LOAD OF CAR STRUCTURE AND INJURIES OF OCCUPANTS IN SIDE IMPACT CAR COLLISIONS WITH TRUCKS AND OBJECTS

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Abstract

Lateral car collisions with trucks or objects account for an important share of side collisions with seriously or fatally injured.
On the basis of 94 car/truck and 58 car/object side collisions the accident characteristics and the injury risks of the car occupants are illustrated.
The typical deformation phenomena hereby caused on the car are indicated and the kinds of structure loads are discussed.

Sommaire

Parmi les collisions latérales ayant pour conséquence des blessés graves ou des morts, un pourcentage important revient aux collisions de voitures de tourisme avec des camions ou des objets.
Basée sur 94 collisions latérales voitures/camions et 58 collisions voitures/objets, l'étude analyse la caractéristique des accidents et les risques des passagers.
L'étude indique les déformations typiques que subissent les voitures de tourisme et discute les problèmes de structure.

Kurzfassung

Seitliche PKW-Kollisionen mit LKW oder Objekten nehmen einen wesentlichen Anteil an Seitenkollisionen mit Schwer- oder tödlich Verletzten ein.
Anhand von 94 PKW/LKW und 58 PKW/Objekt Seitenkollisionen werden die Unfallcharakteristik und die Verletzungsrisiken der PKW-Insassen erläutert.
Die dabei am PKW entstehenden typischen Beschädigungsbilder werden angegeben und die Arten der Strukturbeanspruchung diskutiert.

1. Present state

More intense attention was dedicated within the last years to the problems of car side collisions with regard to occupant protection.
Today producers test side-impact collisions primarily between car and movable obstacles and between car/car or car/pole.
So far only the USA require a lateral 9o degree crash-test with a movable barrier at a 3o kmh collision speed; a regulation within the ECE is in preparation. The lateral car/pole test was carried out mainly within the works to the ESV/RSV program.

These tests, of course, can reproduce the real accident structure load only in an unsatisfactory way, but they furnish results to be reproduced and compared internationally with a justifiable expenditure of tests.
The last years there has been an intensive discussion in this respect, if at all and if so, with which methods side crash-tests are to be performed in a more realistic way.
Above all there are uncertainties as to the question if lateral crash-tests with the movable USA or ECE barrier are sufficient or if additional car/car collisions are necessary, whereby, however, the question of a 'standard car' arises.
Also the kind of barrier and its mass - 1.1oo kg (ECE) respectively 1.8oo kg (USA) - as well as its shape - flat barrier or barrier with deformation structure - are not yet established definitively. New works furnish basical material from the analysis of real accidents [1-8] .

Generally these discussions on side-impact collisions are led mainly with respect to collisions between passenger cars. In accident analyses, however, it has been established that also side collisions of passenger-cars with trucks or objects represent an essential focus of side-impact collisions.
The object of this report therefore is to analyse the significance of car/truck and car/object collisions related to the total number of occupants injured seriously or fatally in side-impact collisions. Works hitherto, with few exceptions, [1, 2]give no indications.
The present work furthermore illustrates the accident characteristics, the resulting damage phenomena and the injury risks, by means of 94 car/truck side-impact collisions and 58 car/object collisions. Improved knowledge of the relations existing in real accidents should contribute to an improvement of today's test methods and to examine realistically the occupants' strains.

2. The accident material

2.1. The method of evaluation

Since 1969 German Automobile Insurers have evaluated almost 15o.ooo car accidents involving injuries to occupants, of which approximately 45.ooo cases furnished sufficiently precise data for a scientific analysis.

The research material presented in this study includes car accidents, in which at least one occupant in one of the vehicles involved suffered a minor injury as from injury severity AIS 1, and concerns the years from 1974 on.

The investigations described in [9, 10] are effected retrospectively on the basis of insurance documents by a team of engineers associated with physicians. This material is evaluated in a multi-phase analysis (figure 1). The present cases correspond to evaluation phase 2, where it was possible to make detailed reconstructions of accident kinematics. Additional information was gained by questioning and interviewing the involved persons. Partly it was also possible to subsequently examine and measure the vehicles.

2.2. Applied definitions

One of the main problems in the international comparison of results on the subject of side-impact collisions is the lack of uniform definitions.

In this report, side-impact collisions are defined as being collisions in which the main deformation was located in the area of the side surfaces (figure 2). According to the direction of impact, the case car in side collisions may be loaded with a predominantly longitudinal or lateral collision force. Typical examples of car/car side collisions with longitudinal and lateral direction of force are shown in [2].

The collision areas on the side surface were defined according to figure 2.

The vehicle damages are defined on the basis of the HUK-Overall Damage Index in five categories [9], whereby the extent and depth of the main deformation and above all the reduction in the protective function of the passenger-compartment are taken into account.
The injury consequences are defined by way of the AIS Classification Scale [11], with the Overall Damage Index and the individual injuries being indicated.

3. Results

3.1. The significance of side-impact collisions

Front/side collisions, with 39%, represent the most frequent type of collision in car accidents involving injuries to occupants [9, 10, 12]. The occupants in the side struck vehicle suffer serious injuries twice as often as the occupants in the frontally striking vehicle [6]. Due to the fact that in front/side collisions one vehicle sustains front and the other side damage, the frequency of cases where the main deformation is located in the side surface of the car, amounts to 20% in accidents of all severity degrees.

As a result of the high injury risk, however,

28% of all fatalities
2o% of all seriously injured (as from AIS 3)
27% of all injured (as from AIS 1)

related to the occupants in car/vehicle accidents, are to be found in side struck vehicles. Corresponding percentages of occupants fatally injured in side collisions are also shown by other accident statistics in Europe and the USA [3, 8, 13].

Taking into consideration the fact that the use of safety belts reduces the risk of injury in frontal collisions by about 5o% [14], even greater significance will in future be accorded to side-impacts in the overall accident situation.

3.2. Accident material of the present study

The present analysis embraces 94 car/truck and 58 car/object side collisions (table 1) involving 144 respectively 127 car passengers.
In car/truck side collisions, with about 7o%, lateral directions of impact dominate. In car/object collisions the ration between lateral and longitudinal direction of impact, with 3o respectively 29 cases, is almost balanced (figure 3).

Table 1 also shows the average degree of damages in car/truck and car/object collisions. In the present material, 41,4% of all car/object collisions concern accidents with damage degrees 4/5 (figure 9), whereby this high percentage in part is to be attributed to a 'negative selection'. Whilst in car/vehicle collisions also minor accidents are reported to insurance companies and police, this is not always the case in single car accidents, and therefore unavoidably analyses of real accidents include a higher share of severe accidents than normal.

Table 2 gives a survey of the overall injuries of car occupants in collisions with trucks and objects. Of 144 car occupants in side-impacts with trucks, 16 persons (11,1%) were injured fatally and 19 (13,2%) were injured seriously (AIS 3/5).
In car/object collisions (with a total of 127 occupants), even 25 persons (19,7%) were injured fatally and 19 occupants (15%) were injured seriously. Similar quota of risk for fatal injuries were established in [1].

