KINEMATIC OF REAL PEDESTRIAN AND TWO-WHEEL RIDER ACCIDENTS AND SPECIAL ASPECTS OF THE PEDESTRIAN ACCIDENT

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S U R V E Y

The traffic accident development of the FRG for 1973 and 1974 shows that the total number of pedestrians and two-wheel riders killed as traffic participants in 1973 (51 p.c.) was higher than that of passengers killed in cars (49 p.c.) (14*). Due to different decrease of the absolute numbers, in 1974 by 22 p.c. for passengers (speed limitation, belt-user quota, etc.), and merely 2 p.c. for exterior road users, this correlation moved to a proportion of 56 p.c. of the latter.

The relative frequency of accident fatalities among age groups of injured traffic participants (fig. 1), a measure for the danger to traffic participants, is greatest with pedestrians and two-wheel riders and shows a positive incline for children with reducing, and adults with increasing age. From this follows that the aim of the passive safety of motor vehicles, i.e. the reduction of accident consequences, can only extensively be realized by cutting down the vehicle aggressiveness towards pedestrians and two-wheel riders.

For effective measures as far as the vehicles are concerned, but partly also for the reconstruction of accidents, the following points of investigation are of special importance:-

a) Analysis of the kinematic of real pedestrian and two-wheel rider accidents

b) Lay-out of parts of the vehicle exterior in accordance with the stressability of body regions, quantitatively by tracing the strongest traumatising exterior vehicle elements, and qualitatively by its correlation to the through this strongest traumatised body region.

Presupposition for the engagement of effective measures is the evidence of reliable results from real accident cases. While essential contributions were made regarding the passenger protection, such results are still widely missing in the pedestrian and two-wheel rider accident. This account is to be a contribution with a tendency to this thematic.

* number in parentheses designate references at end of paper

EXISTING RESULTS

- The average impact speeds for accidents with pedestrians are with adults 11 m/s (12), with children 7.8 (12), and 10.4 m/s (17), and 50 p.c. of the impact speeds for all pedestrians are under the value of 9.1 (16) and 9.4 m/s (18).

- The throw-on distance of the pedestrian increases according to the areas of vehicle contour, with the body-size of the pedestrian and the impact speed, and is with V-contours greater than with pontoon contours (16) (1). With pontoon contours, at a similar impact speed, it is for two-wheel riders bigger than for pedestrians (18).

- The lateral throw-off distance in real child pedestrian accidents depends on the impact point on the vehicle as well as the walking direction of the pedestrian (17) and shows the same tendency as with adult dummies (2).

- The throw-off distance for child pedestrians is 26 p.c. longer, compared to the one of adults for a group of all contour types (1).

- Without variation of contour types in real pedestrian accidents, children are normally more endangered than adults, but the elderly adult is more endangered at higher speeds (1). This corresponds with Fischer (5) who established that children sustain less severe injuries at higher speeds than adults.

- According to Patrick and to experiments from Japan, the primary impact with the vehicle is less dangerous than the secondary with the pavement (11). On the other hand, our dummy experiments (2) and investigations of real pedestrian accidents (16) (18) (5) (1) show that the overall injury degree OAIS (21 as well as the injury severity to the head is higher with the primary impact than with the secondary. The latter is also different according to Asthon (3), who established this relation only for perilous or fatal injuries.

- There is no difference in injury severity caused by secondary collision (road) between pontoon and V-shaped cars (1).

- The secondary severity of injuries to adult pedestrians who were involved in an accident, is with pontoon contours up to AIS 3 considerably higher than for children (18).

- Up to 40 km/h impact speed, the pontoon shaped cars cause more severe injuries than V-shaped cars which cause at 43 km/h less severe injuries (1). This is contrary to (5) (7) (8).

- A higher Traumatising Degree (frequency x severity of injuries) resulted from (16) (1) from the pontoon contour, compared with the V-contour for child pedestrians, and an opposing relation for people older than 15 years of age.

- The design of the front end drastically influences the rank of the most aggressive exterior vehicle parts (1). This is contrary to the results of (5) (7) (10).

- Body regions exposed to the highest risk (injury frequency multiplied by mean average injury severity) are endangered in this line of order:- head, shank, pelvis, thorax, for people over 15 years of age, and head, thigh and abdomen, for children (18). Differences are apparent when divided into different contour types.

- The head is the center of gravity in the traumatising of body areas of exterior traffic participants and takes first place as the cause of fatal injuries (18).

- For pedestrians the head is the part of body which sustains life-threatening or fatal injuries, and is more often injured by the vehicle than by contact with the pavement (3).

- Experiments with a dummy for head/vehicle impacts disclosed that the head/vehicle impact speed is for adults from 0.8 to 1.2 times that of the vehicle/pedestrian impact speed (15).

ACCIDENT SITUATION

This investigation is based on 230 medically and technically thoroughly documented real vehicle/pedestrian, and 127 two-wheel rider accidents, mostly from urban regions. The dates for these accidents were recorded by interdisciplinary data acquisition, mostly in Hannover, but also in Berlin.

A comparison of the usable single case analyses of the Accident Research Group of Hannover, with reservation, with the results of the traffic accident development of the FRG for 1973/74 (fig. 2) shows a higher involvement rate of child pedestrians, due to the fact that our investigation teams do not work during the night.

For the quantitative optimisation of the vehicle exterior, the allocation of primary impact points of cases with personal damages at the vehicle exterior has to be taken into account. From the relative frequency of primary impact points

Research programs, financed by the Federal Authorities of Road Systems, Cologne, FRG.

on the vehicle (fig. 3) it can be seen that the vehicle is contacted to 41 p.c. by pedestrians, and to 60 p.c. by two-wheel riders most frequently at the central region of the vehicle front, at least 25 p.c. of the vehicle width away from the vehicle edge. There will be a possible underrepresentation of the side impact on the vehicle, due to the fact that almost only cases are documented in which physical parameters, such as the impact speed, could be calculated. Pedestrians get up to 92 p.c., and the two-wheel riders up to 54 p.c. laterally hit. The most common impact points are found to 47 p.c. on the left side of the pedestrians body, and on the front of the two-wheel vehicle.

GENERAL KINEMATIC DATA

An analysis of the ratio of impact points with primary head injuries to pedestrians, in relation to the number and position of impact points caused to the pelvis at the vehicle front side can be seen from fig. 4. The most frequent primary head impacts occure in the region between 30 and 50 p.c. of the vehicle width, measured in walking direction of the pedestrian. This not symmetrical to the middle of the vehicle front area, in connection with the decrease of the frequency of primary head impacts to the vehicle edge could, because of its correspondence to the lateral throwing distance (fig. 13 - 15) from which the lateral speed components result, gets in the region between 30 and 50 p.c. to zero.

To illustrate the kinematic of real pedestrian and two-wheel rider accidents and as a reference figure for the severity of injuries, the collision speed at the beginning of the crash was determined. For pedestrians the latter was established from skid marks, road surface, collision point and decreasing vehicle speed in consequence of power conversion during the collision phase. The speed vector vertical to the impact area was calculated from the driving direction of the two-wheel rider at the time of collision, and the skid marks of the two-wheel vehicles, under consideration of a not full-plastic impact. In exceptional cases the impact speed was established with the help of drivers statements (fig. 5). In regression analyses with different set-ups, the best correlation was found for set-up III, followed by its lowest variance.

A comparison between the impact speed, in which up to 50 p.c. of collisions with personal damages happen (perished means here in the diagrams the group of fatally and not fatally injured persons) (fig. 6), show with two-wheel riders with 12.3 m/s a higher value than for pedestrians (9.5 m/s). 90 p.c. of pedestrian collisions occur below 15 m/s.

To determine the effect of parameters of vehicle and traffic participants on the kinematic of motions, the vertical height of center of gravity of pedestrians and two-wheel riders were calculated (fig. 7.8), taking into account the heel height of shoes worn by pedestrians and the usually forward-bent sitting position of the two-wheel rider (4) (20). For the child-pedestrians 50 p.c. of the height of centers of gravity were below 71.3 cm, and for people from 15 years of age upward below 96 cm. For two-wheel riders whose 50 p.c. value exceeds that of the pedestrians by 2.5 cm, an essential difference results after the type of the two-wheel vehicle.

For child and adult pedestrians, motor cyclist and cyclist result - with similar contour types - in their proportions differing points of resultant impact forces (fig.9). The position of these impact forces is, in turn, a result of the vehicle front geometry, and climb in their vertical height from the V via the pontoon to the box contour. The outcome of this is transversal and rotary acceleration. Because of their direction pedestrians and two-wheel riders in collision with pontoon and V-contours, are thrown on to the vehicle. Child pedestrians get thrown on V-contours, with pontoon contours, however, only the older children. With the box contour no further throw-on to the vehicle occurs, after the first primary contact, due to its high and almost closed front contour.

Generally an impact of the bumper against the lower extremities occurs at the begin of the collision, and from this results a rotary acceleration around the center of gravity in body. The impact to the pelvis of the adult pedestrian, respectively the two-wheel rider, by the front edge of the bonnet of V and box contour follows immediately after this and causes - at least in the first and third case - a strong translatory acceleration component.

SPECIAL KINEMATIC DATA

The THROW-ON-DISTANCE is of importance to the constructive reduction of primary injury severity, in order to create a safer permissible vehicle contour for the most common range of collision speed, ocurring in urban traffic. For its illustration its relation to the vertical distance between the center of gravity in the body and the front edge of bonnet, respectively the bumper, as well as the impact speed were analysed.

For the detection of tendencies, linear regression curves were calculated for every region, and only cases of vehicles involved in frontal collision have been used.
For pedestrians in collision with pontoon shaped vehicles (10) the throw-on distance increases mainly with the height of center of gravity as well as with the collision speed.

