MAINPOINTS OF THE ENDANGERING BY DIFFERENT VEHICLE FRONT CONTOURS, THEIR ELEMENT/BODY REGION COMBINATIONS, AS WELL AS THE TYPE OF INJURIES PRODUCED

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The aim of this paper is first the determination of the degree of real endangering of pedestrians caused by different types of vehicle front contours, respectively their elements, to give a line of order for the employment of use value orientated measures.
The analysis of real traffic accidents-especially of in-depth single case analyses- gives secondly the opportunity of the methodically investigation of biomechanical layout priorities for the single vehicle elements under competing consideration of both main groups of the pedestrians. Calculating the aggressivity of costs as consequence of injuries of vehicle element/body region-combinations, containing the distribution of accidental and traffic participant parameters, priority for the layout of vehicle elements is given to the body region, which is thereby most strongly traumatised.
For a total evaluation of the aggressivity all relevant kinds of collision have to be considered, that is the frontal as well as the relevant corner to side collision of motor cars.

INTRODUCTION

An essential prerequisite for the employment of effective measures of high use value for motor cars, with the aim of reducing the trauma of exterior road users, are findings of the traffic accident research about the influence of vehicle-, traffic participant- as well as accident-parameters on the suffered trauma. When analysing real accidents contrary to anthropometric dummy tests, the following correlations are eliminated:

- dummy/human body
- vital/postmortem tissue

On the other hand such an analysis is supplemented by the possibility of

- in-depth consideration of the parameter age
- analysis of groups with representative age distribution
- evaluation of the overall trauma of the body from medical point of view

Analyses of real traffic accidents with exterior road users made up till now show, that too much stress is put on vehicle front collisions, i.e. corner/side collisions are neglected. The latter are of special importance when determining mainpoints of injury

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models and their specific causes, as well as determining main-points of aggressivity of the overall vehicle exterior and its single elements and the reasons herefor are the following

- with pedestrian collisions 20,9% of the primary impact points are located at the corner/side area of passenger cars (76,5% frontal), see Fig. 1.
- with pedestrian collisions 27% of the primary impact points are located at the corner/side area of trucks (56% frontal), see Fig. 2.
- with two-wheel riders about 38% of the primary impact points are located at the corner/side area of passenger cars (about 60% frontal) [2].
- the primary vehicle impact areas with exterior road users are distributed asymmetrically at the vehicle outside, for instance with pedestrian collisions at the right third part of the front of passenger cars (32,2%, left 23,5%) respectiveley at the right side area (12,5%, left 8,4%), see Fig. 1 and 2.
- some of the accident parameters, for instance the vehicle impact speed show significant different distributions in frontal collisions compared with corner/ side collisions, see also Fig.3.
- different pedestrian kinematics in corner/side collisions compared with frontal ones vary the type of accident loading to pedestrians, too.

Considering the importance of corner/side impacts, for instance with regard to the frequency of involvement, it has to be analysed whether this kind of collision is also of medical relevance. If this question is positively answered, consequence thereoff is that for a total valuation of the exterior safety of motor cars, only a common analysis of front to corner/side collision modes will give efficient points of application for use value oriented measurements.

ACCIDENTAL SITUATION

KIND OF COLLISION

For a quantitative optimisation of the vehicle exterior,which will be mostly independent from todays aggressivity of exterior vehicle elements, to a far reaching extent, the primary impact areas of pedestrians at the vehicle outside show by their position and frequency those contact areas, to which special interest has to be paid when trying to reduce the biomechanical loading on exterior road users.
For the distributions shown in Fig. 1 and 2 292 cases investigated by the Traffic Accident Research Group Hanover, as well as 800 police reports of traffic accidents with high documentation quality from the area of Hanover, were used. From these cases the primary impact point on motor cars as well as the walking direction of the pedestrian at the time of collision could clearly be taken. When assigning primary impact areas at the front corner of the vehicle this was done by considering the position of the pelvis impact area, i.e. if the impact area was outside the vehicle front

and for instance only one leg was hit by the bumper, then this case was assigned to the vehicle side.

It is clearly to be seen that vehicle corner/side collisions are underrepresented in the cases of the Traffic Accident Research Group, a reason for this is probably the limited reconstructability of vehicle impact speeds with primary contact areas at the vehicle side.

When viewing the overall statistic the primary impact area at vehicle is most often the vehicle front: 76.5% with passenger cars (56% with trucks) followed by the side (20.9% with passenger cars and 27% with trucks) and the rear of the vehicle (2,6% with passenger cars and 17% with trucks). Additionally the impact directions to pedestrians caused by passenger cars are found in the lateral regions by 73,8% (69% with trucks), in the front regions by 17,7% (20% with trucks), and in the dorsal ones 8.5% (11% with trucks) related to the whole body. The number of cases with primary impact areas of pedestrians at the back side of trucks -which is quite high with 17%- also makes measures necessary in the framework of an overall optimization, which protect against this kind of collision.

COLLISION TYPE

By investigation of the frequency of individual combinations of primary impact areas at the vehicle exterior and impact directions of pedestrians it is possible to establish a line of order of collisions types according to their frequency rate. This is a prerequisite especially for an efficient testing of the vehicle exterior -without concidering any aggressivity rate- by using anthropometric dummies. The symmetrical primary impact areas were put together and converted into a walking direction of pedestrians from the right, see Fig. 3 and 4.

The four most frequent collision types are with:

Front type contour	primary impact point vehicle/pedestrian		frequency rate
passenger cars	front,right third	9o'clock	19.9 %
(V, P, T)	front,center third	9 "	10,8 %
	front,right third	10 "	9,7 %
front	fender,right side	12 "	8,5 %
trucks (K)	front,right third	9 "	23,9 %
	front,right third	10 "	8,5 %
	front,left third	9 "	7,0 %
front	fender,right side	12 "	7,0 %

On the whole these four collision types comprise only 48,9% (passenger cars) or 46,4% (trucks) of all combinations found in real accidents. But it is remarkable, too, that the running of pedestrians into the side area of the front fender ranges already in the fourth position.

VEHICLE IMPACT SPEED

Considering the position of primary impact points at the vehicle exterior, Fig. 5 shows a significant difference (Behrens-Fischer-Test[3]) between the injury severity in vehicle front and corner/side collisions with median values of 9.5 m/s (front collision) and 11.3 m/s, respectively. In general 50% of all vehicle impact speeds are located under 9.9 m/s and 50% range with highest occurence dentisity between 5.8 and 10.6 m/s. When differentiating according to front contours (see Figs. 10, 12, 13) medians in cases with front collisions are found to 9.2 m/s (P/T), 9,6 m/s (V) and 11.1 m/s (K), whereby the latter shows significantly higher injury potential than the others. This shows also that the K-contour is, already due to its collision speed, an aggressive vehicle.

Fig. 6 shows a corresponding distribution of several relevant collision types. With passenger cars a significant difference of the impact speeds in front collisions can be detected between cases where the primary impact points are situated in the center third compared with cases where the impact points lie in the first third part of the front when pedestrians run into the vehicle front. Thus the median value of v_{KF} for the center front is with 8.6 m/s significantly below the frontal corner/side area with 11.8 m/s. Furthermore the distributions of V/P/T- and K-contours with impact points in the outer third part of the vehicle front are significantly different, too, with medians of 11,8 m/s and 12,5 m/s. Herefrom for the relevant collision types with different front contour types the following test speeds can derive in a first approach (up to the scope of highest occurence dentisity)

Front contour type	primary impact point vehicle/pedestrian		test speed (v_{KF50})
V/P/T	front,right third	9 or 10 o'clock	11,8 to 12,3 m/s.
V/P/T	front,center third	9 "	8,6 m/s.
V/P/T	front fender, right side	12 "	10,2 m/s.
K	front,right third	9 "	12,5 m/s.

