Collisions of Heavy Trucks against Cars, Two-Wheelers and Pedestrians

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ABSTRACT and SUMMARY

Collisions of heavy trucks with cars, two-wheelers and pedestrians are analyzed with regard to their frequency, their injury potential and collision mechanisms. 129 crashes of trucks with other four-wheel-vehicles (totally 163 injured occupants and 247 vehicles) were analyzed in detail. The most dangerous impact configuration was truck-front to car-front; therefore deformable underrun protection elements in the *front* would have a much higher injury reduction potential for car occupants than the classical *rear* underrun protection bars; the mean ISS for car occupants (13,5) was highest for front to front impacts and relatively low for car-front to truck-rear impacts (mean ISS 4).

If involved in a collision, the fatality risk for truck occupants was as low as 0.17% whereas it was 0.45% for car occupants (all collisions types), i.e. 2.5 times higher. Truck occupants had injuries of MAIS 3 and more only in single truck crashes and truck-truck impacts.

Another sample discussed contains 87 collisions of trucks against two wheelers or pedestrians. As to the frequency and injury severity (sum of ISS values) the *front* of the truck was most hazardous for pedestrians and motorcycle users, the *left* truck side for oncomming motorcycles and the *right* side was the most frequent and dangerous impact location for bicycles and mopeds. Predominantly head and lower extremities were injured often and severely.

INTRODUCTION

It has been an experience of crash investigators for decades that the collision of a heavy vehicle such as a truck against a car or even an unprotected road user such as a two-wheeler or a pedestrian is a disaster for the small partner. This is a consequence of simple physical reflection regarding the disadvantageous mass ratio and the geometrical incompatibility of the two collision partners. Numerous scientific papers and reports document this unsatisfactory situation (e.g. Appel 1979, 1989, 1990; Danner 1989; Dejeammes 1985, Langwieder 1987, 1988, 1989; Middelhauve 1978, 1988; Otte 1987, 1990; Riley 1980, 1981; Seiff 1985). Högström proposed some side protection devices on a scientific basis in 1973 already; some designs go back to the year of 1912!

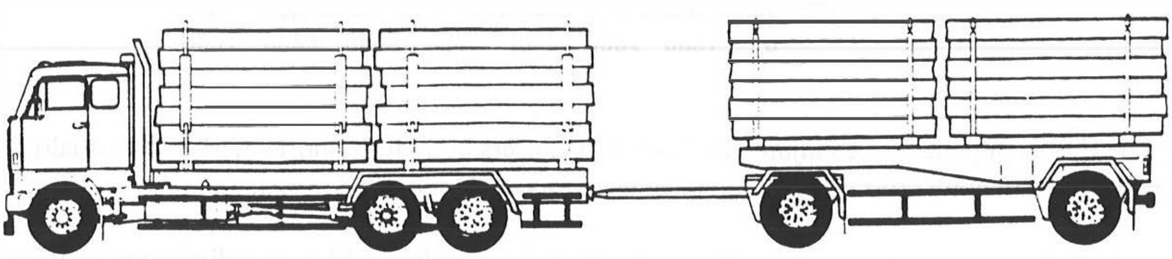

Fig. 1. Early proposal of side rails to protect two-wheelers from underruning (Högström 1974).

Given these facts it is rather strange that rule makers, governements and truck manufacturers have yet *not* taken adequate measures in a general and efficient manner to protect other road users. It seems therefore important to investigate collisions of cars, two-wheelers and pedestrians with involvement of a truck (heavy goods vehicle with more than 3'500 kg) in different countries in detail. Since the well known findings are not repeated in this paper only a choice of results is presented.

METHODS

In a first section the official data of the Swiss Bureau of Statistics (Bundesamt für Statistik, 1988) are further analyzed as to the involvement of trucks.

The second section contains especially collected data in the Canton of Zurich (except the two cities Zürich and Winterthur) during the three years 1984 to1986. Police data (report and photographic documentation) and medical data from hospitals, general practitioners or autopsy departments were available for:

- 247 vehicles
- 111 collisions truck-car/van
- 11 single truck collisions,
- 7 truck to truck impacts. A total of
- 136 trucks were involved in these 129 collisions and
- 163 people were injured MAIS >=1,
- 31 of them being truck occupants.