To realise the importance of the throw-on distance with regard to the 50 p.c. impact speed in urban regions, applied to the groups adult and child pedestrians, the geometrical parameters of typical representatives of these groups will have to be used. From the 50 p.c. values by fig. 7 results that the windscreen contact, respectively a throw-on distance of more than 100 cm will be possible (dynamic average height of front edge of bonnet = 72.3 cm) at 50 p.c. impact speed for adult pedestrians (ΔCg = +25 cm) and one in the region of 25 to 49 cm for child pedestrians (Δcg = +10 cm). A roof contact for adults is possible at a level of the 90 p.c. impact speed. For the V-contour (fig. 11) (dynamic average height of the bumper 34.2 cm) the 50 p.c. impact speed means a greater throw-on distance because there will - beside the windscreen impact - possibly be an impact to the roof with people over 15 years of age (Δcg = 64 cm) and one between 50 to 74 cm for children (Δcg = 37 cm).

For the two-wheel rider (fig. 12) results from this by their 50 p.c. impact speed and the height of their center of gravity (shown in fig. 6 and 7) that the typical cyclist (Δcg = + 24 cm) will possibly have contact with the roof of pontoon contours and the typical motor-cyclist will have a throw-on height of less than 50 cm.

The throw-off distance in real pedestrian accidents is of special importance for questions of accident reconstruction. It occurs in and perpendicular to the driving direction and is defined as the distance between impact spot on the road and final position of the pedestrian.

The throw-off distance in driving direction is primarily dependent on the impact speed of the vehicle, body height (size) and position of the primary (bumper) and the secondary (front edge of bonnet, respectively the bonnet) position of impact point on the vehicle, as with slanting contact areas it will lead to a dispersion of the resulting impact force into horizontal and vertical vector. Only cases were used in which the vehicles emergency brakes were operated, at least shortly behind the point of collision.

The throw-off width perpendicular to the driving direction (fig. 15), as seen from the linear regression curves, is primarily dependent on the walking direction of the pedestrian and the position of impact point to the middle of the vehicle front. The influence of the latter can be allocated to arrowed vehicle parts, like bumpers, front line of bonnets, respectively rounded-off bonnets. A generally bigger lateral throw-off distance occurs to the child pedestrian. A comparison basing on the common pontoon contour (fig. 15) shows - according to the regression curves - an even bigger lateral throwing distance for children. The partly overlapping of the 90 p.c. confidence intervals of the regression co-efficients must, however, not be overlooked.

The analysis by influence of the contour type shows - under consideration of adult pedestrians - a significant difference between the contour types with a big lateral throwing distance of the V-contour (fig. 14).
The influence of the impact speed - concurring cause for the big distribution of dates - can from fig. 13 and 15 only be seen in a greater number of big lateral throwing distances.

It can be seen from the illustration of the throw-off distance of child pedestrians in driving direction for different positions of impact points - under consideration of various velocity levels - that with contact in the border areas no big transversal throw-off distance occurs (fig. 16).

Taking a sample of cases in which the impact points on the vehicle front did not lie near the edge, the throw-off distance was shown in relation to the collision speed. To point out significant differences through contour types as well as influence through the body height of the pedestrian, the dates were analysed according to the groups:- child, people over 15 years of age, two-wheel rider, pontoon, V- and box contour.

In fig. 17 , the initial dates and the results of the regression analysis for pontoon contours are shown. The lowest variance was found through linear regression set-ups with cubic share. For child pedestrians a 20 p.c. bigger throwing distance occurs. The same tendency is found by a mathematical simulation program (6) with a bigger throwing distance of the lighter pedestrian.

A comparison of the throw-off distance of pontoon contours with that of V-contours (fig. 18) and box contours (fig. 19) shows the largest throwing distance for pontoon contours, followed by V- and box contours (fig. 20). In view of the low number of cases, no clear distinction caused by age groups of people could be detected for the V-contour. For the box contour a merely linear increase of the throw-off distance with impact speed is apparent.

The result of child dummy experiments, without distinction by contour types, show a tendency in fig. 20 to a bigger throwing distance of the dummy, compared with the living human being. For two-wheel riders and pontoon contours a nearly linear dependancy of the throw-on distance to the impact speed (fig. 21) was shown.

SPECIAL ASPECTS OF ENDANGERED BODY REGIONS

For the analysis of influences of various parameters on the traumatising of pedestrians, the confrontation of the injury severity, according to AIS (22) above the average impact speed will be used in the following. The calculation of mean values is made horizontally (average speed for a certain injury severit degree). This has the advantage of average values being up to lower numbers of cases ascertained from normally spread-out densities.

Presupposition for comparison by a parameter is the conformity of the average impact speed of both comparable groups. In order to arrive with different average impact speeds at a sound declaration, a factor AISm/Vm was calculated. The value (p) of the random probability shows whether a significant difference between the average values of AIS degrees exists for each parameter.

The value (s) of the standard distribution is a measure for the allocation of dates (impact speeds) to their single AIS-degrees.

The diagrams to injury frequency, aggressivity and influence of the parameter impact speed, refer only to accidents in which the vehicle was not impacted in the edge area on the vehicle front.

An analysis of the dates by primary and secondary injury severity of pedestrians (fig. 22, 23) divided into impacted contour types, shows for children and other people a greater danger from the primary (vehicle) collision. Merely on the basis of AIS 2 are these results not definite.

The vehicle exterior reveals differing aggressive contacts depending on traffic participant group, but also on contour type.

The impact with the ponton contour leads with children to abdominal, with small children to thoratic, respectively head impact, with the front edge of the bonnet. With adults it leads - as a result of the center of gravity in body being situated above the height of the front edge of the bonnet - to a rotation around this area and to an impact of thorax and abdomen against the front bonnet, respectively the windscreen area. Higher impact speeds cause a rotation of the center of gravity in body around this contact area with consecutive impact to the roof of the vehicle.

The mutual aggressive vehicle regions for the three traffic participant groups proved to be the bumper, front edge of bonnet and lower corner of windscreen.

From emergency braking at the time of contact results, as far as the vehicle is concerned, a sliding-back of the traffic participant - throwing-off after throwing-on - through his lesser deceleration, compared with that of the vehicle. Following this, the pedestrian hits the road surface in a slanting position with the remaining speed and - after another delay - comes to rest.

The greatest common primary danger (AISm/Vm) comes for children from the box and for people over 15 years of age from the pontoon contour. As quantitative aspect for the optimisation of the vehicle exterior, the injury degree of the pedestrian, at the 50 p.c. speed limit, is of special importance. Up to 9.5 m/s the pontoon contour shows with child pedestrians, and almost up to 9.5 m/s, with people over 15 years of age, the greatest primary danger degree.

On the basis of the most frequent contour type, the pontoon contour, it has to be established whether a different primary danger to body regions results, according to the level of average impact speeds.

The lower average impact speeds and, therefore, a greater danger are in the region AIS 1 + 3 for abdomen and lower extremities of child pedestrians, on the same level (fig. 24). From AIS 5 and 6 the head region is more in danger.

Up to the level of the 50 p.c. impact speed of pedestrians, the lower extremities of people over 15 years of age are most endangered, especially those of elderly adults, followed by injuries to thorax and head injuries (fig. 25).

As the head faces the generally greatest danger, due to the injury frequency (18), and the low average speed levels of high injury severity degrees, a differential division by age groups and contour types (fig. 26) is necessary.

The greatest danger results for children from the box contour, followed by the pontoon contour and the V-contour, for people over 15 years of age - also on the level of the 50 p.c. impact speed.

A subdivision by the also greatly endangered lower extremities (shown in fig. 24 and 25) shows a generally highest degree of danger from the pontoon contour, for elderly pedestrians, also up to the 50 p.c. impact speed (2)).

For the analysis of Injury Models of pedestrians in connection with different contour types, concerning age groups, injury frequency and degree as well as a Relative Traumatise Degree of various body regions were determined. The Relative Traumatise Degree (RTD), a further development of the Traumatise Degree (TD) (17) is defined here for the first time, as product of the injury frequency, with the square mean AIS, divided by average impact speed with the simplification of a quadratic variation between AIS, respectively OAIS values and a linear one for its dependance on the impact speed, also comparisons with existing various speed levels are possible. Finally it should be a usable measure for the total traumatic damage to a body region, without ignoring the physical parameters.

The endangered body regions of child pedestrians (fig. 28) are the head with box contours, the thigh with pontoon, and the shank with V-contours.

The endangered body regions of child pedestrians (fig. 29) are the head for box contours, followed by V- and pontoon contours, the shank with V- and pontoon contours, and the thorax with box and the pelvis with V-contours.

AGGRESSIVITY OF EXTERIOR VEHICLE PARTS

The correlation of injured body parts and the injury causing vehicle part offers the possibility to adapt the deformation characteristic single vehicle elements to the biomechanical values of the primarily injured body regions. The aim of this investigation is to find out which vehicle element is the most dangerous for which body region, which age group, and to give priorities to details on vehicles in line of order of their aggressivity.

Divided into typical contour types (fig. 30), the head of child pedestrians receives the highest RTD through the radiator area of the box contour, as well as the first half of bonnet of the pontoon contour. With the V-contour the bumper causes the highest RTD to the shank of the child.

For people up to 15 years of age the highest RTD is caused by the bumper of V-contours, to the shank with V-contours, followed by the bumper of pontoon contours to the shank, and to the head by the windscreen frame of the V-contour.

For the most common pontoon shaped vehicle can be said by fig. 31 that the position of impact points at the vehicle front contour does not only influence the primary injury frequency of the head, but also the degree of suffered injury severity (fig. 32). For pontoon contours the edge area proved to be the most aggressive one. From the V-contour comes - besides the edge area - on running into the vehicle - the greatest danger, and also from 0 to 20 p.c. behind the middle of the vehicle front, measured in walking direction. An explanation for this fact could be a bigger sideways throw-on distance for the V-contour. The aggressive A-post would so only be touched when colliding primarily at an impact point near the middle of the vehicle. Self-explanatory for this would also be the absence of primary head injuries for impact points in the area within 70 to 100 p.c. at the vehicle front.