Further relevant test speeds can be derived from characteristic values of the distribution, which in tempory steps could reduce the degree of agressivity of vehicle exteriors in an increasing extent, for instance v_{KF50} (step 1) (V/P/T-front collision 9.3 m/s), (step 2)v_{KF50}, i.e. the upper limit of a 50-%-range of highest occurance dentsitiy (V/P/T-front collision 10,8 m/s), or $v_{KF} + s_{VKF50}$, the upper point of inflection of the frequency distribution (V/P/T-front collision 14.6 m/s).

INJURY MODEL

An examination, whether the corner/side impact is also of medical relevance, is generally made upon the basis of an overall injury model of pedestrians, i.e. without differentiating according to contour forms, see Fig. 7. The endangering degrees ATD (Absolute

Traumatic Degree) and RTD (Relative Traumatic Degree, normalized to v_{KF50} = 9.3 m/s) are calculated according to model [4] and weighted by costs resulting from injuries as follows:

$$ATD = (f_{iR} \sum_{i=1}^{n} \frac{1}{n} AIS)\ [AIS],\ RTD = ATD\ (a+bv_n) / \sum_{i=1}^{n} \frac{1}{n} (a+bv_i) \quad or$$

$$v_n / \sum_{i=1}^{n} \frac{1}{n} v_i \ [AIS]$$

or related to vehicle elements taking directly into account the produced costs resulting from injuries, as this is later than calculated as ACD (Absolute Cost Degree) or RCD (Relative Cost Degree) as follows:

$$ACD = f_{iE_i} \sum_{i=1}^{n} \frac{1}{n} C_i\ [DM],\ RCD = ACD\ (a+bv_n)^x / \sum_{i=1}^{n} \frac{1}{n} (a+bv_i)^x \quad or$$

$$v_n^x / \sum_{i=1}^{n} v_i^x \ [DM]$$

f frequency of injuries, respect. of cause of injuries related to total number of cases
a,b linear regression factors of OAIS = f (v); $v = v_{KF}$
C Cost as injury sequence of single AIS degrees
n number of cases
R Index for body regions
E Index for vehicle elements
x regression exponent of OAIS = f(C) for different age groups.

The evaluation of the trauma is here effected by the RTD, which, with the aim of a real comparision between the two opposed groups, eliminates the influence of different mean vehicle impact speeds, to a far reaching extent in contrast to the also stated ATD.

The body region most often traumatised is the head region for both kinds of collisions, also when considering the different age groups. The corner/side collision lies here with its RTD only slightly below the one of the front collision. With respect to endangered parts, the abdominal region ranks second with front collisions of children followed by the femur; however, with persons aged 15 and on this is the thorax followed by shanks.

With corner/side collisions of children the region mostly endangered after the head is the neck - in one case a rupture of the larynx-followed by injuries to the neck spine column; with persons aged 15 and on these are the shanks likewise followed by the spine column.

In general, however, the number of injured body regions - on the average 3.4 or 4.7 with front collisions compared with 2.7 to 3.5 with corner/side collisions - shows, that the tendency for multiple injuries is higher with front collisions.

CAUSES OF INJURIES
With the aim of an use/costs - or at least an use value oriented design of the vehicle exterior, in order to be able to bring into a line of order the necessity of measures to increase the external safety according to their urgency and thus to safeguard an efficient use of the means at our disposal, a valuation of the causes of injuries according to their resulting injury costs is undertaken here. An evaluation of the aggressivity of individual groups is therefore being done with the following aims in mind:

- Aggressivity of vehicle front contours in order to find out the specific characteristics of the different contours designating their aggressivity, or to find out optimal front contours, i.e. their positive characteristics.

- Aggressivity of vehicle elements from vehicles classified according to their typical front contours in order to find a line of order of their aggressivity , respectively to establish a line of order of expected maximum use value.

- Aggressivity of vehicle element/body region combinations in order to derive layout priorities under consideration of the distribution of road traffic participant- and accident parameters for the vehicle elements, especially those with the highest aggressivity rate, with relation to the body region most traumatized by them under competition of the age groups of traffic participants.

- As with front collisions as well as with corner/side collisions some vehicle elements causes injuries in both cases and also with corner/side collisions children also bump against windscreens and windscreen frames, which therefore are at least also for this age group of relevance, in the framework of an overall consideration here front and corner/side collisions are valuated together.

COST/AGGRESSIVITY OF VEHICLE FRONT CONTOURS
A comparison of the severity of the overall trauma as well as of the costs resulting from injuries of different vehicle front contours, also related to different age groups, under consideration of their accident involvement rate in front collisions,, can be seen by Fig. 8.

In consideration of accident involvement rates of the different front contour types related to all pedestrians, the P-contour causes with an average of DM 60.000,-- of costs resulting from injuries the highest absolute Cost Degree (f · ACD) followed by the K-, T- and V-contour. An analogous line of order is also arrived at with relation to age groups, where only with children the rank of order is exchanged with K- and T-contours.

An evaluation of the contours on the basis of the same level of vehicle impact speeds leads via the RCD in the case of the T-contour to the highest relative injury cost aggressivity as related to the entire group of pedestrians; this is followed by the K-, the P-, and the V-contour. The latter, for instance, causes only 37% of injury costs of the T-contour at v_{KF50} = 9.3 m/s. This goes to show, too, that the high aggressivity (ACD) of the K-front contour observed in real accidents is predominantly a consequence of its higher mean impact speed.

The smallest RCD, this means the smallest specific cost aggressivity is caused with children by the V-contour and with persons aged 15 and on by the P-contour. With regard to children this is caused by the lack of a marked front end of bonnet with the V-contour, and with regard to persons aged 15 and on this is caused by the existance of such a marked front end with the P-contour, due to which a head/windscreen frame impact is avoided to a far reaching extent.

COST/AGGRESSIVITY OF EXTERIOR VEHICLE ELEMENTS

As the trauma suffered by a certain age group depends on the impact speed of the respective body region as well as on the rigidity of the impact area on vehicle, and as vehicle elements which are only reached at high collision speeds are often erroneously considered to be more aggressive than the ones which are usually reached, also a valuation of the RCD is carried out here - see Fig. 9, whereby results for elements with a low contact frequency are also considered and made sure. Thus it is also possible to compare vehicle elements of different front contour types qualitatively with one another. As a supplement also the ACD is given for a quantitative valuation.

It must be taken into account that the corner/side impact included in the evaluation of the accident research material used here is strongly underrepresented in the case of passenger cars with 8% as compared with normally 20.9% according to its frequency also in the RCD and ACD.

No differentiation was made between bonnet and fender, i.e. they were not separately evaluated, as no such differentiation can be made in most real cases with regard to load direction of pedestrians as moreover a dividing up transverse to the symmetry plane according to typical contact regions of children or persons aged 15 and on - first and second half - seems to be more sensible on the whole. With K-contours the bonnet was divided up in upper (first half) and lower (second half) of bonnet.

