For the occupant behaviour, the figure compares the acceleration values for head, chest and pelvis of driver dummy, as obtained through tests and simulation.

The kinematics of the occupant model is plotted at rate of 10 milliseconds in comparison of the sequence of a car-to-car test, drawn from a high-speed film, which, at rate of 10 milliseconds, shows the motion of dummy's head and chest with respect to the occupant compartment. The kinematics is very similar.

The results of validation, for both the structural behaviour and occupant behaviour, can be considered to be in accordance with expectations. The methodology allows:

—Comparison of the values measured in moving barrier-to-car test, at a given velocity, with the allowable limits.

—Evaluation of structural and occupant behaviour for the impacted car as well as the impacting car.

—By simulating increasing collision velocity, identification of the velocity at which the allowable limits are reached by one car or by both cars, i.e., the quantitative evaluation of compatibility of this pair of cars.

—By extending the analysis to more models, it is possible to evaluate the compatibility between different models of a fleet and to considerably reduce the number of tests that would be necessary.

The simulation cannot be better than the scatter of experimental data. The use of reliable dummies and reliable tolerance criteria is of paramount importance.

Volvo Traffic Accident Research System as a Tool for Side Impact Protection Evaluation and Development

HANS NORIN, ANNA NILSSON-EHLE,
CHRISTER GUSTAFSSON
Volvo Automotive Safety Centre
Volvo Car Corporation

ABSTRACT

In this report Volvo Traffic Accident Research System is described. Volvo has a combination of multidisciplinary and statistical investigation which gives a representative picture of the traffic accident situation and also gives a deep insight into parameters that influence the occupant injury-production.

This accident material, which covers about 12.000 of the most severe Volvo accidents, in Sweden, has been the basis for an analysis of the side impact problem area.

The traffic environment as experienced by the Volvo car, in terms of accident type distribution, obstacles, etc., is compared with corresponding data in other accident materials.

Conclusions from this comparison and analysis of the distribution of different types of injuries, are used to determine important side impact parameters. These parameters indicate the test methods that should be used to give a good simulation of the real traffic environment.

The need of subsystem testing as a complement to full-scale testing is discussed with the complex traffic environment as background.

INTRODUCTION

The demands that are made on a modern car are comprehensive. This applies, not least, to the aspects of design that are intended to protect the occupants in case of a road accident. The requirements placed on the car manufacturer are controlled to some extent by current legislations. Reproducible test methods in laboratories represent only a certain number of specific collision situations which agree, more or less, with the actual accident situations that arise on the road.

In order to achieve designs which give the optimum possible protective effect, it is essential to obtain information on what actually happens in a road accident, in relation to the car design, including information on the injuries caused to the occupants of the car.

Consequently, we decided to carry out special accident research in parallel with the normal laboratory collision testing. The knowledge gained in this way can be related, in the laboratory, to the car design.

In this report, Volvo Traffic Accident Research work is described and applicated at the side impact problem.

VOLVO TRAFFIC ACCIDENT RESEARCH SYSTEM

The main task of the Accident Research System is to collect information on what happens to a car and its occupants in a traffic accident. In order to maintain the quality of this work at as high level as possible, we have divided up our activities into two main fields. (See Fig. 1.)

Multidisciplinary Accident Investigation

The multidisciplinary Accident Investigation Group studies approximately 100 road accidents each year. These are investigations in depth which means a thorough technical examination of the car (see Figure 2) together with a close analysis of the occupant injuries that occurred. Specially trained technicians are responsible for the vehicle examination, while the analysis of injuries is carried out by a doctor who is associated with the Group. In addition, records are kept of the traffic situation at the time of the accident. This helps us to obtain an understanding of the effect of the traffic environment on the accident and its consequences.

The multidisciplinary Accident Investigation Group operates in two zones—local and distant. The local zone covers a geographical area within one hour's driving time from our office in Gothenburg. At the scene of the accident, we document the traffic situation by means of photographs, measurements, interviews with the police, rescue personnel, etc. An examination of the vehicle is carried out and this is later supplemented by more detailed and extensive investigation after the vehicle has been transported to a workshop.

We obtain the information that a road accident involving a Volvo car has occurred, through our co-operation with the police, the rescue services and the regional SOS alarm centre. There is always one member of our group in readiness to visit the site of an accident, all round the clock.

The distant zone consists primarily of the rest of Sweden, but also includes other countries, if accidents occur which we consider to be of particular interest. We obtain information on these accidents from the police, the National Swedish Road Safety Office, the Insurance Companies and our own Service organisation. All have been informed on the type and severity of accident in which we are interested. This gives us wide flexibility; our areas of interest, naturally, change from time to time.

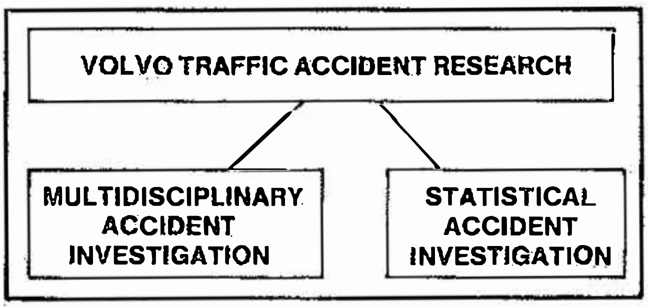


Figure 1. Volvo traffic accident research.

