INFLUENCE OF FRONT-END-DESIGN OF PASSENGER CARS ON INJURIES OF PEDESTRIANS IN CAR-TO-PEDESTRIAN COLLISIONS

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1. Introduction

In [1,2] were questions like frequency and severity of injuries for various body parts, (combined to "Traumatise Degree") as well as injury frequency and and severity caused by exterior car parts (combined to "Aggressivity" or "Endangering Degree") discussed. Furthermore was the influence of car parameters like front shape (Boxer, pontoon, V), front length and curbmass investigated. The following results or better tendencies were found out:

- The design of the front-end influences drastically the rank of the most aggressive exterior car parts.
- pontoon- and V-shaped contours behave in their overall endangering differently in different impact speed ranges
- an influence of the front length to the severity of the suffered injuries could not clearly be seen
- heavy cars produce more severe injuries than light cars. This statement should to some extent be diminished, considering that heavy cars reveal on average a lower impact speed than light cars [3].

This paper deals also with the question of the correlation between car parameters and injuries of pedestrians in real accidents. But the car parameters were choosen more systematically and differently. Special attention was paid to the question of the optimal bumper hight under consideration of injuries caused by the bumper as well as under consideration of the overall injury severity of the pedestrian.

2. Parameters describing the Front-end Geometry

According to Fig. 1 five parameters were choosen to describe the front-end geometry:

h_B bumper hight
h_F front hight
l_F front length

l_E recess of the fictive front edge

r_E radius of the real front edge

Two of these parameters, l_E and r_E, turned out to be connected. Their product enables one to distinguish numerically the three evident contour types (see Fig. 2):

Trapezium	T
Pontoon	P
Sloping	S

Therefore only four independent parameters remain for describing the front end geometry.

3. THE SAMPLE

Within three years in Hannover and lately also in Berlin some 850 accidents were investigated at-the-scene by an interdisciplinary team.* For this purpose 181 pedestrian accidents with frontal vehicle impact were analysed. The share of the children is dominant on behalf of the investigations during the day. Within the contour types the pontoon cars predominate (see Fig. 2). The impact velocity, the parameter with the strongest influence on injury severity, was carefully recalculated and reconstructed in each ease.

4. METHOD OF EVALUATION

The method of evaluation can be demonstrated for example at Fig. 3, showing the correlation between injury severity and impact velocity for different parameters. The injury severity is classified using the 1975 final addition of the Abbreviated Injury Scale (AIS).

The process of averaging is not done vertically (mean AIS versus v) but horizontally (mean v versus AIS). This method has advantages because the special sample size is small and averages are calculated in principle from normally distributed histograms. Disadventageous is that curves forming a pair only can be compared if the speed distributions are equal. This condition is controlled by calculating the mean impact speed v_m for each special sample.

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All together in each figure for each special sample is declared:

n -	number of eases (excluded are cases, beeing the only one on a certain AIS level)
p %	random probability
s m/s	standard deviation
v_m m/s	mean impact speed (excluding one-case-points)
AISm AIS	mean square value (including one-case-points)
AISm/v_m	v-related mean injury severity

In the case of having in the future a large sample size available the direct way of vertically averaging seems to be favorable even though the scaling of the AIS might be nonlinear and even though the histograms are not normally distributed.

5. INFLUENCE OF BUMPER HIGHT

Just now the optimum hight of bumpers on passenger cars in Europe is in discussion. With reference to the aspects

- pedestrian protection
- occupant protection in car-to-car side impacts
- occupant protection in truck-to-car side impacts
- lights protection in low speed collisions

the ISO Standard 2958 "Road vehicles - Exterior protection for passenger cars" prescribes a bumper hight of 445 mm.

Expecially with regard to the dominant aspects of pedestrian protection (knee impact) and side impacts a lower bumper hight is requested by several authors [4] to [7].

In opposite for severe accidents our recent results of dummy tests indicate a higher risk of head injuries with lower bumper hights caused by shifting the head impact into the region of the windscreenframe [8].