To determine the aggressivity of exterior vehicle parts, two new aggresivity indexes were defined. The first as a product of injury frequency and average AIS (RA), caused by contact with the vehicle element. A new one, shown for the first time, gives more consideration to the non-linearity of the Abbreviated Injury Scale, by taking the product of injury frequency and square of the square mean value of the injury severity, called Relative Aggressivity Degree (RAD), also caused by vehicle element contact. Depending on the contour type, the child receives the highest RAD with box contours through the bumper, with pontoon contours through the front-end of bonnet, and with the V-contour through the bumper. People over 15 years of age suffer the highest RAD by the front-end of bonnet and with the box contours by the front bonnet and lower corner of windscreen, with the V-contour by the bumper.

S U M M A R Y

The investigation of 230 real pedestrian and 127 real two-wheel rider traffic accidents (not all results are statistically assured, due to the limited number of cases), shows the following important tendencies:-

- 50 p.c. of traffic accidents involving injured pedestrians occured up to 9.5 m/s and with two-wheel riders up to 12.3 m/s impact speed.

- The throw-on distance increases mainly with body height, but also with impact speed of the vehicle. At 50 p.c. of the impact speed there will possibly be an impact to the windscreen area for adult pedestrians in collision with pontoon and one to the roof with V-contours. At the 50 p.c. impact speed of cyclists there will be possibly an impact to the vehicle roof.

- Thc lateral throw-off distance is highest for children and V-contours.

- The throw-off distance is - at the same impact speed - biggest for children and increases from the box to V- and the pontoon-contour. For the two-wheel rider it results in a nearly linear incline with the impact speed.

- The primary injury severity of pedestrians is for all age groups and contour types at all impact speeds more serious than the secondary. There are differences between age groups, depending on the contour types.

- Up to high average impact speeds, the abdomen of the child is more severely injured than the head. For people over 15 years of age, the lower extremities are more endangered, replaced at higher average impact speeds by thoratic and head injuries.

- The box contour causes the highest injury severity, depending on impact speed, to child pedestrians, and the pontoon contour to people over 15 years of age.

- The highest RTD of body regions of pedestrians shows for the child the head, followed by the thigh with pontoon, the shank with V-contours. The highest RTD for people over 15 years of age results also for the head, followed by the shank with V- and pontoon contours.

- The most aggressive vehicle parts for pedestrians, measured by RAD, are the bumper of box contours for children, followed by the front-end of bonnet of pontoon contours for people over 15 years of age, and the upper and lower part of the bonnet of box contours for children.

The knowledge about typical injury models of pedestrians, children as well as adults, provides in connection with aggressivity analyses of the vehicle exterior criterias for the optimisation of the vehicle outside with the aim to reduce accident consequences. Measures have to start at the most aggressive vehicle element and followed by development of an optimal vehicle front geometry, under consideration in line of action with the most traumatised body regions of exterior road users.

R E F E R E N C E S

(1) APPEL,H. STÜRTZ,G. GOTZEN,L.
Influence of Impact Speed and Vehicle Parameter on Injuries of Children and Adults in Pedestriam Accidents IRCOBI, Birmingham, England, September 1975.

(2) APPEL,H. KÜHNEL,A. RAU,H.
Einfluß der Eigenbewegung eines Fußgängers auf die Verformung des Fahrzeugverbandes beim Zusammenstoß Fahrzeug-Fußgänger.
Forschungsbericht Nr. 183, Institut für Landverkehrsmittel, TU Berlin.

(3) ASHTON,S.J.
The Cause and Nature of Head Injuries sustained by Pedestrians IRCOBI, Birmingham, England, September 1975.

(4) COTTON,F.S.
The Center of Gravity in Man
American Journal of Physical Anthropologie
Philadelphia, USA, Vol. 18. No. 3, Jan-Mar 1934.

(5) FISCHER,A.J. HALL,R.R.
The Influence of Car Frontal Design on Pedestrian Accident Trauma Accident Analysis and Prevention, Vol. 4, 1972.

(6) GLÖCKNER,H.
Möglichkeiten und Grenzen der rechnerischen Simulation des Fußgängerunfalls
Lecture at the AFO/GUFU/ILM-TUB Seminar
Köln, FRG, Oktober 1975.

(7) HALL,R.R. and FISCHER,A.J.
Some Factors Affecting the Trauma of Pedestrians Involved in Road Accidents
The Medical Journal of Australia, 1972, 1.

(8) HALL,R.R. VAUGHAN,R.G. and FISCHER,A.J.
Pedestrian Crash Trauma and Vehicle Design in New South Wales, Australia
Third International Congress on Automotive Safety
San Francisco, USA, July 1974.

(9) KÜHNEL,A.
Preliminary unpublished Results of Child-Pedestrian-Dummytests, April 1976.

(10) MACKAY,G.M.
Injury to Pedestrians
CCCMS, NATO, Brussels, Belgium, February 1972.

(11) MC LEAN,A.J.
Car Shape and Pedestrian Injury
National Road Safety Symposium
Cauberia, Australia, March 1972.

(12) MC LEAN,A.J. and MACKAY,G.M.
The Exterior Collision
SAE 700434

(13) SACHS,L.
Angewandte Statistik
FRG, Springer Verlag, 4. Auflage, 1974.

(14) Statistic Federal Office, Wiesbaden, FRG
Straßenverkehrsunfälle 1973, 1974
Kinderunfälle im Straßenverkehr 1974, VC-81, Okt. 1975

(15) STCHERBATCHEFF, G. and others
Reconstitutions Experimentales d'Impacts Tete-Vehicule de Pietons Accidents
IRCOBI, Birmingham, England, September 1975

(16) STÜRTZ,G. SUREN,E.G. GOTZEN,L. RICHTER,K.
Analyse von Bewegungsablauf, Verletzungsursache, -schwere und -folge bei Fußgängerunfällen mit Kindern durch Unfallforschung am Unfallort.
IRCOBI, Lyon, France, September 1974 and
Der Verkehrsunfall, February 1975, Heft 2.

(17) STÜRTZ,G. SUREN,E.G. BEHRENS,S. GOTZEN,L.
Biomechanik realer Kinderfußgängerunfälle
International Congress for Traffic Matters and Traffic Accidents (Traumatology)
Ankara, Turkey, Mai/June 1975.

(18) STÜRTZ,G. SUREN,E.G. GOTZEN,L. BEHRENS,S. RICHTER,K.
Kopf-, Hals- und Wirbelsäulenverletzungen und Todesursachen bei Äußeren Verkehrsteilnehmern
IRCOBI, Birmingham, England, September 1975.

(20) SWEARINGEN,B.B. and YOUNG,I.W.
Determination of Centers of Gravity of Children sitting and standing
Civil Aerospare Research Institute, Federal Aviation Agency
Oklahoma City, USA, No.AM 65, August 1965.

(21) The Abbreviated Injury Scale (AIS)-Preliminary- 18 th Conf. of American Association for Automotive Medicine
USA, Dezember 1974.

(22) The Abbreviated Injury Scale (AIS) -1976 Revision-
American Association for Automotive Medizine, USA, 1976.

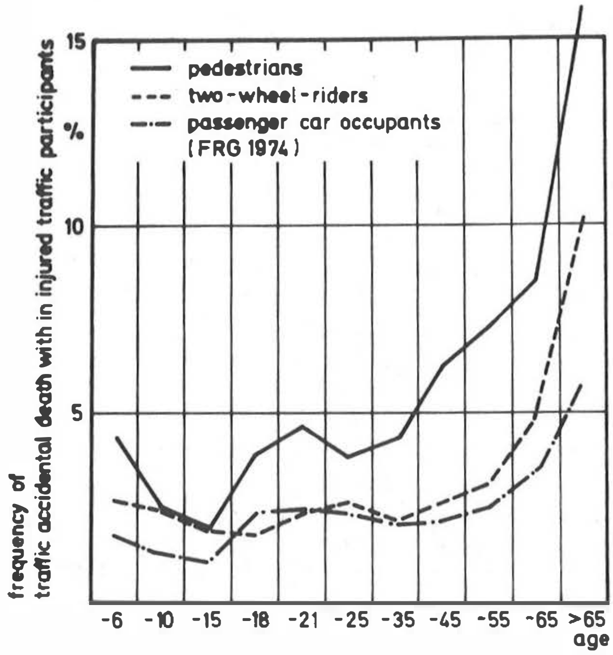


Fig.1 Relative mortality of different traffic participants versus age

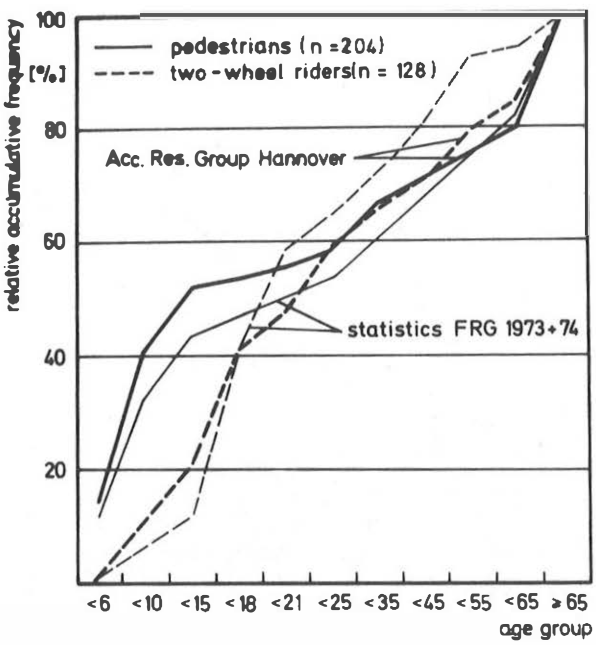
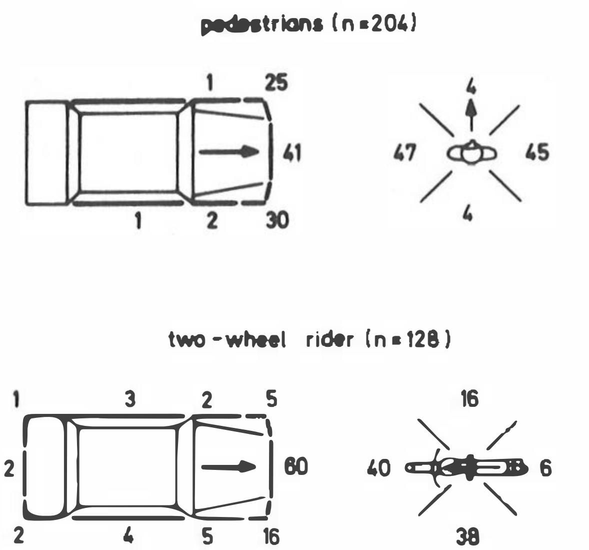


