THE FREQUENCY AND SEVERITY OF INJURIES TO THE OCCUPANTS OF CARS SUBJECTED TO DIFFERENT TYPES OF IMPACT IN ACCIDENTS: AN INVESTIGATION OF BRITISH ROAD ACCIDENTS FROM POLICE RECORDS

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It is obviously desirable that money and effort spent on designing cars to give maximum occupant protection should be spent to the best advantage. The designer therefore needs both a theoretical understanding of the design problem and a knowledge of the relative importance of guarding against the different types of impact. The theory of car collisions has been treated comprehensively in a previous paper by the authors[1]; the present paper gives results of an investigation of the importance of the different types of impact in British accidents. For a better understanding of these practical results, however, it will be useful first to give some of the findings of the theoretical analysis.

Accidents are usually classified under the headings of 1) single vehicle accidents, 2) head-on collisions, 3) intersection accidents, 4) rear-end accidents, and 5) side-swipes when one vehicle strikes a glancing blow on another. The vehicle designer, however, is concerned not so much with accident types as with the different types of impact (including overturning as an impact) which occur in these accidents; these impacts are a) frontal, b) side, c) rear , and d) overturning. Ref 1 was an extensive investigation of the effect of these impacts on cars and their occupants in accidents of all types. The main conclusions were:

1) The short duration initial impact, lasting for about 0.1 second, constitutes the important part of almost all collisions, since unrestrained occupants nearly always strike the inside of the vehicle during or shortly after the end of this period.

2) It is known[1] that most frontal impacts in head-on collisions and single vehicle accidents are off-centre, and there is therefore a tendency for rotation of the car to occur. It was shown, however, that rotation is of secondary importance since the rotation of a car during the time that elapses before the occupants of the front seats strike the windscreen or instrument panel is so small that the point of impact is displaced sideways by less than 4 inches compared with impacts without rotation.

3) The energy dissipated in crushing in a symmetrical head-on collision is $\frac{\frac{1}{2}M_1M_2(V_1-V_2)^2}{M_1+M_2}$ where M_1, M_2, V_1, V_2 are the masses

and initial velocities of the two vehicles. This total energy loss cannot be changed for the better by vehicle design. Only the way in which the energy dissipated is shared between the two vehicles can be changed since this depends on the relative stiffnesses of the fronts of the vehicles. The same conclusion is very closely true for asymmetrical collisions.

4) The influence of mass ratio in collisions cannot be overstressed. This effect is well known, but its influence on the severity of impact is often not given the importance it deserves. For example, in a head-on collision between a car weighing 1 ton and a bus weighing 5 tons, each travelling at 30 mile/h, the velocity changes are inversely proportional to the masses of the vehicles; that of the car is 50 mile/h and that of the bus only 10 mile/h.

5) Collisions with walls or hedges are common features of single vehicle accidents. At angles of approach of 40 degrees or more, the impacts may be regarded as frontal ones.

6) Most impacts to the sides of cars occur in intersection collisions, and in a large proportion the paths of the two vehicles are at about 90 degrees. As might be expected, the worst conditions in the struck car occur when intrusion takes place in line with the front seat occupants.

7) The theory helps one to understand what probably happens when ejection has been found to have taken place. In the frontal impacts which occur in head-on collisions with other vehicles or with posts or walls, impact of the front seat occupants with the windscreen or instrument panel is almost certain to have occurred before ejection, and is probably the most important factor in producing injury.

Ejection without serious impact with the inside of the car is most likely to occur in intersection collisions, in overturning accidents, and to a minor extent in collisions with walls and posts.

The data used in the paper

The sources of data were mainly police accident records in Hampshire, Essex, and Swansea, covering the years from 1965 - 70; the sample included urban and rural areas of three different types (urban roads were arbitrarily defined as those with speed limits of 30 or 40 mile/h and rural roads as those with higher speed limits). The accidents all resulted in injury to one or more car occupants, and the injuries were classified as slight, serious or fatal, in accordance with the Department of Environment classification, as follows:-

Slight injury: an injury of a minor character such as a sprain or bruise,

Serious injury: an injury for which a person is detained in hospital as as 'in patient', or any of the following injuries whether or not he is detained in hospital: fractures, concussion, internal injuries, crushings, severe cuts and lacerations, severe general shock requiring medical treatment,

Death: died within 30 days of an accident.

These three categories of injury are often considered to be too broad, and many workers use a 5 point scale; however, a vast store of information exists in police records in terms of the DoE classification, and in the past many valuable researches have been carried out and deductions made on the basis of the triple classification. One of the purposes of the present investigation was to assess the value of these police records in providing information useful to vehicle designers.

The areas studied

To obtain some idea of the variability in the accident pattern in different parts of the country, the data were collected from 3 areas. Altogether 1596 accidents were examined, 415 from Essex (225 rural and 190 urban), 905 from Hampshire (556 rural and 344 urban), and 276 from Swansea (72 rural and 204 urban); the variation in the ratios of rural to urban accidents is, of course, to be expected from the arbitrary nature of the police divisions. For comparison, it should be noted that in Britain as a whole in 1969 38 per cent of injury accidents to car occupants occurred in rural and 62 per cent in urban areas.

