RISK DISTRIBUTION OF CAR PARTS IN TRAFFIC ACCIDENTS

by

H. Appel and J. Wüstemann

Technical University of Berlin

INTRODUCTION

To develop cars which meet the safety requirements it is necessary to know which parts of the car cause with which frequency and with which severity injuries. This knowledge can only be derived from in-depth-accident-analyses. Such studies were made previously by Bohlin (1), Bäckström/Andersson (2) and Appel (3), (4).

THE SAMPLE

In this study the sample of the accident investigation of the Medical University of Hannover and the Technical University of Berlin (sponsered by the Bundesanstalt für Straßenwesen) is used. The accidents occured in the years from 1973 to 1980.

In these investigations each injury of the victims is localized, assessed using the Abbreviated Injury Scale (AIS) and the causing part determined. The exact analysis of each injury contains the consequence that a complex injury is treated as a sum of several injuries. This results in a high average number of injuries per victim.

In the following tables, of course, not all injury causing parts can be shown, but those which show an important contribution.

Furthermore it should be noticed that the criterion for an accident for getting into the sample is the existence of physical injury. This has the consequence that it is impossible to compare injury severities in dependence of only one accident parameter.

DEFINITION OF THE RISK DEGREE

The potential risk of car parts cannot be described only by the induced injury frequency or the induced average injury severity. Even the product of frequency and severity (assessed by AIS) cannot give a satisfying description of the potential risk of car parts because the AIS is characterized by a linear increase of the injury severity.

A better weighting of the severity degrees can be given by the costs of the injuries. Especially the costs calculated by Stürtz (5) are useful for this purpose. In comparison with those of Jäger/Lindenlaub (6) they have the advantage that the lethality rate of every AIS-class is considered. For the year 1979 result the following costs (7):

AIS 1: 6 600,-- DM	AIS 4: 270 000,-- DM
AIS 2: 34 000,-- DM	AIS 5: 670 000,-- DM
AIS 3: 120 000,-- DM	AIS 6: 880 000,-- DM

The evaluation of each AIS-class by the injury costs offers the advantage that it is possible to evaluate every kind of the frequency distribution over the AIS-classes. For example table 1 makes this evident: The bumper as well as the first half of the hood are participating with 15 % in causing injuries. Both are showing an average injury severity of 1.6 (AIS). Nevertheless the injury costs of the first half of the hood are twice as high as the bumpers'. The reason is given by the different distribution concerning the AIS-classes.

Therefore the injury costs offer a possibility of evaluation and give a much better evidence than a combination of the average AIS and the injury frequency

Another advantage is the illustrative description by the familiar dimension.

RESULTS OF ACCIDENT ANALYSIS

COLLISION BETWEEN CAR AND PEDESTRIAN

Using the age as criterion the pedestrians were differentiated in four groups:

- below 9 years
- 10 to 17 years
- 18 to 44 years
- above 44 years

The results are shown in the tables 1 to 4.

The most dangerous part for children is the hood edge. It causes twice as high injury costs as the second dangerous part: the radiator. But this part gets no importance for the other age groups any more. But the hood edge is again a great potential risk for the group living more than 44 years. Special notice must be given to the second half of the hood. This is the most dangerous part for the adults. For the group beyond 44 also the first half of the hood is very important.

The road is indeed the most frequent injury cause, but it is only combined with a low average severity and low costs.

In the group of pedestrians beyond 44 years it is conspicious that the total costs per pedestrian are higher than the maximum possible account of the lethal injury. As mentioned before this depends on the polytraumatisation of nearly every injured person and the evaluation of each single injury.

In the group beyond 44 the polytraumatisation is mostly pronounced. While there occure 8.9 injuries per victim only 4.8 to 5.3 occure in the other groups. This fact is not only explained by eventually more serious accident parameters in this group, but shows the lower level of physical condition in this age.

