in Austria: 199 trucks (7.0 – 8.0 t GVW)***

⇒ trucks in the 7.0 – 7.5 t GVW represent a large market segment in some EU countries (typical distribution service truck)

* source: Department for Transport, UK
** source: Kraftfahrtbundesamt, Germany
*** source: Bundesanstalt Statistik Oesterreich
# Costs For Traffic-Related Injuries


<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1,312,600</td>
<td>1,164,119</td>
<td>1,100,000</td>
<td>14,300,000</td>
<td>1,338,000</td>
</tr>
<tr>
<td>Severe</td>
<td>147,460</td>
<td>83,972</td>
<td>166,600</td>
<td>2,600,000</td>
<td>179,000</td>
</tr>
<tr>
<td>Slight</td>
<td>11,370</td>
<td>3,755</td>
<td>23,800</td>
<td>150,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1,447,490</td>
<td>1,176,000</td>
<td>1,000,000</td>
<td>16,269,000</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Severe</td>
<td>168,260</td>
<td>81,800</td>
<td>50,000</td>
<td>2,503,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Slight</td>
<td>16,750</td>
<td>3,579</td>
<td>22,000</td>
<td>113,000</td>
<td>30,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment Method</th>
<th>willingness to pay</th>
<th>human capital</th>
<th>willingness to pay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remarks</td>
<td>definition for slight and severe injuries different from other countries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Revised Benefit Estimations E.A. vs. Rigid FUP

Minimum benefit of e.a. over rigid FUPS (old pass. car fleet assumed):

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Benefit Range</th>
<th>Monetary Benefit Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>-148 to -159</td>
<td>-162.8 to -174.9 mill. €</td>
</tr>
<tr>
<td>Severely injured</td>
<td>-1168</td>
<td>-98.1 mill. €</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>+1168</td>
<td>+4.4 mill. €</td>
</tr>
</tbody>
</table>

\[ \Sigma \text{ Savings} = \text{Fatalities} -148 \text{ to } -159 \Rightarrow -162.8 \text{ to } -174.9 \text{ mill. } € \]

244.1 mill. € to 255.2 mill. €

500 mill. € when highest monetary values are applied

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Car-to-Truck Compatibility
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Static test loads in points, separately applied:

**P1, P3:** 25 kN or 12.5% of permissible mass (GVW)

**P2:** 100 kN or 50% of permissible mass (GVW).
Maximum Test Loads Acc. to Dir. 70/221/EEC

- Test load in P1, P3 max. 25 kN or 12.5% of vehicle permissible mass (GVW), whichever is lower
- Test load in P2 max. 100 kN or 50% of vehicle permissible mass (GVW), whichever is lower

![Graph showing test loads in P2 vs. vehicle GVW](graph.png)
Rear Underrun Protect. Acc. to Dir. 2006/20/EC


- higher test loads in P1 and P3

- vehicles with air, hydraulic suspension etc. in normal driving position (height) for testing

- explicit permission of RUP with divided cross member if required by hydraulic loading platforms
Divided RUP Devices

Divided RUP cross members appear to be the rule already although products with undivided cross members are available.
FUP And RUP Real-World Performance

Front underrun protection (FUP) acc. to Directive 2000/40/EC improves protection of accident opponent

Rear underrun protection with significant deficits

Source: Landsberg a. Lech Volunteer F.D.

Source: Friedberg Volunteer F.D.
Penetration of Truck Fleet With FUP

Time until approx. 50% of truck fleet (of one registration year) taken out of service determined from German registration statistics

⇒ It takes until 2012 that 50% of 2003 model year (last year without legal FUP requirement) is replaced by new trucks, complying with 2000/40/EC

Deletion of Trucks with First Year of Registration 1996 in Germany (Trucks with Standard Bodywork)
Conclusions

Cost of improved underrun protection
- Energy-absorption feature adds 50 – 100% to cost of rigid FUPD
- Improved rear underrun protection possible, esp. for on-road trucks and trailers, with acceptable additional cost and mass

FUPS equipment rate on trucks in EU
- Potential – and need – for extension of FUP fitment requirement to vehicles (“off-road” acc. to current definition) that are currently exempt

Current underrun legislation in EU
- Consider inclusion of trucks ≤ 7.5 tons GVW in strength requirement for FUP
- Raise strength requirements for RUP of trucks ≤ 20 tons GVW to better reflect real-world situation
Thank you for your attention!

Appreciation is extended to the truck manufacturers DaimlerChrysler, DAF, Iveco, MAN, Renault Trucks, Scania, Volvo Trucks who provided sales figures and F.X. Meiller and other trailer manufacturers who provided cost estimations on underrun protection equipment.