From results of the analysis of real accidents Fig. 3 to 8 deal with the question whether a high or low bumper is superior. Starting with the mean bumper hight as point of separation (39.1 cm for trapezium and pontoon contours, 34.2 cm for sloping contours) two groups of bumper hights are formed. For the three contour types and the three age groups the injuries are differentiatet into "bumper caused injuries" and "overall injuries".

On principle one of two competitive curves reveals better if it is shifted to higher impact speeds. But for example in Fig. 3 it can be seen that the connection of the mean values - due to the small size of each special sample - dont give smooth curves. Furthermore one can observe at maximum a difference of 3.6 m/s in the mean impact speeds of the competitive samples. This difference may be a systematical or random difference.

Concentrating to a hypothetic, comprehensive and velocity normalized measure of aggressivity, namely the criterion $AISm/v_m$ of the v-related mean injury severity, the ambiguous curves can be judged by only one figure. On the basis of the v-related mean injury severity in Fig. 9 and 10 the influence of a low bumper hight for different contour types and age groups is shown. The comparision comprehends only three rough rating groups:

+ positive influence

0 no influence

- negative influence.

Fig. 9 reveals the unexpected result that the bumper hight has all together no influence on the injury severity caused directly by the bumper. But a low bumper hight is of positive influence in reference to the overall injury severity, see Fig. 10. These two results, to some extent confirmed in our experimental tests [8], are in conflict with the present interpretation.

6. INFLUENCE OF THE FRONT EDGE HIGHT

Fig. 11 and 12 describe in detail in Fig. 13 in summary the influence of a low front hight. The results belong only to T and P contours and injuries caused only by the front edge. A low front hight is supposed to be lower than the mean hight of 72.3 cm. All together neither a positive nor a negative influence can be stated.

7. INFLUENCE OF THE FRONT LENGHT

A front length shorter than the mean value of 124.5 cm has for adults a positive influence on the injuries caused by the bonnet, windscreen frame and windscreen as far as T and P contours are concerned (see Fig. 14 and 15). This result contradicts the results of dummy tests and is in conflict also with intuitive considerations on the motion sequence. Possibly the conflict will be cleared up if the stiffness or the mass as parameters correlated with size are introduced in the investigations. Furthermore one should consider that injuries caused by the windscreen itself are fairly slight [2].

8. INFLUENCE OF THE CONTOUR TYPE

Comparing the three contour types on the basis of OAIS there are alltogether no large differences. For children the S contour reveals as superior (see Fig. 16 to 19).

9. CONSLUSIONS

With reference to the overall injury severity or to the injuries caused by particular car parts the influence of the four most significant geometrical car parameters were investigated in real car-to-pedestrian accidents.
The two- or three-step variation of the four geometrical parameters

bumper hight
front hight
front length
contour type

gave roughly as results:

- no influence of a low bumper hight with regard to injuries caused by the bumper
- a positive influence of a low bumper hight with regard to the overall injuries
- no influence of a low front edge hight on the corresponding injuries
- no or positive influence of a short front length on the bonnet/windscreen caused injuries
- on the average no influence of the different contour types on the overall injury severity

All together no drastical influences of the geometrical parameters could be observed. For this several reasons may be of importance:

a) the sample size is to small
b) only some of the various parameters are investigated
c) the choosen parameters are coupled with other parameters like mass and stiffness
d) the compared samples are originated from the reality. Therefore the

differences of the mean values are lower than they would be in laboratory tests

e) there is in reality on the average no difference between the three contour types with reference to the overall injury severity.

With reference to the last stetement that would mean the search for the best contour type is useless. Each type has its own advantages and disadvanteges and the disadvanteges have to be softened by special measures.