The third section describes 87 collisions of trucks against unprotected road users (pedestrians, bicycle, moped, motorcycle) all of them being injured MAIS >=1.

RESULTS

1. Swiss nationwide data

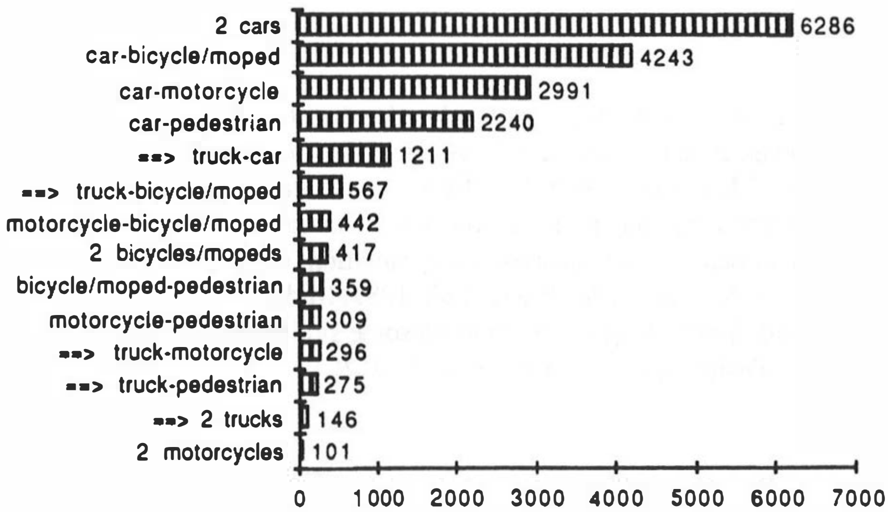

Fig. 2. Collision partners and injured and killed road users in Switzerland 1987. 19'883 casualties with at least two moving objects. Truck involvement is specially indicated (==>).

Truck involvement was seen with 2'495 among 19'883 casualties (= 13%) in collisions with at least two collision partners during 1987 in Switzerland (Fig. 2). Most frequent were casualties in collisions of the type truck-car (1211) and truck-bicycle/moped (567) whereas the types truck-pedestrian, truck-motorcycle and single truck collisions were much less frequent. To these figures the 315 collisions of trucks against fixed objects have to be added (Fig. 3).

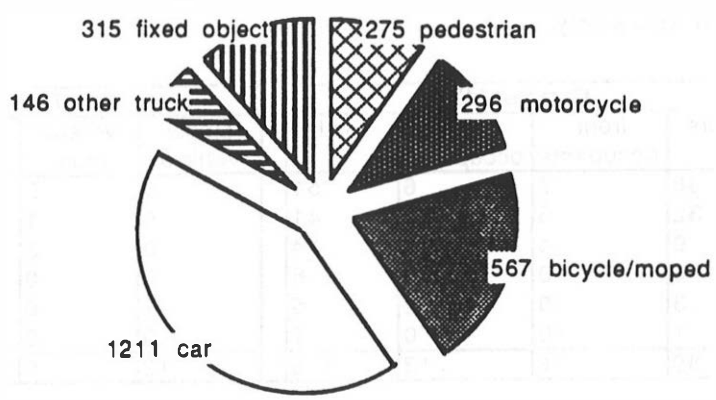

Fig. 3. Truck related collisions: Injured and killed road users in Switzerland 1987.

In order to get a fairly large sample we collected the data from three years (Table 1): With all involved occupants (with or without injuries) of four-wheel-vehicles (cars, vans and trucks) trucks were involved in only 5%; the share of the truck occupants among those injured as well as those killed was around 2% each. If involved in a collision, the fatality risk for truck occupants was as low as 0.17% whereas it was 0.45% for car occupants, i.e. 2.5 times higher.

Category	involved	w. minor injury	w. severe injury	fatality
Truck	8'437	206	103	18
Truck-trailer	3'396	72	42	5
Tractortrailer	1'568	46	24	4
Trolleybus/coach	2'900	321	102	1
Heavy vehicles	**16'301**	**645**	**271**	**28**
For comparison				
Light vehicles (4 wheels)	**308'973**	**26'747**	**14'965**	**1'389**

Table 1. Occupants of trucks and light four-wheel-vehicles in Switzerland, 1984-1986.