Fig.2 People-age-groups involved in pedestrian and two-wheel rider accidents



(dates in p.c. of the Traffic Accident Research Group Hannover)

Fig.3 Relative frequency of primary impact points for motorcar, pedestrian and two-wheel rider

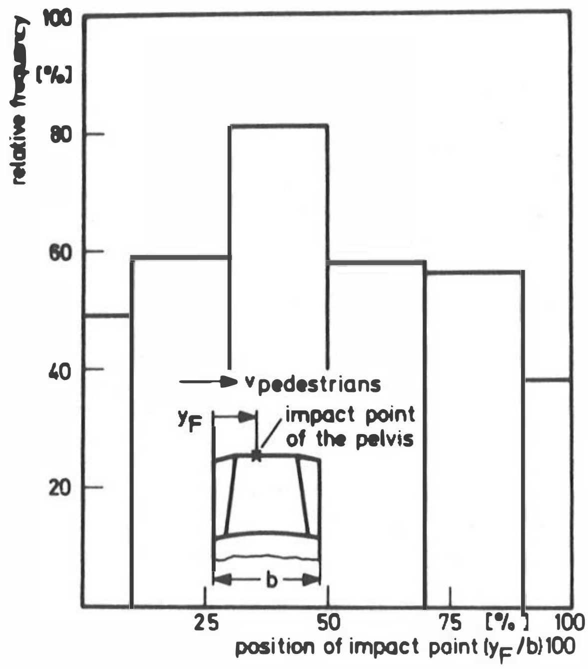


Fig.4 Relative frequency of primary headinjuries related to the number and position of impact points of the pelvis at vehicle front side (only pontoon- and V-contours, n = 175)

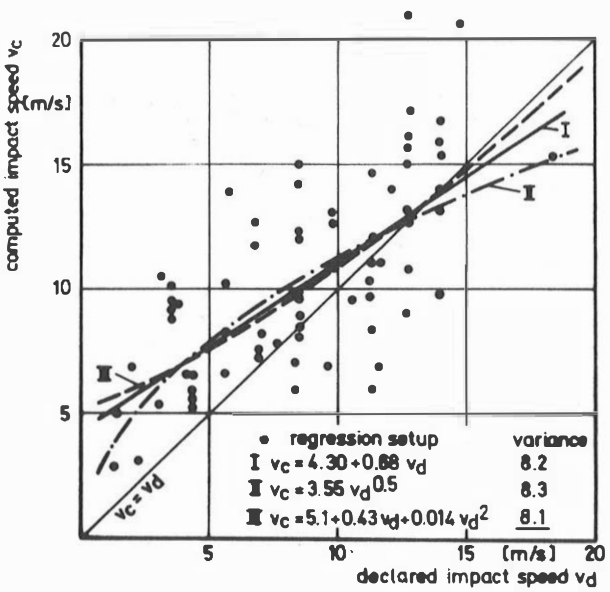


Fig. 5 Comparison of declared (driver) and computed impact speed (n = 71)

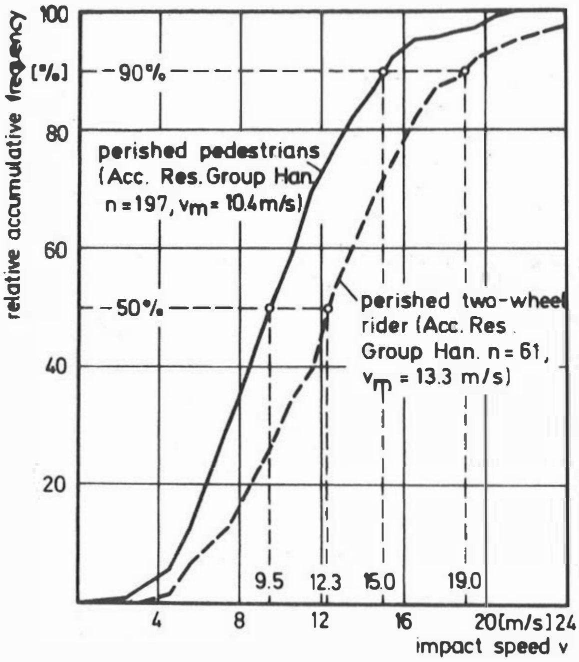


Fig. 6 Relative accumulative frequency of difference impact speeds perpendicular to the front of motorcars in pedestrian and two-wheel rider collisions

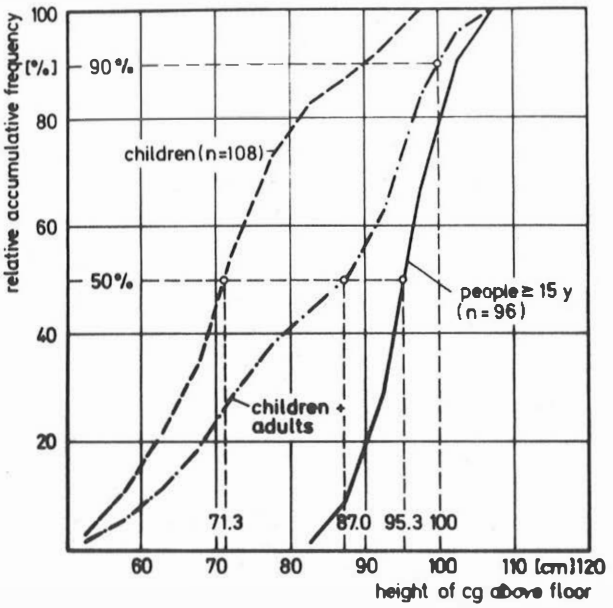


Fig. 7 Relative accumulative frequency of the vertikal height of center of gravity in body for perished pedestrians

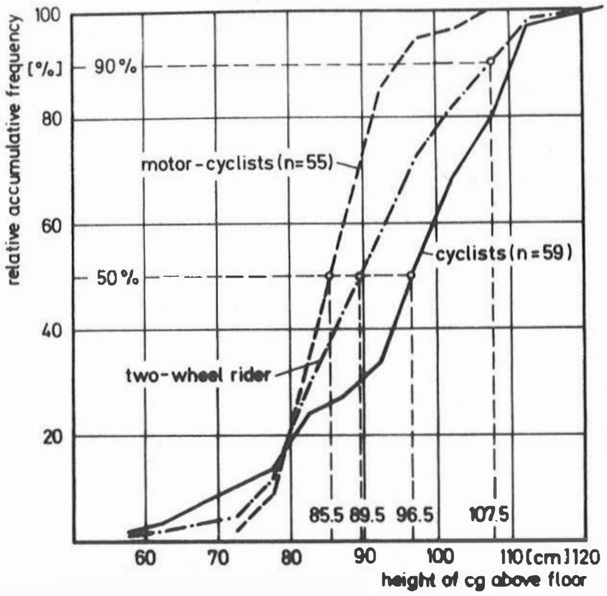


Fig. 8 Relative accumulative frequency of the vertikal height of center of gravity in body in sitting position for perished two-wheel riders

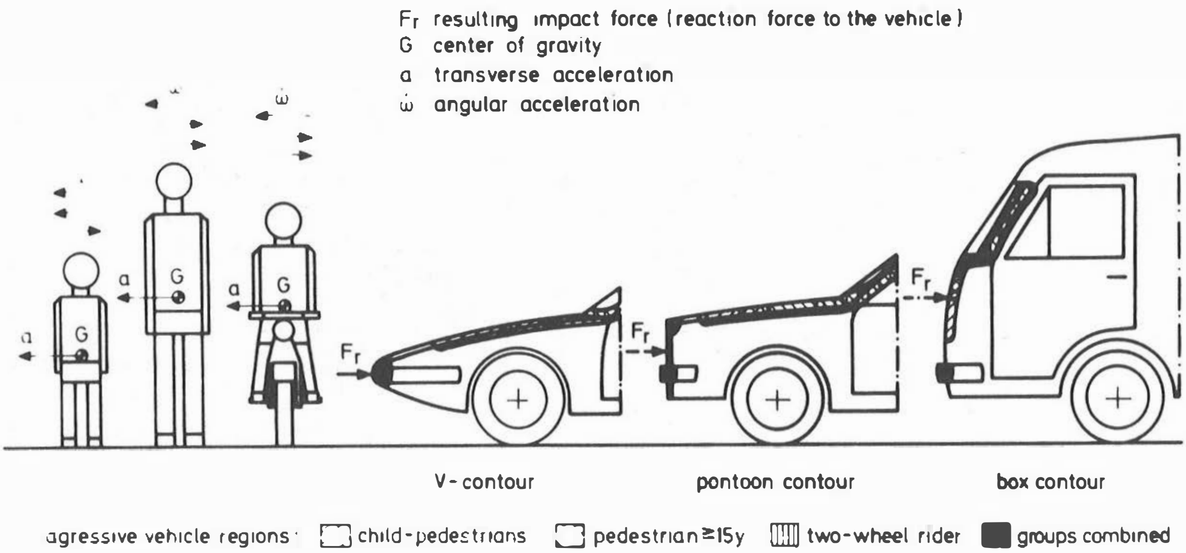


Fig 9 Influence of the vehicle front geometry to the resultant initiated force and to the vector of rotary and transvers acceleration of pedestrians and two-wheel riders