10. REFERENCES

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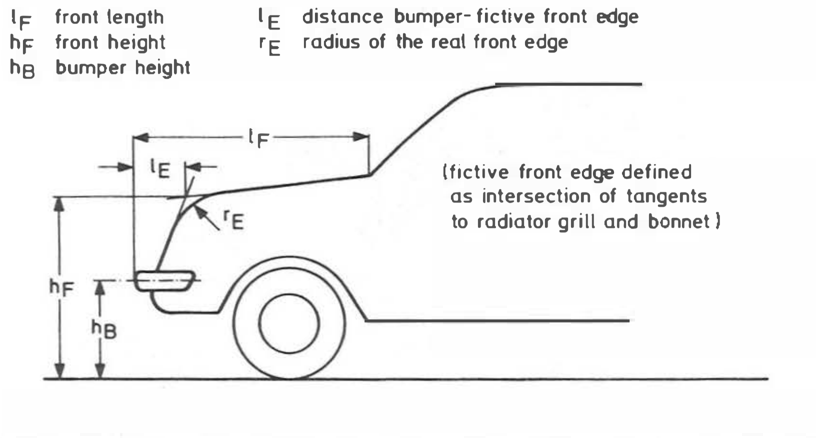
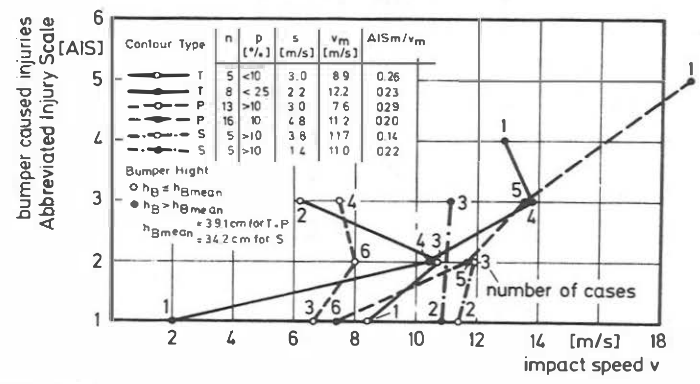
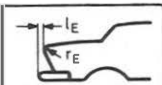
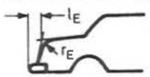
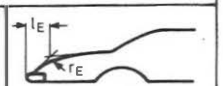


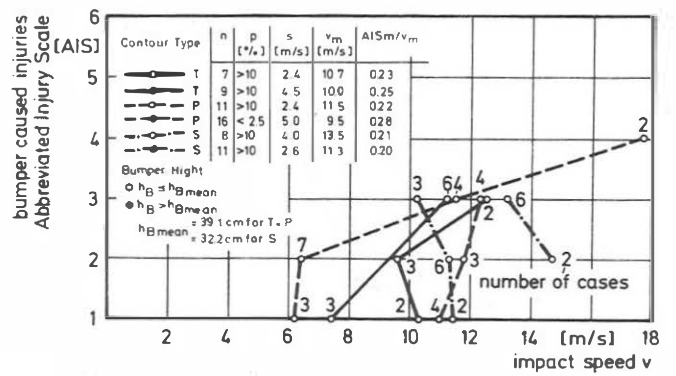
ILM TU-Berlin	Varied parameters of the vehicle front geometry	7602 Fig. 01 Ap/St/Be



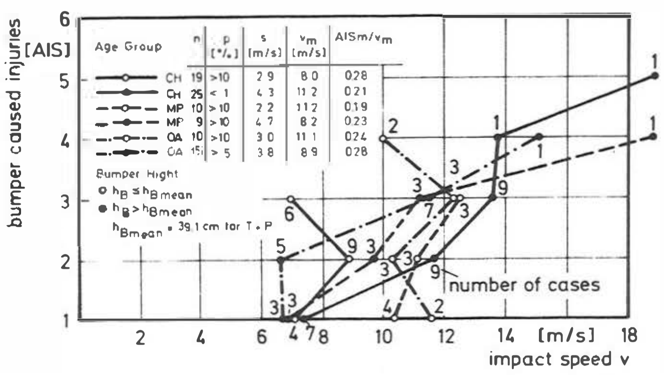
ILM TU-Berlin	Medium impact speed versus bumper caused AIS of child pedestrians	7602 Fig. 03 Ap/St/Be

