A Study of Motorway (M.1) Fatalities*

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Motorways are specifically designed for motor-vehicles ; crossing traffic, pedestrians, and bicycles are, at least in intention, eliminated. The result is a great saving in time, with increased efficiency ; but, in spite of these advantages, accidents resulting in serious injuries or deaths to car occupants are far too frequent.

The nature and causes of road injuries are of particular concern to the Road Injuries Research Group. A certain number of accidents, including vehicle collisions, are inevitable on all types of road, but we believe that serious injuries to car occupants are to a large extent preventable. This concept is not in conflict with the main thesis that injuries are best prevented by preventing accidents in the first place ; rather it recognizes the limitations, under current conditions, of total accident prevention and deals with an important human aftermath—the reduction of deaths and severity of injuries through revisions of injuring potentialities in car and road design and in current motorway usage.

Motorways represent a new style of motoring, and, since they are increasing rapidly, it is of great interest and importance to gain information about the injury-producing accidents that have already occurred on the M.1.

Material Studied

We would have preferred to analyse all injury-producing accidents on the M.1 over the period covered in this study, but such was the wide distribution of the injured between a large number of hospitals and general practitioners responsible for treatment that we could not gather all the essential details of information. Instead we have studied the 74 deaths occurring after accidents on the M.1 between its opening in November 1959 to 31 December 1962 ; a further fatal accident involving two car occupants which occurred in April 1963 has been included, making a total of 76. In three of the fatalities a

necropsy was not performed, so that injury detail is available in 73 of the 76 cases.

In all cases the material studied has included the police inquiry into the detailed circumstances of the accident with their diagrams of the positions of the vehicles and their occupants after the crash, together with photographs of vehicle damage. There was, further, the coroner's inquest proceedings from which evidence was sifted to determine the probable sequence of events and such details as time, road, and weather conditions. The exact extent of injuries was gathered from the necropsy reports made by consultant pathologists. The information from each accident has been summarized in a standard manner so as to permit study of the varying features. Finally, we have made a comparison between fatal accidents on the M.1 and those this Research Group has previously studied on other types of road.

Types of Road User and the Nature of Their Injuries

The types of road user involved in fatal accidents on the M.1 are very different from those on other types of road. For example, pedestrians are the most frequent victims in urban road fatal accidents, and on country roads about 30% of these fatalities are to motor-cyclists. Of the 76 fatalities investigated in this study 84% were the occupants of cars or heavier vehicles and only 8% were motor-cyclists. The remaining 8% were persons on their feet at the time of the accident ; these cases classified as "pedestrians" are discussed later.

The nature of injuries to vehicle occupants, based on necropsy study, is set out in Table I, which for purposes of comparison

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TABLE I.—Major Injuries of Fatalities on M.1 and Vehicle Occupant Fatalities on Other Roads

	Fractures						Major Internal (Soft-tissue) Injuries										Total Injuries	Serious Blood Loss	Deaths	Average No. of Injuries per Fatality
	Spine	Legs	Arms	Pelvis	Ribs, Sternum, Clavicle	Skull, Face	Brain	Cord	Kidneys, Adrenals	Lungs	Liver	Spleen	Stomach, Bowel	Bladder, Urethra	Other Internal Injury	Major Blood-vessels				
M.1:																				
Pedestrians	1	1	1	1	8	6	5	1	2	3	3	2	1	—	—	3	38	5	6	
Motor-cyclists	—	2	—	1	1	4	5	—	—	1	—	—	—	—	—	1	15	1	6	
Vehicle occupants	9	14	13	17	55	53	47	3	9	41	26	19	4	3	5	25	343	36	61	5.6
	10	17	14	19	64	63	57	4	11	45	29	21	5	3	5	29	396	42	73	
For comparison (vehicle occupants):																				
Unrestricted-speed roads (non-motor-way)	5	10	11	4	35	37	42	6	3	31	17	10	2	—	1	13	227	31	61	3.7
Restricted-speed roads	3	6	4	7	24	38	43	2	2	26	8	8	2	3	—	9	185	27	61	3.0