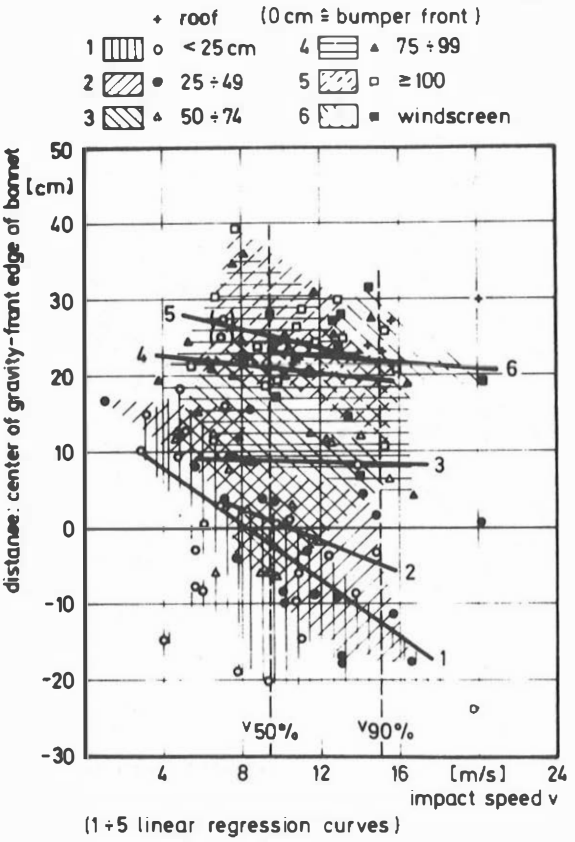


Fig. 10 Throw on wide for pedestrians versus impact speed for passenger cars with pontoon contour in frontal collision

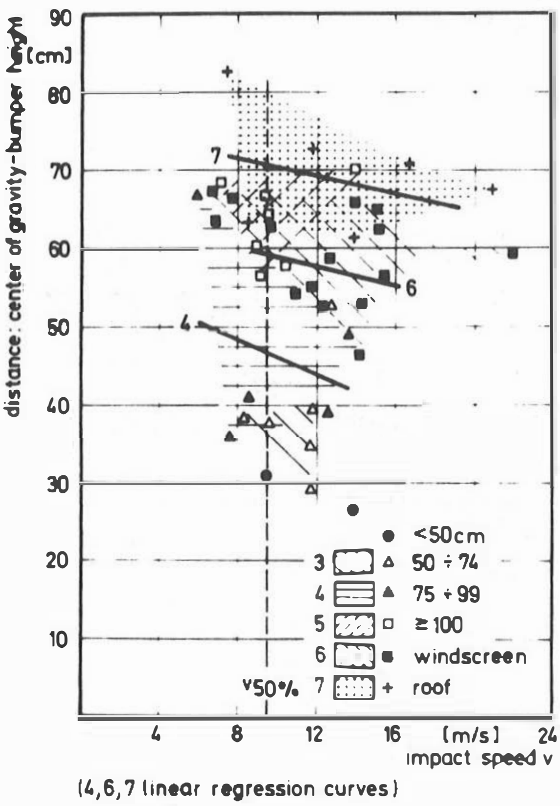
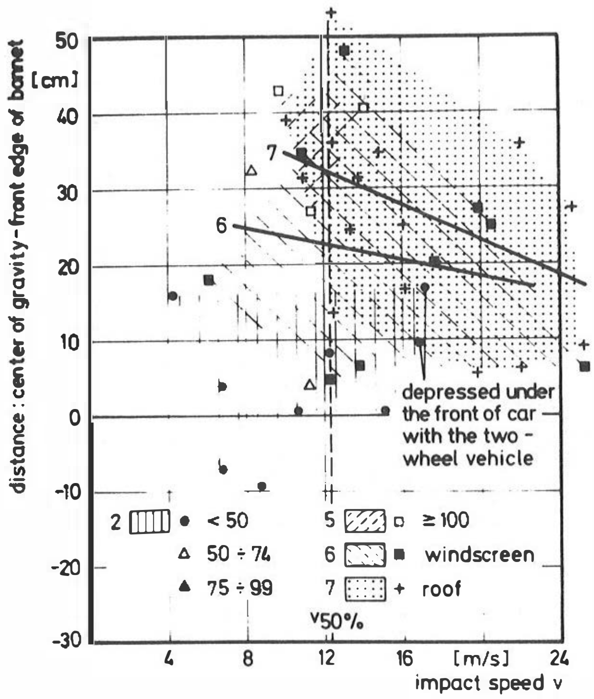


Fig. 11 Throw on wide for pedestrians versus impact speed for passenger cars with V-contour in frontal collision



(2,6,7 linear regression curves)

Fig. 12 Throw on wide for two-wheel-rider versus impact speed for passenger cars with pontoon-contour in frontal collision

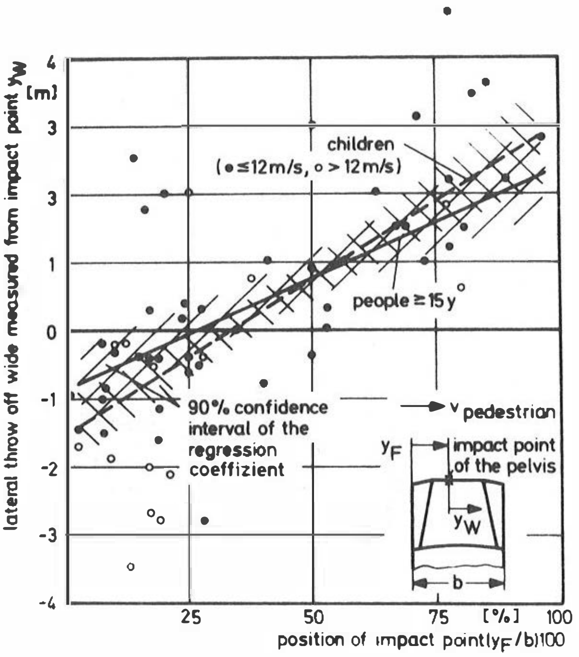
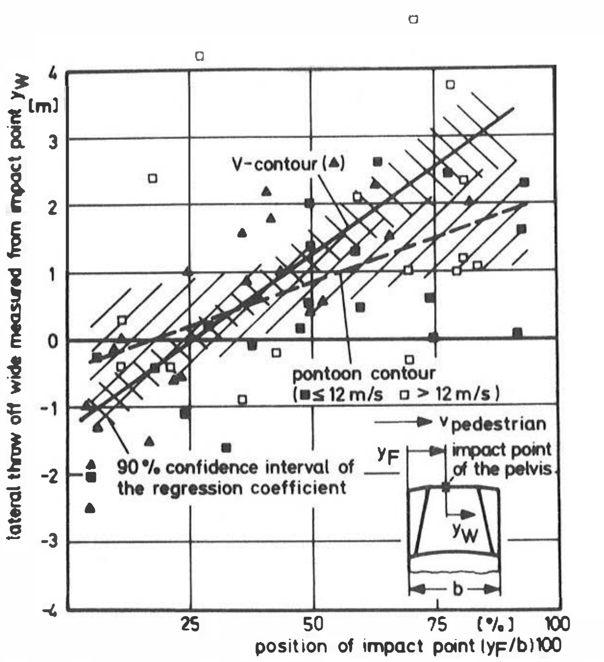
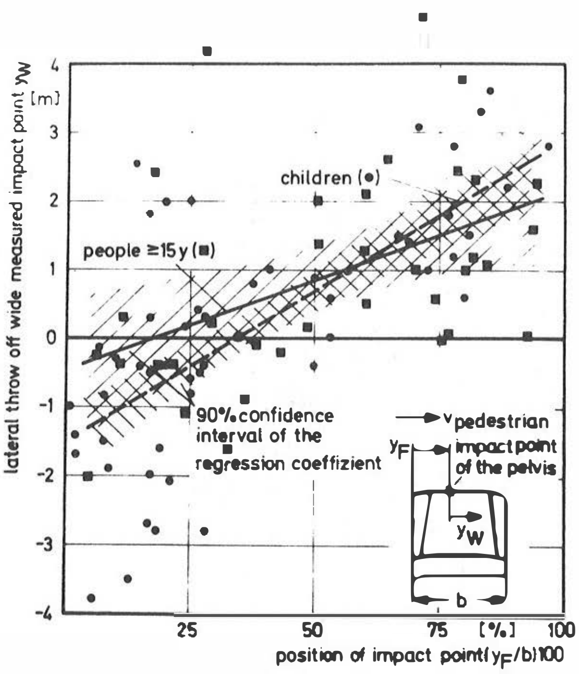


Fig. 13 Lateral throw off wide of pedestriansin walking direction versus position of impact point at vehicle for different people age groups