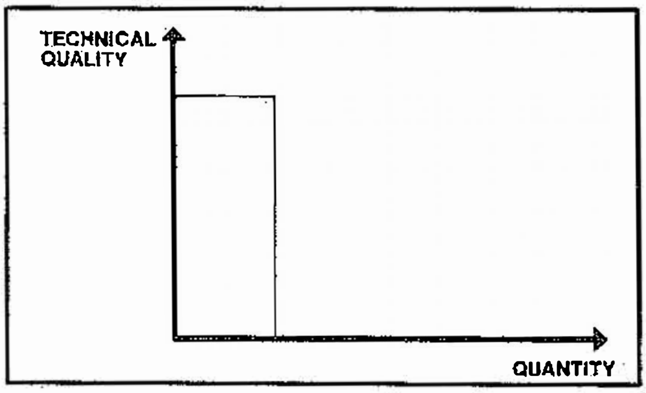


Figure 2. Multidisciplinary accident investigation.

Statistical Investigation

Our collection of accident statistics differs from the work of the multidisciplinary Accident, since these statistics cover a large number of accidents in which Volvo cars are involved. This activity is not regarded as a deep study of the design of the car. (See Fig. 3.)

Our association with our own Insurance Company, Volvia, gives us a unique opportunity of following up accidents to Volvo cars. At present about 400.000 Volvo cars are insured by Volvia and, of these, approximately 45.000 are involved in an accident of some kind each year. From amongst these accidents we select about 2.000 of the more serious accidents. (See Fig. 4.)

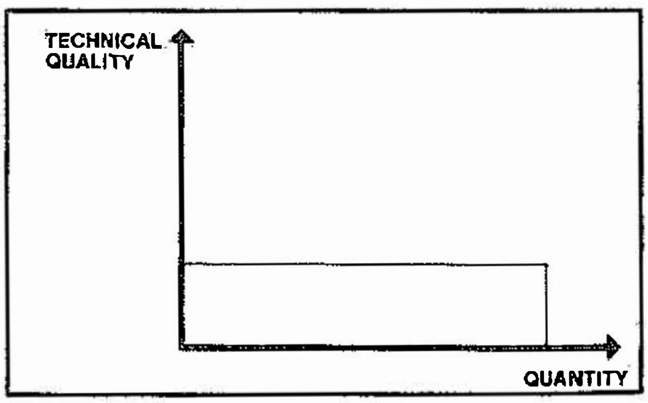


Figure 3. Statistical investigation.

In this way we gather information on all the serious accidents involving Volvo cars in Sweden. So far we have gathered statistics on 12.000 serious accidents.

Through the co-operation of the Volvia Damage Inspectors we obtain photographs of the cars damaged in all of these accidents. From the photographs, we assess the deformation of the car and this is then coded, using the International CDC System (1).

We also send a questionnaire to the owner of the car asking for information on how the accident occurred, how many passengers were in the car, etc. This questionnaire form is then supplemented by the police reports and the medical reports from the hospital which treated the injured. The injury reports are analyzed by our doctor who codes this information, using the International AIS System (2). All the information concerning the accident is processed and stored using a special computer program; it can then be used in various types of accident analysis work. The information routes are shown in Figure 5.

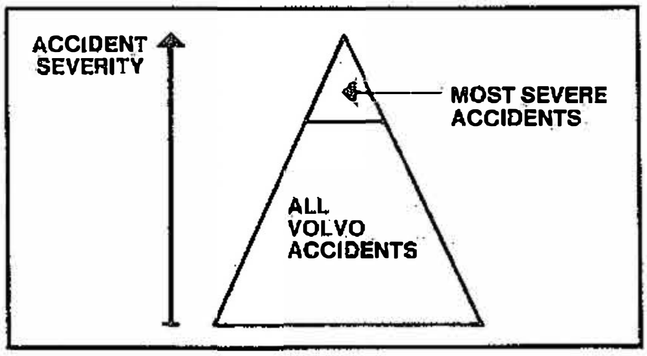


Figure 4. Selection of serious accidents.

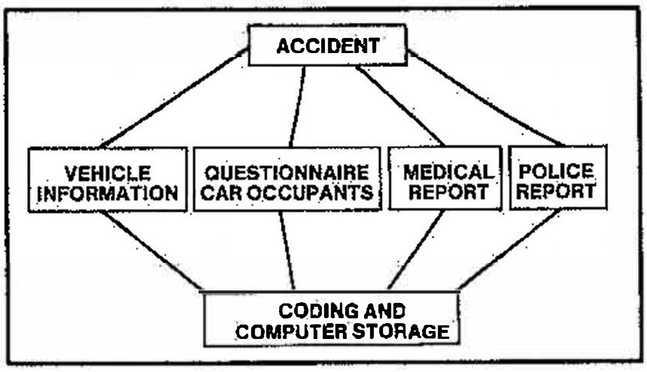


Figure 5. Data collection, accident statistics.