Table 1 shows important differences between the areas in the percentages of the different types of accident; it also contains figures for Britain (England, Scotland and Wales) in 1969. For the three areas combined the agreement is quite good for urban areas, but poor for rural areas, when compared with the national figures.

The percentages of commercial vehicles and buses involved in car accidents also showed considerable variation from one area to the other, particularly in the urban areas (Table 2) but when the three areas are taken together, they are not very different from the national averages.

In rural areas 66 per cent of serious injuries (including deaths) occurred in frontal impacts, 18 per cent in side impacts, 15 per cent in overturning, and only 1 per cent in rear impacts; similar figures for urban areas are 74 per cent, 16 per cent, 8 per cent, and 2 per cent.

The severity of impacts of various types

Although the areas studied differed from the national pattern in the proportions of accidents of the various types, it was thought that the severities of the different types of impact would probably be representative of the country as a whole. Severity was measured by fatal and serious injuries per impact (see Table 3), and it should be noted that, except for single car accidents, this figure is lower than that given by the ratio of fatal and serious injuries to all injuries, since in two or more vehicle accidents, the occupants of some of the vehicles will escape injury. The figures in Table 3 give a more accurate measure of risk of serious injury than does the ratio of fatal and serious injuries to all injuries, a measure of severity commonly used. For single car accidents, an estimate of this figure has had to be made, and this is given in brackets.

Taking the Table as a whole, the values of risk in urban areas, particularly for single car and head-on frontal impacts, appear to be abnormally high. This is believed to be a characteristic of the three areas studied. A direct comparison with the national figures could not be made but Table 4 gives a comparison of the ratios of fatal and serious accidents to all injury accidents for the four main types of accident in the three areas studied and in the country as a whole.

All the ratios in the urban areas of Essex, Hampshire and Swansea are higher than in the country as a whole, on the average by 25 per cent, but the agreement is much better in the rural areas. No explanation has yet been found for the abnormally high urban risks and investigations are continuing since, if the reasons can be found, some remedial action may be possible in areas of this kind. In the meantime these urban figures together with the more representative rural ones may be used to assess the relative risks in the various types of impact.

As might be expected, the Table shows that the risk of serious injury and death is particularly high in all collisions with commercial vehicles, especially in rural areas. This finding is in line with the work of other authors[2][3]. In 1969 26 per cent of all fatal accidents to car occupants were collisions with commercial vehicles; nearly three-quarters of these fatal collisions occurred in rural areas.

The severities in frontal impacts of cars against other cars are in the order which might be expected from the relative velocities at impact. The differences are much less marked for collisions between cars and commercial vehicles, particularly in rural areas, where all such collisions involve a high risk of serious or fatal injury.

The high risk of serious injury to the occupants of struck cars in intersection collisions has often been emphasised and much effort and money has been spent on the study of protective measures. The Table confirms this high risk but shows that the occupants of the striking car in such collisions should not be forgotten since they are also subjected to a high risk of injury in what, for them is usually a frontal impact.

In rear-end collisions between cars attention is usually concentrated on the struck car, in which neck injuries may be sustained due to whiplash. Table 3 shows that the risk of serious injury in the striking car which suffers a frontal impact is two to four times greater than that in the struck car. Neck injuries in the struck car are mainly stiff or strained necks; this is generally true even when the striking vehicle is a commercial vehicle.

In about one-half of the single car accidents in rural areas, and in one-quarter in urban areas overturning occurred, and resulted in one of the highest figures for severity, both in rural and urban areas.

It had been hoped that the figures in a table of severities such as Table 3 would have been generally applicable, but it appears that in the three areas chosen the accidents in the urban areas were unusually severe. While this is disappointing from one point of view, it raises interesting points regarding local differences in accident patterns which it is hoped to pursue further.

Some characteristics of the accidents

The circumstances in which the various types of impact occur are given in Table 3. From the police records a number of interesting features of these accidents may be deduced. Many others have been omitted because of lack of space.

In single vehicle accidents injury results either from an impact to the car or from overturning or very rarely from both. The impacts were nearly all frontal (94%). The most common objects struck are given in Table 5.

Trees, poles and similar objects were struck in about 45 per cent of the impacts, lamp columns being the most common obstacles in towns. The ratios of fatal and serious to all accidents for these impacts were 0.67 in rural and 0.62 in urban areas - both very high, and showing only a small difference between rural and urban areas. Similar results have been reported by Starks and Miller[4].

Almost all the side impacts occurred at intersections - about 97 per cent in rural areas and 95 per cent in urban areas.

The reports of intersection accidents often gave enough detail including dimensioned sketches for an estimate to be made of the angle between the longitudinal axes of the vehicles at the moment of impact, and of the speed of the struck car and sometimes that of the striking car. Table 6 gives the estimated angles and Table 7 the estimated speeds in accidents in the Hampshire area.