Corresponding investigation of 1.669 car/car side-impact accidents with 2.8o9 occupants revealed a risk for fatal injuries of about 1,2% and for serious injuries (AIS 3/5) of about 4%. Even if these accident materials are not be compared directly with one another, the extremely high risk for serious/fatal injuries in car/truck and above all in car/object collisions becomes apparent.

Table 3 moreover gives a division of the overall injuries according to longitudinal respectively lateral direction of impact in side collision. In virtue of the much higher structure load in lateral side collisions, the percentage of serious/fatal injuries thereby is significantly increased.

Table 3 thus shows that the focal point of injury risks lies mainly in lateral side collisions, that, however, also the problems in side collisions with longitudinal direction of impact may not be overlooked.

3.3. Significance of car/truck and car/object collisions in comparison to car/car side collisions.

Table 4 reflects the kinds of accidents shown in the official accident statistics of the Federal Republic of Germany [15] and the number of involved cars. From HUK-investigations the share of side damaged cars in car/car collisions is known with approximately 2o%; investigations on car/truck accidents revealed that in 12,5% of these accidents the car sustains side damage.

With a cautious estimate from [6, 16], in car/object collisions a share of side damages of about 25% can safely be assumed. In about 55% of these collisions, fixed obstacles are struck laterally. From this it is possible to estimate an ascertained lower limit of the number of passenger-cars with side damages in car/object collisions. A change in reasonable limits of these estimated percentages does not change the priorities of the results.
Side damages of cars therefore predominantly (78%) result from car/car accidents, car/object side collisions account for approximately 17,4% and car/truck collisions for 4,6%. In virtue of the established quota of risk for serious and fatal injuries depending from the partner of accident, it is now possible to estimate the significance of the individual kinds of accident for all side-impact collisions. For reasons of the above mentioned 'negative selection of severe car/object collisions', the quota of risk indicated in table 2 were reduced to the half.
Nevertheless, car/object side collisions account for the predominant share of fatally injured occupants. Inspite of their relatively rare appearance, car/truck collisions have an over-proportionally high significance because of the extremely high injury risk.

The improvement of compatibility in lateral car/car collisions therefore represents an important means to reduce the injury consequences, however, it may not be overestimated in its effects. The search for structural countermeasures to avoid unfavourable deformation characteristics in car/object and car/truck side collisions has to be aided by an improved knowledge of the real accident damage and by crash-tests closely related to reality; constructive measures resulting therefrom represent an important condition for the reduction of the aggravating risk in side collisions.

4. Deformation characteristics of vehicles in side collisions

4.1. Impact areas

According to the division in figure 2 , table 6 indicates the impact areas in car/truck side collisions and table 7 in car/object side collisions.

In car/truck collisions (table 6) with lateral direction of impact, in 72,6% of the cases, the main deformation is located in the area of the passenger-compartment. It is hereby significant that collision area II with 37% prevails, i.e. that not only the door area, but also A-pole and front axle are located within the area of main deformation. This principally favourable 'broad area of force load', however, practically has only little influence in car/truck accidents, as the point of force load is high in collisions with trucks and as therefore front axle, crossbar and door sill can only absorb a small amount of deformation energy. In car/truck side collisions with longitudinal direction of impact, the share of impact area I is significantly increased with 33,3%. Nevertheless, the passenger-compartment is often included in the area of main deformation with 47,6%, a fact which is to be attributed mainly to the unfavourable form aggressivity of trucks.

Longitudinal car/object side collisions, on the other hand, to 67,9% are limited on collision area I, up to the front axle. There, however, frequently severe deformations arise by a hooking in the area of the front axle or in the area between front axle and A-pole (figure 8).
In lateral car/object side collisions, more than three quarters of the cases present the particularly unfavourable form of collision with direct force load in the passenger-compartment. Thereby above all collision area III is struck extremely frequently with 46,7%.

4.2. Nature of passenger-compartment damage

For the cases with direct force load in the passenger-compartment, figure 4 shows the extent of the areas of main deformation for car/truck and car/object collisions. In case of an area of main deformation extending over several of the 1o zones, a multiple counting was made.
Figure 4 thus shows that car/truck collisions nearly always involve the entire area of the front doors, also the A-pole is strongly deformed with a 9o% probability. The focal points in car/object collisions are located immediately in front of the B-pole (damage probabilitiy 65%). In the structure of the passenger-compartment, the B-pole has a main supporting function. By way of this intended stiffness, a hooking in this area is favoured, leading to an increased stress load on the occupants by the local intrusion in the sitting area. A stiffening of the door surfaces therefore should possibly be performed in such a way that in this area

the possibility of hooking is reduced, respectively that even a repulsive effect is increased.

As already in [2], the deformations of the passenger-compartment were sub-divided into two typical forms, namely

- the triangular form
- the rectangular form.

Examples of these forms of intrusion are given in figure 5. Figure 6 shows the location and depth of intrusion for these typical forms of damage. The marking indicates in the case of triangular intrusion the respective location of maximum intrusion depth, and in the case of rectangular intrusion the centre of the intrusion area.

In the present material truck collisions predominantly (72%) concern rectangular intrusions; object collisions, here predominantly car collisions with trees/poles, presented exclusively triangular characteristics. The maximum intrusion depth in car/object collisions generally is located in the area in front of the B-pole. A surprising factor is that almost all triangular intrusions in trucks are to be found in the area of the A-pole, so that a massive indentation of the entire front of the vehicle has occurred.

The rectangular intrusion in car/truck collisions generally is limited to a depth between 2o cm and 5ocm. It therefore is not significantly higher than the intrusion depths in car/car collisions established in [2], normally presenting static deformations up to 4o cm. The problem of car/truck collisions therefore does not depend so much on the depth of intrusion, but rather on the nature of this deformation.

Triangular intrusions on the other hand much more frequently result in a depth in the region between 4o cm and 5o cm. Inspite of this, the majority of these cases presented sufficient survival space. The extreme injury consequences are to be attributed predominantly to the 'inner collision' with the deformed side structure, whose frequently scarse upholstery produces a short distance speed change of the occupant with considerable increase of acceleration; moreover the already deformed side structure causes an unfavourable pointed force load directly on the occupant.

5. The effects of vehicle deformation on injuries

The overall risk of injury depending on the accident type has already been shown in table 2. Additionally this chapter shall deal with the typical injury characteristics in as far as there is a direct relation to the vehicle deformation.