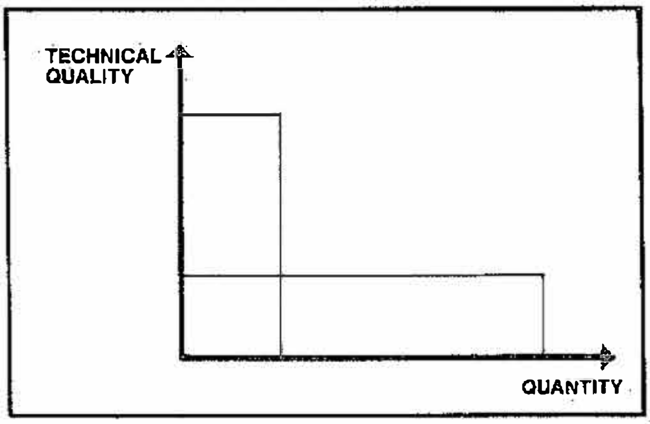


Figure 6. Combination of multidisciplinary and statistical accident investigation.

Combination and Use of Accident Investigations

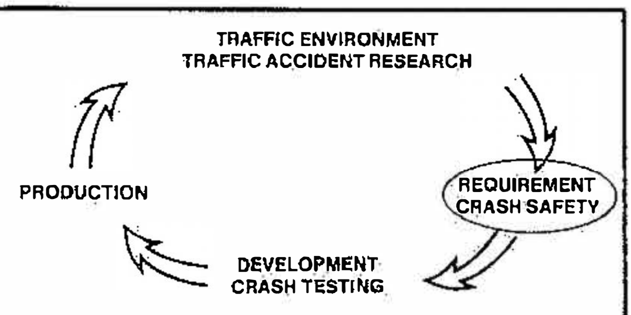
This combination of multidisciplinary and statistical accident investigation gives a deep insight into the crash behaviour of our vehicles and also a possibility to obtain a representative picture of the whole traffic accident problem area. (See Figure 6.)

An example from this work is described in the following example.

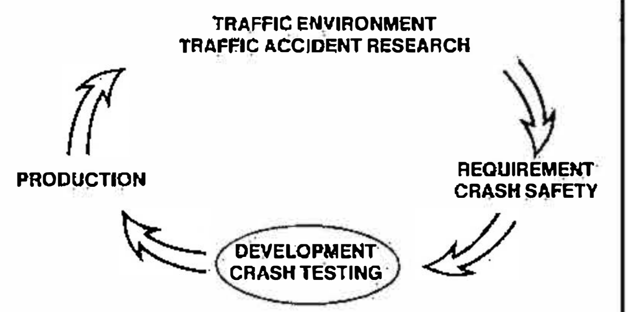
We discovered from study of accidents carried out by the multidisciplinary Accident Investigation Group that the steering wheel in our cars deformed in a front impact accident in such a way that drivers who were not wearing a seat belt received typical chest injuries on impact with the wheel. The wheel, nevertheless, fulfilled all the current legal requirements. To find out if this type of injury was common in this particular type of accident, we carried out an analysis of our extensive accident statistics. The result from this analysis showed that this typical chest injury was more common than we had previously thought. We contacted the designers involved and discussed with them various proposals for improvements in design of the steering wheel. The result was a completely new type of steering wheel, designed with a large impact area so that the force of impact would be spread out over a wider area of the rib cage. We then followed up accidents to cars fitted with the new wheel and we were able to show that in accident situations similar to those studied previously, this typical chest injury had been eliminated.

In the above example, we have described how our traffic investigation work can provide direct feedback of information to the Design Department.

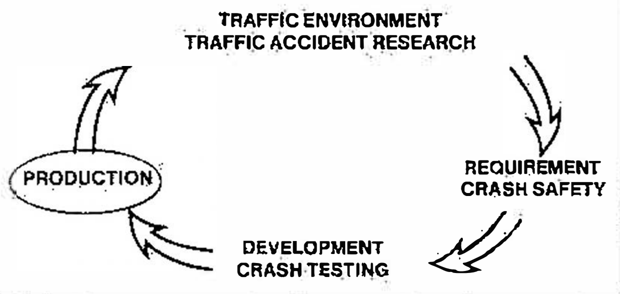
Another important aspect of our work, is our co-operation in setting standards for collision safety in future products. The knowledge which is being continually built up by the members of the Group, on traffic accidents and associated problems, is used in setting standards which are as appropriate as possible to the actual traffic environment. This work can be described (3) as follows:



The knowledge gained from traffic accident research is used in establishing the requirements for the safety properties of a car.



These requirements then provide the basis for the work of design and development. Collision tests form a part of this work and the experience gained by traffic accident research is utilized.



Later the car is produced and sold to the customers. This means that it begins to be exposed to actual traffic environments. We can now follow up the road accidents in which our car is involved, and so obtain information on how well we have succeeded in suiting our car to the actual traffic environment.

ACCIDENT STATISTICS

During the past decades, large numbers of road accident statistics have been presented in many parts of the world. The statistics are, in many cases, contradictory and give a confused picture to those who try to use them.

The reason why particular aspects, e.g., side impact accidents, appear to give very different results depends on a number of factors. One of the most important of these is the manner in which accident information is gathered. This in its turn is often determined by the opportunities that are available for obtaining the accident information.

For example, a medical specialist, interested in traffic injuries, may select only those accident cases which arrive at this clinic. Research workers with alcohol and drugs as their main field of interest may, perhaps, guide the statistics so that they include accidents in which these factors are relevant. The selection of accidents may also be governed by the practical possibility of reaching the sites of accidents, for example, accidents occurring on a particular section of motorway, or in a particular town or district.