includes our previous findings of fatal injuries to vehicle occupants from accidents occurring on other types of road. By chance the total of 183 deaths to vehicle occupants on various types of road have divided themselves into equal groups of 61. The M.1 shows a much greater multiplicity of injuries per fatality (5.6) than any other type of road (3 to 3.7). There are those who maintain that when death occurs the number and severity of injuries are unimportant. This to a degree is true, but if the objective is to avoid death an examination of the detail of injuries is important. Table I, for example, shows a substantially increased incidence among M.1 fatalities of injuries to "major blood-vessels"; this relates to the very large vessels entering and leaving the heart (sometimes combined with injuries to the heart itself). There were also significant increases of severe injuries to other important intrathoracic structures and to abdominal viscera. These are body areas associated with instantaneous or very early death when combined, as they often have been, with head injuries. For such severity of injuries surgery has little to offer; the alternative is the better protection of these vulnerable areas by improved vehicle design and motorway usage.

As with other aspects of motorway accidents—for example, the increased severity of damage to vehicles—the pattern and severity of occupant injuries reflect the greater speed at which, on average, motorway collisions occur (Table II). Another measure of the increased severity of motorway crashes is shown in Table III—the time of death. Fewer fatal motorway injuries (compared with other roads) give time for life-saving treatment in hospital (cf. Gissane, 1963).

TABLE II.—Numbers of Accidents Causing Deaths to Vehicle Occupants on Various Types of Road

	Deaths	Accidents
Restricted-speed roads	61	61 (each causing 1 death)
Unrestricted-speed roads	61	52 (43 causing 1 death; 9 causing 2 deaths)
M.1	61	47 (37 causing 1 death; 7 causing 2 deaths; 2 causing 3 deaths; 1 causing 4 deaths)

TABLE III.—Age-groups and Time of Death in Hours After Accident of 61 Vehicle Occupant Fatalities (M.1)

Age-group (Years)	Instantaneous	Up to 6 Hours	6 to 12 Hours	Over 12 Hours	Total
0–<15	1	—	—	—	1
15–<30	8	5	3	2	18
30–<45	18	5	—	3	26
45–<65	7	4	—	2	13
65+	—	—	—	3	3
Total ..	34	14	3	10	61
	48		13		

Types of Accident

The manoeuvres of vehicles in all accidents on the M.1 have been analysed by Newby and Johnson (1963). They found that more than half the vehicles involved remained throughout on their own carriageway. About one-quarter first went off the road to their near side and about one-fifth went off the road to the off side. Finally, about 9% ran on to or across the opposing carriageway. These various manoeuvres result in different injuring circumstances. We have analysed these events as they relate to fatal injuries.

Of the 61 vehicle occupants killed in motorway accidents, 23 were occupants of 23 vehicles which remained in their own carriageway, 7 were ejected, and 6 vehicles overturned. There were 18 deaths of occupants in 16 vehicles which left the road without entering the opposing carriageway; 10 were ejected and 8 of the vehicles overturned. A further 20 occupants were killed in 13 accidents in which their vehicles crossed into the opposing carriageway, in eight the cars came into collision

with other vehicles, and in three of these (included above) the driver of the vehicle in its correct carriageway was also killed. As with vehicles which merely mounted the shoulders, a high proportion of the fatally injured occupants of vehicles which crossed into the opposing carriageway (12/20) were ejected and three vehicles overturned.

Another approach to the classification of these crashes is to consider first those involving a single vehicle and next those involving two or more vehicles.

Single-vehicle Fatal Accidents

In these accidents there were several contributing factors, including errors on the part of the drivers; faults of the vehicle, including its tyres; weather conditions; and the design of motorway intersections. Vehicles went out of control for various causes. Noteworthy examples are:

1. An articulated lorry travelling at about 35 m.p.h. with a 10-ton load failed to negotiate a bend leading off the motorway, hit the kerb and overturned, killing its driver. The bend was later tested at various speeds by a police patrol car; the maximum speed which that car could safely hold the road was 28 m.p.h. Safe maximum speed is relative to many considerations, including the manoeuvrability of the vehicle. In this study accidents have been relatively frequent at or near motorway approach and exit roads.

2. Testing the performance on the M.1 of recently acquired cars has resulted in more than one single-vehicle accident. At a speed estimated at 60–70 m.p.h. a recently acquired second-hand car "began to bump up and down, got out of control, overturned, and somersaulted several times," killing its driver. The tread of a rear tyre (a remould) had stripped off. After the accident the tyre was still inflated; we do not know if the owner-driver of this car knew that the tyre was a remould.