For pedestrians on the whole the following line of order of produced costs resulting from injuries (RCD) according to front contour types for the individual vehicle elements is arrived at, whereby the especially endangered age groups are stated, too:

Ponton/Trapezoid (P/T)	V-contour (V)	box-contour (K)
1. front end of bonnet T /children	bumper /persons aged 15 and on	upper bonnet region /persons aged 15 and on
2. front end of bonnet P /pers. aged 15 and on	second half of /pers. aged 15 and on	lower bonnet region /persons aged 15 and on
3. bumper /pers. aged 15 and on	windscreen frame /pers. aged 15 and on.	bumper /persons aged 15 and on
4. first half of bonnet /children	first half of bonnet /pers. aged 15 and on.	windscreen/persons aged 15 and on

Taking a look at the ACD the result remains unchanged with the P/T-contour up to rank 4; with the V-contour ranks between 1, 2, and 3 are changed and with the K-contour a change of rank takes place between rank 4 and 5 as well as 6 and 7.

Assuming that approximately three times as many corner/side impacts are appearing with regard to the distribution of impact areas - taking as a basis the traffic accident reports of the large area of Hanover, the tire/lateral wheel area with P/T-contours causes on general an RCD of DM 6300,--, for instance, and is thus already higher than the cost aggressivity of the lower corner of windscreen. With V-contours there is an analogues increase of the RCD for the side of the front fender including the wheel opening to the level of the first half of the bonnet.

With K-contours tire/lateral wheel area ranks at the 5th position according to its RCD, caused exclusively by "overrolling injuries" especially in the children's age group.

Compared with priorities for the vehicle to reduce the seriousness of primary collisions the importance of measures to reduce the seriousness of the secondary collision ranks only on the fifth to seventh place behind individual vehicle elements. The share which primary collisions take up with produced costs resulting from injuries related to the whole collision shows also its ratio of follow-up costs with regard to secondary collision. With a quotient of 7.4 (P/T), 13.2 (V) and 9.3 (K) the costs resulting from injuries with primary collisions are on the average ten times as high related to v_{KF50} (V/P/T) = 9.3 m/s.

COST AGGRESSIVITY OF VEHICLE ELEMENT/BODY REGION-COMBINATIONS

After determining the aggressivity rank of individual vehicle elements of different front contour types important is to find those body regions which are most seriously traumatized by the respective vehicle element. Considering the influence of the age group on the biomechanical loading capacity of body regions when designing the external vehicle elements, children and persons aged 15 and more are treated here as competing factors. Determination of layout priorities is effected separately according to front contour types via the RCD; but as a supplement here, too, the ACD is stated for the possibility of an absolute evaluation.

PONTOON/TRAPEZOID - CONTOUR (P/T)
For P/T-contours - see Fig. 10 - most often involved in traffic accidents can be taken the following use value orientated layout of the most aggressive vehicle elements to the loading capacity of body regions which are most strongly traumatized by them.

1. Front edge of bonnet (T)	41700,--DM/	head children	16600,-- DM	(!)
		abdomen children	15400,-- DM	
		thight pers. ≥15y	14900,-- DM	
2. Front edge of bonnet (P)	26400,--DM/	pelvis pers. ≥15y	16200,-- DM	(!)
		abdomen pers. ≥15y	13200,-- DM	
		spine column persons ≥15y	9400,-- DM	
3. Front bumper	22600,--DM/	shank pers. ≥15y	21000,-- DM	(!)
		knee pers. ≥15y	10500,-- DM	
		thight children	7000,-- DM	
4. First half of front bonnet	15100,--DM/	head children	14400,-- DM	(!)
		head pers. ≥15y	6200,-- DM	
		thorax pers. ≥15y	5400,-- DM	
(5. Road surface	13200,--DM/	head pers. ≥15y	13100,-- DM)	
		head children	9200,-- DM)	

The sum of the individual cost values can here possibly be higher than the values of the orders 1 to 5 in Fig. 9, as for instance one vehicle element can possibly traumatise several body regions, and on the other hand they represent average values related to costs resulting from injuries to all persons in consideration of age groups.

Fig. 10 is further supplemented by a chart of types of injuries caused by the individual vehicle elements of P/T -contours, and Fig. 11 includes an aggressivity line of order based upon Fig.10, thus the typical type of load can be deducted and the following layout priorities can be stated:

- The front edge of bonnet with T-contours, the traumatizing effect of which is rare, but which hits the head region of little children with serious consequences, causes due to its mostly linear contact area most serious skullbrain-traumas followed by serious organ injuries of the abdominal region of children as well as femur fractures with serious soft tissue lesions as well as pelvis fractures of persons from age 15 and on. - Layout priority: head region of children.

- The front edge of bonnet of P-contours causes due to its more surface contact area, which brings about a larger vertical dimension, a strong decrease of abdominal traumas as well as a limited increase of skeletal thoratic injuries of children. For persons aged 15 onwards this causes an increase of trauma especially of the pelvis but also of the abdominal region. This is also the maincause for spine column injuries - mostly in the lumbar vertrebral region (LWS) - of persons from 15 years of age on. - Layout priority: pelvis- and partly abdominal region of persons from 15 years on; paying heed to the children's head region.

- The bumper mainly causes fractures in the lower extremities of both age groups especially of tibia/ fibula and partly also with persons over 15 years of age in the knee region, respectively with children fractures of the femur. - Layout priority: tibia/ fibula of persons from 15 years of age on, protection of the children's femur.

- The first half of the front bonnet causes mainly Skull-Brain-Traumas (SBT) with children, but also in a small number of cases SBT incl. fractures as well as skeletal thoratic injuries in the age group of persons aged 15 and on. - Layout priority: head region of children.

- The impact on the road surface mainly causing SBT with both age groups with fractures of the head region whereby especially persons from 15 years on are endangered.

- The second half of the front bonnet mainly causes SBT accompanied by skull fractures of persons from 15 years and on, too, but it also causes skeletal injuries of the thoratic region. - Layout priority: head region of persons from 15 years of age on.

- The lower corner of windscreen causes severe SBT, but as consequence of the distribution of vehicle impact speeds, these are rare. Often they are accompanied by skull fractures. These mentioned injuries apply to persons from 15 years of age on. This vehicle element is also the main cause of injuries to the neck spine column (HWS) in this age group. - Layout priority: head region of persons from 15 years of age on; paying heed to the neck spine loading for the same age group.

- Head lights and sourrounding area are mostly causes of pelvis fractures but also to a smaller degree they cause abdominal injuries of persons from 15 years of age on, respectively, with children they cause soft tissue lesions in the thigh and shank area. - Layout priorities: pelvis region of persons from 15 years on, and paying heed to soft tissue injuries on general, but especially with regard to children.

- Upper A- post causes exclusively Skull-Brain-Traumas accompanied by skull fractures and partly by moderate soft tissue injuries with persons from 15 years of age on. - Layout priority: head region of persons from 15 years of age on; paying heed to soft tissue injuries of the head.

- The windscreen mainly causes first degree SBT partly with skull fractures and frequently in connection with slight soft tissue injuries with persons from 15 years on. Important head injuries are observed with children, only they are caused by SBT. - Layout priority: head region of persons from 15 years on. As the rest of vehicle elements show a substantial lower aggressivity rate - partly caused by their underrepresentation - layout priorities are appraised under reservation as follows:

- tire and wheel lateral surface: tibia/fibula of children.
- outside mirror: head region of persons from 15 years of age on; paying heed to the children's head region.
- side of front fenders, wheel opening: tibia/fibula of children; paying head to soft tissue injuries.
- frontal roof edge: head region of persons aged 15 years and on.
- front spoiler: feet region of persons from 15 years of age on; tibia/fibula of children.
- front area of car, radiator grille: pelvis fractures of persons from 15 years of age on; paying heed to soft tissue injuries.
- side door, door handle: head region of children.

With T/P-contours injuries to the abdominal region of children - such as kidney contusion or spleen rupture - are previously found with vehicle impact speeds of 1.8 respectively 6.3 m/s. The majority of pelvis injuries of persons from 15 years of age on, caused by the front edge of bonnet, are pelvis circle fractures, and are found from 3.3 to 6.8 m/s on.