5.1. The risk exposure of impact/opposite-side-passengers

In comparing the injuries of impact/opposite-side-passengers, difference is made between main deformation inside and outside the passenger-compartment (table 8). Even if the

figures for several categories of injuries are not yet to be considered as definitively established, according to the partner of accident - truck or object - a completely different tendency shows up, to be attributed to the differing structure load.
It is characteristic for this comparison that principally the change of speed of the compartment is equal for impact- and opposite-side passenger. Differences, however, result mainly through the nature of inflow of energy, occurring directly by the side surface for the impact-side-passenger; as for the opposite-side-passenger, it is determined according to his trajectory from the point of impact and the locally available interception way.

The decisive statement of table 8 is the high risk of the impact-side-passenger, resulting in a fatality risk of 8 - 11% in collisions outside the passenger-compartment and increasing by two or three times with main deformation in the passenger-compartment. In car/object collisions of the 4o impact-side-passengers alone 15 were injured fatally. A surprising factor also is the high risk of the opposite-side-passenger for fatal injuries, particularly in collisions outside the passenger-compartment, nearly corresponding to the risk of the impact-side-passenger. This risk could be reduced considerably by the use of safety belts; the present material, however, predominantly concerns non-belted passengers.
In side collisions an essential danger of injury for the opposite-side-passenger seems to exist in the deformation of the upper area of the A-pole, with a tearing-down of the roof, frequently occurring mainly in car/truck collisions. It is exactly in this area that the non-belted opposite-side-passenger strikes very frequently during his frontal-lateral movement.

5.2. Characteristic individual injuries to the various body areas

The individual injuries of occupants in lateral collisions are relatively well known from several studies [1, 2, 3, 4]. In this connection only head, thorax and abdominal injuries are to be dealt with, giving typical pointers to trajectory/inflow of force for impact and opposite-side-passengers.
As comparative figures the frequencies of injury in car/car accidents [12] are also included here.
Table 9 shows the frequency of injury, i.e. the occurring of injuries as from AIS 1 and the number of serious injuries as from AIS 3, each related to the number of uninjured/injured impact and opposite-side-passengers.
The frequency of injuries as from AIS 1 hereby points to the operating of an injury-causing force - therefore irrespective of the different partners of accident almost identical frequencies of injury show up: For the impact-

side-passenger head injuries about 51%, thorax injuries 27% and abdominal injuries 17%; for the opposite-side-passenger head injuries 60%, thorax injuries on the average 32% and abdominal injuries 10%.

A surprising result of the present material of car/truck and car/object side collisions is that as to head injuries of the opposite-side-passenger, both frequency and serious/fatal injuries as from AIS 3 are within the same range as for the impact-side-passenger. Serious thorax injuries on the other hand are two to four times higher for the impact-side-passenger.
For the impact-side-passenger sitting within the local area of intrusion in car/object collisions, serious head injuries with 20,4 % are extremely high. On the other hand characteristic for car/truck collisions is the - even in comparison to object collisions - extremely increased share of serious thorax injuries (14,3%). This fact can be explained directly by the nature of damages in car/truck collisions (see next chapter).

The high risk of injury of the opposite-side-passenger mentioned before, above all is based on serious head injuries resulting in the high percentage of 16,3% in collisions with trucks. Main cause also for this is the characteristic deformation in the roof/A-pole area on the impact side. The danger to hit this risk area could be largely avoided by the use of safety belts.

6. Categorization of characteristic deformations

The analysis of the present material showed that car/truck and car/object collisions lead to a few characteristic types of structure deformations, which are to be elucidated in examples. Comparative figures of the frequency of the individual forms are not to be indicated at moment. These investigations, however, will be continued in future and intensified also with regard to velocity changes and corresponding forms of deformation.

6.1. Car/object collisions

The present material mainly includes side collisions with trees/poles. By way of the local force load, these collisions represent the most unfavourable form of deformation in car/object collisions.

Three fundamental forms of deformation are to be distinguished:

In collisions with longitudinal direction of impact a deformation of the entire side area is characteristic, whereby according to the angle of force load, stiffness of side structure and roof, a typical hooking with maximum intrusion after a continuous process of penetration may occur. An example for a severe deformation shows figure 7. A stiffening of the side area of cars, mainly with regard to an improved repulsive function, could represent a counter-measure.

Another typical form are deformations in the area between front axle and A-pole, which result from object collisions with lateral or longitudinal direction of impact (figure 8). Even with relatively low collision speeds severe deformations may result from the extreme hooking effect.

The third form - approximately rectangular object collision in the area of the passenger-compartment - leads to the most severe injury consequences. Two characteristic structure loads are to be distinguished in this connection:

Figure 9 thereby largely corresponds to the deformation phenomena known from crash-tests; a depth of intrusion is equally marked over the entire side area from door sill to roof.

Another form of structure load is present in those cases (figure 10), in which door sill/body platform showed only minor deformation and the main deformation is located above all in the area of the roof.

Further studies will have to be conducted on the question, of what these two forms of deformation depend on and what influences arise from structure characteristics.

6.2. Car/truck collisions

In truck collisions there are completely different forms of deformation depending on lateral respectively longitudinal direction of impact. The form aggressivity of the truck front has a decisive influence on the extent of deformation.

The destruction of large side areas of the passenger-car is characteristic for truck side collisions. According to the relative movements of the vehicles, characteristic deformations result.

When the contact area is in front of the A-pole, the frontal side area of the roof frequently is severely damaged, respectively the roof is even torn off (figure 11).

In collisions in the area of the front door (figure 12), the result is a strong deformation of the B-column and frequently the latter is also torn off, whereby a most severe destruction of the passenger-compartment in the area of the back seats results.

In these collisions with longitudinal direction of impact, the mass aggressivity of the truck can only operate in part. Improvements therefore consist mainly in a concentrated aggressivity reduction of the truck front, in avoidance of protruding massive edges.

A particularly dangerous form of deformation results from a more acute angle of impact (approximately 45 degrees) of the truck, whereby frequently a massive triangular intrusion in the area of the passenger-compartment occurs. Depending on mass and form aggressivity of the truck, such deformations can already occur at relatively low collision speeds (figure 13).

In the particularly frequent car/truck collisions with lateral direction of impact, the size of the truck leads to two different characteristic structure loads:

With smaller trucks (up to 7,5 tons), the bumper predominantly provokes damages in the central area of door and side surface, whereas with heavier trucks the bumper fastened higher up leads to damages in the upper third of the side surface (figure 14).

In collisions with smaller trucks (figure 15) at collision speeds of about 3o kmh and more, already considerable intrusions occur, the deformations of the roof, however, remaining limited even at higher speeds. The deformation of the roof occurs predominantly by a direct contact with the truck front, leading to a deformation in horizontal direction.

With heavier trucks, the higher point of impact leads to a deeper intrusion in the area of the passenger-compartment, whereby the roof is torn down on A and B-pole and subsequently is strongly pushed to the inside by direct contact with the truck front (figure 16). This mechanism is intensified also by the factor that the wheels of the car opposite to the impact side are loaded with a vertical force, because of the high point of impact with big trucks. Thus a lateral movement of the passenger-car is restricted and in extreme cases it is even forced under the truck (figure 17).