V-contour (n = 20, $r2 = 0.67$, $p < 1\%$), $y_W = -1.36 + 0.052(y_F/b)100$
pontoon contour (n = 38, $r^2 = 0.21$, $p < 1\%$), $y_W = -0.43 + 0.026(y_F/b)100$

Fig. 14 Lateral throw off wide of pedestrians (≥15 y) in walking direction versus position of impact point at vehicle for pontoon- and V-contours



children (n = 53, $r^2 = 0.47$, $p < 1\%$), $y_W = -1.49 + 0.043(y_F/b)100$
people ≥ 15 y (n = 38, $r^2 = 0.21$, $p < 1\%$), $y_W = -0.43 + 0.026(y_F/b)100$

Fig. 15 Lateral throw off wide of pedestrian in walking direction versus position of impact point at vehicle for pontoon-contour and different people age groups

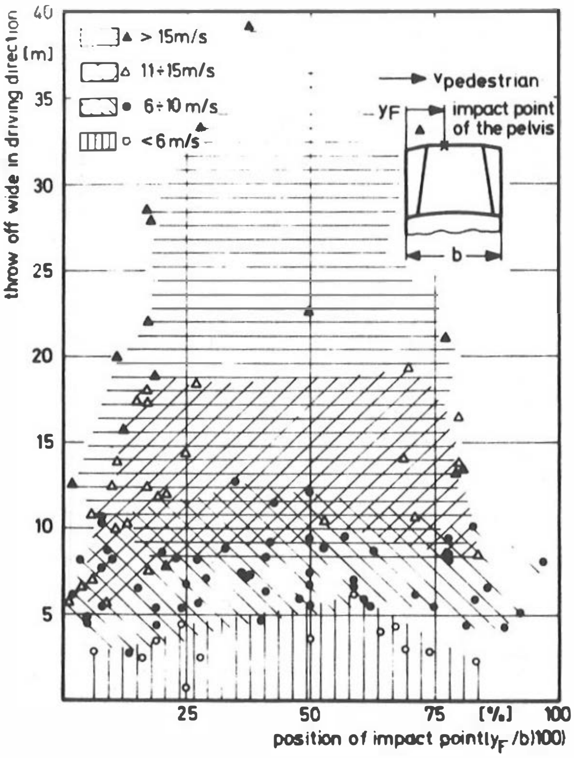


Fig.16 Throw off wide of pedestrians in driving direction versus position of impact point

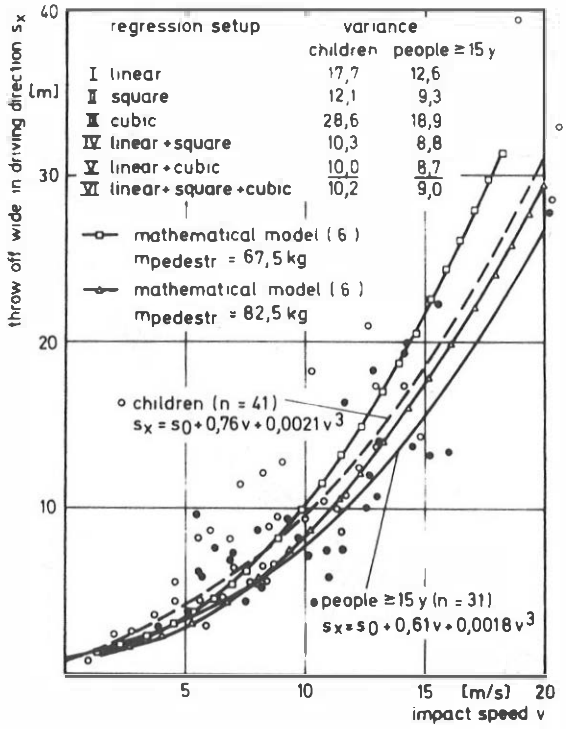


Fig.17 Throw off wide in driving direction for central vehicle front-impact with pontoon-contours and pedestrians dependent on impact speed and people age.

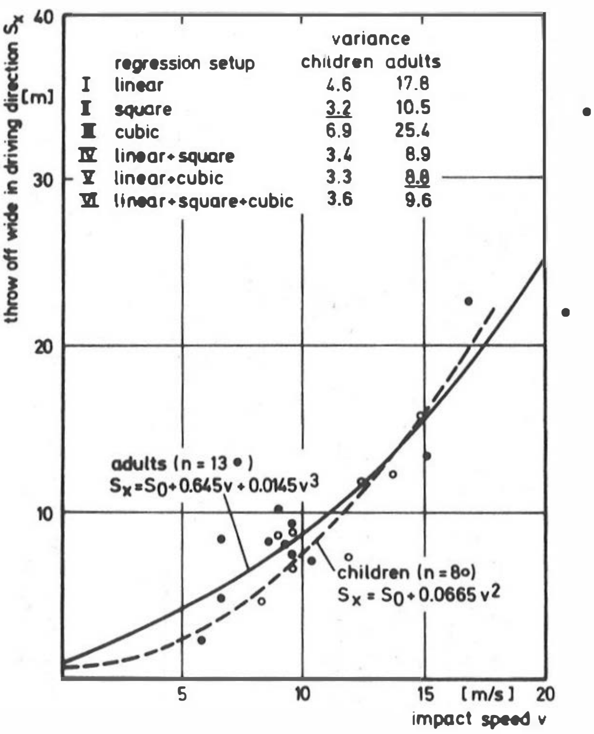


Fig.18 Throw off wide in driving direction for central vehicle front-impact with V-contours and pedestrians dependent on impact speed and people age

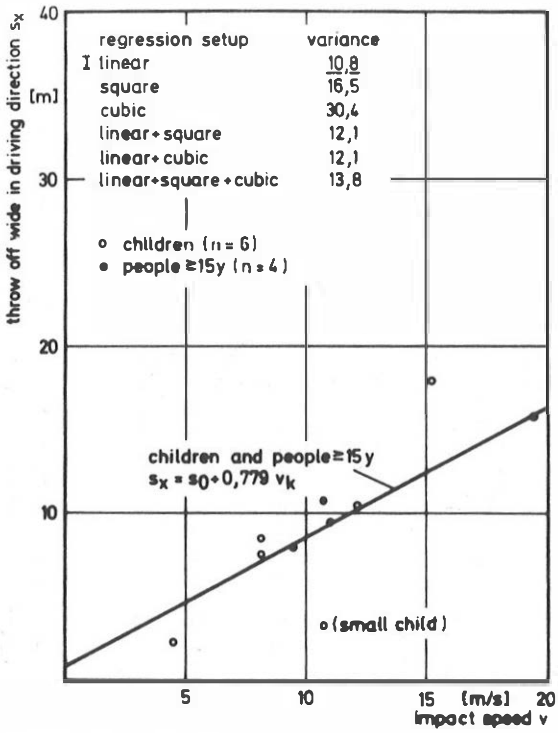


Fig.19 Throw off wide in driving direction for central vehicle front-impact with box-contours and pedestrians dependent on impact speed and people age.

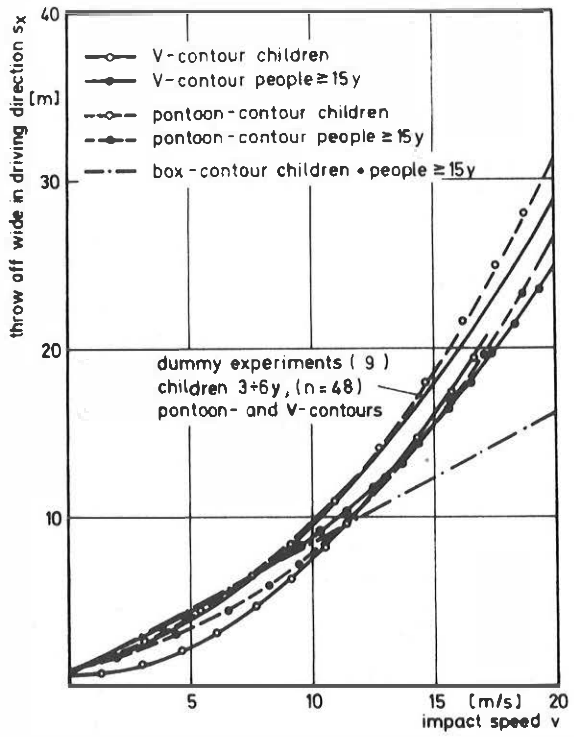


Fig.20 Comparison of throw off wides in driving direction and central vehicle-front impact for different contourforms and people age groups

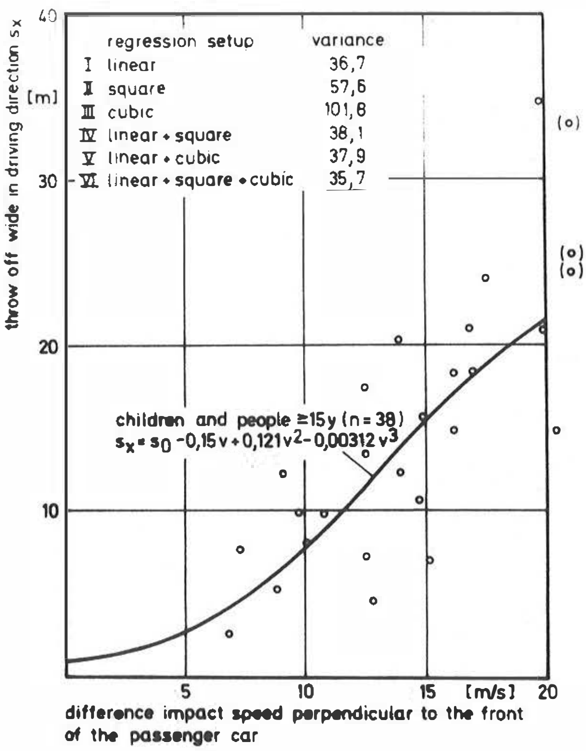


Fig.21 Throw off wide in driving direction for central vehicle front-impact with pontoon-contours and two-wheel-ridersdependent on impact speed.