Front End Contour Types / Age Groups		Trapezium T  $\frac{1}{r_E l_E} \geq 0.11\,[cm^{-2}]$	Pontoon P  $0.11[cm^{-2}] > \frac{1}{r_E l_E} > 0.0065\,[cm^{-2}]$	Sloping S  $\frac{1}{r_E l_E} \leq 0.0065\,[cm^{-2}]$
		e.g. BMW 520	e.g. Volve 244	e.g. VW-Beetle
Children (<15years)	CH	31	50	18
Middle Aged People (15y≤MP<60y)	MP	7	21	14
Older Adults (≥60 years)	OA	12	17	11

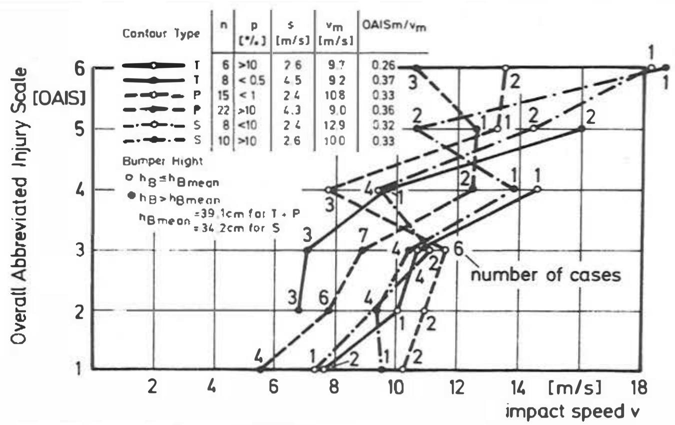
ILM TU-Berlin	Number of cases of frontal car-pedestrian collisions versus people age groups and contour types	7602 Fig. 02 Ap/St/Be



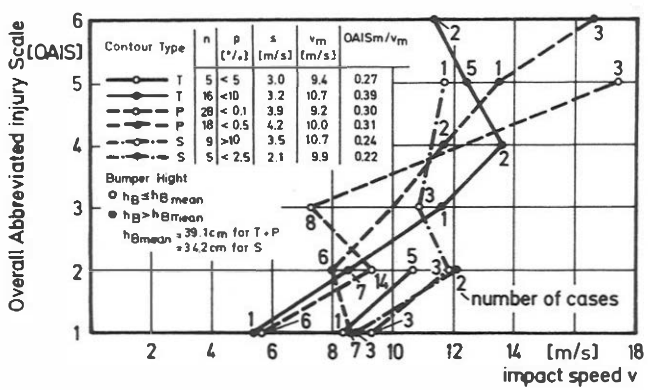
ILM TU-Berlin	Medium impact speed versus bumper caused AIS of adult pedestrians	7602 Fig. 04 Ap/St/Be



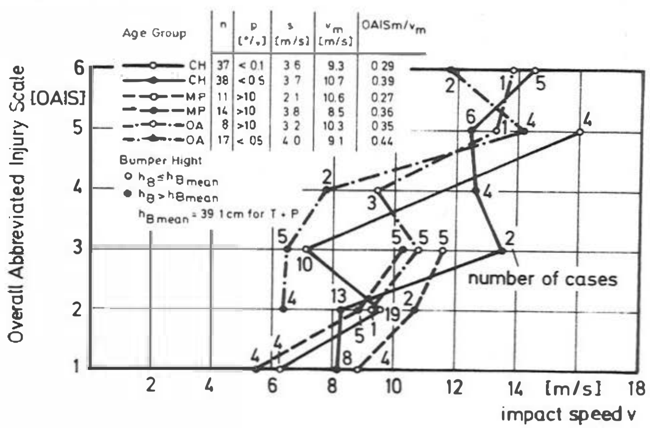
ILM TU-Berlin	Medium impact speed versus bumper caused AIS for T and P contours	76 02 Fig. 05 Ap/St/Be