V-CONTOUR (V)

For the second frequent front contour involved in pedestrian accidents, the V-contour the following layout priorities can be derived from figure 12:

- bumper: tibia/fibula of persons from 15 years on; paying heed to the childish femin
- second half of front bonnet: head and thorax of persons from 15 years on; paying heed to their neck spine column.
- windscreen frame: head of persons from 15 years on, paying heed to their neck spine column.
- first half of front bonnet: head of children, paying heed to thorax and abdomen of persons from 15 years on.
- side of front fenders, wheel opening: tibia/fibula of children.

Other vehicle elements show a lower aggressivity rate,partly influenced by underrepresentation,for which layout priorities can be taken also from Fig. 12.

BOX-CONTOUR (K)

For the front contour which show smallest involvement rate in pedestrian accidents,the K-contour,the following layout priorities can be derived from Fig. 13.

- upper half of front bonnet:thorax with paying heed to the neck spine area of persons ≧ 15years;paying heed to child head regions.

- lower half of front bonnet:abdomen with paying heed to thorax of persons ≧ 15years,also to children's head region.

- bumper:abdomen and tibia/fibula of persons ≧ 15years;paying heed to children's pelvis

- windscreen:head with paying heed to neck region of persons ≧ 15y.

With regard to other vehicle elements,which show a lower aggressivity rate,partly influenced by underrepresentation, layout priorities can be taken from Fig.13, too.

DISCUSSION

In the framework of a use value orientated overall optimization of the vehicle exterior it must be aimed to determine the order of aggressivity of single vehicle elements also for determination of biomechanical layout priorities to find out line of order by injury requence costs of combinations of vehicle element body regions primary based on cases with vehicle front and corner/side collisions with pedestrians.The latter kind of collision is of special interest due frequency of occurence and its traumatological relevance. Layout of external vehicle elements,i.e.impact areas of pedestrians,should be harmonized-according to their order of aggressivity-to biomechanical loading capacity of body regions which are most seriously traumatized by the respective vehicle element,or which causes the highest costs resulting from injuries.
If the vehicle exterior is designed according to the biomechanical loading capacity of body regions of persons ≧ 15years,this measure proves to be of only small efficiency with regard to children,which likewise have also to be protected,as mass forces of the latter group are much lower than ones of the former group at same impact speeds.Consequence is that for some exterior vehicle elements exist a need for two different levels of reaction forces.
Thus it would be optimal to have a contact stiffness adepted to the femur of children,e.g. in case of bumper impact,with a pre stiffnes of low level and in the reverse case added by one for pers. ≧ 15year

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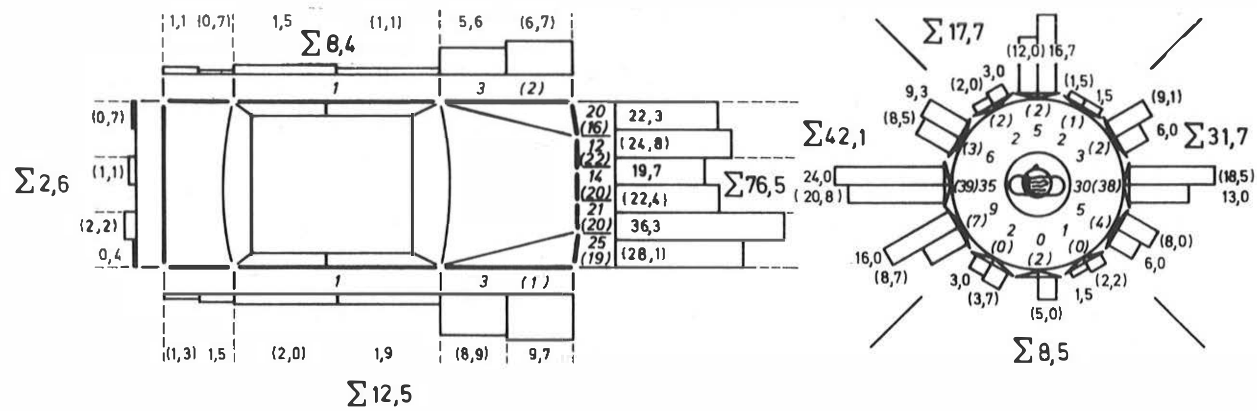
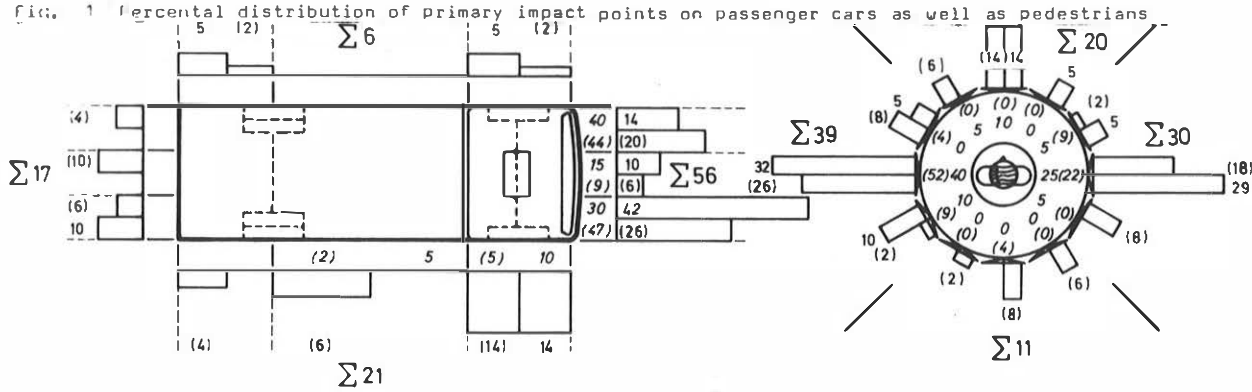


inside(transverse): Traffic Acc. Res. Group Han. children n = 119, (pers.≥15y n = 130)
outside(straight): Police records Han.area (1976); children n = 269, (pers.≥15y n = 460)

Fig. 1 Percental distribution of primary impact points on passenger cars as well as pedestrians



inside(transverse): Traffic Acc. Res. Group Han. children n = 20, (pers.≥15y n = 23)
outside(straight): Police records Han.area (1976); children n = 21, (pers.≥15y n = 50)

Fig. 2 Percental distribution of primary impact points on trucks as well as pedestrians

primary imp. point at vehicle		primary impact point at pedestrian (clock) 1	2	3	4	5	6	7	8	9	10	11	12	Σ
front left[1]	○	3	12	17	7			1	8	7	4		1	60
	□		23	42	10	1		7	14	16			1	114
front middle[1]	○		2	9	4	1		4	9	19	3	1	1	53
	□	1	8	27	9	1	4	4	12	24				103
front right[1]	○		1	6	5	3		3	23	39	15	3		98
	□	1	7	9	14	6	7	4	11	47	21	1	2	130
right in front[2]	○								2		3	3	18	26
	□				2	1	6			3	6	2	21	41
right middle[3]	○												5	5
	□						1						8	9
right in back[4]	○	1							1				2	4
	□								2				4	6
back left[1]	○													
	□			1						2				3
back middle[1]	○													
	□			2	1	1				1				5
back right[1]	○												1	1
	□		2	1				1	1	1	1	1	2	10
left in front[2]	○		1	2			5	1		2	2	1	11	15
	□	3	2	3								1	12	31
left middle[3]	○												4	4
	□	1										1	3	5
left in back[4]	○			1									2	3
	□	1			1								1	3
Σ	○	4	16	35	16	4		8	43	65	25	8	45	269
	□	7	42	85	37	10	23	17	40	96	39	9	55	460