The two tables indicate that in most of these intersection accidents the struck car was struck at right angles while moving slowly across the path of the striking vehicle.

Almost all impacts to the rear of the car occurred in rear-end accidents when one vehicle was following another; a few occurred in intersection accidents. There were many multiple concertina collisions in which several vehicles travelling in line each ran into the one in front; on rural roads 36 out of 106 rear-end accidents involved more than one vehicle; on urban roads 42 out of 107 were of this type. Some of the injuries recorded as due to a rear impact may, therefore, have resulted from a frontal impact with the vehicle ahead.

Almost all overturning occurred in single car accidents. Table 8 gives the manoeuvres of cars before overturning. It is notable that in only a small proportion (about one-quarter) of these accidents was there first an impact with an object other than the kerb or verge, and that the kerb or verge was mentioned in a large proportion of the rural accidents.

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References

1. GRIME, G and Jones, I S. Car collisions - the movement of cars and their occupants in accidents. Proc Instn Mech Engrs, 1969-70, 184 (Pt 2A), 5.

2. Ruffel Smith, H P. A study of fatal injuries in vehicle collisions based on coroners' reports. LR316, Crowthorne, Road Research Laboratory.

3. GISSANE, W and Bull, J. Fatal car occupant injuries after car/lorry collisions. Brit Med J, 13 Jan 1973, 1, 67-71.

4. STARKS, H J H and Miller, M M. Roadside equipment and accidents. RRL Report No 22, Crowthorne, Road Research Laboratory.

Table 1: Percentages of injury accidents in rural (R) and urban (U) areas

Type of accident	Essex		Hampshire		Swansea		All 3 areas		Britain	
	R	U	R	U	R	U	R	U	R	U
Single car	45	29	24	21	38	34	30	26	45	26
Head-on	29	24	19	13	45	10	24	15	27	14
Intersection	13	26	35	44	6	29	27	36	15	36
Rear-end	10	16	18	17	7	25	15	19	13	24
Side-swipe	3	5	4	5	4	2	4	4	0.1	0.3

Table 2: Percentages of injury accidents involving commercial vehicles and buses

Essex		Hampshire		Swansea		All 3 areas		Britain 1969	
Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
19	23	27	18	21	12	24	18	19	22

Table 3: Severities of impact

Type of impact	Deaths + serious injuries per impact					
	Rural			Urban		
	Car v car + single car	Car v CV	Car v car + CV	Car v car + single car	Car v CV	Car v car + CV
FRONTAL						
Single car	0.56 (0.45)	-	0.56 (0.45)	0.60 (0.48)	-	0.60 (0.48)
Head-on	0.40	0.64	0.59	0.40	0.46	0.57
Striking car - intersection	0.29	0.69	0.38	0.17	0.69	0.22
Striking car - rear-end	0.15	0.69	0.34	0.12	0.27	0.14
Striking car - side-swipe	0.57	0.56	0.56	0.30	0.7	0.5
SIDE						
Struck car - intersection	0.41	0.63	0.44	0.18	0.67	0.23
REAR						
Struck car -rear-end	0.04	0.06	0.04	0.07	0.06	0.06
OVERTURNING						
In single car accidents	0.73 (0.59)	-	0.73 (0.59)	0.76 (0.61)	-	0.76 (0.61)

Table 4: Values of the ratio $\frac{\text{fatal + serious}}{\text{all accidents}}$ x 100

Type of accident	Essex, Hampshire, Swansea		Britain 1969	
	Rural	Urban	Rural	Urban
Single car	48	47	44	36
Head-on	46	41	45	29
Intersection	45	29	38	19
Rear-end	27	19	31	16

Table 5: Objects struck in single car accidents

Objects struck	Fatal accidents		Serious Accidents		Slight Accidents		All Accidents	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Trees, poles and the like	5	2	25	22	14	15	44	39
Walls, hedges and the like	0	0	13	8	16	16	29	24
Verges and ditches	0	0	1	0	10	0	11	0
Other objects	0	0	5	9	5	20	10	29
Totals	5	2	44	35	45	51	94	92

Table 6: Angles between colliding vehicles in 342 intersection accidents

Type of road	About 90 degrees (per cent)	About 45 degrees (per cent)	Less than 30 degrees (per cent)
Rural	54	28	18
Urban	62	29	9

Table 7: Speeds of struck vehicles in 245 intersection accidents in Hampshire (mile/h)

Type of road	<10 mile/h (per cent)	<20 mile/h (per cent)	<30 mile/h (per cent)	Not known (per cent)
Rural	26	56	62	38
Urban	18	49	60	40

Table 8: Manoeuvres of cars before overturning

Area	Lost control	Hit kerb or verge	Hit pole type object	Hit wall type object	Hit other object	Totals
Rural	29	27	8	6	3	73
Urban	11	3	4	6	1	25