ILM TU - Berlin	Medium impact speed versus OAIS of adult pedestrians	7602 Fig. 07 Ap/St/Be



ILM TU-Berlin	Medium impact speed versus OAIS of child pedestrians	7602 Fig.06 Ap/St/Be



ILM TU - Berlin	Medium impact speed versus OAIS for T and P contours	7602 Fig. 08 Ap/St/Be

Age Group \ Contour Type	T	P	S
CH	0	-	+
MP + OA	0	+	0
CH	-		
MP	0		
OA	0		

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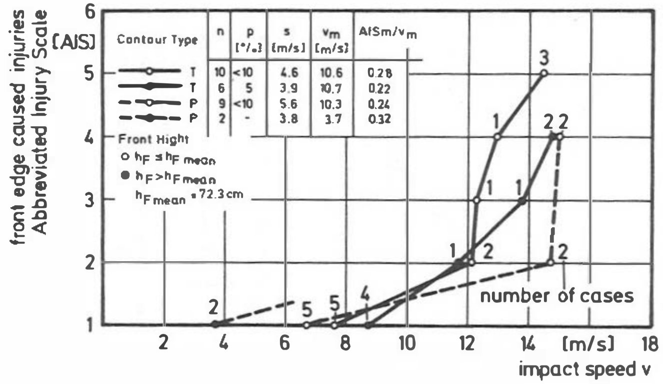
Influence of a low bumper hight
Criterion: bumper caused $AISm/v_m$

7602 Fig.09

Ap/St/Be



ILM
TU-Berlin

Medium impact speed versus front edge caused AIS
of child pedestrians

7602 Fig. 11

Ap/St/Be

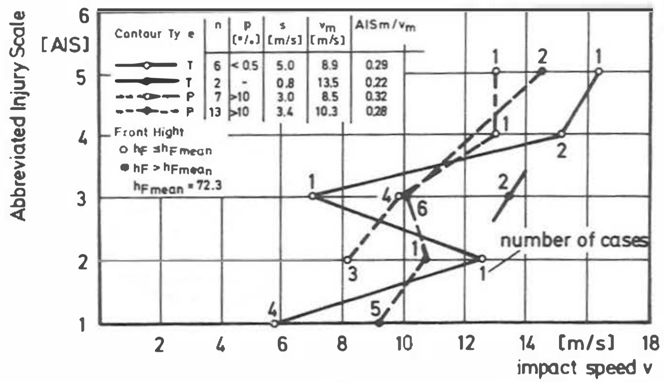
Age Group \ Contour Type	T	P	S
CH	+	0	0
MP + OA	+	0	0
CH	+		
MP	+		
OA	+		