3. A high-performance car travelling at very high speed hit the off-side kerb of the fast lane, "flew into the air, crossed its own carriageway, and ended overturned in a ditch on the near side." Its young driver lived long enough to say that he went to sleep after a 200-mile early-morning journey.

It may be significant that almost two-thirds of the fatal vehicle accidents on the M.1 occurred to southbound traffic, though we have been unable to obtain evidence of the length of each journey before the accident.

Each of the single-vehicle accidents caused a single death, except one involving a lorry which mounted the near-side bank and collided with a bridge, killing both its occupants. There is a suspicion that a heart attack of one of the occupants caused this vehicle to leave the road.

Accidents Involving Two or More Vehicles

Almost any error on the part of a driver or failure of his vehicle or its tyres can result in collisions between vehicles in the same or opposing carriageway. The most serious injuries can occur to the occupants of vehicles not at fault. In this limited study several noteworthy features emerge.

In double-vehicle collisions it is the occupant of the smaller vehicle who is much more likely to be fatally injured (Fig. 1). In the 21 double-vehicle collisions on the M.1, in which 28 vehicle occupants were killed, a lorry was involved in 14 and a van in one—but only the occupants of the smaller vehicle were killed. In the remaining six collisions the second vehicle was another car. In our studies of 52 fatalities resulting from collisions between a lorry and another vehicle on all types of road, deaths to lorry occupants occurred on only four occasions and each resulted from collisions between lorries. Collisions between cars and lorries are a serious hazard to car occupants on the M.1. Contributing factors to the severity of injuries are the higher average speed of the lighter vehicle at the time of impact and the larger mass of the heavier vehicle. In collisions between vehicles of the same size the occupants of the

better-engineered car would seem to have more chance of survival. In a head-on collision, when each vehicle's speed was estimated at 60–70 m.p.h., one car broke up into three main sections of its assembly, and pieces of the vehicle and its three occupants were scattered widely over the motorway; its occupants had no chance of escaping death or serious injuries. The other car's passenger compartment was badly crushed (Fig. 2), yet it was in one piece and had its driver not been ejected his survival was probable.

FIG. 1.—In double-vehicle collisions it is the occupants of the smaller vehicle who are more likely to be injured.

FIG. 2.—Vehicle damage resulting from head-on collision at speed of vehicles of equal size. One car broke up into the three main sections of its assembly; the passenger compartment of the better-engineered car offered some protection to its occupant.

Collisions in which one vehicle strikes the rear of another are more common on the motorway than on other roads. There were five examples of the occupants of the rear lorry being killed in this type of collision between lorries. In three the lorry collided into was stationary, having been involved in a previous accident; in two the lorry in front was moving abnormally slowly. In such collisions the driver's cab of the rear lorry is submitted to two forces; the first, its frontal impact against the other lorry; the next, the forward movement of the rear lorry's load against the cab. Fig. 3 illustrates such a collision, and another not infrequent hazard, the interlocking of the two vehicles. Up to two hours have been occupied on two occasions; first, in separating the interlocked lorries; and next, in extracting the badly injured occupants from their crushed cab.

Seven fatal accidents to car occupants occurred as the result of striking the rear end of lorries. In a previous report (Gissane and Bull, 1961) we noted the dangerous rear overhang of many lorry designs. Fig. 4 is an example of this particular hazard to car occupants.

Causation of Injuries

There are three main causes of vehicle-occupant injuries.

1. The movements of occupants within their vehicle at something like the speed of the car as it went into the crash. The severity of the impacts against internal features of the car is responsible for the nature and multiplicity of the resulting injuries. The sequence of movements has been well established by American research in prearranged collisions at various speeds and types of crash using anthropometric dummies as occupants. Vehicle furniture or luggage in the passenger compartment, if not securely tied down, can add to the severity of the injuries. A notable example is the rear load of lorries.

2. The deformation of the passenger compartment can cause direct impact injuries as the bodywork collapses and at the same time the occupant moves towards the area of deformation. The sides and roof of the passenger compartment should be as strong as reasonable engineering can make them in order to protect occupants in side collisions and overturning. In high-speed collisions, if the vehicle assembly is not strong, it can disintegrate, leaving its occupants completely exposed.