When accident statistics are being analysed, it is important that information should be available as to how the accidents included in the statistical material were selected. Thus it is possible to avoid use of the accident information in a manner which the author had not intended.

A large number of traffic accident research workers have presented results and summaries of accident investigations on side impact collisions.

The following is an attempt to analyse the Volvo accident statistics systematically, so that the different types of side impact collision can be quantified, with respect to the nature and severity of the injuries caused.

In the previous section we described how the accident data are collected. The information used here is from the

Volvo Accident Statistics gathered during the years 1974-1979.

This information covers all the serious accidents (from the point of view of vehicle deformation) that occurred to Volvo 140 and 240 cars, in Sweden, during the above mentioned years.

Complete documentation is available for each accident, giving vehicle deformation, information on occupants and their injuries and a description of the environmental conditions and the sequence of the accident.

The basic data used for this analysis covered 12.000 accidents. Accidents in which any of the occupants of the vehicle received injuries AIS 2 have been selected from this total.

The accidents to Volvo cars have been divided up into a number of different types. These are shown in Table 1. The table also shows the proportion of each type of accident where the maximum injury level in the car was AIS $\geq$ 2 and AIS $\geq$ 4.

An attempt has been made, in Table 1, to arrange the Volvo accidents according to their "traditional" type.

In most presented accident materials "front impacts" stands for more than fifty percent of all accidents.

"Multiple accidents" and "other accident" form normally a low proportion.

In our material (see Table 1) "front impacts" stands for less than forty percent. It may be thought that frontal collisions form a low proportion of the total, whilst multiple accidents and "Other" form a high proportion. There is however considerable deformation of the front of the car in accidents involving big animals, driving under trucks and in most multiple accidents, or in accidents caused by running off the road. It is believed that, in many statistical summaries, a large proportion of these accidents are classified as frontal collisions.

Analysis of the consequences of personal injury normally requires a relatively complete separation of the different types of accidents right down to such a level that assessment of each individual injury is as certain as possible.

The accidents shown in the upper part of Table 1 as side collisions, include the accidents where the significant deformation was applied to the side of the vehicle.

In addition to the accidents regarded in the Volvo accident classification as side collisions, there are also sideswipe accidents and certain offset accidents.

In Table 2 below, these have been extracted from the total number of accidents.

We see from Table 2 that about one third of the accidents with injuries AIS $\geq$ 2, and AIS $\geq$ 4 are accidents which are often called side collisions.

A corresponding proportion of side collisions is reported in many other investigations (4).

Sideswipe I accidents are those in which the vehicle is hit in front of the A-pillar, with deformation of the A-pillar and of the floor/bulkhead. This type of accident which, to some extent, is comparable with the severe Offset I accident, should not be regarded as a side collision, nor analysed statistically together with other side collisions.

The same applies to Sideswipe II accidents. According to our definition, these accidents are those in which the impact on the side is at an angle of less than 30° to the longitudinal line of the vehicle.

The nature of both the vehicle deformation and the occupant injuries differs between Sideswipe I and Sideswipe II accidents.

Sideswipe accidents are not included in the following analyses.

Impact Area

Based on the discussion in the previous section the analyses will now include only the accidents in which the impact takes place on the left or right side of the vehicle, as shown in Figure 7.

Table 1. Distribution of accidents types for accident with maximum injury level AIS 2-6 and AIS 4-6.

		AIS 2–6	
FRONT IMPACT	FRONT IMPACT	27.0	
	OFFSET I	4.8	
	OFFSET II	3.0	
SIDE IMPACT	SIDESWIPE I	4.2	1/3
	SIDESWIPE II	1.9	
	IMPACT L. SIDE	13.4	
	IMPACT R. SIDE	10.0	
REAR END IMPACT	REAR END IMPACT	2.1	
ROLLOVER	ROLLOVER	10.8	
	OVERTURNING	0.8	
MULTIPLEACCIDENT	MULT. IMPACTS	5.1	
	IMPACTS AND ROLL.	8.2	
OTHER	RUNOFF ROAD	5.3	
	UNDER TRUCK	0.8	
	BIG ANIMAL	2.6	
		100%	

Table 2. Accident where the significant deformation is applied to the side of the vehicle.

	AIS 2–6	AIS 4–6
Sideswipe I	4.2 %	5.2 %
Sideswipe II	1.9 %	2.2 %
Left side	13.4 %	13.0 %
Right side	10.0 %	11.8 %
Total	29.5 %	32.2 %