2. Truck occupants and car occupants in collisions with trucks (1984-86 Canton Zurich only)

The favourable mass ratio protects truck occupants in collisions against cars to a great deal from injuries. In truck to car impacts no injury of MAIS >=3 occurred with truck drivers but the corresponding car drivers were injured MAIS >=3 in over 20% (19 of 89, Table 2). The most dangerous impact configuration for the car occupants was truck front to car front; the mean ISS of these car occupants was 13.5, the highest of all car-truck collision subsamples. The *front* of the 136 trucks was deformed in 35 cases by a car front whereas the truck *rear* part was impacted only 4 times by a car front. These rear impacts caused once a MAIS 2 and twice a MAIS 1 casualty (mean ISS 4) in the car occupants. Therefore, the underrun protection devices should be integrated above all in the *front* of the truck which is much more hazardous to car occupants than the rear part of the truck. Riley (1985), Appel (1989 and 1990) and Danner (1989) have shown promissing experimental passive safety elements around the truck protecting car occupants. Only other trucks or fixed objects have a certain injury potential for the truck occupants: the mean ISS was highest in truck to truck collisions (7.2) and single truck impacts (6.5). In 7 of the latter 11 cases the truck rolled over. In these circumstances a three-point belt would certainly reduce the injury severity for the truck occupants and can therefore be recommended; however, since the crashes producing injuries to truck occupants are reletively rare and the truck drivers in general seem to wear seat belts only reluctantly, a mandatory seat belt law for truck drivers is not a priority in road safety.

	Cars (n=101)				Trucks (n=136)			
Injury Severity (MAIS)	drivers	front occupants	rear occupants	total	single vehicle	versus truck	versus car	total
1	38	7	6	51	5	5	6	16
2	32	5	4	41	6	1	4	11
3	9	4	1	14	0	3	0	3
4	6	0	0	6	0	0	0	0
5	3	0	2	5	1	0	0	1
6	1	0	0	1	0	0	0	0
Total	89	16	13	118	12	9	10	31

Table 2. Injury severity of 149 car and truck occupants (excl. vans), Canton Zurich, 1984-1986.

3. Trucks and unprotected road users (1984-86 Canton Zurich only)

With regard to the construction of protecting elements around the truck for unprotected road users it is important to know the contact areas of the truck and their injury sequelae. Fig. 4 shows that the *front* of the truck is the most often contacted area for pedestrians and two wheelers as well: 42 of the 85 cases where an exact contact area could be defined involved the truck front. Pedestrians and each of the three two wheeler categories were affected similarly conceming the frequency; however, pedestrians and motorcycle users had a much higher injury severity (Table 3). It is evident from Table 4 and Fig. 6 that the highest injury potential - especially for pedestrians and motorcycles - is located at the truck *front* (sum of ISS values 654 versus 338 for the left, 186 for the right side and 189 for the rear).

The right side was contacted often by bicycles but was particularly dangerous for moped drivers (total ISS 266). Since the moped is allowed to drive 30 km/h (some drive 40 km/h) the overtaking process of the also relatively slow truck takes a rather long time. Case analysis showed that during this overtaking process the intimidated driver can loose control and falls under the wheels even without being previously impacted by the truck side. In these situations flat side guard panels can prevent the two-wheeler from being caught by a uneven side structure and overrun. Nüssle (1989) also pointed out that low speed is typical: 1/3 to 1/2 of these truck collisions took place at driving speed of less than 10 km/h. It therefore can be concluded that a side guard is not necessarily a heavy steel structure; light weight flat plastic panels would be efficient in these low speed situations. Another crucial area was the left truck side for oncomming motorcycle drivers (total ISS 132) and in the rear for pedestrians being overrun in reversing manoevers (total ISS 105).

In all these lateral contacts buses and coaches performed much better since they have a flat side guard by construction.

