



Pedestrian Safety in Frontal Car Collisions

Assessment of current car models regarding pedestrian safety performance using the UDV-Method



Content

- Assessment Procedure
- Results
 - 40 km/h
 - 40 km/h [uplifting bonnet]
 - 40 km/h [uplifting bonnet + airbag]
 - 30 km/h
 - 20 km/h
- Summary



Introduction

- Results are based on a loss prevention project (2008-2010) of German Insurers Accident Research (UDV)
- Conducted by Forschungsgesellschaft Kraftfahrwesen mbH Aachen Institut für Kraftfahrzeuge – RWTH Aachen University (Mr Hamacher and Mr Bovenkerk)

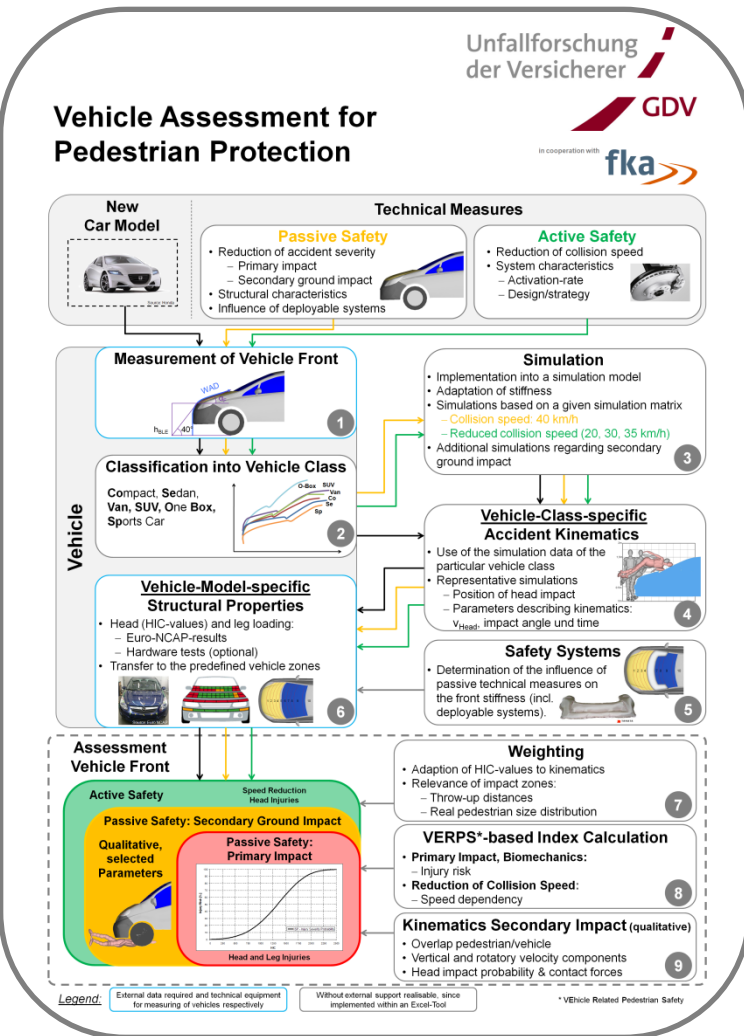




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Assessment Procedure Modules



Workflow

Vehicle Choice

Measurement and Classification into Vehicle Class (1+2)

Simulation and Accident Kinematics (3+4)

Structural Properties and Safety Systems (5+6)

Weighting and Adaptation of HIC-Values (7)

Index Calculation (8)

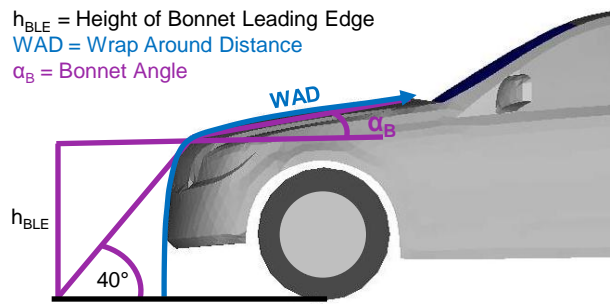
Assessment of Secondary Impact (9)

Assessment Procedure

Measurement and Classification into Vehicle Class (1+2)

Measurement of Vehicle Front

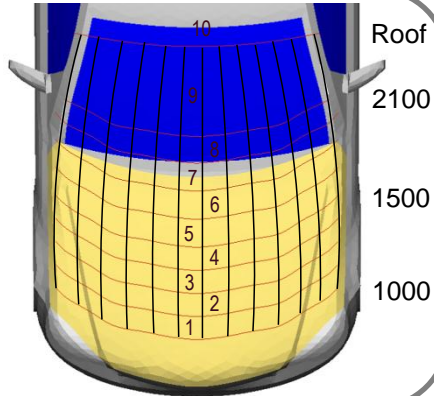
h_{BLE} = Height of Bonnet Leading Edge
 WAD = Wrap Around Distance
 α_B = Bonnet Angle



1

Vehicle Zoning

- Subdivision as well as expansion of Euro-NCAP-test zones
- 10 WAD*-zones

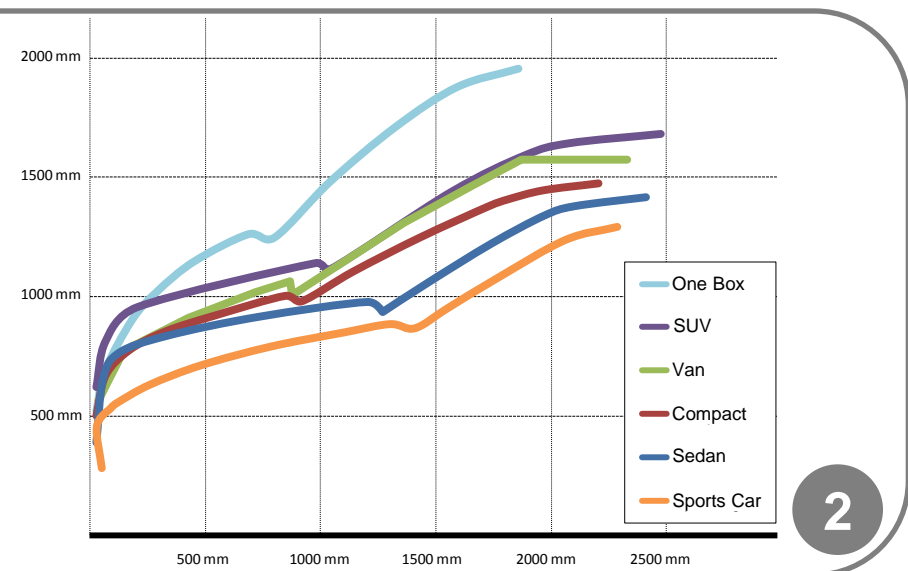


* Wrap Around Distance

Classification into Vehicle Class

- 6 classes:
 - Compact
 - Sedan
 - Van
 - SUV
 - One Box
 - Sports Car

Example vehicle: Sedan





Assessment Procedure

Simulation and Accident Kinematics (3+4)