COLLISION BETWEEN TRUCK AND PEDESTRIAN

The most dangerous area of trucks is the front end. In the process of data aquisation it is very difficult to distinguish which part of the front end is the injury causing one (see table 5), because the front end of trucks is much too stiff so that there are left no tracks in the collision with pedestrians. In conclusion it is too stiff for any energy dissipation during the collision with pedestrians.

Another striking fact is the risk of a second contact by overrun examining the highest average injury severity and the second rank in frequency.

COLLISION BETWEEN CAR AND BICYCLIST

It is evident that the bicyclist is thrown higher onto the car than the pedestrian. For the bicyclist the windscreen, the frontal roof edge, the second half of the hood and the a-pillar are the most important injury causing parts in this sequence (see table 6).

The road is the most frequent injury cause again. The resulting average costs are even higher than those of the pedestrians.

CAR DRIVER

First of all it is necessary to distinguish between belted and not belted driver (see table 7 and 8).

For the not belted driver the most serious injury cause is the steering system. Being one of the four most frequent causes it shows the highest average injury severity. The second rank in this order of precedence is taken by objects outside the passenger compartment. Once more this shows the importance of using the belt.

Also considerable importance have injuries caused in side collisions. The inner side of the passenger compartment is treated comprehensivly because often the injury cause cannot be localized exactly.

Concerning the belted drivers it is conspicious that they have a higher average injury severity in total and higher injury costs. This fact cannot be interpreted as a real disadvantage of the belt because the existence of physical injury is the main criterion for getting into the sample. Therefore it must be reckoned that in our sample the belted drivers were involved in more severe accidents than the not belted ones.

Nevertheless the data show that the belt systems of current standard should be improved because the belt is the most serious injury cause for belted drivers. This fact is not only caused by the frequency, but also by the severity of the injuries.

Causing injuries the steering system gets nearly the same importance for the belted drivers as the belt. Indeed these injuries are not as serious as for the unbelted drivers.

Apart the steering system the a-pillar is responsible for serious injuries especially for not belted drivers. For this group the most frequent injury cause is the windscreen and the instrument panel at which the bottom limiting the leg room is emphasized. Remarkably the belt doesn't mitigate the potential risk of this part of the instrument panel.

The same fact is valid for the inner side-area which also is a serious injury cause for the belted driver.

The tables 9 and 10 show the influence of car weight to the injury causes for the belted driver.

The tables show that in severe collisions the belt of the current standard is not able to avoid the contact with other parts like the windscreen, the a-pillar and the steering system in smaller cars. The steering system is the most important injuring factor for drivers of cars below 1000 kp total weight. For

cars between 1000 and 1500 kp it's potential risk is only half as high.

On the other hand the importance of the belt as injury cause is increasing enormously in this second group. One reason is that in this car size the advantages of the belt get more effective. Certainly another reason is the insufficient standard of the belt today.

FRONT SEAT PASSENGER

As for the driver the same distinction is made for the front passenger: belted and not belted (see tables 11 and 12).

The role of the steering system for the driver is taken over by the instrument panel for the front seat passenger. The only difference is that the belt is more effective in avoiding the contact with the instrument panel than avoiding the contact of the driver with the steering wheel. Only the contact with the bottom of the instrument panel (leg room) cannot be prohibited at all.

The belt seems also to have no influence on the contact with the inner side-area which causes very serious injuries.

Objects outside of the passenger room have the same importance for the unbelted front seat passenger as for the unbelted driver.

The windscreen is of more importance for the unbelted passenger than for the unbelted driver. In the case of belted occupants it is remarkable that the belt seems to be more effective for the front seat passengers than for the drivers to avoid the contact with the windscreen.

This fact seems to be valid for the effectiveness of the belt as whole. The belted front seat passenger is less injured than the belted driver.

REAR SEAT PASSENGER

The sample of rear seat passengers is not great enough to distinguish between belted and not belted passengers (see table 13).

The most dangerous part for the rear seat passenger is the front seat. With 55 % it is also the most frequent injury cause.