	Contact area on truck								
	front		right		left		rear		
Victim	mean ISS	n	mean ISS	n	mean ISS	n	mean ISS	n	Total
Pedestrian	**27**	9	8	3	-	0	**35**	3	15
Bicycle	7	11	8	6	15	3	4	2	22
Moped	6	10	**38**	**7**	9	1	8	**8**	26
Motorcycle	**23**	**12**	-	0	**22**	**6**	3	4	22
Mean ISS / Total	16	**42**	**21**	16	19	10	11	17	85

Table 3. Frequency and mean ISS values caused by different contact areas on the truck.

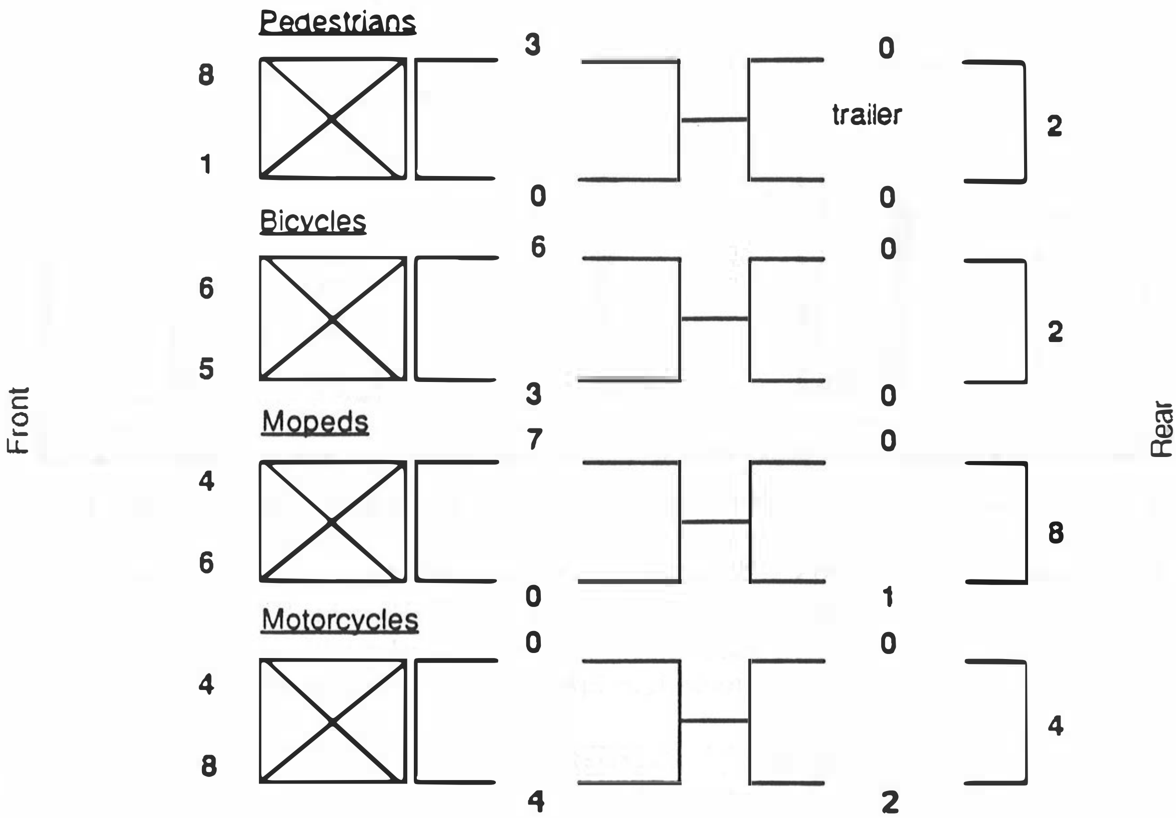

Fig. 4. Truck areas contacted by different injured or killed road users.

Victim	Contact area on truck			
	front	right	left	rear
	total ISS	total ISS	total ISS	total ISS
Pedestrian	**241**	24	0	**105**
Bicycle	77	48	45	8
Moped	60	**266**	9	64
Motorcycle	**276**	0	132	12
Total	**654**	**338**	186	189

Table 4. Sum of ISS values caused by different contact areas on the truck, see also Fig. 6.