primary imp. point at vehicle		prim. imp.point at ped. calc. to walk.direct. f. right[5] (clock) 6	6 Σ	7	7 Σ	8	8 Σ	9	9 Σ	10	10 Σ	11	11 Σ	12	12 Σ
front left[1]	○			1,5	2,3	4,8	5,6	4,8	5,2	1,9	1,7		0,1	0,4	0,3
	□			2,8		6,1		5,4		1,5		0,2		0,2	
front middle[1]	○		0,6	1,9	1,4	4,8	4,7	10,4	10,8	1,9	3,0	0,4	0,7	0,4	0,3
	□	0,9		1,1		4,6		11,1		3,7		0,9		0,2	
front right[1]	○		1,0	1,1	1,1	11,2	7,0	20,8	19,9	10,0	9,7	2,2	1,0		0,3
	□	1,5		1,1		4,6		19,3		9,6		0,2		0,4	
right in front[2]	○		1,5			0,7	0,6	0,7	1,4	1,5	1,9	1,5	1,4	10,8	8,5
	□	2,4				0,4		1,7		2,2		1,3		7,2	
right middle[3]	○		0,1										0,3	3,4	2,7
	□	0,2										0,4		2,4	
right in back[4]	○					0,4	0,6	0,4	0,1			0,4	0,3	1,5	1,2
	□					0,7						0,2		1,1	
back left[1]	○								0,4						
	□							0,7							
back middle[1]	○				0,1		0,1		0,4						
	□			0,2		0,2		0,7							
back right[1]	○				0,1		0,1		0,3		0,4		0,1	0,4	0,4
	□			0,2		0,2		0,4		0,7		0,2		0,4	

○ children
□ pers. ≥ 15 years
△ all pedestrians
1 one third of vehicle front breadth
2 front bumper till lower A-post
3 lower A- till C-post
4 lower C-post till back side bumper
5 percental values

Fig. 3 Frequency of collision types in pedestrian accidents with passenger cars and injury sequence in the area of Hannover under special consideration of age groups

primary imp. point at vehicle	1	2	3	4	5	6	7	8	9	10	11	12	Σ	6 Σ	7 Σ	8 Σ	9 Σ	10 Σ	11 Σ	12 Σ
	primary impact point at pedestrian clock													prim. imp. point at ped. calc. to walk. direct. f. right[5] clock						
front left[1] ○ □	 	1 1	2 3	 2	 	 1	 	 1	 2	 	 	 	3 10			4,8 2,8 2,0	4,8 △7,0 8,0		4,8 1,4	
front middle[1] ○ □			1 2					1 	 1				2 3			4,8 1,4	4,8 △5,6 6,0			
front right[1] ○ □	1 		1 2		 1		 1		6 6	1 3			9 13	2,0 1,4	4,0 2,8	4,0 2,8	38,1 △23,9 18,0	9,5 △8,5 8,0		
right in front[2] ○ □			 2					1 	1 2		 2	1 1	3 7			4,8 1,4	4,8 △7,0 8,0		4,0 2,8	9,5 4,2 2,0
right middle[3] ○ □												 3	 3							6,0 4,2
right in back[4] ○ □												 2	 2							4,8 △5,6 6,0
back left[1] ○ □				 1		 1							 2	2,0 1,4				2,0 1,4		
back middle[1] ○ □				 1	 1	 1			 2				 5	2,0 1,4	2,0 1,4	2,0 1,4	4,0 2,8			
back right[1] [1] ○ □			2 		 1	 1				 1			2 3	2,0 1,4	2,0 1,4	2,0 1,4	9,5 2,8			
left in front[2] ○ □											 1	1 	1 1							
left middle[3] ○ □																				
left in back[4] ○ □												1 1	1 1							
Σ	1 	1 1	6 9	 4	 3	 4	 1	2 1	7 13	1 4	 3	3 7	21 50							

○ children
□ pers. ≥ 15 years
△ all pedestrians
1 one third of vehicle front breadth
2 front bumper till A-post
3 A-post till rear axle
4 rear axle till back side bumper
5 percental values

Fig. 4 Frequency of collision types in pedestrian accidents with trucks and injury sequence in the area of Hannover under special consideration of age groups

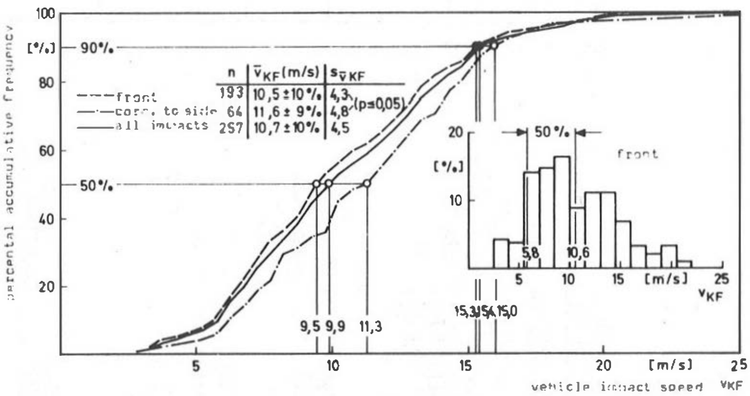


Fig. 5 Distribution of vehicle impact speeds in pedestrian accidents with injury sequence for different primary impact points at the vehicle exterior (only cases of the Traffic Accident Research Group Hannover)

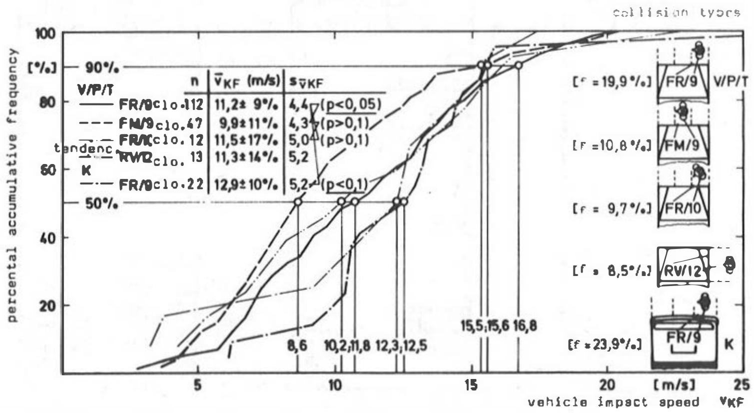
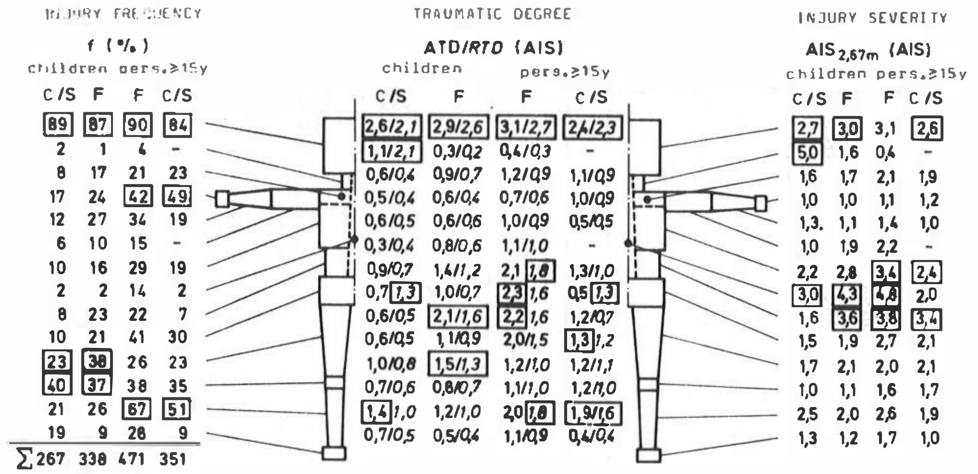