Simulation

- Implementation into a simulation model
- Adaptation of stiffness
- Simulations based on a given simulation matrix according to real accident events:
 - **Passive Safety:**
 - Pedestrian crossing in front of vehicle front
 - Collision speed: 40 km/h
 - **Active Safety:**
 - Reduced collision speed (20, 30, 35 km/h)
 - 4 Pedestrian Models:

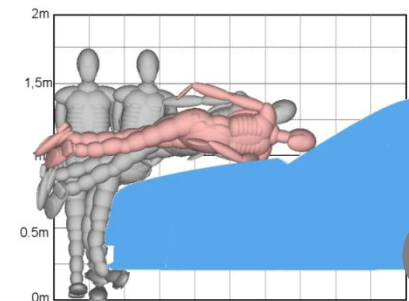
▪ 6yo-Child, 5%-Female, 50%	& 95%-Male
└──┬──┘	└──┬──┘
Children	Adults
- Additional simulations regarding secondary ground impact

3

Example vehicle: Use of the already existing kinematics of the class Sedan

Vehicle-Class-specific Accident Kinematics

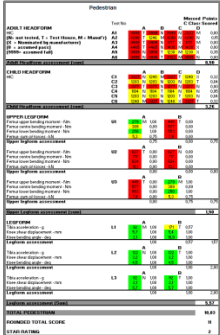
- Use of the simulation data of the particular vehicle class
- Evaluation of representative simulations:
 - Position of head impact
 - ➔ Throw-up distances
 - Parameters describing kinematics:
 - V_{Head}
 - Impact angle
 - Impact time



4

Assessment Procedure

Structural Properties and Safety Systems (5+6)



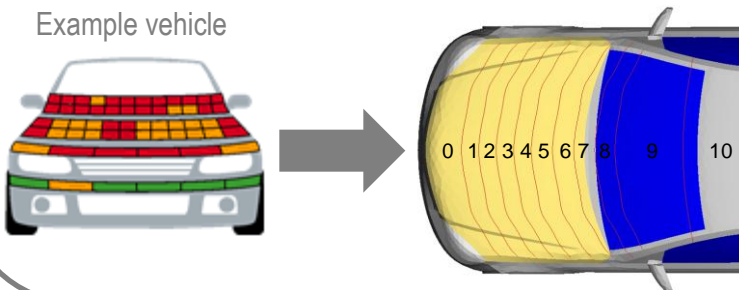
Position: ...
 Model: ...
 Year: ...
 ...

Euro-NCAP-Spreadsheet of the car to be assessed

Vehicle-Model-specific Structural Properties

- Head (HIC-values) and leg loading:
 - Euro-NCAP-results
 - Hardware tests (optional)
- Transfer to the predefined vehicle zones

Example vehicle



6

Safety Systems

5

- Determination of the influence of passive technical measures on the front stiffness (incl. deployable systems).



Vehicle Class Comparison

- A-pattern for a vehicle independent assessment of a class

	1	2	3	4	5	6	7	8	9	10	11	12	WAD [mm]
10	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Roof
9	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	2100 - WSS
8	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	1950 - 2100
7	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	1800 - 1950
6	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1650 - 1800
5	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1500 - 1650
4	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1375 - 1500
3	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1250 - 1375
2	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1125 - 1250
1	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	1000 - 1125

Assessment Procedure

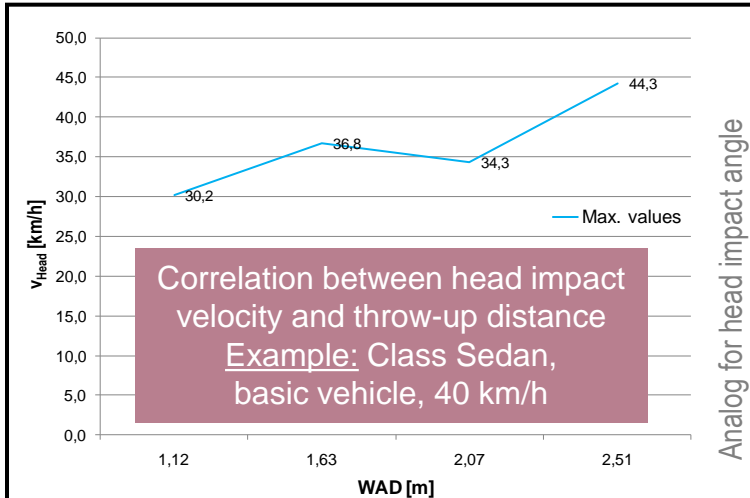
Weighting and Adaptation of HIC-Values (7)

Weighting

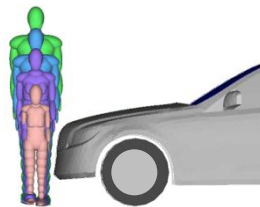
- Relevance of impact zones:
 - Throw-up distances
 - Real pedestrian size distribution (children and adults)
- Adaptation of HIC-values to:
 - V_{Head}
 - Impact angle
 Kinematics factors

7

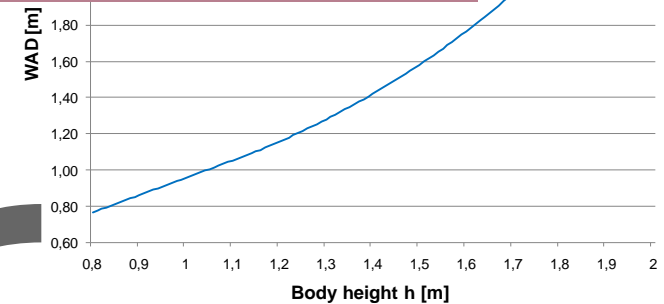
Impact velocity and -angle for each WAD-zone