3. Ejection of occupants out of their vehicles can add a further sequence of forces, as they make impact with the road or roadside furniture or are hit by passing vehicles.

So far as is possible the objects in the vehicle causing injury to its occupants have been identified and are listed in Table IV. In such attribution there must be a wide margin of error, for occupant movements and impacts in any crash sequence are generally too quick for accurate recognition.

We have endeavoured to relate the nature of injury to the known detail of vehicle damage. For example, when necropsy evidence has revealed gross damage to a driver's chest, its contents, or the upper abdomen, and the car damage has shown a grossly deformed or broken steering-wheel and a displaced column, the inference is clear. When complicated compression-type fractures of the knees, thighs, and hips are associated with gross damage to the dashboard this evidence has been considered to be sufficient. When major intrathoracic and intra-abdominal injuries have occurred on the side of a car occupant's body exactly opposite the crushing of the passenger compartment the evidence again has been regarded as valid.

Some of the injuries resulting from sudden deceleration are undoubtedly due to the relative movements of soft tissues within their walled cavities. The mechanisms of closed brain and brain-stem injuries due to brain movements within the skull are well established. Similar movements undoubtedly occur within the thoracic and abdominal cavities, resulting in injuries to their contained soft tissues. For example, the aorta is most often torn at the junction of its arch and the descending part where the latter is tied down by the first intercostal branches; we have noted such tears in association with bruising of the

anterior surface of the heart itself. For the purposes of Table IV the cause is "not known" in the sense that no particular external structure caused the injury.

Ejection Out of Vehicles

Ejection of occupants out of vehicles generally occurs through doors flying open from failure of the latch when door movement occurs within its frame during the distortions of the passenger

compartment in the crash sequence. Other causes of ejection include children playing with door handles; ejection through windcreens, side windows, and the roof; and, in two instances on the motorway, of the car breaking up into many separate parts. The incidence of ejection is probably higher on the motorway than on other types of road. Of the total car-occupant fatalities on the M.1, 56% were ejected. The proportion was even higher for car drivers: 18 (62%) were ejected in a total of 29 car-driver fatalities. The incidence of ejection was lower in fatal accidents to lorry-drivers (1 and 8).

FIG. 3.—The driver's cab of the rear lorry in this type of collision is submitted to two forces, the frontal impact against the other lorry and the forward movement of the rear lorry's load; the resulting crushing of the cab is mainly responsible for its occupant's injuries. After such collisions the two vehicles are often securely interlocked, adding to the difficulties of removing the injured from their cabs.

FIG. 4.—The dangerous rear overhang of many lorries has been responsible for seven fatalities to car occupants in this type of collision on the M.1.