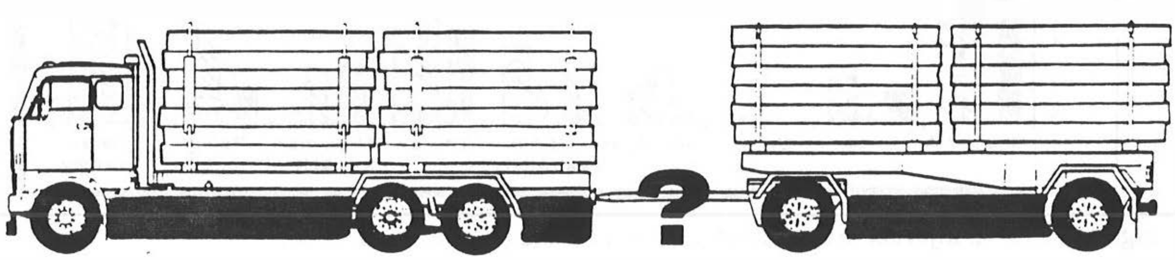

Fig. 5. Flat side guards prevent two-wheelers and pedestrians much more effectively from being thrown under the truck than simple side rails (see Fig. 1.) Moreover, thy reduce noise and water spray.

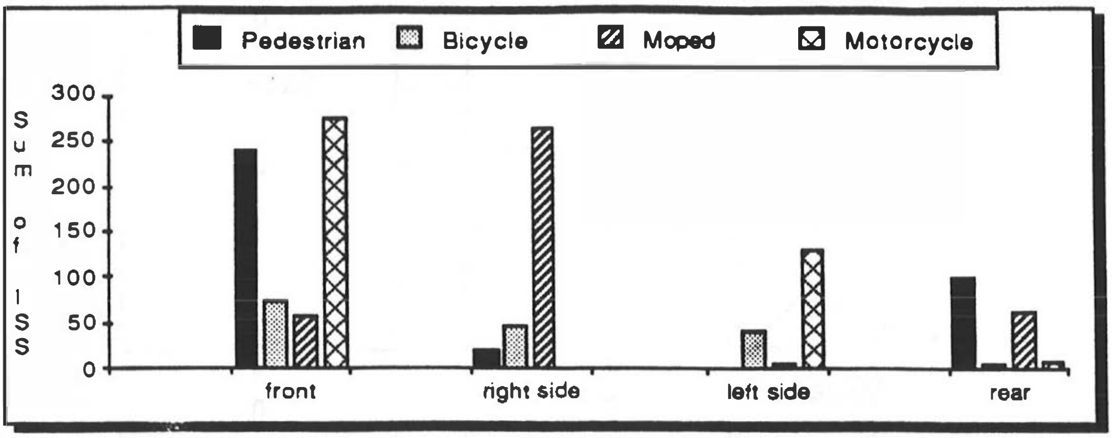

Fig. 6. Sum of I[illegible]alues caused by different contact areas on the truck (figures see table 4).

The local distric[illegible]of the AIS >=2 injuries was not essentially different for the four categories: The exposed head w[illegible]ured often and severely (Table 5, Fig. 7). The other body end - the lower extremities - was expo[illegible] in a similar manner, above all in two wheeler collisions. The pelvis of moped users was endangered when an overrun took place. Spine and abdomen were not an injury focus at all.

	Pedestrians (n =15)				Bicycle (n = 22)				Moped (n = 27)				Motorcycle (n = 23)			
	AIS				AIS				AIS				AIS			
Body region	2	3 - 5	6	total	2	3 - 5	6	total	2	3 - 5	6	total	2	3 - 5	6	total
Skull/brain	4	2	3	9	6	3		9	8	2	1	11	1	3	2	6
Face	1	1		2	1			1	1	1		2	2	1		3
Spine				0				0		1		1				0
Shoulder	1			1	3			3	1			1				0
Upper extremity	2			2	1	1		2	2			2	3	1		4
Thorax	2	1	2	5	1			1	2	3	1	6	1	3	1	5
Abdomen/back	3			3	1	1		2	1	2		3		1		1
Pelvis	1	1		2	1			1	1	4		5	1			1
Lower extremity		3		3	2	3		5	4	6		10		7		7
Total	14	8	5	27	16	8	0	24	20	19	2	41	8	16	3	27

Table 5. AIS >=2 injuries to 87 unprotected road users.