Impact probabilities of the WAD-zones for children and adults

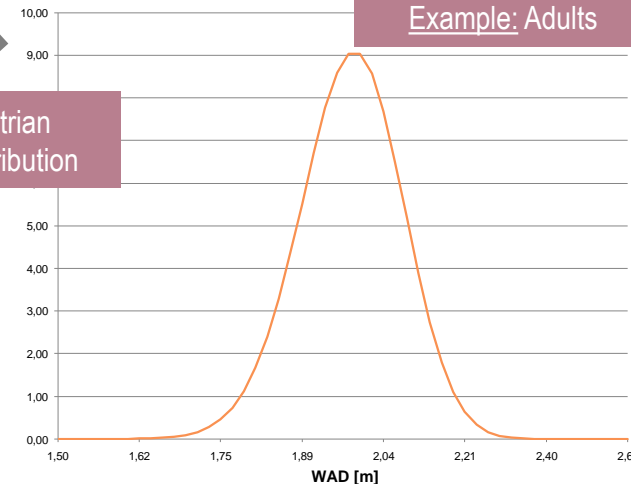


Correlation between body height and throw-up distance
 Example: Class Sedan, basic vehicle, 40 km/h



Relevance of impact zones
 Example: Adults

Pedestrian size distribution





Assessment Procedure

Index Calculation Head Loading (8)

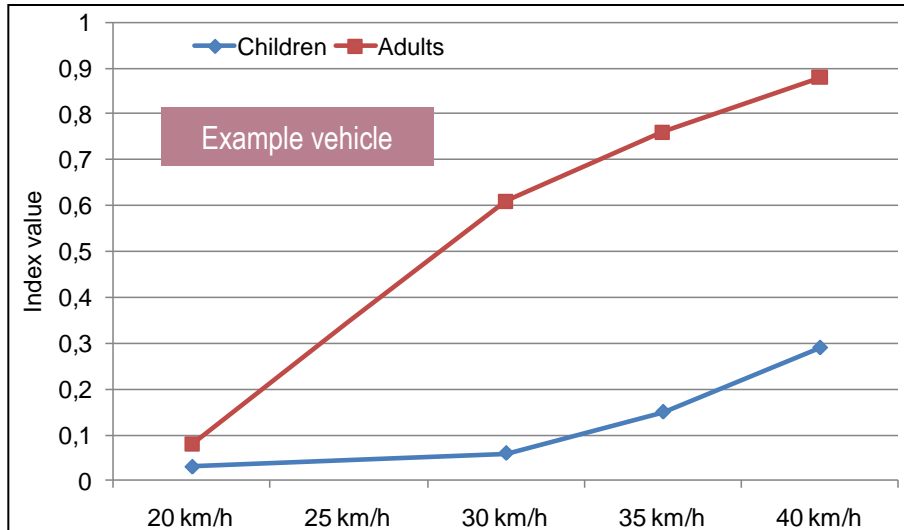
VERPS*-based Index Calculation

- **Primary Impact, Biomechanics:**
 - Summation of the injury risks in consideration of the relevancies of the WAD-zones
 → Index value for the vehicle front
- **Reduction of Collision Speed:**
 - Lower index values

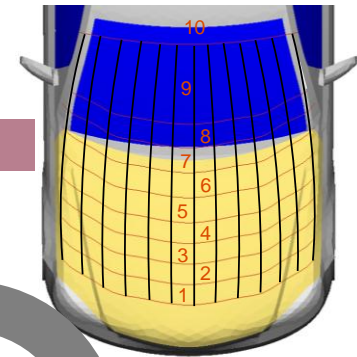
8

* Vehicle Related Pedestrian Safety

↑ Correlation between collision speed and index value



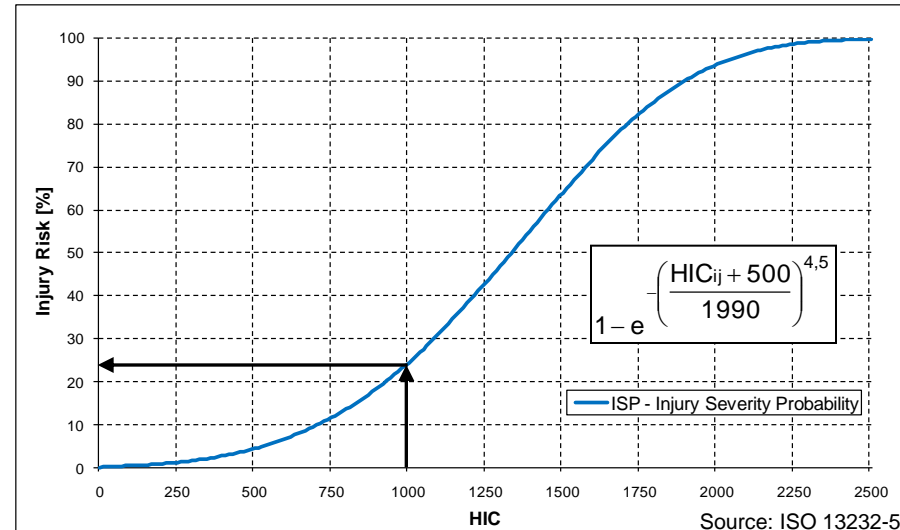
Basis: 40 km/h



WAD-Zone	Relevance [%]	
	Child	Adult
10	0	0
9	0	11
8	0	54
7	0	32
6	1	3
5	7	0
4	26	0
3	34	0
2	24	0
1	7	0

Injury Risk

Calculation of an injury risk for each field of the vehicle front based on the adapted HIC-values