TABLE IV.—Injuries and Injuring Objects—Vehicle Occupant Fatal Cases on M.1

Injuring Objects	Fractures						Major Internal (Soft-tissue) Injuries										Other Soft-tissue Injuries					Total No. of Injuring Objects							
	Spine	Legs	Arms	Pelvis	Ribs, Sternum, Clavicle	Skull, Face	Brain	Cord	Kidneys, Adrenals	Lungs	Liver	Spleen	Stomach, Bowel	Bladder, Urethra	Other Internal Injuries	Major Blood-vessels	No. of Injuring Objects	Major					Minor						
																		Head	Face	Legs	Arms		Trunk	Head	Face	Legs	Arms	Trunk	
Steering column and wheel	—	—	5	3	18	—	—	—	—	12	6	5	1	—	1	7	58	1	—	—	—	2	1	2	4	19	2	2	65
Dash and glove cupboard	—	3	—	—	4	3	3	—	—	1	—	—	—	—	—	—	16	—	—	4	—	—	—	4	8	1	—	—	46
Windscreen and frame	—	—	—	—	2	—	3	—	—	—	—	—	—	—	—	—	5	1	2	—	—	—	4	1	—	—	—	—	23
Other and flying glass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	1	—	—	—	—	1	—	8	—	16
Roof	1	—	—	—	—	6	7	—	—	—	—	—	—	—	—	—	14	1	1	—	—	—	—	—	—	—	—	—	26
Foot controls	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	4	—	—	—	—	—	—	—	—	6
Door pillar	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	1	—	—	—	1	—	3
Near-side body work	—	—	—	—	2	—	—	—	—	2	1	2	—	—	1	—	8	—	—	—	—	—	—	—	—	—	—	—	9
Off-side body work	—	2	2	—	1	—	—	—	—	2	1	1	—	—	—	—	8	—	2	1	—	—	—	—	1	—	—	—	12
Doors	—	—	1	—	—	—	—	—	—	1	1	1	—	—	—	1	6	—	—	—	—	—	—	—	—	—	—	—	6
Front seats	1	—	—	—	1	1	1	—	—	2	2	—	—	—	1	—	9	1	—	—	—	—	—	—	3	1	1	—	15
Crushing of vehicle (injuring feature not known)	1	4	2	4	10	7	6	—	2	9	4	3	2	2	1	6	63	4	4	3	3	2	1	3	2	—	—	2	87
Parts of other vehicle	—	1	2	1	4	9	7	—	3	2	2	1	—	—	—	34	1	4	3	1	1	1	1	1	6	4	—	—	52
Road furniture	—	—	1	—	1	3	2	—	—	1	2	—	—	—	—	10	2	2	1	2	1	1	—	—	—	—	—	—	17
Injury during ejection	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	7
Hit ground	1	—	—	2	3	12	12	1	1	5	3	3	—	—	—	2	45	—	3	2	1	1	9	1	7	4	—	—	83
Interior fittings, unspecified	—	—	—	1	3	1	1	—	—	—	—	—	1	1	—	—	8	—	—	—	—	—	—	1	8	6	—	—	25
Not known	4	2	—	4	7	8	4	1	3	4	4	4	—	—	—	8	53	2	2	1	—	—	—	—	—	—	—	—	58
Totals ..	9	14	13	17	55	53	47	3	9	41	26	19	4	3	5	25	343	16	20	18	6	7	26	33	49	29	9	556	

Lorry drivers and their mates are more often crushed within their cab.

Ejection adds another sequence of forces to those already experienced within the vehicle. American research workers state that ejection increases the incidence of serious and fatal injuries fourfold. Many of the fatal injuries in this study were caused by ejection, but we have often found it difficult to differentiate injuries occurring within the vehicle from those due to ejection.

Misuse of the Motorway

The regulations governing the motorway imply that there should be no crossing traffic, no opposing traffic, and no pedestrians. However, 22 of the 76 deaths studied were caused under circumstances which, according to regulations, should not have occurred. Thirteen were caused by vehicles crossing into the opposing carriageway (in one of them it is difficult to establish whether the crossing was due to a nervous illness or a deliberate act). A further fatal accident occurred to the occupant of a car in collision with a lorry which deliberately crossed the central reservation to the opposite carriageway. Two fatal accidents occurred after cars entered the motorway in the wrong direction; it is difficult to establish whether this was by neglect or intent.

The six "pedestrian" fatalities are of particular interest. Two were drivers of vehicles which had broken down; one attempted to cross the road on foot to obtain help and was hit by three cars in succession; one was fixing a tow-rope to his lorry when it was hit by another lorry. Two were on official duty: one, a police sergeant, was pushing a broken-down vehicle off the motorway; the other an ambulance attendant, was helping to lift an injured person on to a stretcher. Two further pedestrian deaths were those of motorway-maintenance workers: one was trapped between a compressor and its towing lorry, the other was struck by a van when lighting warning lamps around a repair area. Some maintenance workers have a peculiar disregard for the dangers of the motorway. One of us watched a young maintenance worker run across both carriageways no fewer than six times during the brief period it took the "overhead observer" to eat his lunch. Yet there were two near-by bridges the worker could have used.

Discussion

Completely adequate figures are not yet available, but it seems likely that the risk of fatal accidents to *car occupants and perhaps to lorry drivers per vehicle mile travelled is appreciably higher on the motorway than on other types of road*. This study shows that fatal motorway accidents cause a much greater severity and multiplicity of injuries to vehicle occupants than occurs on other roads; indeed, their injuries are much more serious and multiple than those of motor-cyclists and pedestrians injured elsewhere. Of all fatalities on the motorway, 84% were to occupants of cars or heavier vehicles—thus the type of road user most often involved in fatal accidents is very different from the types using other roads. It would appear that the greater speed made possible by good road engineering has been offset by increased hazards resulting mainly from driver behaviour.