Fig. 6 Distribution of vehicle impact speeds in pedestrian accidents with injury sequence for different collision types and types of vehicle front contours



Injury frequency f (%) children C/S	children F	pers.≥15y F	pers.≥15y C/S	Traumatic degree ATD/RTD (AIS) children C/S	children F	pers.≥15y F	pers.≥15y C/S	Injury severity $AIS_{2,67m}$ (AIS) children C/S	children F	pers.≥15y F	pers.≥15y C/S
89	87	90	84	2,6/2,1	2,9/2,6	3,1/2,7	2,4/2,3	2,7	3,0	3,1	2,6
2	1	4	-	1,1/2,1	0,3/0,2	0,4/0,3	-	5,0	1,6	0,4	-
8	17	21	23	0,6/0,4	0,9/0,7	1,2/0,9	1,1/0,9	1,6	1,7	2,1	1,9
17	24	42	49	0,5/0,4	0,6/0,4	0,7/0,6	1,0/0,9	1,0	1,0	1,1	1,2
12	27	34	19	0,6/0,5	0,6/0,6	1,0/0,9	0,5/0,5	1,3.	1,1	1,4	1,0
6	10	15	-	0,3/0,4	0,8/0,6	1,1/1,0	-	1,0	1,9	2,2	-
10	16	29	19	0,9/0,7	1,4/1,2	2,1/1,8	1,3/1,0	2,2	2,8	3,4	2,4
2	2	14	2	0,7/1,3	1,0/0,7	2,3/1,6	0,5/1,3	3,0	4,3	4,8	2,0
8	23	22	7	0,6/0,5	2,1/1,6	2,2/1,6	1,2/0,7	1,6	3,6	3,8	3,4
10	21	41	30	0,6/0,5	1,1/0,9	2,0/1,5	1,3/1,2	1,5	1,9	2,7	2,1
23	38	26	23	1,0/0,8	1,5/1,3	1,2/1,0	1,2/1,1	1,7	2,1	2,0	2,1
40	37	38	35	0,7/0,6	0,8/0,7	1,1/1,0	1,2/1,0	1,0	1,1	1,6	1,7
21	26	67	51	1,4/1,0	1,2/1,0	2,0/1,8	1,9/1,6	2,5	2,0	2,6	1,9
19	9	28	9	0,7/0,5	0,5/0,4	1,1/0,9	0,4/0,4	1,3	1,2	1,7	1,0
Σ 267	338	471	351								

front impact (F) : children(n=139, $\bar{v}_{KF}$ = 10,1±11%[m/s]), persons≥15y(n=125, $\bar{v}_{KF}$=10,5±12%[m/s]
corner/side impact (C/S): children(n= 52, $\bar{v}_{KF}$ = 11,0±11%[m/s]), persons≥15y(n= 43, $\bar{v}_{KF}$= 9,6±12%[m/s])

Fig. 7 Injury frequency , - severity and Traumatic Degree for body regions of pedestrians from different age groups under consideration of primary impact points at the vehicle exterior

vehicle front contours	all persons $OAIS_m/OAIS_n$	all persons f·ACD	all persons ACD/RCD (DM)	children(n=139) $OAIS_m/OAIS_n$	children f·ACD	children ACD/RCD (DM)	persons ≥15y (n=125) $OAIS_m/OAIS_n$	persons f·ACD	persons ACD/RCD (DM)
F (f=0,363)	3,5 / 2,7±0,6	60 000	165 300 / 88 000	3,3/2,7± 0,6	47 300	130400/ 62200	3,6/2,8± 0,6	74 300	204600/ 111 500
T (f=0,262)	3,5 / 3,1±0,7	41 500	158 500 / 118 900	3,5/2,9±0,6	37 800	144 400/ 85 600	3,5/3,8 ± 1,0	48 400	184 800 / 228 600
V (f=0,213)	3,4 / 2,4±0,8	35 000	164 200 / 44 100	2,1/1,3± 1,2	9500	44400/ 3900	4,0/3,2± 0,6	54 100	254 100 / 121 500
K (f=0,152)	4,3 / 2,9±0,6	46 700	288 200 / 97 000	4,2/2,3±0,6	34700	214 100/ 30000	4,4/3,4 ± 0,6	55 700	343700/ 181 800

f acc. involvem. rate (Han. 1976) , $OAIS_n = OAIS_{2,67n}$, $OAIS_n$ and RCD normalised to $v_{KF50\%}$ (V/P/T) = 9,3 m/s

Fig. 8 Average and normalised Overall Injury Severity ($OAIS_m/OAIS_n$), Absolute and Relative Cost Degree (ACD/RCD) as well as ACD of the whole collision under consideration of traffic accident involvement rates of different front contour types as well as age groups of the pedestrians (f·ACD) for vehicle front collisions

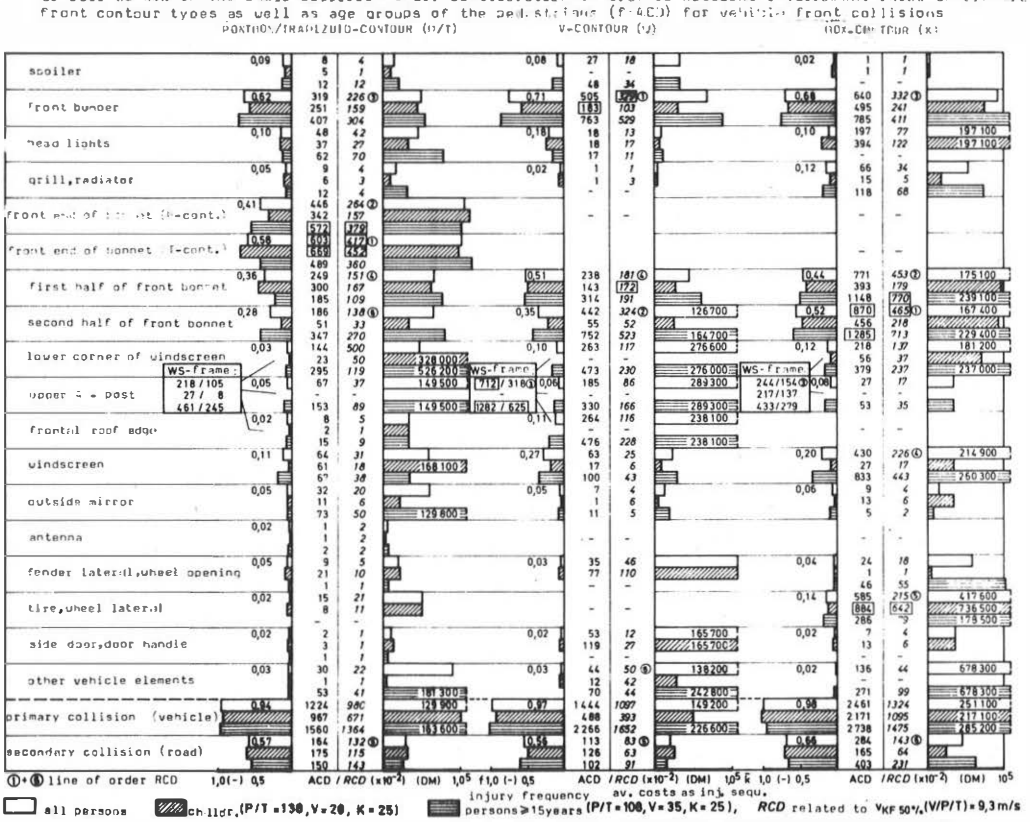


Fig. 9 Costs as injury sequence by exterior vehicle elements respectively by ground impact in pedestrian accidents under consideration of different vehicle front contours as well as people age groups