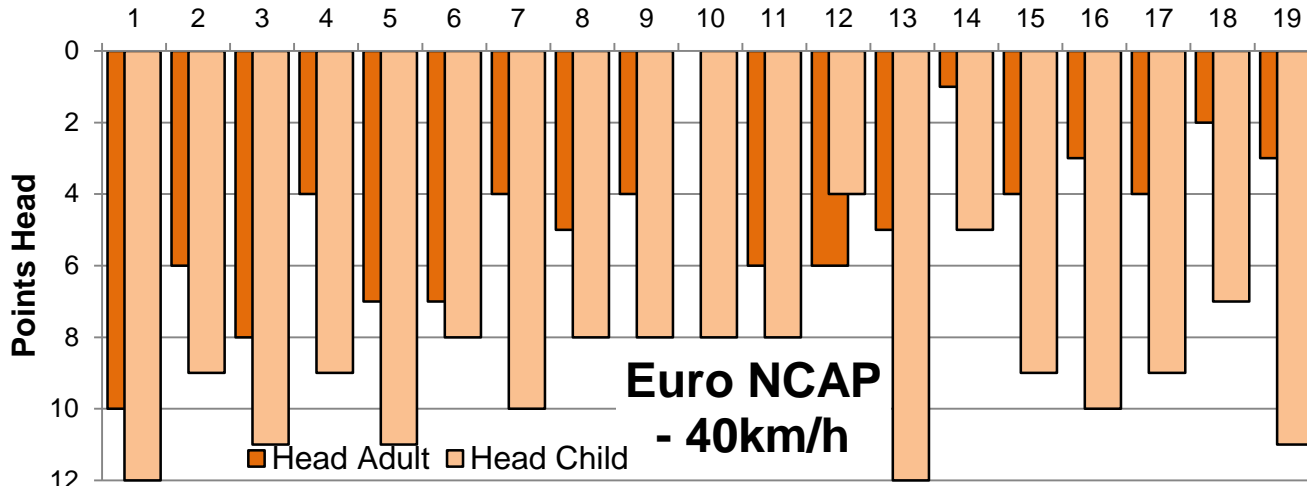


Content

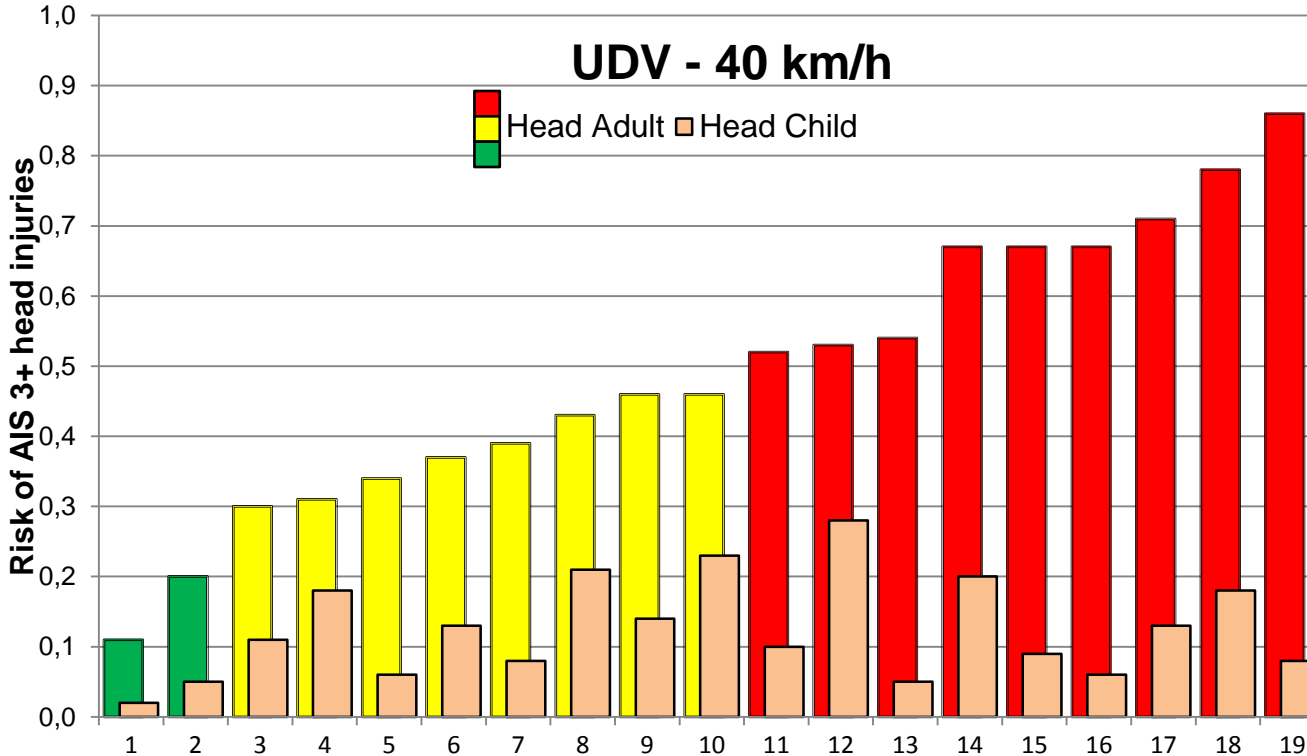
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7. Praxiskonferenz
Fußgängerschutz



19 cars from 2010-2011,
which have been tested
by Euro NCAP



	Vehicle Class according to Euro NCAP	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,11	0,02
2	Execut. Saloon (upl. b.) (B)	0,20	0,05
3	Small MPV (A)	0,30	0,11
4	Small MPV (B)	0,31	0,18
5	Supermini (A)	0,34	0,06
6	Small Family Car (A)	0,37	0,13
7	Small MPV (C)	0,39	0,08
8	Small MPV (D)	0,43	0,21
9	Supermini (B)	0,46	0,14
10	Small Family Car (B)	0,46	0,23
11	Small MPV (E)	0,52	0,10
12	Execut. Saloon (upl. b.) (C)	0,53	0,28
13	Small Off-Road (A)	0,54	0,05
14	Small Off-Road (B)	0,67	0,20
15	Supermini (C)	0,67	0,09
16	Large MPV (A)	0,67	0,06
17	Large Family Saloon (A)	0,71	0,13
18	Small MPV (F)	0,78	0,18
19	Small Family Car (C)	0,86	0,08
	Average	0,49	0,13