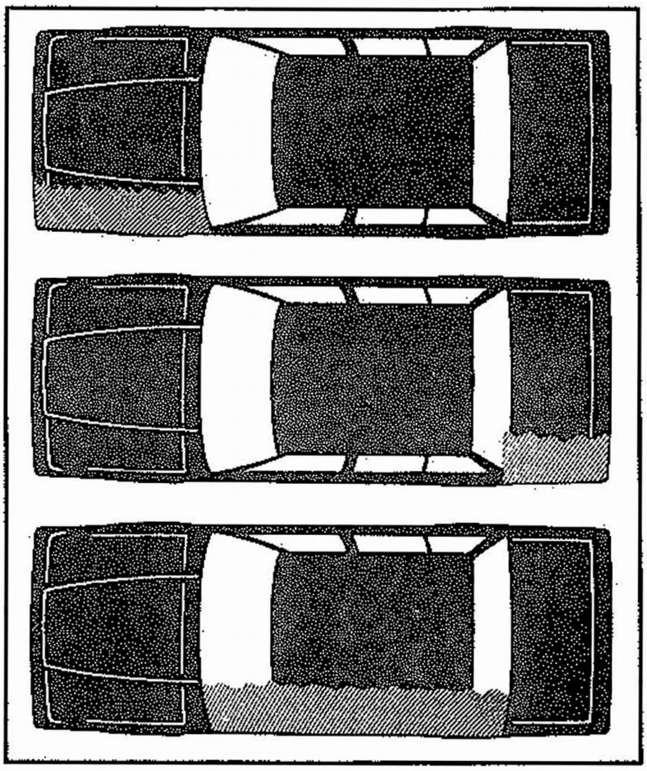


Figure 7. Impact area.

We can divide up these accidents into three different cases, according to the location of the deformation.

If we now consider these accident situations with reference to the frequency of the personal injuries, we find, as shown in Table 3 that the accidents in which there was significant deformation of the occupant compartment constitutes 73% of the accidents ≥ AIS 2 and 100% of the accidents ≥ AIS 4.

In most of the side impact collisions, where the impact takes place in front of, or behind the occupant compartment, the risk of severe injury is small.

It is clear, however, that collisions with the occupant compartment are those which, from the point of view of occupant injuries, should be given priority in development of better side impact properties. Only this type of accident is dealt with in the following analysis.

Table 3. Location of deformation vs. injury severity.

	AIS 2–6	AIS 4–6
DEFORMATION OF OCCUPANT COMPARTMENT	73%	100%
DEFORMATION OUTSIDE OCCUPANT COMPARTMENT	27%	0%
	100%	100%

Location of Occupants

The extent and type of occupant injuries caused by side impact collisions with the occupant compartment, vary according to where the occupant was sitting in the car.

If we compare the risk of injury to near-side occupants with that of off-side occupants, during side impact collisions against the occupant compartment, we see that the risk of injury, both ≥ AIS 2 and ≥ AIS 4, is approximately twice as great for those on the near-side. (See Table 4.)

We will now further concentrate our attention on the near-side occupants of the vehicle, but before this let us devote a few lines to the off-side occupants.

The frequency of different types of injuries (chest, head, etc.) to the off-side occupants differs from that for the near-side occupants. The occupants of the off-side are not affected as much by the vertical extent of the deformation. On the other hand, the extent of inward buckling is significant for the risk of injury to the off-side occupants. In most of the cases in which off-side occupants received serious or fatal injuries, the victim was thrown out of the car. For these, as for other car users, the seat belt has an obvious beneficial effect.

Comparison of the frequency of injuries to off-side occupants, wearing belts and not wearing belts (not including persons thrown out of the car), shows an injury-reducing effect of the wearing of belts. Corresponding comparisons for near-side occupants do not show any significant effect from use of the seat belts.

Now, let us return to discussion of the near-side occupants of the car.

Figure 8 shows the extent of the risk to various parts of the body in the case of near-side occupants with injuries ≥ AIS 2.

We can see from this figure that amongst the occupants with AIS ≥ 2 61% had chest injuries and 39% had head injuries, of severity ≥ AIS 2.

From Table 5 we can see that injuries of severity AIS ≥ 2 in our statistics, consist of 34% chest, and 22% head injuries. We can see that there is a change in the proportions between the parts of the body as severity

Table 4. Injury frequency for near-side and offside occupant for different injury levels.

	AIS 2–6	AIS 4–6
NEAR-SIDE OCCUPANT	28,0%	10,4%
OFF-SIDE OCCUPANT	15,2%	4,5%

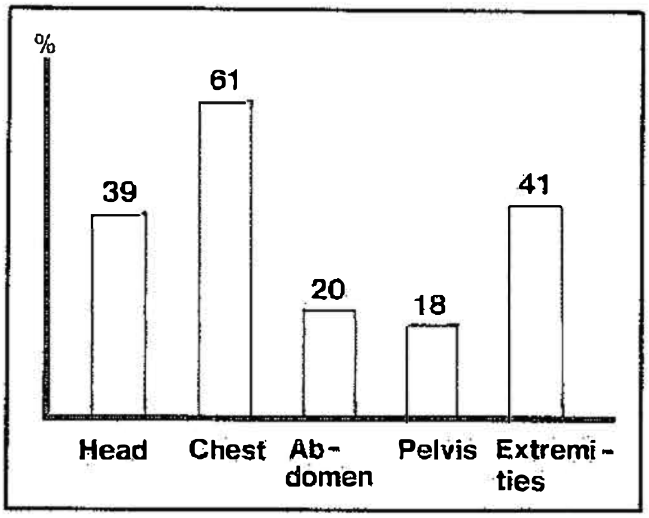


Figure 8. Frequency of injury to various parts of the body AIS ≥ 2, for near-side occupants with max injuries ≥ 2.

increases, but this is the result, to some extent, of the character of the AIS scale (2).