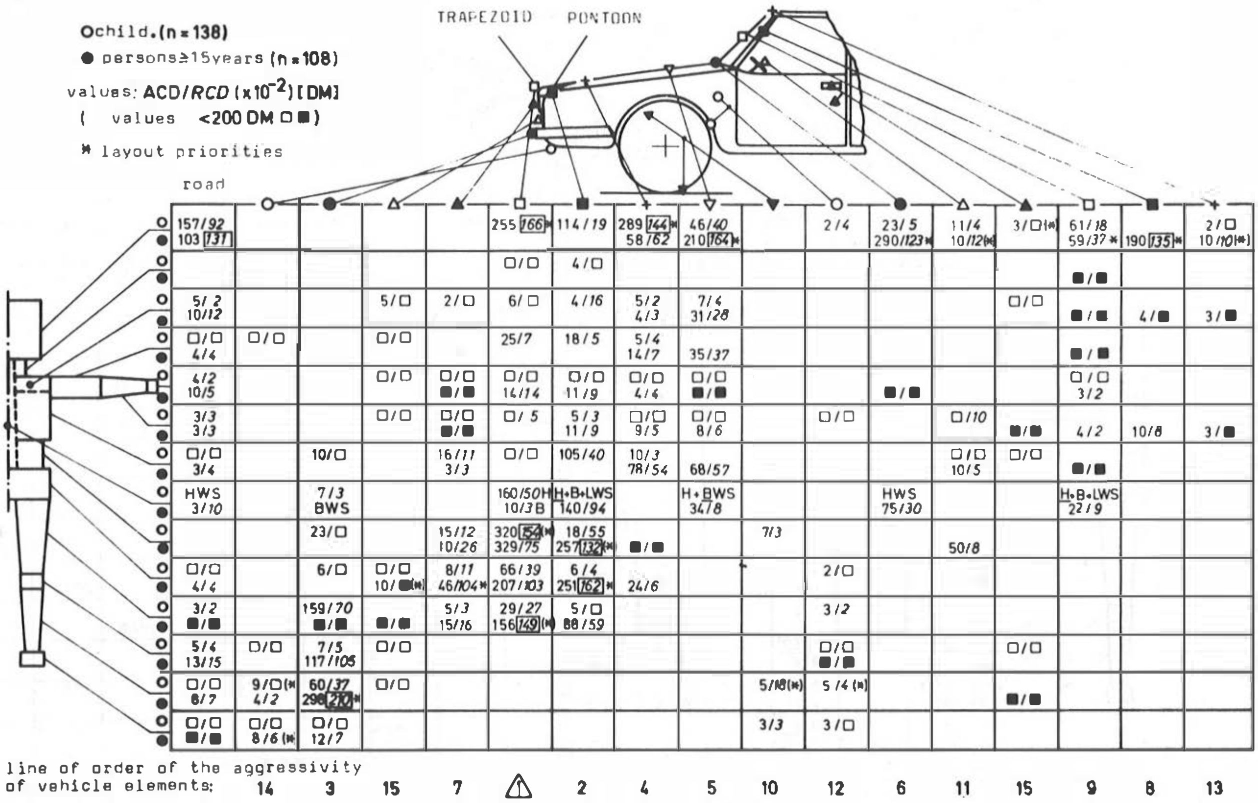


Fig. 10 Costs as injury sequence of exterior vehicle element / body region combinations in pedestrian accidents with P/T - front contours under consideration of people age groups

	vehicle element	type of injury : W soft tissue F sceletal I intern. organs	child. (n = 138) f [%]	child. ATD/RTD	child. AIS	pers.≥15y(n = 108) f [%]	pers. ATD/RTD	pers. AIS
13	spoiler	W	8	0,4/0,2	1,0	10	0,4/0,4	1,0
		F	2	0,5/0,2	2,4	2	0,5/0,4	2,0
		I		-			-	
3	front bumper	W	41	0,8/0,7	1,2	50	1,0/0,8	1,3
		F	28	1,7/[1,4]	2,6	46	2,0/[1,7]	2,7
		I	2	0,9/0,5	4,6		-	
8	head lights	W	10	0,6/[0,5]	1,5	4	0,4/0,4	1,4
		F	2	0,4/0,3	2,9	5	0,9/[1,0]	2,9
		I	1	0,3/0,4	2,0	1	0,5/0,8	3,0
14	grill,radiator	W	6	0,4/0,3	1,2	3	0,3/0,2	1,0
		F	1	0,3/0,3	2,0	1	0,5/0,3	3,0
		I		-			-	
2	front end of bon. Pontoon-contour	W	15	0,5/0,4	1,0	42	0,8/0,7	1,1
		F	11	1,2/0,8	2,9	38	2,1/[1,8]	3,1
		I	17	1,7/[1,2]	3,3	8	1,6/1,1	4,2
1 (△)	front end of bon. Trapez.-contour	W	42	1,0/1,0	1,3	27	0,6/0,6	1,0
		F	18	1,8/1,4	3,5	15	1,6/[1,4]	3,2
		I	24	2,4/[2,0]	4,0	9	1,8/1,1	4,5
4	first half of front bonnet	W	34	0,4/0,3	1,0	16	0,5/0,4	1,0
		F	7	1,1/0,8	2,9	8	0,5/0,3	3,3
		I	29	1,9/[1,5]	3,0	7	1,2/[1,0]	3,4
6	second half of front bonnet	W	12	0,6/0,5	1,3	32	1,1/0,7	1,1
		F	2	0,6/0,4	2,4	16	1,5/[1,4]	3,1
		I	9	0,9/[0,8]	2,3	19	1,5/1,2	2,8
7	windscreen frame	W	2	0,2/0,1	1,0	17	0,7/0,6	1,4
		F		-		9	1,7/1,2	4,1
		I	2	0,8/[0,6]	4,0	13	2,0/[1,6]	4,2
9	windscreen	W	4	0,3/0,2	1,0	19	0,6/0,5	1,2
		F	1	0,5/0,2	3,0	3	0,7/0,5	2,7
		I	3	1,0/ 0,7	3,8	8	0,8/[0,7]	2,3
11	outside mirror	W	5	0,5/[0,4]	1,6	3	0,3/0,3	1,0
		F	1	0,2/0,1	1,0	2	0,5/0,4	2,4
		I	2	0,4/0,3	2,0	4	0,9/[0,7]	3,2
12	fender lateral wheel opening	W	7	0,4/0,3	1,0	1	0,2/0,2	1,0
		F	4	0,6/0,4	2,0		-	
		I	1	0,2/0,2	2,0		-	
10	tire,wheel lat.	W	2	0,4/0,3	1,5			
		F	2	0,4/0,6	2,0		-	
		I	1	0,5/0,3	3,0			
15	side door,door handle	W	3	0,3/0,2	1,0	2	0,2/0,2	1,0
		F		-			-	
		I	1	0,3/0,3	2,0		-	
5	road	W	55	0,3/0,8	1,1	50	0,8/0,8	1,0
		F	5	0,3/0,6	2,5	13	1,1/1,0	2,2
		I	17	1,4/[1,1]	2,7	16	1,2/[1,3]	2,4