Assessment* of the Risk of AIS 3+ Head Injuries for Adults

Risk of AIS 3+ head injuries for adults

UDV-Assessment

100% - 92%

Grade 1

0.00 – 0.20



good

91% - 81%

Grade 2

80% - 67%

Grade 3

0.21 – 0.50



acceptable

66% - 50%

Grade 4

49% - 30%

Grade 5

0.51 – 1.00

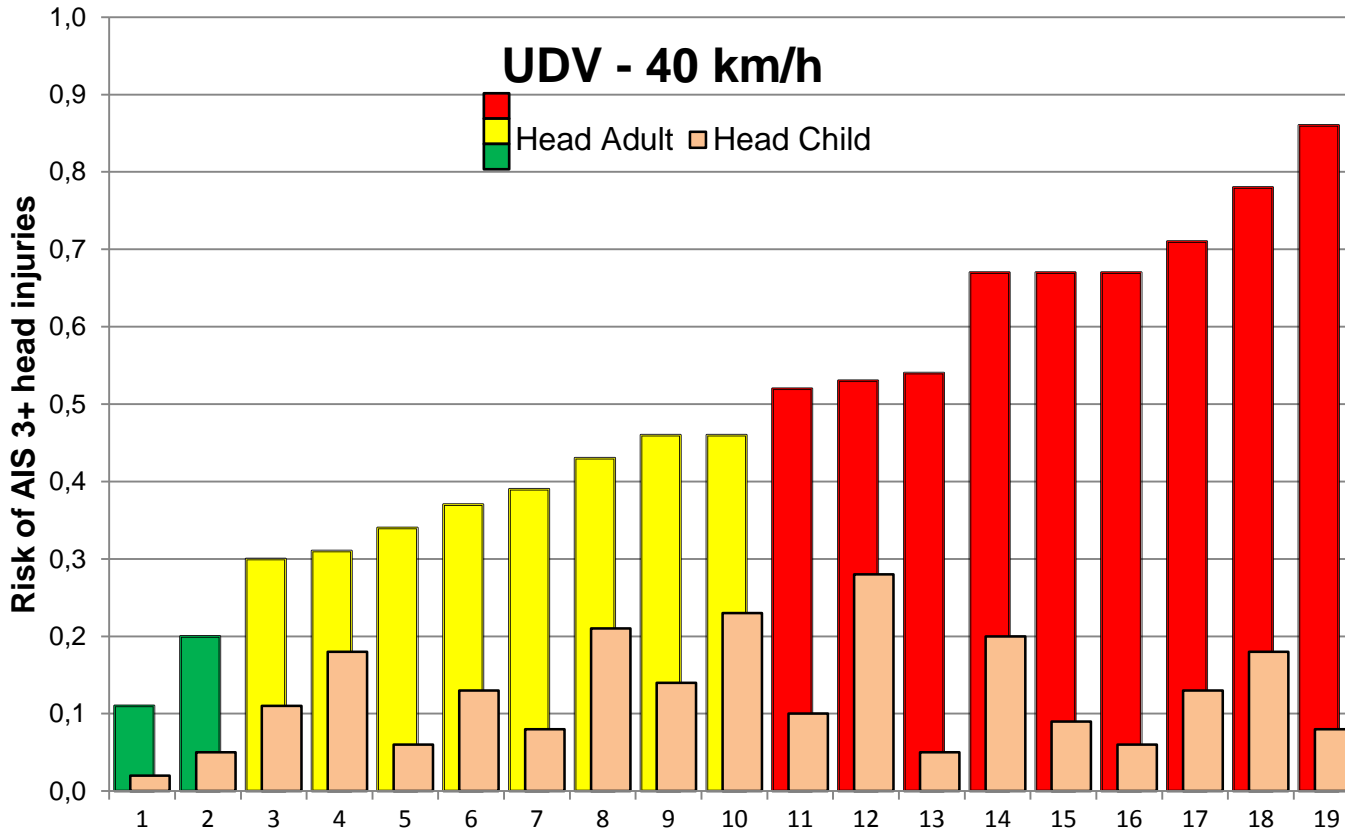


poor

29% - 0%

Grade 6

* According to the definition of school grades by the German Association of Retailers and Industry (DIHK)