The part of the body which has the highest frequency of injury is the chest, which accounts for one-third of all the injuries of severity AIS ≥ 2. We can see that the proportion of chest injuries increases with increase in severity of injury.

The various objects with which collisions occur cause different deformations, and the question arises as to whether the distribution of injuries shown above, depends on the nature of the object with which impact takes place.

Table 6 shows the relationship between injuries AIS 2-6 and the collision objects: car, truck and pole/tree.

In Table 6, the lower part, "chest + head" means that 8% of the near-side occupants, in a car-to-car side impact, sustained both head and chest injuries ≥ AIS 2.

"Abdomen, due to chest", means that the abdominal injuries are caused by the chest injuries (broken ribs).

Table 5. Proportion of injuries to various parts of body.

	AIS 2–6	AIS 4–6
HEAD	22%	24%
CHEST	34%	44%
ABDOMEN	11%	24%
PELVIS	10%	4%
EXTREMITY	23%	4%
	100%	100%

Table 6. Frequency of injury, according to parts of body, AIS-2-6 and collision object, for near-side occupants with max injury AIS ≥ 2.

Parts of body	Car	Truck	Pole/tree
Head	21 %	56 %	56 %
Chest	63 %	72 %	33 %
Abdomen	21 %	28 %	–
Pelvis	13 %	28 %	11 %
Extremities	29 %	39 %	78 %
Chest + head	8 %	39 %	11 %
Abdomen, due to chest	17 %	17 %	–

We see that 21% of the near-side occupants who were injured (AIS ≥ 2) in accidents in which a car was the object of impact received head injuries, compared with 56% of near-side occupants with injuries AIS ≥ 2, in accidents where the object of impact was a truck.

In car and truck accidents, 63% and 72% respectively of the near-side occupants (AIS ≥ 2) received chest injuries, whilst only 33% of the accidents in which there was collision with a pole, caused injuries of this type. In pole accidents, on the other hand, injuries to extremities are much more frequent.

Table 6 above shows the relative frequence in each of the groups of accidents. Table 7 below shows the proportion of injuries to each of the parts of the body divided up according to the object of collision.

It is possible to read from this table that, of all the head injuries, 25% resulted from car-to-car accidents, 50% from car-to-truck accidents, and 25% from car-to-pole accidents.

Table 7 gives us some measure of the "true traffic environment". We see, for example, that although, according to Table 6, the risk of head injuries is equally great in pole accidents and in truck accidents; in actual fact half of all head injuries occur in truck accidents, whilst only a quarter occur in pole accidents. Most of the chest injuries occur in collisions with cars, even though the risk of chest injury is somewhat greater in the case of collisions with trucks.

The combination of injuries to chest and head is most

Table 7. Occupant injuries, classified according to object of collision.

	Car	Truck	Pole/tree	
Head	25 %	50 %	25 %	100 %
Chest	48 %	42 %	10 %	100 %
Abdomen	50 %	50 %	–	100 %
Pelvis	33 %	56 %	11 %	100 %
Extremities	33 %	33 %	33 %	100 %
Chest + head	20 %	70 %	10 %	100 %
Abdomen, due to chest	57 %	43 %	–	100 %

usual when the object of the collision is a truck, while injuries to the Abdomen resulting from primary chest injury is more usual when the object of collision is a car.

To study more closely the effect of deformation on injury, we have prepared Table 8 below, in which we show the relative injury distribution for the various objects of collision.

Table 8. Classification of injuries according to object of collision.

AIS 2 – 6	CAR	TRUCK	POLE / TREE
HEAD	14%	25%	31%
CHEST	43%	32%	19%
ABDOMEN	14%	13%	–
PELVIS	9%	13%	6%
EXTREMITY	20%	17%	44%
	100%	100%	100%

This shows us that in collisions with cars, chest injuries predominate; in collision with trucks, head and chest injuries are about equally frequent; and that finally, in the case of collisions with poles, head and extremity injuries are predominant.

On the basis of the accident material, we can put forward the following:

—Depending on the type of collision object, different types of deformation occur, and these in their turn cause characteristic occupant injuries.

—When collision takes place with a car, it is mainly the doors that are deformed, and there is no extensive damage to the floor and roof zones.

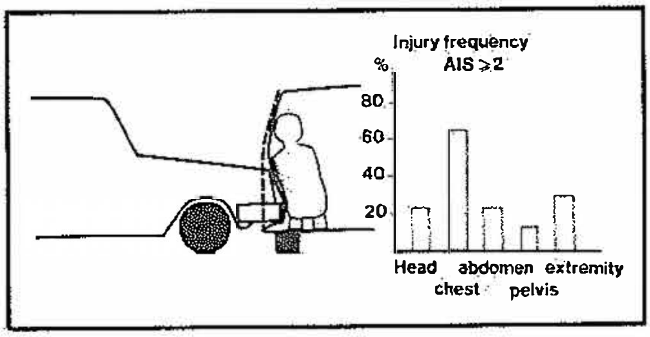


Figure 9. Injury risk in car-to-car side impact.

The force of the collision is concentrated at chest height and this causes a high proportion of chest injuries, many of them in combination with abdominal injuries.

In collisions with trucks, the door is deformed (often higher up than in collision with a car) and at the same time the roof zone is damaged.