Furthermore the roof gets a remarkable importance for the rear seat passenger. The injuries caused by it are rather serious.

In comparison with the other car occupants belted as well as not belted rear seat passengers get the less serious injuries.

SUMMARY

This study is able to show the engineer parts or areas to which he should pay his attention to construct less aggressive cars. This study shows that there are parts or areas which have an eminent importance for the road user concerned by the type of accident.

By which expense a mitigation of these aggressive parts or areas should be realized a cost/benefit-analysis must show.

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/ped (DM)*
road	187	23	0	0	1	0	211	34	1.1	21 000
overrun	6	6	2	3	0	2	19	3	2.5	23 900
front end **	21	4	3	5	0	0	33	5	1.8	15 500
bumper	51	34	6	2	0	0	93	15	1.6	21 500
radiator	14	6	9	2	7	0	38	6	2.5	51 600
headlights	10	4	0	0	0	0	14	2	1.3	1 600
hood edge	31	12	5	9	13	0	70	11	2.4	96 500
hood, 1st half	59	28	0	3	5	0	95	15	1.6	43 000
hood, 2nd half	4	8	2	0	0	0	14	2	1.9	4 200
fender	13	6	3	2	0	0	24	4	1.8	9 300
windscreen	2	3	0	0	0	0	5	1	1.6	900
a-pillar	1	1	0	0	0	0	2	0	1.5	300
total	399	135	30	26	26	2	618	100	1.6	289 200

total number of injured pedestrians (till 9 years): 128

table 1 injury causing parts for the pedestrians aged up to 9 years (collision with cars)

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/ped (DM)*
road	43	8	1	0	0	0	52	22	1.2	14 700
overrun	3	0	0	0	0	0	3	1	1.0	400
front end **	8	0	0	0	0	0	8	3	1.0	1 100
bumper	14	12	3	0	0	0	29	12	1.6	18 700
radiator	10	1	0	0	0	0	11	5	1.1	2 200
headlights	2	1	0	0	0	0	3	1	1.3	1 000
hood edge	17	3	7	0	0	0	27	11	1.6	22 900
hood, 1st half	20	3	2	1	0	0	26	11	1.4	16 200
hood, 2nd half	3	5	0	0	0	0	8	3	1.6	4 100
fender	18	5	1	0	0	0	24	10	1.3	8 900
windscreen	24	6	1	0	1	0	32	13	1.4	25 000
a-pillar	9	1	0	1	0	2	13	5	2.1	54 900
roof edge (front)	1	1	0	0	0	0	2	1	1.5	900
total	172	46	15	2	1	2	238	100	1.4	162 400

total number of injured pedestrians (from 10 to 17 years): 46

table 2 injury causing parts for the pedestrian aged from 10 to 17 years (collision with cars)

* injury costs per injured pedestrian
** not discernible if bumper, radiator, headlights or hood edge

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/ped (DM)*
road	34	7	1	1	1	0	44	17	1.4	31 100
overrun	8	0	10	4	2	0	24	9	2.7	75 000
front end **	11	2	1	3	0	0	17	7	1.8	21 800
bumper	24	16	7	2	0	0	49	19	1.7	42 500
radiator	2	0	1	0	0	0	3	1	1.7	2 700
headlights	1	1	1	0	0	0	3	1	2.0	3 300
hood edge	10	0	3	0	0	0	13	5	1.5	8 700
hood, 1st half	6	2	2	0	0	0	10	4	1.6	7 100
hood, 2nd half	21	3	0	0	6	2	32	12	2.3	122 900
fender	2	1	2	0	0	0	5	2	2.0	5 900
windscreen wiper	2	0	0	0	0	0	2	1	1.0	300
windscreen	26	13	0	0	1	0	40	15	1.4	26 200
a-pillar	5	2	1	0	0	0	8	3	1.5	4 500
roof edge (front)	5	4	2	0	0	0	11	4	1.7	8 300
total	157	51	31	10	10	2	261	100	1.7	360 200

total number of injured pedestrians (from 18 to 44 years): 49

table 3 injury causing parts for the pedestrians aged from 18 to 44 years (collision with cars)