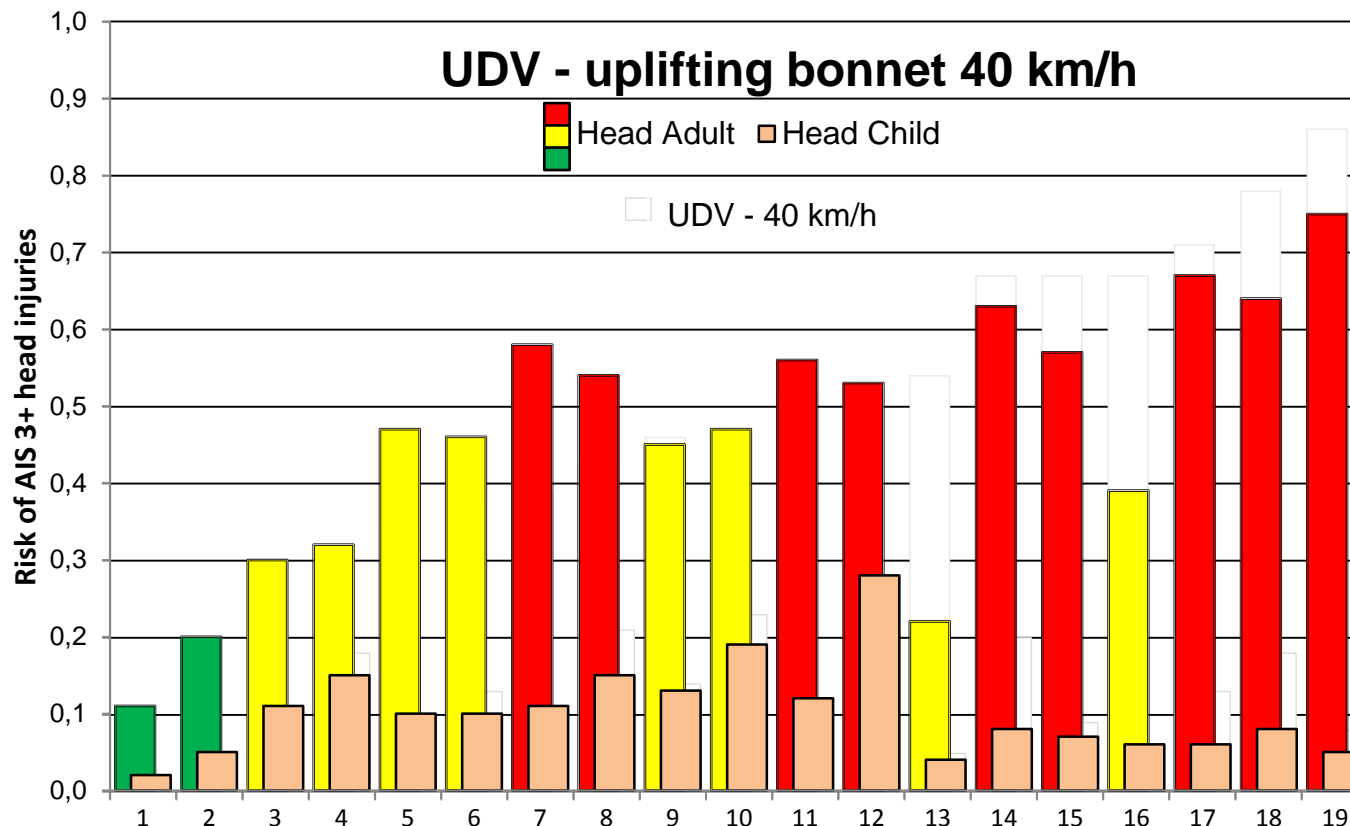


	Vehicle class (acc. Euro NCAP)	Adult	Child		Vehicle class (acc. Euro NCAP)	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,11	0,02	11	Small MPV (E)	0,52	0,10
2	Execut. Saloon (upl. b.) (B)	0,20	0,05	12	Execut. Saloon (upl. b.) (C)	0,53	0,28
3	Small MPV (A)	0,30	0,11	13	Small Off-Road (A)	0,54	0,05
4	Small MPV (B)	0,31	0,18	14	Small Off-Road (B)	0,67	0,20
5	Supermini (A)	0,34	0,06	15	Supermini (C)	0,67	0,09
6	Small Family Car (A)	0,37	0,13	16	Large MPV (A)	0,67	0,06
7	Small MPV (C)	0,39	0,08	17	Large Family Saloon (A)	0,71	0,13
8	Small MPV (D)	0,43	0,21	18	Small MPV (F)	0,78	0,18
9	Supermini (B)	0,46	0,14	19	Small Family Car (C)	0,86	0,08
10	Small Family Car (B)	0,46	0,23		Average	0,49	0,13



Collision Speed 40 km/h

- When comparing Euro NCAP with the UDV assessment method, it becomes clear that both procedures reveal a good rating for cars with a good performance and a bad rating for cars with a bad performance.
- A more detailed differentiation between these two possible ratings can only be made with the UDV method.
- Related to the individual vehicles, it is obvious that there are differences between the ranking for adults and the ranking for children in some cases.

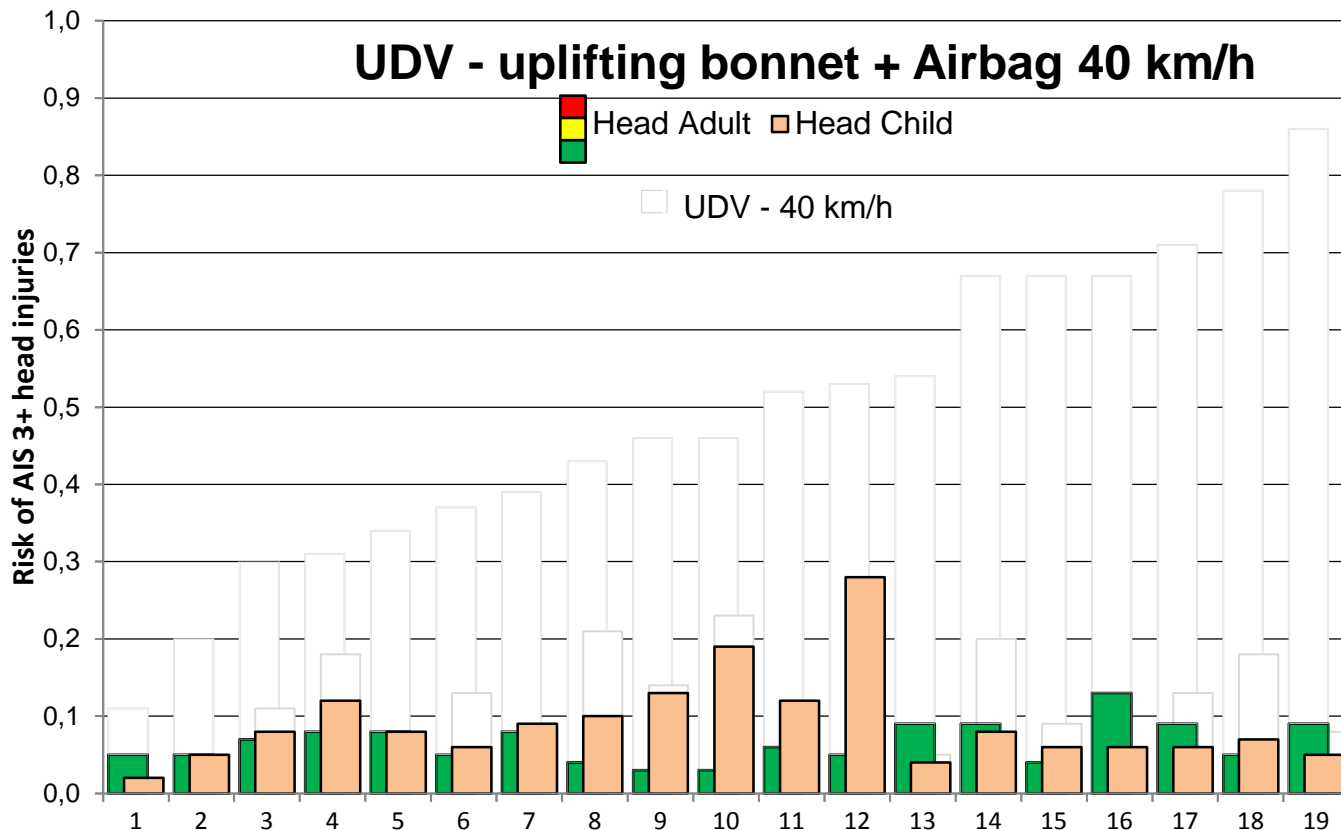


	Vehicle class (acc. Euro NCAP)	Adult	Child		Vehicle class (acc. Euro NCAP)	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,11	0,02	11	Small MPV (E)	0,56	0,12
2	Execut. Saloon (upl. b.) (B)	0,20	0,05	12	Execut. Saloon (upl. b.) (C)	0,53	0,28
3	Small MPV (A)	0,30	0,11	13	Small Off-Road (A)	0,22	0,04
4	Small MPV (B)	0,32	0,15	14	Small Off-Road (B)	0,63	0,08
5	Supermini (A)	0,47	0,10	15	Supermini (C)	0,57	0,07
6	Small Family Car (A)	0,46	0,10	16	Large MPV (A)	0,39	0,06
7	Small MPV (C)	0,58	0,11	17	Large Family Saloon (A)	0,67	0,06
8	Small MPV (D)	0,54	0,15	18	Small MPV (F)	0,64	0,08
9	Supermini (B)	0,45	0,13	19	Small Family Car (C)	0,75	0,05
10	Small Family Car (B)	0,47	0,19		Average	0,47	0,10



Uplifting Bonnet 40 km/h

- The effect clearly depends on the vehicle front shape.
- Minimal improvements can only be selectively recognized for children.
- For adults, even an increase in the AIS 3+ head injury risk is possible.