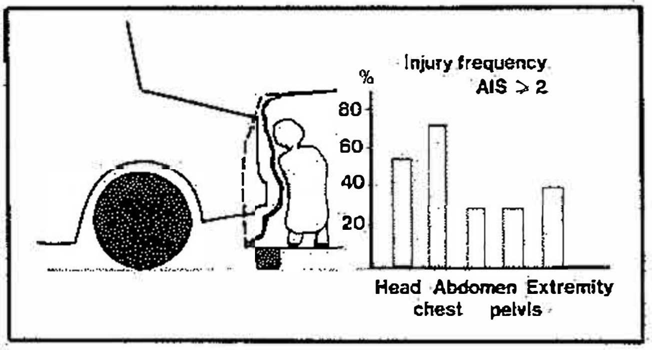


Figure 10. Injury risk in car-to-truck side impact.

—The force is concentrated at chest height, giving a high proportion of chest injuries, but there is also an increased risk of head injuries, because of deformation of the roof edge and risk of direct impact with the collision object.

—In collisions with poles, deformation extends evenly from the floor area up to the roof.

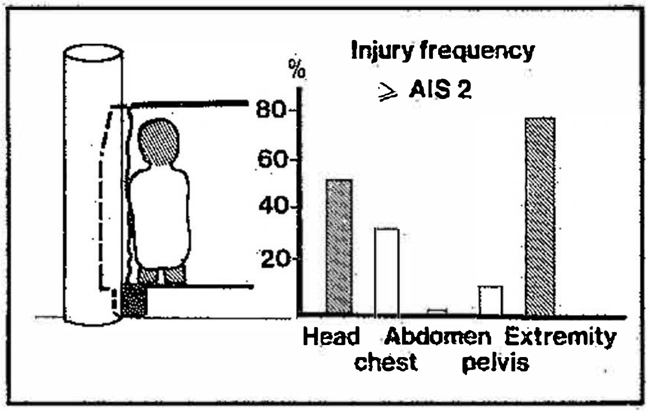


Figure 11. Injury risk in car-to-pole side impact.

In this case the force is distributed relatively evenly over the side of the car in the vertical direction. Severe deformation of the floor zone increases the probability of leg injuries. Furthermore, there is a considerable risk of head injuries caused by impact with the deformed roof and/or the collision object. The proportion of chest injuries is somewhat lower than in collisions with cars and trucks. The reason may be that the forces at chest height are not as concentrated as is the case in a pole accident.

DISCUSSIONS—TEST METHODS

Tabulation and analysis of the statistics on side impact collisions shows the following relationship.

Type of Accident—Type of Deformation—Injury

On the basis of this knowledge, it is possible to design laboratory test methods and to evaluate their potential as means of reducing injuries in traffic accidents.

This has, in fact, been done in a number of cases; mention can be made of the information for NHTSA, ANPRM notice 1, and GM's "Case-by-case analysis of side impact accident files" (5) (6).

NHTSA made a survey in NCSS and concluded that while 65% of the accidents are multivehicle accidents the side impact collision requirements should be based on car-to-car collision tests. Thereafter, much work was devoted to identification of the types of accidents, in the form of angles between vehicles and their speed at the moment of collision. Suggestions and evaluations have been made for a relatively complicated test method with angled tracks.

GM states in a recent report that "a subsystem test strategy offers distinct advantages over the more complex full-scale testing". GM makes a close analysis of their side impact collision information and draws the conclusion that the concept of side impact collisions includes a large number of different types of accidents and injury mechanisms and that, therefore, a test method should include a number of different component tests, and perhaps fullscale testing, in order to cover the range of types of injury.

Our information has been classified and structured so that it is suitable for an analysis intended to give a relevant laboratory description of traffic environments.

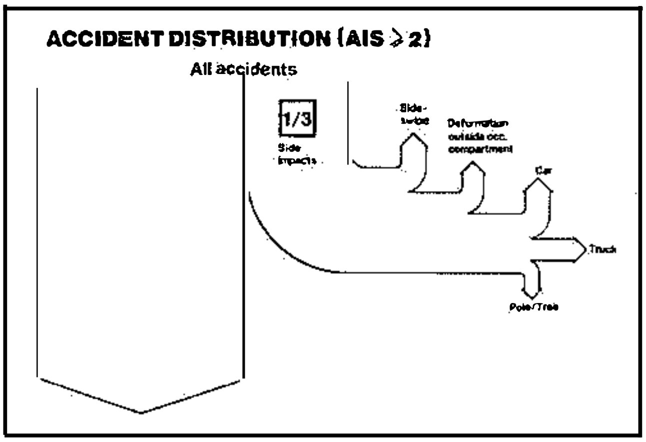


Figure 12. Distribution of side impact accidents.

We have also limited our work to occupants who receive injuries ≥ AIS 2.

We are interested in establishing a basis for transfer of the traffic environment concerned in side impact collisions into the laboratory. It is then misleading to look only at injuries of severity AIS ≥ 4 as the step between severe (AIS 3) and serious (AIS 4) injuries may be small and may depend upon factors which cannot be simulated in the laboratory.

The AIS scale has the characteristics that certain injuries, for example injuries to the extremities, very seldom are recorded as in excess of AIS 3. We consider that we are, therefore, justified in continuing to work with groups AIS 2-6. In this way we see the picture as a whole and obtain more material, to give more accurate assessments.