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/ped (DM)*
road	157	34	7	3	1	0	202	19	1.3	37 000
overrun	26	6	0	0	0	0	32	3	1.2	3 100
front end **	32	14	10	6	5	0	67	6	2.1	56 200
bumper	50	52	33	15	2	0	152	14	2.1	93 800
radiator	7	2	2	0	0	0	11	1	1.5	2 900
headlights	6	6	2	0	0	0	14	1	1.7	4 000
hood edge	38	20	52	23	6	0	139	13	2.6	142 600
hood, 1st half	26	20	13	21	11	2	93	9	2.8	141 100
hood, 2nd half	49	31	8	17	26	3	134	12	2.6	221 200
fender	22	16	6	7	4	0	55	5	2.2	49 0000
windscreen wiper	1	5	0	1	0	1	8	1	2.6	10 900
windscreen	69	32	6	4	7	1	119	11	1.7	73 000
a-pillar	8	8	3	6	5	1	31	3	2.8	53 600
roof edge (front)	6	14	3	6	4	1	34	3	2.7	49 600
total	497	260	145	109	71	9	1091	100	2.1	938 000

total number of injured pedestrians (beyond 44 years): 122

table 4 injury causing parts for the pedestrian aged beyond 44 years (collision with cars)

* injury costs per injured pedestrian
** not discernible if bumper, radiator, headlights or hood edge

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/ped. (DM)*
road	58	7	4	2	3	0	74	14	1.4	52 200
overrun	24	19	16	19	18	4	100	19	3.0	334 800
front end **	113	54	20	22	21	3	233	45	2.1	394 700
bumper	31	11	8	1	3	0	54	10	1.8	54 600
radiator	7	1	0	0	1	0	9	2	1.6	10 700
headlights	6	4	3	0	0	0	13	2	1.8	7 700
hood edge	4	1	0	1	3	0	9	2	2.8	33 400
windscreen	11	3	2	0	0	1	17	3	1.7	18 500
a-pillar	7	2	0	0	0	0	9	2	1.2	1 600
roof edge (front)	0	0	0	0	1	0	1	0	-	9 600
total	261	102	53	45	50	8	519	100	2.1	917 800

total number of injured pedestrians: 70

table 5 injury causing parts for the pedestrians in collision with trucks

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/bike (DM)*
road	236	40	6	2	4	1	289	27	1.3	44 500
overrun	10	5	6	5	2	0	28	3	2.4	21 000
front end **	37	8	6	0	0	0	51	5	1.4	7 100
bumper	47	26	18	3	0	0	94	9	1.8	23 900
radiator	6	1	0	0	0	0	7	1	1.1	400
headlights	5	2	2	1	0	0	10	1	1.9	3 500
hood edge	46	11	11	1	0	0	69	7	1.5	13 000
hood, 1st half	26	5	1	6	5	0	43	4	2.0	31 200
hood, 2nd half	26	12	13	5	8	0	64	6	2.3	50 900
fender	29	0	6	2	2	0	39	4	1.7	15 000
windscreen	4	1	3	0	2	0	10	1	2.5	10 100
wiper windscreen	105	55	21	9	13	1	204	19	1.9	98 300
a-pillar	8	9	2	9	4	3	35	3	3.0	48 000
roof edge (front)	39	21	5	3	5	6	79	7	2.2	63 300
bicycle	27	1	2	0	0	0	30	3	1.2	2 600
total	651	197	102	46	45	11	1052	100	1.7	433 800

total number of injured bicyclists: 174

table 6 injury causing parts for the bicyclists in collision with cars

* injury costs per injured person
** not discernible if bumper, radiator, headlights or hood edge