Besides the unavoidable mass aggressivity therefore above all the formation of the front of trucks is an essential factor for structure load on passenger-cars in side collisions. The high point of inflow of force, even with smaller trucks already above the wheel suspension, leads to the fact that important stiffening elements of the car structure cannot act in their intended deformation resistance. A flat formation of the truck front and as decisive measure a fixation of the bumper as low down as possible, which may of course be contrary to the requirements of use in some vehicles, would be an important contribution to reduce the presently aggravating consequences of car/truck collisions.

Inspite of the extreme structure loads and the problems in distributing the forces acting on cars in side collisions with objects and trucks, there are possibilities for an increased safety.

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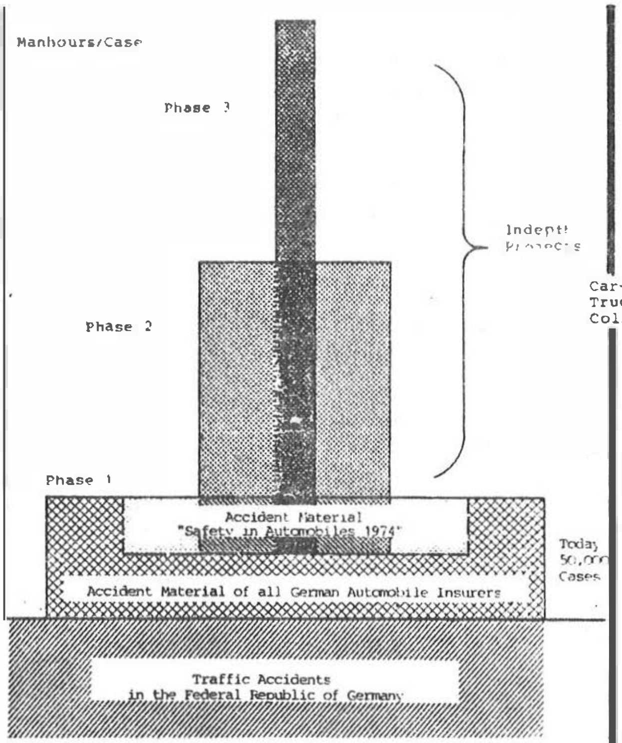

Figure 1: "Safety of Automobiles 1974" Accident Research of the German Automobile Insurers

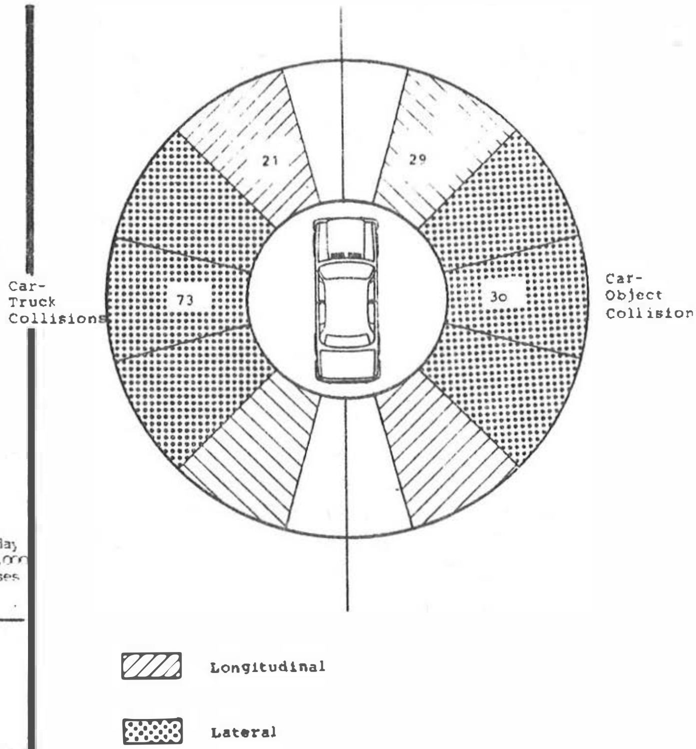

Figure 3: Number of Cases in Car/Truck and Car/Object Side Collisions

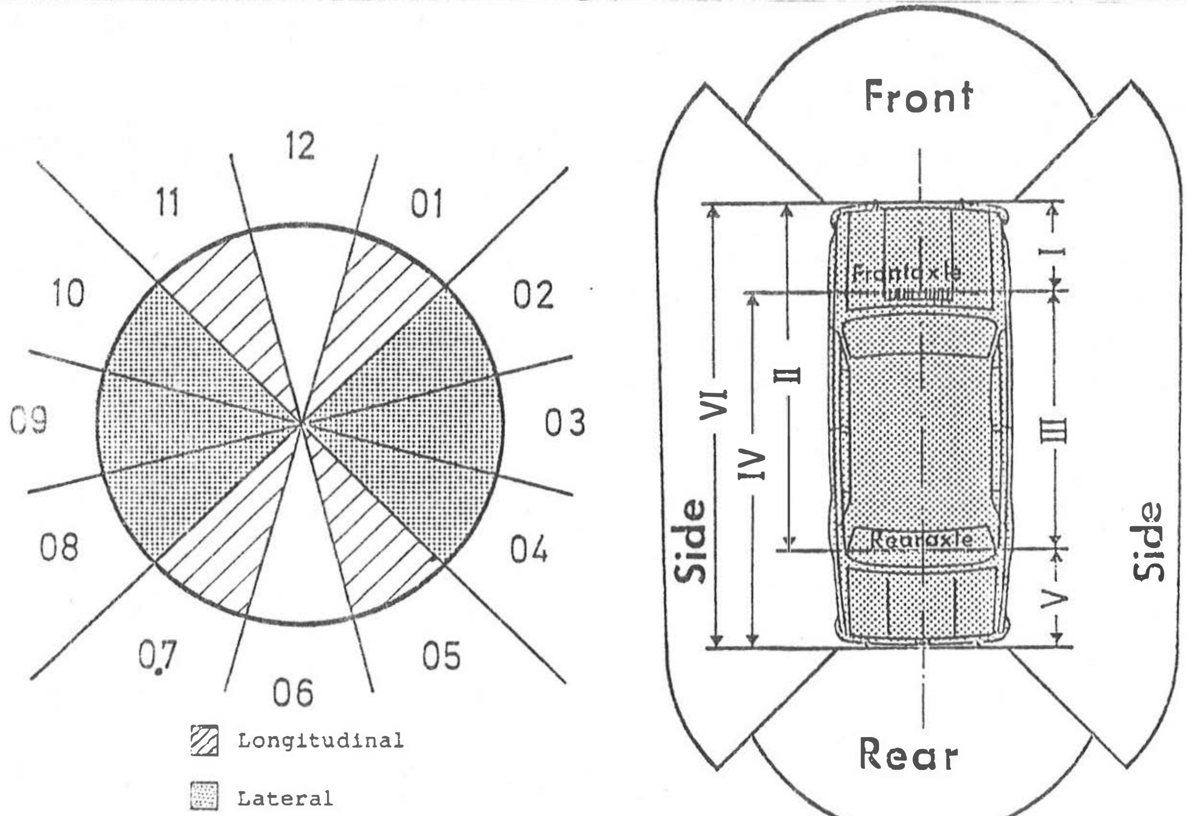

Figure 2: Definition of "Side-Collisions": Classification of Impact Areas and Directions of Impact