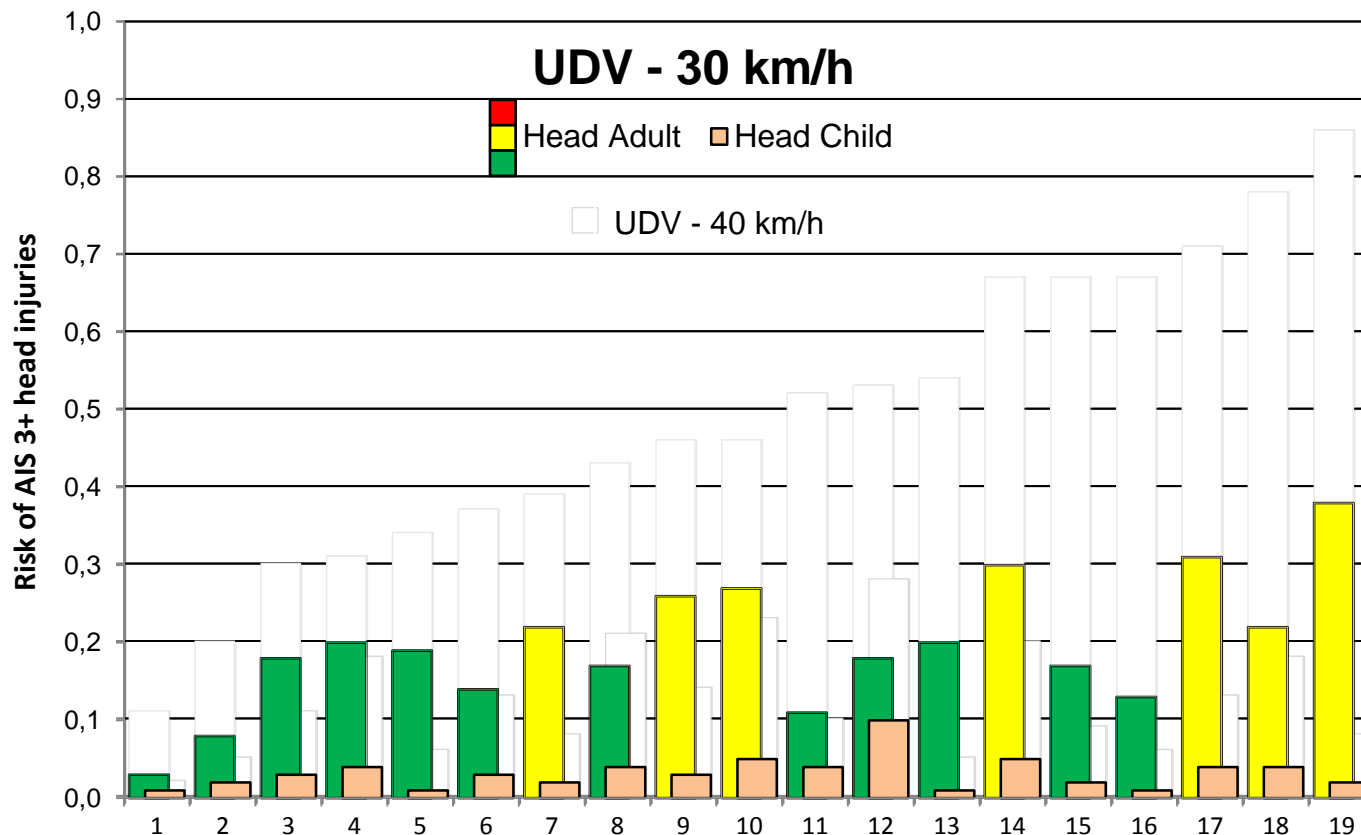


	Vehicle class (acc. Euro NCAP)	Adult	Child		Vehicle class (acc. Euro NCAP)	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,05	0,02	11	Small MPV (E)	0,06	0,12
2	Execut. Saloon (upl. b.) (B)	0,05	0,05	12	Execut. Saloon (upl. b.) (C)	0,05	0,28
3	Small MPV (A)	0,07	0,08	13	Small Off-Road (A)	0,09	0,04
4	Small MPV (B)	0,08	0,12	14	Small Off-Road (B)	0,09	0,08
5	Supermini (A)	0,08	0,08	15	Supermini (C)	0,04	0,06
6	Small Family Car (A)	0,05	0,06	16	Large MPV (A)	0,13	0,06
7	Small MPV (C)	0,08	0,09	17	Large Family Saloon (A)	0,09	0,06
8	Small MPV (D)	0,04	0,10	18	Small MPV (F)	0,05	0,07
9	Supermini (B)	0,03	0,13	19	Small Family Car (C)	0,09	0,05
10	Small Family Car (B)	0,03	0,19		Average	0,07	0,09



Uplifting Bonnet + Airbag 40 km/h

- For adults, a significant reduction of the AIS 3+ head injury risk can be achieved, when comparing it with 40 km/h and no protective measures.
- The effect is almost comparable with that achieved by the autonomous emergency braking system (AEB) at a speed reduction of 20 km/h.
- For children, however, no effect or only a minimal effect is visible.