Motor-cycles are relatively rare on the motorway, but lorries seem to be increasing. It is not unusual to see lorries occupying two lanes, and not infrequently the three lanes. In this study the death of many car occupants resulted from collisions with lorries, and in car-lorry collisions no lorry driver was killed. Lorry-driver fatalities have usually resulted from collisions with other lorries.

Motorway injuries present medicine with most difficult and often insoluble problems. The design of the motorway delays quick ambulance attendance, speedy first aid for the more

seriously injured, and their quick transport to hospital. The complex nature of the more severe injuries requires new standards of hospital treatment. The proposed new hospital accident departments and the new motorways should in some way be related, for time is not on the side of the badly injured or those responsible for their transport and treatment.

Some Recommendations

Since 84% of all fatalities on the M.1 are to vehicle occupants, some non-medical approaches to reduce the existing severity and fatality rates should be considered, for the occupants of cars and heavier vehicles can, at least potentially, be protected from injuries.

1. A minimum and maximum speed limit could reduce the differential velocities of impacts when collisions occur and eliminate many of the accidents caused when attempting to overtake at very high speed. Clear signs indicating the maximum and minimum speeds appropriate to various stretches and motorway approaches would help.

2. The vulnerability of car occupants when their vehicle is in collision with lorries and vans suggests that some kind of segregation of these two types of vehicles would be desirable. For example, heavy vehicles should not be allowed to use the fast lane.

3. An important group of fatal accidents is associated with obstructions in one or more lanes due either to road repairs or to stationary vehicles which may have been involved in a previous accident. Motorway users tend to maintain high speeds on the assumption that the road ahead will be clear. Early warnings of obstructions or of other adverse road conditions ahead could be achieved by central traffic control over specified sections, using modern methods of communication and posting the information on bridges and elsewhere. A television control system has been tried in the United States, and something similar has now been installed in the recently opened Dartford-Purfleet tunnel under the Thames.

4. Another group of accidents was caused by human and mechanical failures while using the road in an otherwise normal manner. Tyre failures were important in several of these instances; in others the driver failed in attention as a result of either tiredness, alcohol, or sudden illness. In all, the high speed of the vehicles at the time of failure contributed greatly to the severity of the injuries. A dangerous combination of youth, high-performance cars, long journeys—particularly at week-ends—going to sleep at the wheel and crashing, is familiar to us from our inquiries in the United States, where very long motorway travel is possible and youth attempts too much. In this regard motorway cafés have a potential safety value.

5. Improved vehicle design can make an important contribution to lessening the present severity of injuries to occupants. From this standpoint safety engineering for car occupants begins where normal engineering ends. Normal engineering has produced vehicles that are intrinsically safe in relation to reasonable motorway speeds. The engineer has emphasized the importance of engine performance, ease of maintenance, precise steering, reliable brakes, good all-round field of vision, and tyre design and maintenance. The road engineer has provided a safe road if it is used in a reasonable manner by well-trained drivers. This study shows that the automobile engineer should now be concerned in "delethalizing" his product in order to lessen the existing severity of injuries and the instantaneous deaths when the inevitable accidents do occur.

In regard to vehicle design the following matters need consideration:

The "Tie Down"

The safer "packaging" of car occupants begins with the seat. It should provide comfort to allay fatigue and be so designed as to give some protection to its occupant. It should be *very* firmly anchored to the body of the car. Since most car seats are made by independent manufacturers there is a need for car manufacturers to provide strong anchoring supports for safer car seats. A British firm has engineered and designed a prototype seat that may meet most if not all of these requirements. It was demonstrated at the 1963 Motor Show. It costs more than the ridiculously low-priced

normal-production car seat, but the pound or two extra cost is a small price to pay for additional safety.