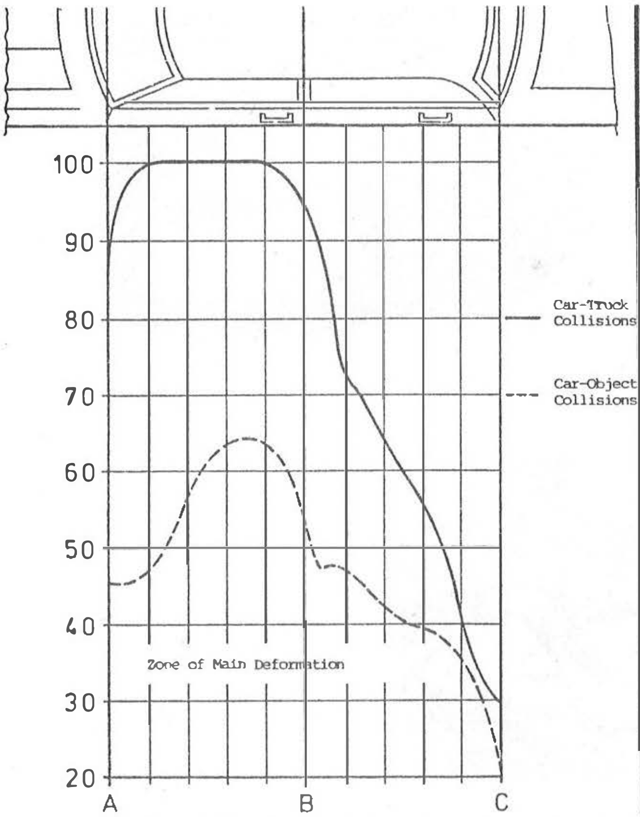

Figure 4: Location of Main Deformation in Horizontal Direction (Impact Areas II/III)