It is possible to distinguish the principal types of injury mechanism.

1. Injuries resulting from an intruding structure, or from direct contact with the deformed side. These injuries are caused to near-side occupants (except in the case of extreme depth of deformation) when the collision object impacts with part of the passenger space.
2. Injuries resulting from impact against the interior. These are injuries caused to occupants beyond the deformation zone—off-side occupants in collisions against the passenger space and all occupants in collisions to the front and rear of the passenger space.
3. Injuries resulting from the person being thrown out of the car.

The injury mechanisms 2 and 3 above, depend on the design of the interior, the properties of the doors and windows and the use of seat belts by the occupants. There is no reason to try to reconstruct all the complicated sequences of events which result in the occupants impacting against the interior, or being thrown out. Safety requirements for all internal fittings and strength requirements for door fastenings and window fastenings increase safety in the same way as obligatory use of seat belts.

Injury mechanism 1 is related to the ability of the vehicle to resist violent impact against the passenger space. Any test method which has the object of reducing injuries resulting from this cause must be able to reproduce the impact in some relevant and reproducible way.

We are only too well aware that the violent impact may be applied in innumerable ways. Which should be selected as a means of reproducing the true traffic situation, in a test method?

Since we are concerned here with the injuries produced by direct violence on the near-side occupant of the car, we should use the spectrum of injuries suffered by these occupants as the starting point, rather than the frequency of the various types of side impact collision.

The most frequently injured part of the body is the chest. In all accidents (AIS ≥ 2) the frequency of chest injuries is 61%. Chest injuries occur at all angles and with all collision objects. Examination of the objects with which the car collides shows that 48% of chest injuries result from side collisions with other cars.

A test method in which deformation of the passenger compartment is caused by a simulated car front should cover 48% of all the chest injuries. The remaining chest injuries occur in 42% in collisions with trucks. The deformation which then occurs at chest height on the door is not unlike that caused by a car under similar collision circumstances. It could, therefore, be assumed that if a car front were used in the laboratory to cause deformation, this would also, to a certain extent, simulate collisions with trucks.

If we look at the specific injury picture in the case of car-to-car collisions, we find that chest injuries are clearly predominant.

The chest injury frequency is 63%. It is thus mainly this type of injury that will occur when a car front is causing the deformation.

It is important to simulate not only the final position of the deformed door but also the dynamic process, i.e., the acceleration of the door in relation to the occupant.

Naturally, it is of most importance that the testing device used in the test has the ability to measure violence to the thorax.

If we go back to Table 7 which shows occupant injuries, classified according to object of collision, we see that the type of testing spoken of above, has a potential of reproducing impact situations which together cause about 90% of all chest injuries. In Table 5, where proportion of injuries to various parts of the body are shown, the chest injuries constitute 34% of all injuries (AIS $\geq$ 2). The Abdominal injuries constitute 11%. Corresponding figures for the AIS $\geq$ 4 injuries are 44% and 24% respectively. The injuries to the abdomen are often associated with injuries to the chest and it is reasonable to believe that a test method that can give about a reduction of chest injuries also will affect the abdominal injuries.

What is the effect of a car-to-car test method on the injuries to other parts of the body?

Table 6 shows that the head injury frequency is a lot higher in accidents involving trucks or poles than in car-to-car accidents. According to Table 7 only 25% of the head injuries appear in accidents where a car has been the collision object. A laboratory simulation of this accident type will probably not reduce head injuries in any major extent. The head injuries appear mostly in accidents where the roof zone is deformed. There is not much written about the simulation of collisions against objects that cause deformations on the roof zone.

It is important that there is work being done with the aim of mapping the injury mechanism behind the head injuries.

Injuries to the extremities are very common in collisions with poles, where the leg area is reduced. It is mainly injuries to the lower extremities, mostly the thigh. There is, as of today, no dummy-related measuring device that measures this kind of injury.

On the basis of the discussion above it seems probable that various kinds of component testing will be required, while the injuries to the head and to the extremities are caused by several different kinds of deformations.

CONCLUSION

* It is important that there is a system to follow up accidents which by its size and method of selection can give a representative picture of the traffic accident situation and which by in-depth studies of accidents can give good information on the causes of individual personal injuries.
* Collisions against the side of the vehicle comprise a large proportion of all accidents which cause personal injury. When development work is done on making cars safer, a large proportion of this work should be devoted towards the question of side impacts.
* Side collisions are however not one homogeneous group of accidents which cause injuries. Where and how on the vehicle side the impact occurs and the object causing it have a large influence on the resulting personal injuries.
* Of all the more serious personal injuries, chest injuries comprise the largest group with approx. one-third.
* A car-to-car test method probably reproduces the great majority of collision situations in which chest injury occurs.
* More research is needed on the occurrence of head and (lower) extremity injuries in side impacts, plus work to permit reproduction at some future date of these injuries in a laboratory environment.
* Volvo will concentrate a proportion of future traffic accident research on a continued programme of side impact studies, with particular emphasis on investigating how various typical injuries occur. In addition, various important parameters which have not been discussed in this report, will be taken up. Some of these are the mutual relationships of direction of force to direction of impact, collision speed—ΔV—door speed—injuries.

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