1 - 15 line of order of aggressivity by produced costs of injury sequence

Fig. 11 Types of injuries caused by exterior vehicle elements of P/T-front contours as well as by ground impact under consideration of age groups

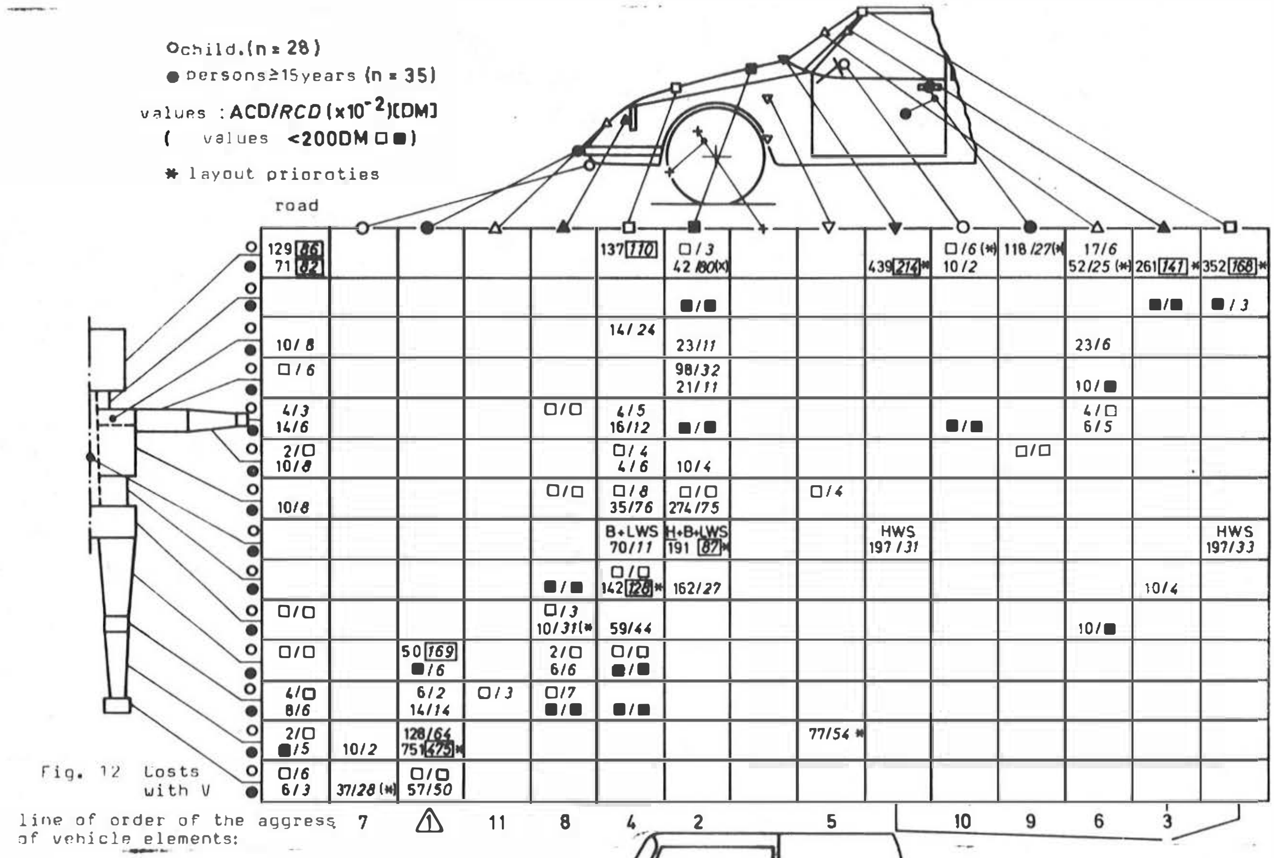


Fig. 12 Costs with V

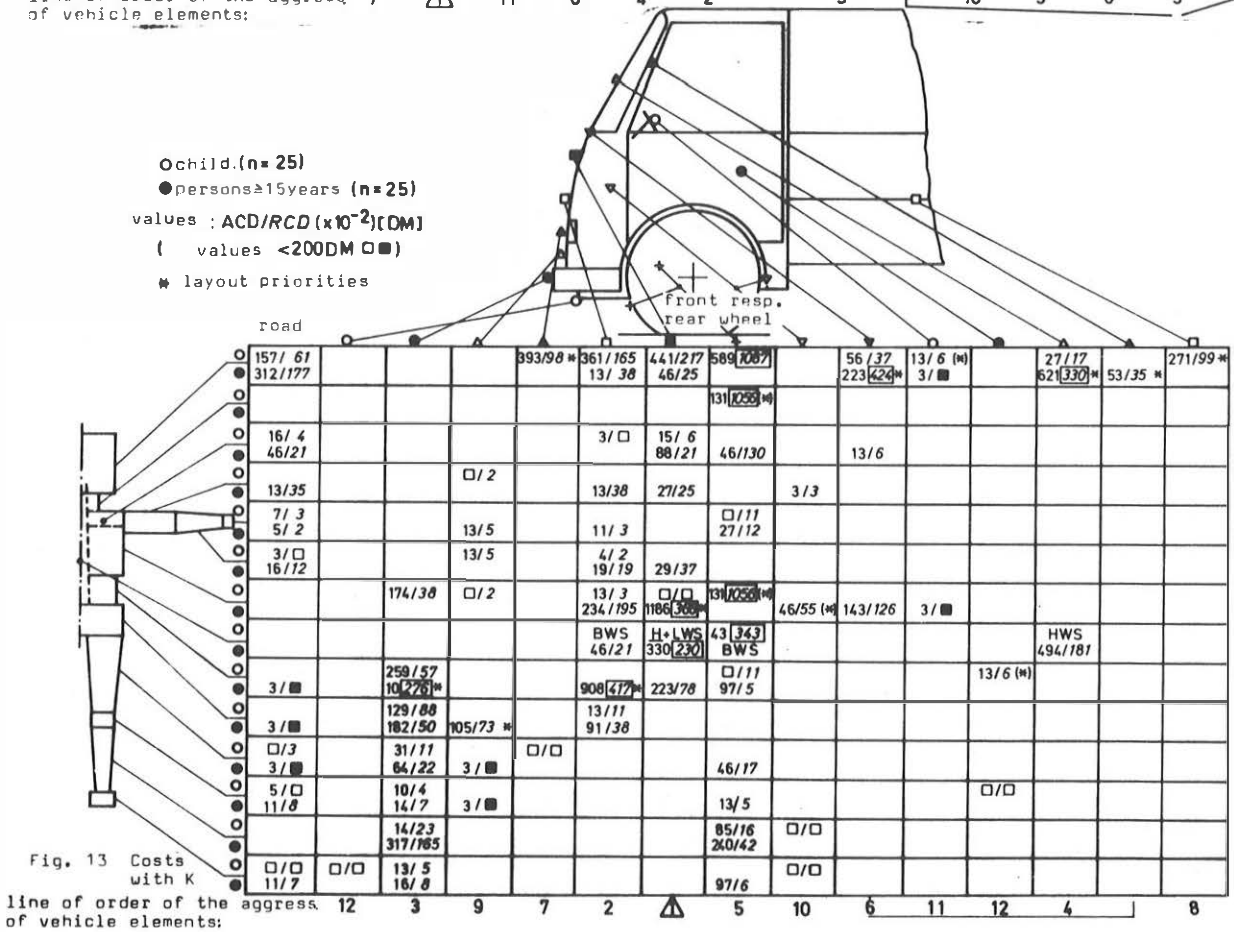


Fig. 13 Costs with K