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	381	158	20	3	6	2	570	23	1.4	30 900
windscreenframe	56	24	10	1	7	3	101	4	1.9	18 300
a-pillar	61	22	16	6	10	11	126	5	2.3	38 500
steeringsystem	177	78	59	46	65	4	429	17	2.4	128 700
instrument panel top	18	6	1	0	3	0	28	1	1.7	4 500
instrument panel middle	30	17	9	4	0	0	60	2	1.8	5 400
instrument panel bottom	312	66	37	3	0	0	418	17	1.4	17 500
instrument panel tot.**	394	95	58	9	3	0	559	23	1.5	31 500
pedals	64	28	8	2	0	0	102	4	1.5	5 300
dashboard	25	11	7	0	1	0	44	2	1.7	3 700
side, inwards	167	73	29	22	15	4	310	13	1.9	48 600
outside of the car	116	49	19	13	17	16	230	9	2.2	61 600
total	1441	538	226	102	124	40	2471	100	1.8	367 000

total number of injured car drivers (not belted): 547

table 7 injury causing parts for the not belted car driver

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	83	28	2	4	2	4	123	12	1.6	30 600
windscreenframe	12	9	1	2	0	0	24	2	1.7	4 200
a-pillar	26	14	5	1	1	1	48	5	1.8	12 200
steeringsystem	124	35	15	11	23	3	211	20	2.0	98 900
instrument panel top	8	6	0	0	0	0	14	1	1.4	1 000
instrument panel middle	9	1	0	0	0	0	10	1	1.1	400
instrument panel bottom	120	17	11	13	0	0	161	15	1.5	24 700
instrument panel tot.**	149	28	11	13	0	0	201	19	1.4	27 000
pedals	32	8	3	0	0	0	43	4	1.3	3 400
dashboard	11	7	6	1	0	0	25	2	1.9	5 200
side, inwards	58	33	13	24	18	1	147	14	2.4	89 600
belt	123	24	11	23	23	0	204	20	2.0	97 900
outside of the car	8	3	3	4	2	2	22	2	2.8	18 700
total	626	189	70	83	69	11	1048	100	1.9	387 600

total number of injured car drivers (belted): 251

table 8 injury causing parts for the belted car driver

* injury costs per injured car driver
** including the injury causing parts which cannot exactly localized there

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	29	8	0	2	2	4	45	9	1.9	51 900
windscreenframe	9	4	0	2	0	0	15	3	1.7	6 500
a-pillar	8	12	4	1	0	1	26	5	2.1	18 500
steering system	48	18	9	11	14	2	102	20	2.4	142 600
instrument panel top	3	6	0	0	0	0	9	2	1.7	2 000
instrument panel middle	4	0	0	0	0	0	4	1	1.0	200
instrument panel bottom	57	6	9	13	0	0	85	17	1.7	45 800
instrument panel tot.**	69	15	9	13	0	0	106	21	1.7	49 200
pedals	15	5	1	0	0	0	21	4	1.3	3 400
dashboard	5	3	2	0	0	0	10	2	1.7	3 300
side. inwards	36	20	9	14	8	0	87	17	2.3	98 600
belt	56	8	6	6	2	0	78	16	1.6	38 200
outside of the car	2	0	3	2	2	2	11	2	3.7	35 500
total	277	93	43	51	28	9	501	100	2.0	447 800