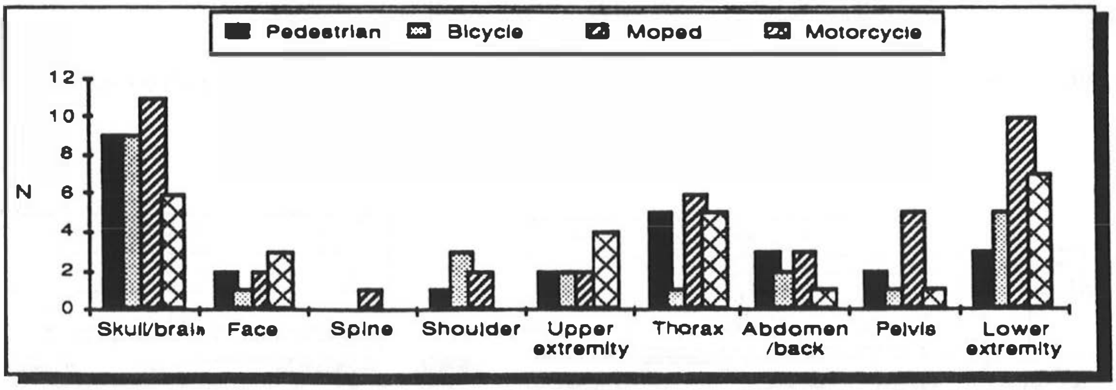

Fig. 7. AIS >=2 injuries to 87 unprotected road users (figures in table 5).

DISCUSSION

Case analysis shows that three point safety belts certainly could prevent *truck occupants* from severe injuries particularly in truck to truck and single truck collisions. However, given the relatively low number of casualties safety belts for truck occupants - particularly with a mandatory seat belt law - are not a number-one-issue in traffic safety.

Advanced protection elements on the *front* of the truck could save much more injuries to car occupants than *rear* end underrun protection systems. Since the truck front is a dangerous contact area also for oncomming motorcycles and for pedestrians the currently developed safety front end structures should also be designed with regard to these two collision types.

All trucks should be fitted with a *flat* side guard to prevent unprotected road users from being thrown under the truck side and overrun subsequently. If the side guard is made out of a number of single bars, the risk of being caught in these open structures is high. The ECE-regulation for new trucks dated April 13, 1989 should be adopted by all countries as soon as possible. Moreover, since trucks generally stay in function for a long period of time, retrofitting of flat side guards should be made compulsory: According to recent calculations of ASTAG (Swiss Utility Vehicle Association; Hess 1990), the cost of retrofitted flat side guard structures indeed is about the doubble of one with an open frame profile (sfr 10'000 vs. 5'000 for single trucks, sfr 20'000 vs. 10'000 for trucks with trailer and sfr 14'000 vs. 7'500 for tractor-trailers). With regard to the high total cost of a utility truck (several 100'000 sfr) this amount is not overwhelming and it could even be reduced in serial production considerably. A side guard is not necessarily a heavy steel structure; light weight flat plastic panels would be efficient since these critical contacts generally occur at low speed.

Taking into account the high injury reducing potential and additional possible advantages of these side guards such as lower air resistance and less noise, prevention of lateral water spray and the possibility of more surface for advertising this amount is very well invested.

CONCLUSIONS

Three point safety belts for truck occupants are certainly recommendable but are not a number-one-issue in traffic safety.

Underrun protection devices should be integrated above all in the *front* of the truck which is much more hazardous to car occupants than the *rear* part of the truck. They could reduce the injury severity for colliding car occupants, motorcycles users and pedestrians.

In all new trucks *flat* side guard panels should be integrated and current trucks should be retrofitted correspondingly. The investment for retrofitting (2 to 5% of the total price of a truck) may pay off even for the company running the truck since the lower air resistance saves fuel. But most of all side guards prevent unprotected road users (users of mopeds and bicycles, pedestrians) from being thrown under the truck side and overrun subsequently by the wheels.

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