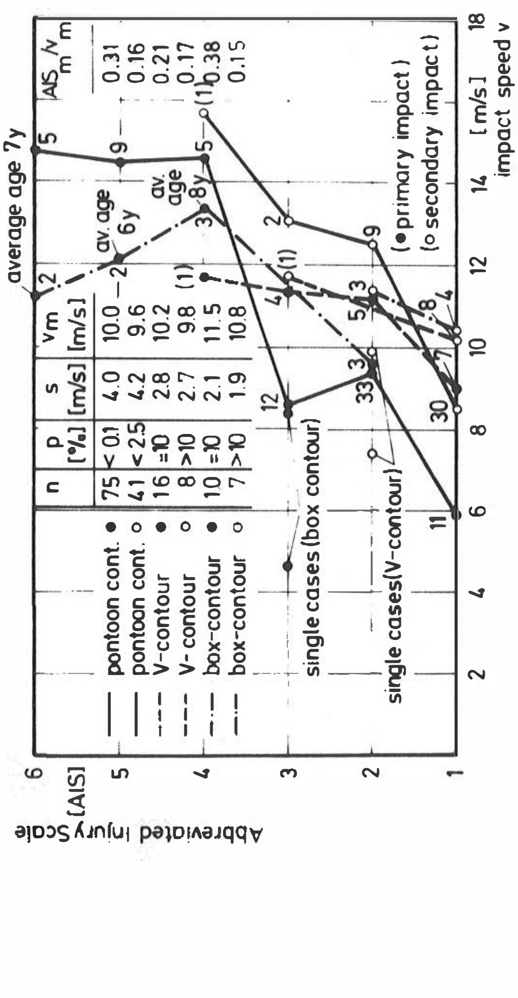


Fig.22 Primary and secondary injury severity of child-pedestrians versus impact speed for different contour types

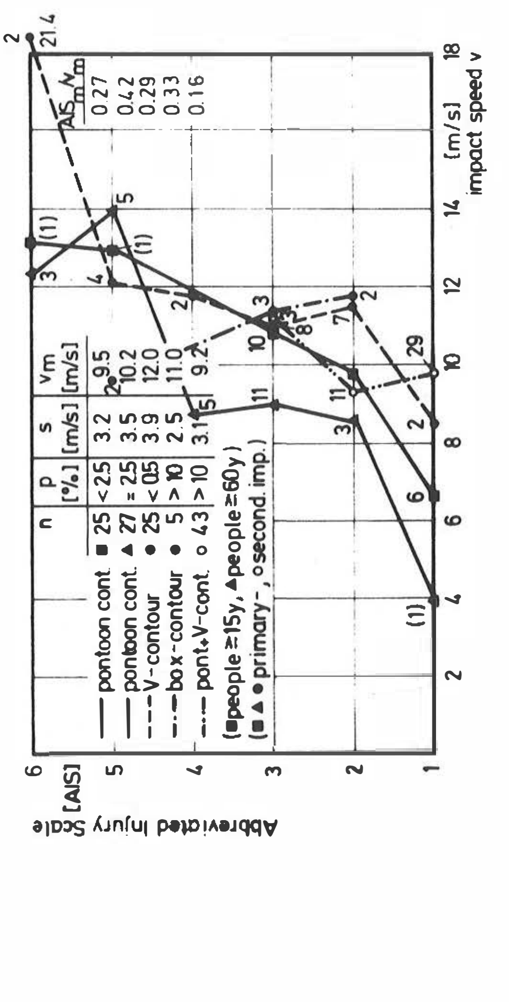


Fig.23 Primary and secondary injury severity of people ≥15 years versus impact speed for different contour types

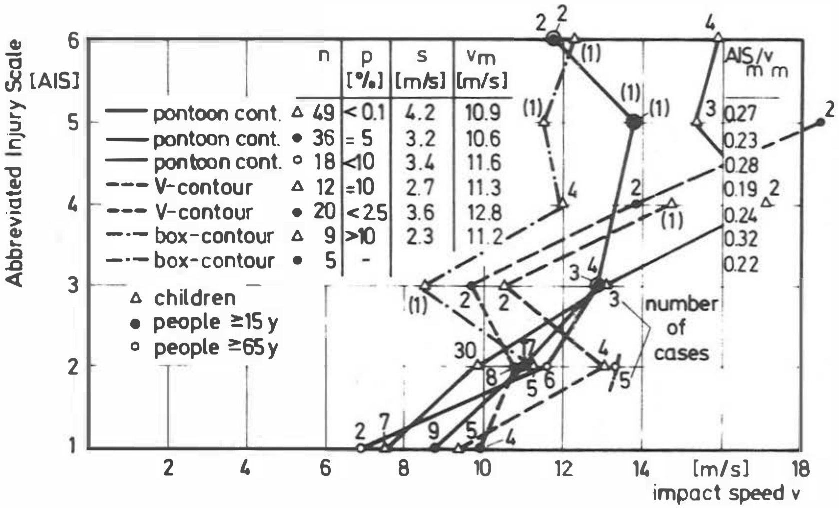


Fig.26 Primary injury severity of the head of perished pedestrians of different age-groups versus impact speed for various contour types

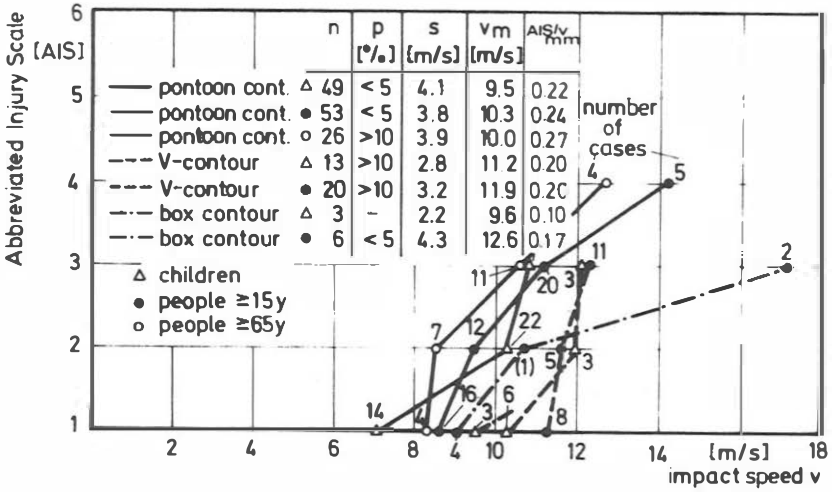


Fig.27 Primary injury severity of the lower extremities of perished pedestrians of different age-groups versus impact speed for various contour types

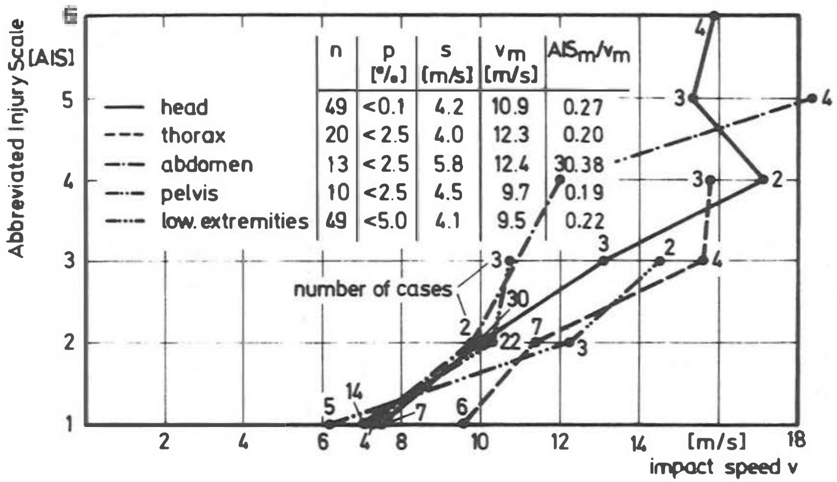


Fig.24 Primary injury severity of body regions of perished child-pedestrians versus impact speed for pontoon-contours (average impact speed $v_m = 9.9$ m/s)

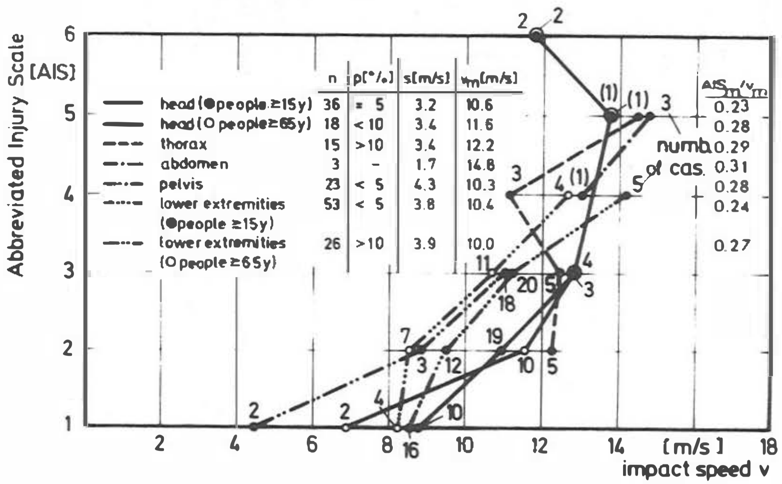
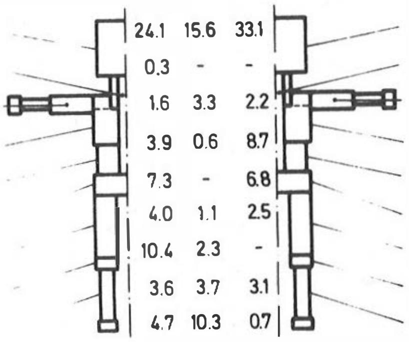