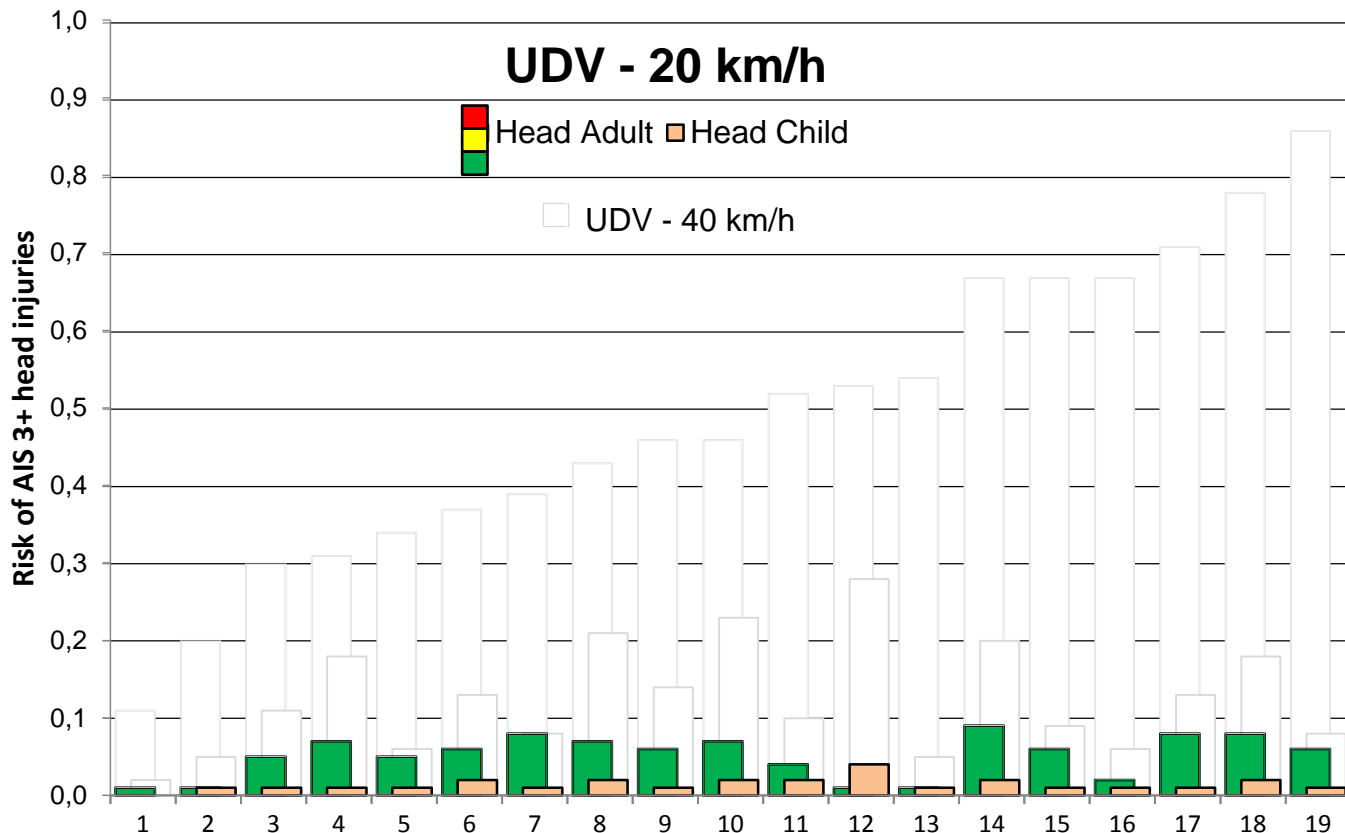


	Vehicle class (acc. Euro NCAP)	Adult	Child		Vehicle class (acc. Euro NCAP)	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,03	0,01	11	Small MPV (E)	0,11	0,04
2	Execut. Saloon (upl. b.) (B)	0,08	0,02	12	Execut. Saloon (upl. b.) (C)	0,18	0,10
3	Small MPV (A)	0,18	0,03	13	Small Off-Road (A)	0,20	0,01
4	Small MPV (B)	0,20	0,04	14	Small Off-Road (B)	0,30	0,05
5	Supermini (A)	0,19	0,01	15	Supermini (C)	0,17	0,02
6	Small Family Car (A)	0,14	0,03	16	Large MPV (A)	0,13	0,01
7	Small MPV (C)	0,22	0,02	17	Large Family Saloon (A)	0,31	0,04
8	Small MPV (D)	0,17	0,04	18	Small MPV (F)	0,22	0,04
9	Supermini (B)	0,26	0,03	19	Small Family Car (C)	0,38	0,02
10	Small Family Car (B)	0,27	0,05		Average	0,20	0,03



Collision Speed 30 km/h

- In comparison to the collision speed 40 km/h, there is a considerable reduction in the AIS 3+ head injury risk both for children and for adults.
- This effect is visible throughout all vehicle fronts.
- A reduction of the collision speed by 10 km/h is already more effective for children than the uplifting bonnet+airbag combination.



	Vehicle class (acc. Euro NCAP)	Adult	Child		Vehicle class (acc. Euro NCAP)	Adult	Child
1	Execut. Saloon (upl. b.) (A)	0,01	0,00	11	Small MPV (E)	0,04	0,02
2	Execut. Saloon (upl. b.) (B)	0,01	0,01	12	Execut. Saloon (upl. b.) (C)	0,01	0,04
3	Small MPV (A)	0,05	0,01	13	Small Off-Road (A)	0,01	0,01
4	Small MPV (B)	0,07	0,01	14	Small Off-Road (B)	0,09	0,02
5	Supermini (A)	0,05	0,01	15	Supermini (C)	0,06	0,01
6	Small Family Car (A)	0,06	0,02	16	Large MPV (A)	0,02	0,01
7	Small MPV (C)	0,08	0,01	17	Large Family Saloon (A)	0,08	0,01
8	Small MPV (D)	0,07	0,02	18	Small MPV (F)	0,08	0,02
9	Supermini (B)	0,06	0,01	19	Small Family Car (C)	0,06	0,01
10	Small Family Car (B)	0,07	0,02		Average	0,05	0,01



Collision Speed 20 km/h

- In comparison to the collision speed 40 km/h, there is a further considerable reduction in the AIS 3+ head injury risk both for children and for adults.
- This effect is visible throughout all vehicle fronts.
- For all vehicles, the risk of AIS 3+ head injury for adults decreases below 10%; for children below 5%.

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 - 40 km/h [uplifting bonnet]
 - 40 km/h [uplifting bonnet + airbag]
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Summary (1/2)

- It becomes obvious that a reduced collision speed (as achieved by AEB) is the first choice for long-term pedestrian safety measures at cars. This is because the effect of this measure is independent from:
 - the front shape of the car
 - the height of the pedestrian.
- In contrary to this, the uplifting bonnet with airbag shows rather little effect for children.



Summary (2/2)

- The uplifting bonnet as a single measure has an effect which is rather selective even for adult pedestrians; this is due to the fact that the vehicle front shape has a higher influence than on other safety measures in discussion. Occasionally, by using the uplifting bonnet as a single safety measure, the situation might even get worse than without using it; furthermore, there is no effect or only little effect visible for children.
- Finally, the accident avoidance (and secondary impact) is an additional advantage that AEB has over other passive safety systems.