total number of injured drivers of cars below 1000 kp (belted): 113

table 9 injury causing parts for the drivers of cars below 1000 kp

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	42	15	2	2	0	0	61	11	1.4	12 100
windscreenframe	3	5	1	0	0	0	9	2	1.8	2 400
a-pillar	18	2	1	0	1	0	22	4	1.4	7 600
steering system	75	18	6	4	9	1	113	21	1.9	76 100
instrument panel top	5	0	0	0	0	0	5	1	1.0	300
instrument panel middle	5	1	0	0	0	0	6	1	1.4	500
instrument panel bottom	63	11	2	0	0	0	76	14	1.2	8 000
instrument panel tot.**	80	13	2	0	0	0	95	17	1.2	9 400
pedals	17	3	2	0	0	0	22	4	1.3	3 500
dashboard	6	4	4	1	0	0	15	3	2.0	7 200
side, inwards	29	17	4	10	13	1	74	14	2.5	105 000
belt	64	16	5	17	21	0	123	23	2.3	156 800
outside of the car	6	3	0	2	0	0	11	2	1.8	5 300
total	340	96	27	36	44	2	545	100	1.8	385 300

total number of injured drivers of cars between 1000 and 1500 kp (belted): 129

table 10 injury causing parts for the belted drivers of cars between 1000 and 1500 kp

* injury costs per injured car driver
** including the injury causing parts which cannot exactly localized there

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	251	131	24	5	5	1	417	32	1.5	53 000
windscreenframe	27	19	2	1	3	1	53	4	1.8	15 100
a-pillar	34	9	5	0	4	1	53	4	1.8	16 800
steering system	7	3	3	0	2	0	15	1	2.1	6 600
instrument panel top	42	12	7	4	7	0	72	5	1.9	26 100
instrument panel middle	46	24	14	4	16	5	109	8	2.4	67 900
instrument panel bottom	151	23	21	4	4	1	204	15	1.5	31 900
instrument panel tot.**	255	66	47	12	35	8	423	31	1.9	154 600
pedals	1	1	0	0	0	0	2	0	1.5	100
dashboard	21	9	8	0	0	0	38	3	1.7	5 000
side, inwards	87	50	39	14	11	8	209	16	2.2	89 800
outside of the car	52	23	12	8	8	10	113	9	2.4	67 400
total	735	311	140	40	68	29	1323	100	1.9	407 500

total number of injured car front seat passengers (not belted): 280

table 11 injury causing parts for the not belted car front seat passengers

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	16	4	0	0	0	0	20	6	1.2	2 400
windscreenframe	2	3	0	1	0	0	6	2	2.0	3 800
a-pillar	6	8	2	0	0	0	16	5	1.8	5 500
steering system	1	1	0	0	0	0	2	1	1.5	400
instrument panel top	18	12	3	0	0	0	33	9	1.5	8 800
instrument panel middle	9	2	0	0	0	0	11	3	1.2	1 300
instrument panel bottom	54	6	5	6	0	0	71	20	1.5	27 500
instrument panel tot.**	87	25	8	8	0	2	130	37	1.6	62 400
dashboard	14	4	1	0	0	0	19	5	1.3	3 400
side, inwards	27	10	4	4	2	1	48	13	1.9	42 600
belt	74	13	4	12	5	0	108	30	1.7	79 200
outside of the car	4	0	0	0	0	1	5	1	2.0	9 000
total	231	68	19	25	7	4	354	100	1.6	208 700

total number of injured car front seat passengers (belted): 101

table 12 injury causing parts for the belted car front seat passengers

* injury costs per injured passenger
** including the injury causing parts which cannot exactly localized there

injury causing parts	injury severity (AIS) 1	2	3	4	5	6	frequen. abs.	%	aver. AIS	costs/car (DM)*
windscreen	14	9	0	0	0	0	23	4	1.4	1 900
windscreenframe	4	4	2	0	1	1	12	2	2.4	9 100
instrument panel tot.	7	1	0	0	0	0	8	1	1.1	400
frontseats	222	46	18	7	13	0	306	55	1.5	73 800
roof	16	10	4	4	2	0	36	6	2.1	15 600
side, inwards	68	31	14	3	3	1	120	22	1.7	32 200
outside of the car	33	16	0	2	1	0	52	9	1.5	9 200
total	364	117	38	16	20	2	557	100	1.6	142 200

* injury costs per injured passenger

total number of injured car rear passenger: 214

table 13 injury causing parts for the car rear passenger

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