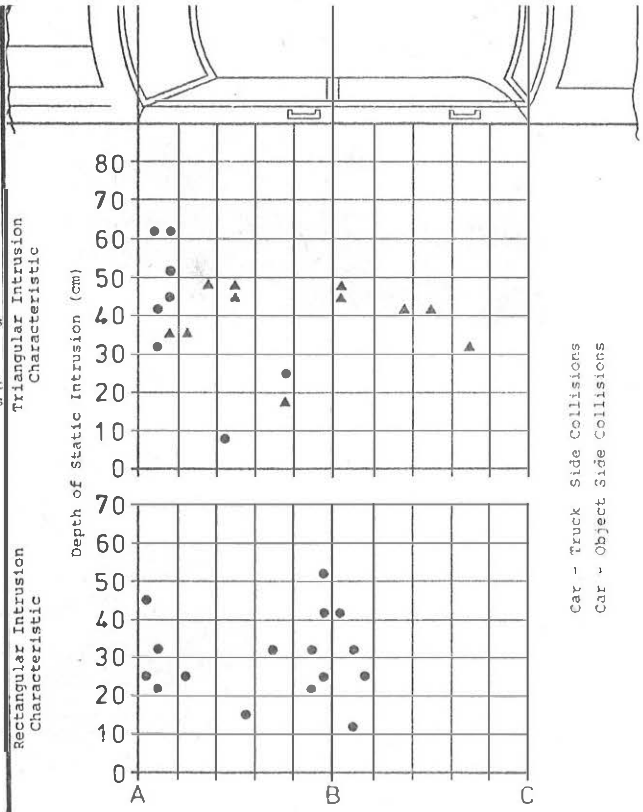

Figure 6: Location and Depth of Intrusion in Triangular and Rectangular Shape

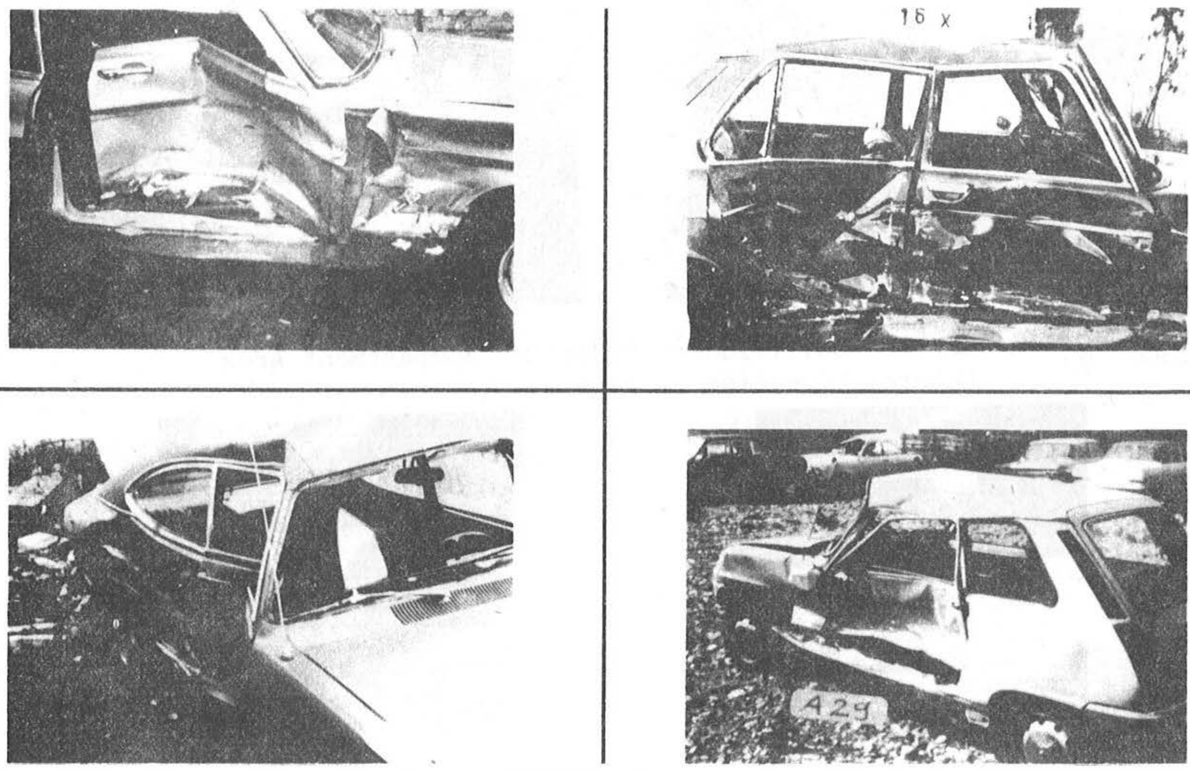

Figure 5: Triangular and Rectangular Instusion Characteristic

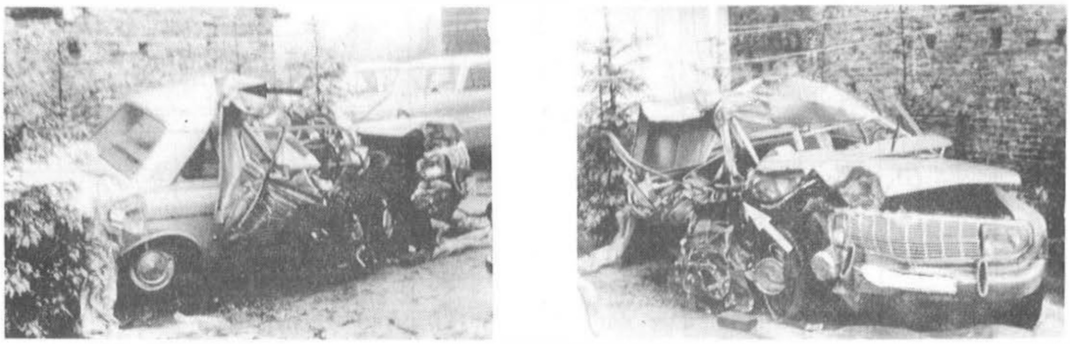

Figure 7: Car/Object Collision with Longitudinal Direction of Impact with Hooking

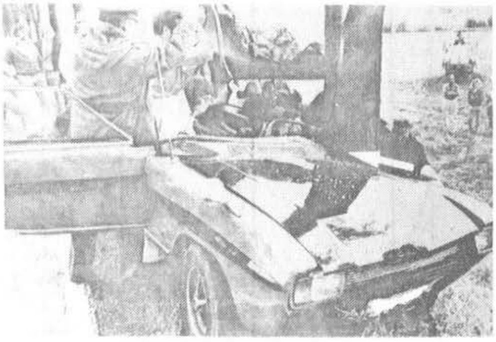

Figure 8: Car/Tree Collision in the Area Between Front Axle and A-Pillar

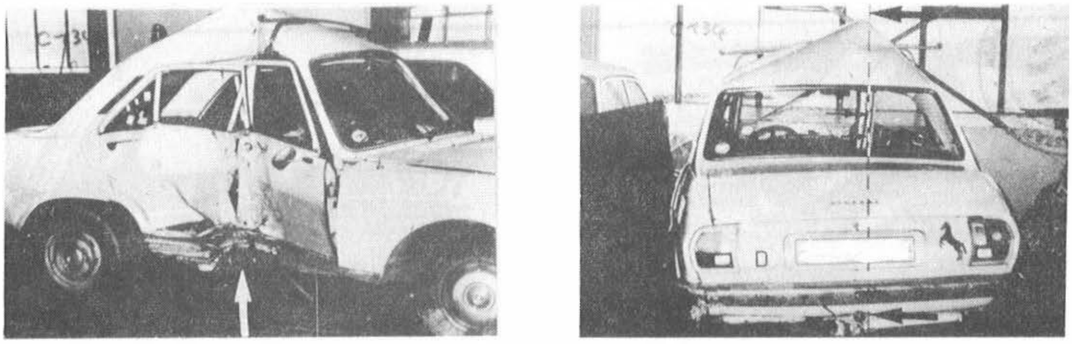

Figure 9: Car/Tree Collision in Passenger Compartment Area (Lateral Direction of Impact)

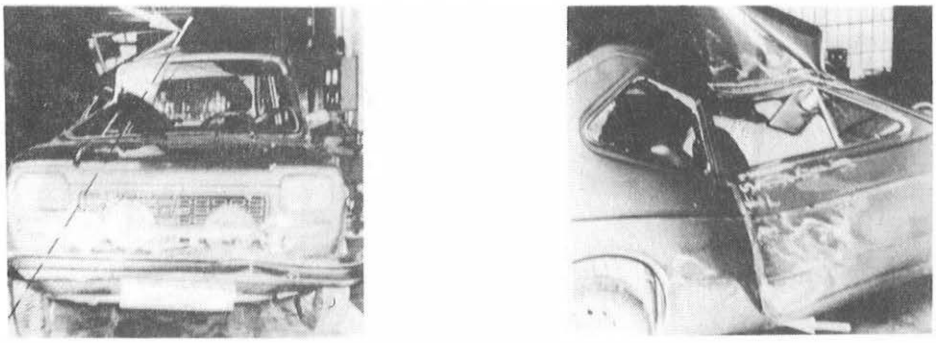

Figure 10: Lateral Car/Tree Collision in Passenger Compartment Area

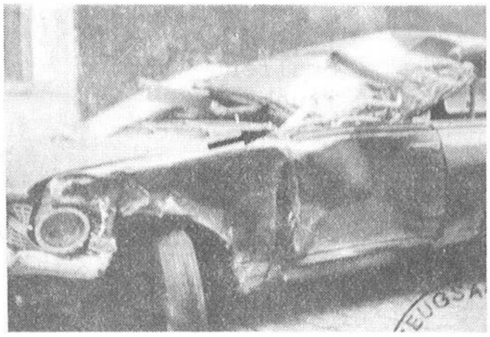

Figure 11: Car/Truck Collision with Longitudinal Direction of Impact (Intrusion in Side Area Before A-Pillar)

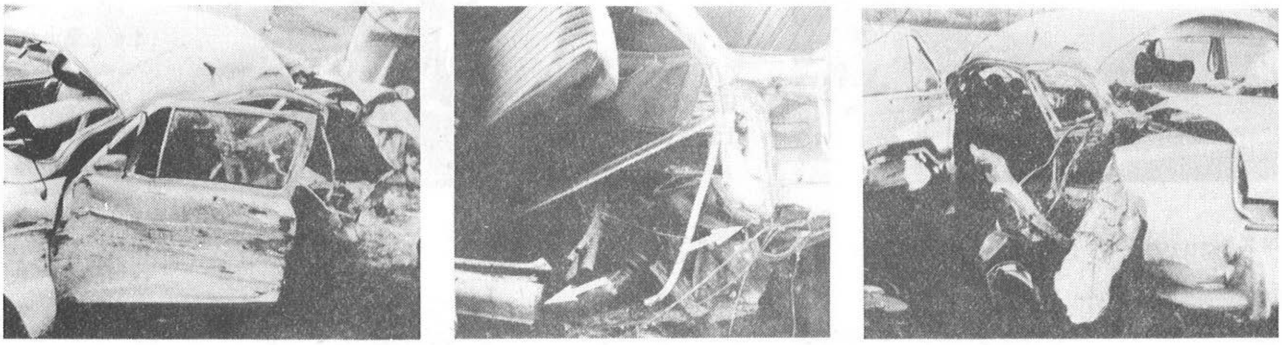

Figure 12: Car/Truck Collision with Longitudinal Direction of Impact (Intrusion in the Area of the Front Door)