Seat belts may be regarded as a personal braking system for each car occupant, preventing the very dangerous injury-producing sequence of occupant movements at and after crash impacts; they are auxiliary to the vehicle's braking system. Ideally they should be integral parts of the seats, so ensuring comfort and proper seat-belt anchorage. In addition to the firm anchorage of all seats and their occupants, all luggage and other solid articles carried in the passenger compartment should be securely tied down so that they cannot become secondary injury-producing missiles. We recently observed on the M.1 the rear passenger compartment of a saloon car stacked high with unrestrained heavy glass containers. The secure retention of the heavy loads on lorries is of vital importance to the safety of their cab occupants (see Fig. 3).

Vehicle Structure

The vehicle should be strong enough in basic structure to hold together after crash impacts, yet should incorporate energy-absorbing devices to decrease the forces of deceleration within the passenger compartment.

James J. Ryan (1962), Professor of Mechanical Engineering, University of Minnesota, claims that the hydraulic shock-absorbing bumpers of his test car reduce the forces transmitted to the passenger compartment and finally to the seat-belts holding its passengers in crashes up to 40 m.p.h. to a quarter of the decelerations with normal bumpers and unrestrained passengers. In principle, the basic and peripheral structure of cars could be designed to deform while absorbing energy. But the passenger compartment should provide special protection for its occupants. We have been particularly impressed with the added strength given to the passenger compartment by incorporating encircling tubular roll bars over sections of the roof, sides, and floor, the floor positions being related to the anchorage of car seats.

All the arguments previously brought forward relating to safer design of steering-wheel and column, the elimination of projections within the passenger compartment, and the efficient padding of areas likely to be struck by occupants apply with equal force to the prevention of injuries on the motorway as on other roads. The high incidence of ejection in fatal motorway collisions, even when the passenger compartment remained relatively intact, again emphasizes the importance of sound door and door-frame design and anti-burst features of door-latches.

We were particularly impressed with a car of British design at the 1963 Motor Show with many safety features, including "a steering-box mounted right back in the dash and a protectively jointed and angled steering-column." As shown in Table I, chest, lung, and major (intrathoracic) vessel injuries are common causes of vehicle-occupant fatalities, particularly to the driver, but they occur with even greater force and severity on the M.1. A safer design of steering-box and steering-column could make a notable contribution to the reduction of these injuries.

Conclusion

Motorways demand new standards of driving skills and user behaviour. New regulations may well be needed to enforce these standards. Motorway users could be helped by clear signs

giving maximum and minimum speeds. More adequate warnings of obstructions ahead would also help.

Every advance in road and vehicle design should be constantly tested by research, not least on how each advance affects road injuries and deaths. Many features of safer vehicle design could be incorporated in all vehicles now in production without great cost or change in their present appearance. Safer car design depends primarily on public demand. That car owners are becoming conscious of the risks of the road is shown by the sale of some millions of safety-belts each year. Safety-belts prevent the dangerous sequence of occupant movements within their vehicle during a crash and the more dangerous risk of ejection out of their cars. Yet in the final analysis much more is required than safety-belts to reduce the severity of injuries recorded in this study of motorway fatalities.

Summary

Details of the accidents causing deaths on the M.1 motorway in 1959-62 have been studied.

Analysis of post-mortem findings shows that each fatality had on average more than five severe injuries (compared with three to four on other roads). The increased severity of fatal injuries on our motorway is also shown by more frequent severe intra-thoracic and intra-abdominal injuries and a reduction of average survival time.

Four-fifths of the deaths were of vehicle occupants, in contrast to findings on other types of road. About one-third of these fatalities occurred in vehicles which remained on their own carriageway, another third occurred in vehicles which crossed to the opposing track, and the remainder occurred in vehicles which went off the road on to the median or shoulder. Relatively few fatalities on the motorway involved motor-cyclists or persons on foot.

Collisions with obstructions on the motorway and with lorries were prominent causes of fatal accidents to car occupants.

Methods for improved protection of vehicle occupants and for safer use of the motorway are suggested.

This study was stimulated by the analysis made by Newby and Johnson (1963) on the manoeuvres of vehicles involved in all types of accident on the M.1 over the period 1959-62. We are grateful to the Road Research Laboratory for providing from that study the sites of all fatal accidents, and to the chief constables and the coroners in the areas concerned, who have given us every facility, together with a great deal of personal help, to study their excellent records. The secretarial assistance of Miss B. J. Roberts has been invaluable.

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