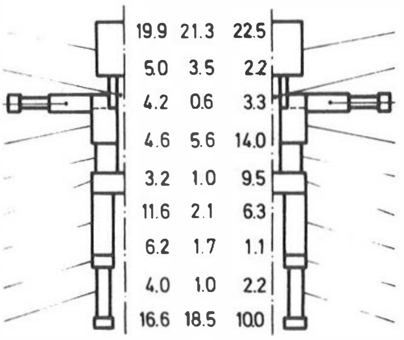
Fig.25 Primary severity of body regions of perished pedestrians ≥15 years versus impact speed for pontoon-contours (average impact speed v_m=9.9m/s)



INJURY FREQUENCY (%) pontoon	V	box	RELATIVE TRAUMATISE DEGREE (% AIS/m/s) pontoon	V	box	INJURY SEVERITY (AIS) pontoon	V	box
90	83	100	24.1	15.6	33.1	2.6	2.0	3.6
1	-	-	0.3	-	-	3.0	-	-
8	22	8	1.6	3.3	2.2	2.0	1.6	3.0
15	6	25	3.9	0.6	8.7	2.5	1.0	3.7
22	-	25	7.3	-	6.8	3.3	-	2.9
22	12	17	4.0	1.1	2.5	1.8	1.0	1.6
47	11	-	10.4	2.3	-	2.2	2.2	-
33	39	33	3.6	3.7	3.1	1.1	1.0	1.0
24	44	8	4.7	10.3	0.7	1.9	2.5	1.0

pontoon contour ($n = 78$, $v_m = 9.8$ m/s), V-contour ($n = 18$, $v_m = 10.5$ m/s), box contour ($n = 12$, $v_m = 10.8$ m/s)

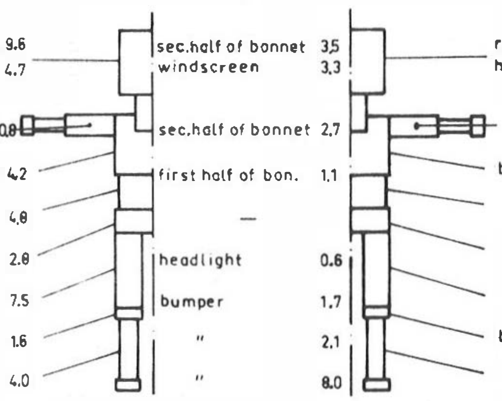
Fig 28 Injury frequency and severity and Relative Traumatise Degree of body regions of child-pedestrians for different contour types



INJURY FREQUENCY (%) pontoon	V	box	RELATIVE TRAUMATISE DEGREE (% AIS/m/s) pontoon	V	box	INJURY SEVERITY (AIS) pontoon	V	box
85	96	100	19.9	21.3	22.5	2.3	2.8	2.7
12	8	13	5.0	3.5	2.2	4.1	5.5	2.0
17	4	25	4.2	0.6	3.3	2.4	2.0	1.6
16	24	50	4.6	5.6	14.0	2.8	2.9	3.4
7	8	38	3.2	1.0	9.5	4.5	1.6	3.0
41	12	25	11.6	2.1	6.3	2.8	2.2	3.0
31	16	13	6.2	1.7	1.1	2.0	1.3	1.0
35	12	13	4.0	1.0	2.2	1.1	1.0	2.0
66	96	50	16.6	18.5	10.0	2.5	2.4	2.4

pontoon contour ($n = 58$, $v_m = 9.9$ m/s), V-contour ($n = 25$, $v_m = 12.6$ m/s), box contour ($n = 8$, $v_m = 12.0$ m/s)

Fig. 29 Injury frequency and severity and Relative Traumatise Degree of body regions of pedestrians ≥15 years for different contour types



pontoon contour RTD ($n = 78$, $v_m = 9.8$ m/s)		V-contour RTD ($n = 18$, $v_m = 10.5$ m/s)		box contour RTD ($n = 12$, $v_m = 10.8$ m/s)	
first half of bonnet	9.6	sec. half of bonnet	3,5	radiator area	21,3
second half " "	4.7	windscreen	3,3	headlight	11,8
first half of bonnet	0.8	sec. half of bonnet	2,7	—	
front edge of bonnet	4.2	first half of bon.	1,1	bumper	6,5
"	4.8	—		"	10,9
"	2.8	headlight	0.6	"	5.0
bumper	7.5	bumper	1.7	—	
"	1.6	"	2,1	bumper	1.6
"	4.0	"	8.0	—	

Fig. 30 Relative Traumatise Degree of body regions of child-pedestrians for most traumatising vehicle parts under consideration of different contour types

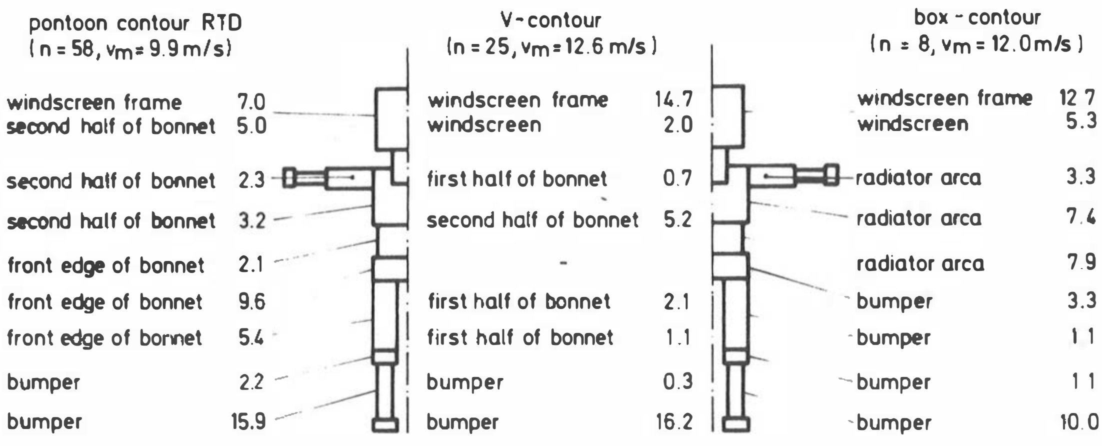


Fig.31 Relative Traumatise Degree of body regions of pedestrians ≥15years for the most traumatising vehicle parts under consideration of different contour types

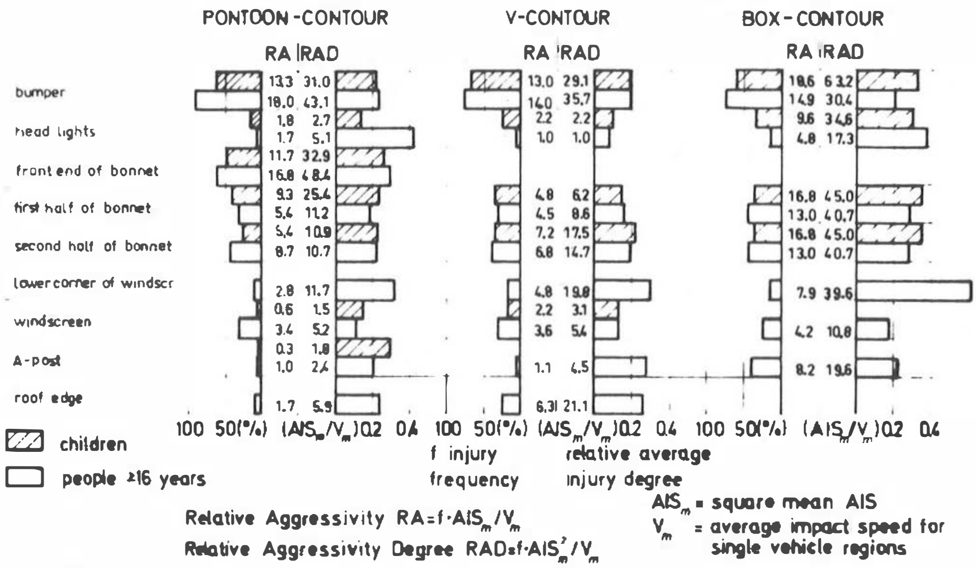


Fig.33 Aggressivity of exterior vehicle parts in pedestrian collision for age, groups and contour types

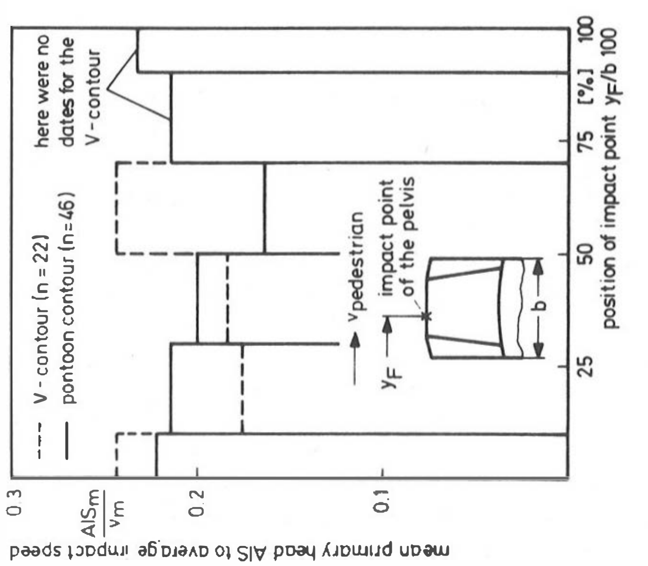


Fig.32 Mean primary Average Injury Severity of the head to average impact speed of groups of impact points at the vehicle front for different contour types