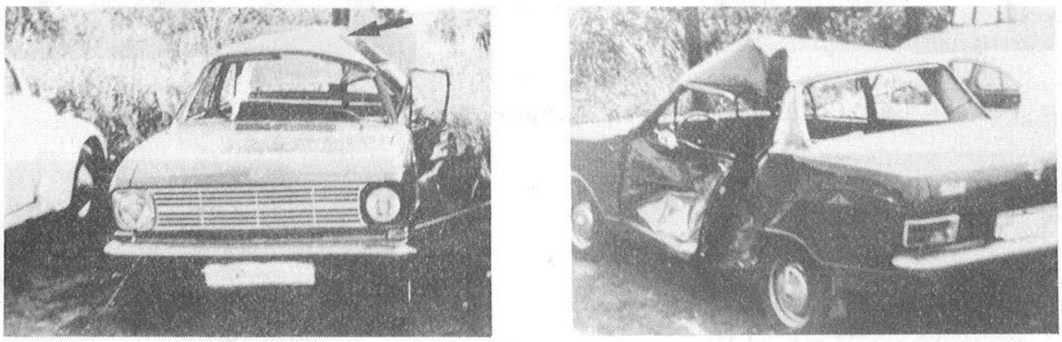

Figure 13: Car/Truck Collision (Angled Impact of Approx. 45 Degrees)

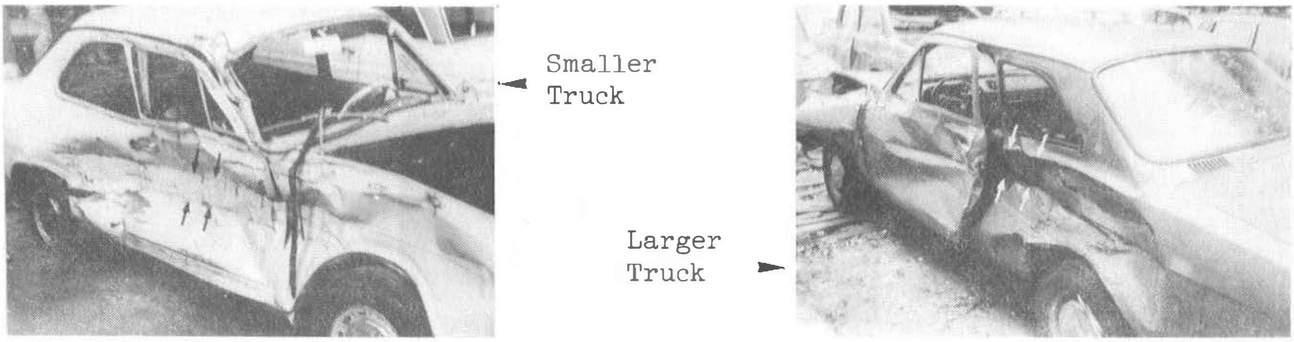

Figure 14: Deformation Characteristic Dependent on Truck Size

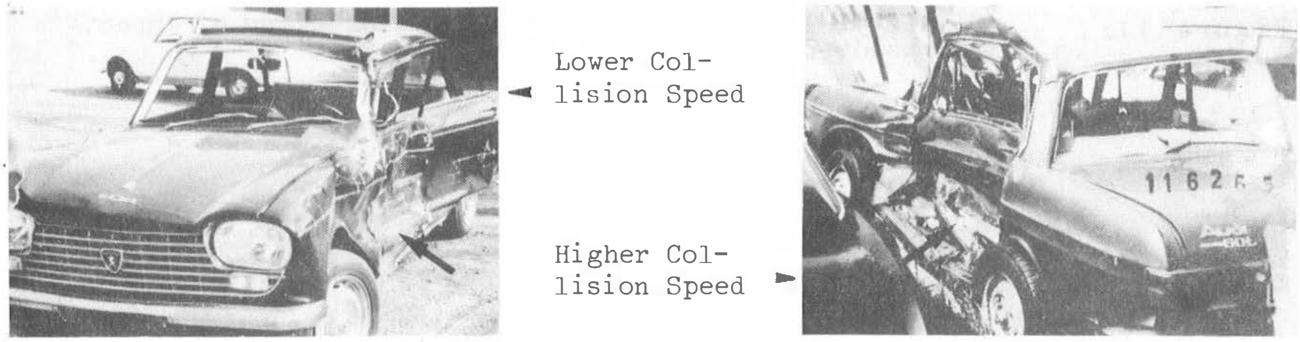

Figure 15: Car Collisions with Smaller Trucks

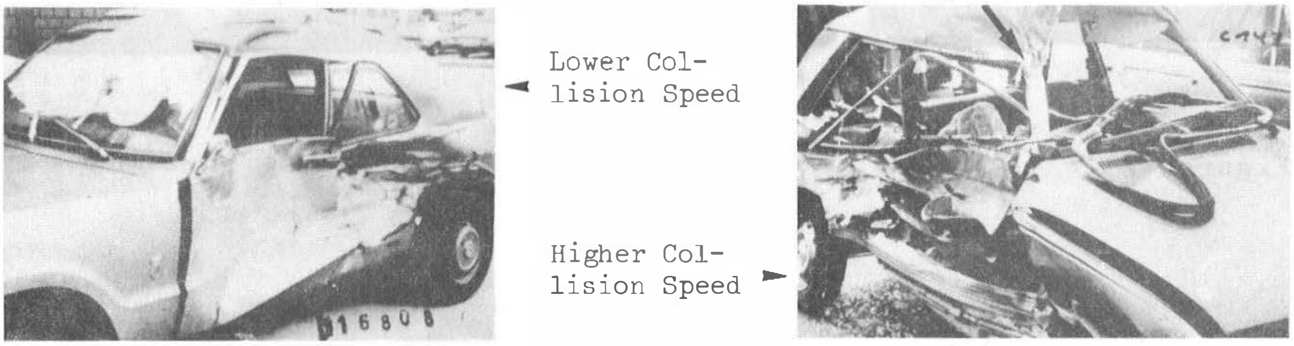

Figure 16: Car Collisions with Larger Trucks

Figure 17: Car/Truck Collision with a High Point of Structure Load

		Side Collisions		Total
		Car-Truck Accidents	Car-Object Accidents	
Side Struck Cars	No.	94	58	152
	%	61,8	38,2	100
Number of Occupants		144	127	271
Included Accidents with Severe Car Damage	No.	28	24	52
	%	29,8	41,4	34,2
Average Degree of Damage		2,9	3,2	-