ILM
TU-Berlin

Influence of a low bumper hight
Criterion: $OAISm/v_m$

7602 Fig. 10

Ap/St/Be



ILM
TU-Berlin

Medium impact speed versus front edge caused AIS
of adult pedestrians

7602 Fig. 12

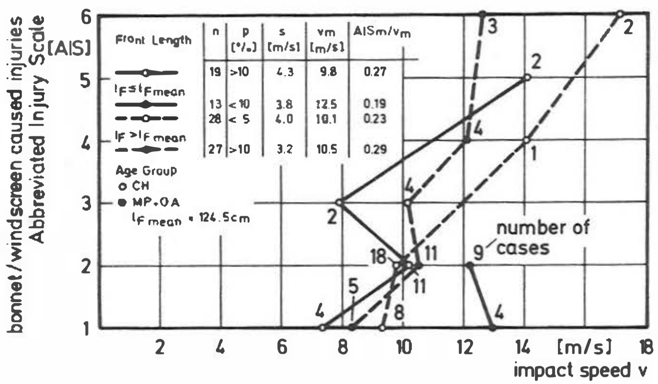
Ap/St/Be

Contour Type / Age Group	T	P
CH	-	?
MP + OA	?	0

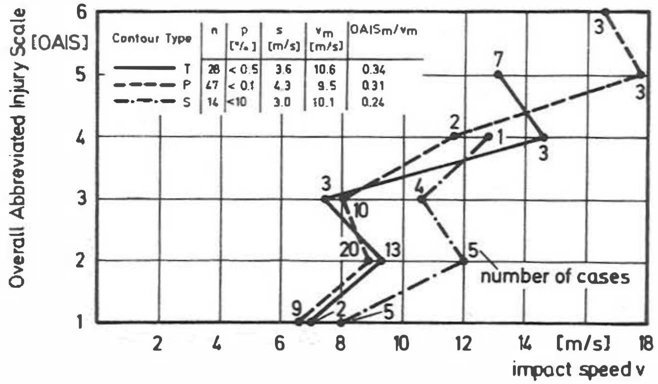
ILM TU-Berlin	Influence of a low front edge hight Criterion: front edge caused $AISm/v_m$	7602 Fig. 13 Ap/St/Be

Contour Type / Age Group	T	P
CH	0	
MP + OA	+	

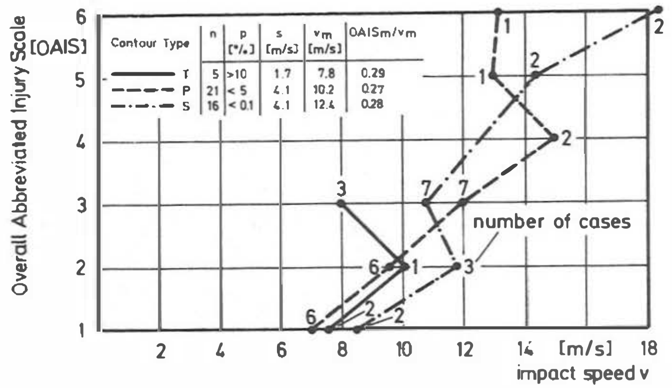
ILM TU-Berlin	Influence of a short front length Criterion: bonnet and windscreen caused $AISm/v_m$	7602 Fig. 15 Ap/St/Be



ILM TU-Berlin	Medium impact speed versus bonnet/windscreen caused AIS for T and P contours	7602 Fig. 14 Ap/St/Be



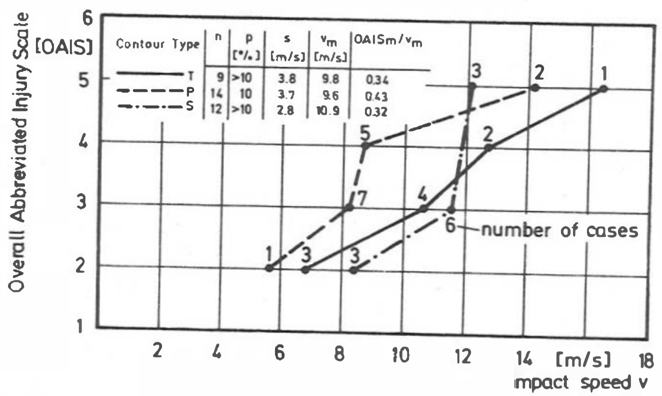
ILM TU-Berlin	Medium impact speed versus OAIS of CH pedestrians	7602 Fig. 16 Ap/St/Be



ILM TU-Berlin | Medium impact speed versus OAIS of MP pedestrians | 76 02 Fig.17 | Ap/St/Be

Age Group \ Contour Type	T	P	S
CH	0	0	+
MP	0	0	0
OA	0	-	0

ILM TU-Berlin | Comparision of different contour types Criterion: OAISm/v_m | 7602 Fig.19 | Ap/St/Be



ILM TU-Berlin | Medium impact speed versus OAIS of OA pedestrians | 76 02 Fig. 18 | Ap/St/Be