Table 1 Research Material of this Report

Side Collisions							
		Car-Truck Accidents	%	Car-Object Accidents	%	Total	%
Number of Cases		94	61,8	58	38,2	152	100
Number of Occupants		144	100	127	100	271	100
Injured Occupants	Fatal	16	11,1	25	19,7	41	15,1
	Severe/Critical	19	13,2	19	15,0	38	14,0
	Moderate	19	13,2	22	17,3	41	15,1
	Minor	77	53,5	35	27,5	112	41,4
Uninjured Persons		13	9,0	26	20,5	39	14,4

Table 2 Injury Severity to Occupants in Side Collisions with Trucks and Objects

Side Collisions						
Lateral	Car-Truck Accidents	%	Car-Object Accidents	%	Total	%
Number of Cases	73	70,8	30	29,2	103	100
Number of Occupants	113	100	67	100	180	100
Injured Occupants: Fatal	15	13,3	17	25,4	32	17,8
Injured Occupants: Severe/ Critical	16	14,2	8	11,9	24	13,3
Injured Occupants: Moderate	15	13,3	12	17,9	27	15,0
Injured Occupants: Minor	60	53,0	19	28,4	79	43,9
Number of Uninjured Occupants	7	6,2	11	16,4	18	10,0

Side-Collisions						
Longitudinal	Car-Truck Accidents	%	Car-Object Accidents	%	Total	%
Number of Cases	21	42,8	28	57,2	49	100
Number of Occupants	31	100	60	100	91	100
Injured Occupants: Fatal	1	3,2	8	13,3	9	9,9
Injured Occupants: Severe/ Critical	3	9,7	11	18,3	14	15,4
Injured Occupants: Moderate	4	12,9	10	16,7	14	15,4
Injured Occupants: Minor	17	54,8	16	26,7	33	36,2
Number of Uninjured Occupants	6	19,4	15	25,0	21	23,1

Table 3 Risk of Injury in Lateral and Longitudinal Side Impact Collisions

Car-Accidents with Occupant Injury in W. Germany 1974 [15]		
Car-Car-Accidents	78268	54,4%
Car-Truck-Accidents	14803	10,3%
Single-Car-Accidents	50805	35,3%
Total	143876	100%

Table 4 Number of Car/Car, Car/Truck and Single Car Accidents in W.Germany 1974

Accident Type	Number of Cars Involved Source: [15]	Side-Damaged Cars in %	Side-Damaged Cars in W. Germany	%	Occupants Total	Estimation of Injured Occupants: Severe/ Critical	%	Fatal	%
Car-Car	156.536	21	31.306	78,0	53.220	2.128	4	638	1,2
Car-Truck	14.803	12,5	1.850	4,6	3.145	409	13	346	11
Single-Car	50.805	25	7.000*	17,4	11.900	952	8	1.071	9
Total	143.876		40.156	100	68.265				

*Total/Object Collisions with Side Damage 12719 Cars
thereof approximative 5719 Collisions without Fixed Obstacle Contact
7000 Collisions with Fixed Obstacle Contact

Table 5 Approximative Number of Side-Struck Cars, Dependent on Accident Type in W. Germany 1974

Impact Area / Direction of Side Collision	I	%	II	%	III	%	IV	%	VI	%	Passenger Compartment %	V	%	Total	%
Car-Truck Accidents															
Lateral	18	24,7	27	37,o	16	21,9	6	8,2	4	5,5	72,6	2	2,7	73	1oo
Longitudinal	7	33,3	3	14,3	2	9,5	3	14,3	2	9,5	47,6	4	19,1	21	1oo
Total	25	26,6	3o	31,9	18	19,1	9	9,6	6	6,4	67,o	6	6,4	94	1oo

Table 6

Car/Truck Collisions

Impact Areas versus Direction of Side Collision

Impact Area / Direction of Side Collision	I	%	II	%	III	%	IV	%	VI	%	Passenger-Compartment %	V	%	Total	%
Car-Object Accidents															
Lateral	4	13,3	6	2o,o	14	46,7	3	1o,o	1	3,3	8o,o	2	6,7	3o	1oo
Longitudinal	19	67,9	3	1o,7	2	7,1	1	3,6	2	7,1	28,5	1	3,6	28	1oo
Total	23	39,6	9	15,5	16	27,6	4	6,9	3	5,2	55,2	3	5,2	58	1oo

Table 7

Car/Object Collisions

Impact Areas versus Direction of Side Collision

Side Collisions		Car-Truck		Car-Object	
Impact Area		I + V	II + III + IV + VI	I + V	II + III + IV + VI
Fatalities AIS 6	Impact Side	2 8,3	9 15,3	3 11,1	15 37,5
	Opposite Side	1 5,6	4 8,7	3 1o,o	4 13,3
Severely Injured Persons AIS 3 - 5	Impact Side	3 12,5	9 15,3	5 18,5	4 1o,o
	Opposite Side	1 5,6	6 13,o	4 13,3	6 2o,o
Slightly Injured Persons AIS 1 + 2	Impact Side	15 62,5	39 66,o	14 51,9	17 42,5
	Opposite Side	13 72,2	31 67,4	13 43,4	13 43,4
Uninjured Persons	Impact Side	4 16,7	2 3,4	5 18,5	4 1o,o
	Opposite Side	3 16,6	5 1o,9	1o 33,3	7 23,3
Total Occupants on the Impact Side		24 1oo%	59 1oo%	27 1oo%	4o 1oo%
Total Occupants on the Opposite Side		18 1oo%	46 1oo%	3o 1oo%	3o 1oo%

Table 8 Risk of Injury to Impact/Opposite Side Passengers, with/without Involvement of Passenger Compartment

Impact - Side Passengers				
	Injury Risk	Head	Chest	Abdomen
Car-Truck Accidents	Number of Occupants 63 ≙ 100%	49,2	30,2	17,5
	Injuries AIS 3	11,1	14,3	7,9
Car-Object Accidents	Number of Occupants 49 = 100%	53,1	22,4	16,3
	Injuries AIS 3	20,4	4,1	10,2
Total	Number of Occupants 112 = 100%	50,9	26,8	17,0
	Injuries AIS 3	12,5	9,8	8,9

Opposite - Side Passengers				
	Injury Risk	Head	Ches	Abdomen
Car-Truck Accidents	Number of Occupants 43 = 100%	69,8	44,2	7,0
	Injuries AIS 3	16,3	4,7	2,3
Car-Object Accidents	Number of Occupants 50 = 100%	52,0	22,0	12,0
	Injuries AIS 3	12,0	4,0	2,0
Total	Number of Occupants 93 = 100%	60,2	32,3	9,7
	Injuries AIS 3	14,0	4,3	2,2

Table 9 Injuries to Body Areas of Impact/Opposite Side Passengers in Car-Truck and Car-Object Collisions