ROAD TRAFFIC ACCIDENTS

Epidemiology, Control, and Prevention

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CONTENTS

TABLES

PREFACE

Accidents today are among the leading causes of death—in some cases the number-one cause—in many parts of the world, particularly the more highly industrialized nations. The number of minor as well as serious injuries and the human suffering and economic loss due to disabilities caused by accidents is inestimable. Thus while medical science has conquered the ravages of many diseases, accidents have become a new "epidemic" of public health importance calling for equal effort for control and prevention.

Among all types of accidents—in the home, in places of work (e.g., mines and industries), at play (e.g., sports) and elsewhere—those causea by motor vehicles claim the largest toll of life and tend to be the most serious. The present study of road traffic accidents by Dr. L. G. Norman, Chief Medical Officer of the London Transport Executive, is an outgrowth of the interest in this problem that was aroused by the 1961 World Health Day with its theme, "Accidents and Their Prevention". As the first in a series of studies that will deal with the various kinds of accidents from the epidemiological, etiological and preventive points of view, it is a review of the latest information on the subject, intended not only for public health authorities but for transport authorities, teachers, citizens' groups, and the many other categories of workers concerned with the promotion of safety on the roads.

GENERAL CONSIDERATIONS

Two deaths were registered in 1896 in Great Britain as due to motor vehicles; one was registered in the United States in 1899. From these small beginnings a terrible stream of deaths and injuries has followed. In 1951 the United States recorded its 1 000 000th death in road traffic accidents, and other countries which have become highly motorized have suffered similarly. This catastrophic loss and injury is a public health problem demanding urgent attention. Many of the deaths are of young people; in addition to numerous family tragedies, they represent a serious economic loss to the community. In highly motorized countries, road traffic accidents are now the commonest cause of death in adolescents and young people, particularly males. A large proportion of the beds in the male surgical wards of hospitals are occupied by young men injured in road accidents, many of them maimed or permanently disabled.

The problem of road traffic accidents on a large scale has arisen for the first time in the present century. All other epidemics throughout history have been due to the onslaught of agencies external to man, principally the protozoa, bacteria, and viruses; but road accidents are caused by man himself. A terrible penalty of mortality has already been paid as the cost of integrating the motor vehicle into modern life. The motor vehicle itself has developed from somewhat primitive beginnings to a stage at which a set of armchairs, fully enclosed in a mass of metal often weighing a ton or more, can be hurled from a standstill to fifty or sixty miles an hour or more in a matter of seconds by the lightest touch of a couple of levers, and can attain far higher maximum speeds in smoothness and comfort. And all this occurs on roads that were mostly built for horse traffic: it is not surprising that an accident problem has arisen. Much attention has been devoted to improvements in the performance of motor vehicles, mainly in their acceleration and in the maximum speed attainable. With some exceptions, such as research in the design of tires and brakes, insufficient care has so far been given to safety factors in the vehicle itself, a problem that is now increasingly engaging the attention of manufacturers. It may be postulated straight away that the great majority of road accidents are preventable, but a considerable increase in community effort will have to be made if prevention is to become effective.

It is interesting to note that a somewhat similar problem arose in the nineteenth century during the early development of railways. After William Huskisson, former President of the Board of Trade of Great Britain, was killed by a train at the opening of the Manchester and Liverpool Railway in 1830, railway tracks were segregated from all other traffic, including pedestrians. This would appear to be the safest line of development for the handling of motor traffic, particularly in built-up areas and on main roads, where there are the heaviest volumes of motor transport. Ritchie, in 1846, analysed the causes of railway accidents and made proposals for their prevention; several of his suggestions have since become standard practice.

Because road traffic accidents have grown to their present numbers only during the twentieth century, traditional methods have generally been applied to deal with them: coroners' inquests or similar investigations of the cause of death, police inquiries on liability, compensation for personal injury and damage to property. But no one administrative authority is charged with the business of *prevention*, although many national and local voluntary safety councils and committees, automobile associations, and other voluntary bodies, often with government support, have made, and continue to make, a considerable contribution to road safety. At the First International Congress of Traffic Police, held at Eindhoven in 1957, road safety measures were discussed and recommendations made, in particular for the education of road users, especially children (*Rev. int. Circ. Sécur. rout.*, 1957).

As a public health problem, road accidents are amenable to treatment by the methodology applied to epidemic disease, including the detailed investigation of individual incidents and the application of epidemiological techniques, as discussed in a later chapter. It is probable that different types of accident have different causes and that different accident types should therefore be considered separately, as with different diseases, but too little is yet known of the causes of road accidents to permit their separation into different " diagnostic " groups. Different descriptive groupings of accidents are, of course, used in classification and can be extremely valuable.

It is surprising, in view of the large numbers of casualties on the roads, that public concern for prevention does not yet seem to be sufficiently aroused. When a fatal accident occurs in air or rail transport a full inquiry and investigation are held, but these are not usual for road accidents, although the numbers killed are very much greater. Perhaps the gradual increase in road fatalities, overshadowed by two major wars in some of the more motorized countries, has tended to produce apathy and indifference. There are signs, however, of an awakening public interest, and it is to be hoped that public opinion will demand effective preventive action. A healthy and aggressive social attitude towards road traffic accidents and their prevention is of great importance and can be encouraged by educative procedures. In countries which are now entering a phase of increasing motorization, many of the lessons painfully acquired in highly developed countries can be applied and the opportunity should not be missed.

All road users are concerned in the prevention of accidents, but attention must focus especially on drivers of motor vehicles, because they may endanger the lives of other road users as well as their own. It is increasingly realized that driving is a privilege and not an inherent right: a privilege that can and should be withdrawn if it is shown that it may endanger others.

Although the numbers of road accidents are high, one difficulty in studying them is the relative rarity of accidents in relation to the large numbers of vehicles and road users. This unfortunately provides some justification for the commonly held " it can't happen to me " attitude, which is not conducive to safety. The number of miles the average driver travels before experiencing a personal-injury accident is impressive. When one considers the achievements of human beings on the roads in a detached way—for instance, by trying to determine what sort of automatic device could be introduced to do the job instead—one is lost in admiration for their success. Thus, in the United States in 1959 the average driver would have had to travel about 400 000 miles before becoming involved in an accident resulting in injury to a person severe enough to cause death or disablement beyond the day of accident. At an average speed of 30 miles an hour, this represents a driving time of about 13 000 hours. As the average "development time " for an accident is probably less than ten seconds, drivers appear to possess remarkable powers of concentration. It has even been suggested that the limit of human performance is being reached in this respect and that the consequent accidents are the inevitable price of motorization. This view should not be accepted. It has been demonstrated in other fields, in industry for example, that accidents are preventable, and motor vehicle accidents, it is already clear, are similarly susceptible to appropriate accident prevention measures.

Finally, in the prevention of mortality among the injured in road accidents, a high standard of emergency care is vitally important. Modern accident surgery has an important place in the emergency facilities, and the casualty and the surgical team should be brought together in the shortest practicable time after an accident.

There is no panacea that will prevent all road traffic accidents; organized team-work by people in many disciplines, such as educators, engineers, medical practitioners, psychologists, and enforcement officers, is necessary for effective prevention. At present, the road traffic accident problem does not appear to be under control.

CHAPTER 1

IMPORTANCE OF ROAD TRAFFIC ACCIDENTS

Mortality and morbidity from road traffic accidents assume greater importance as a country becomes more highly developed—partly because of the increase in numbers of accidents, but also because their relative importance increases as mortality and morbidity from other causes, such as infective and parasitic diseases, decline. Countries and territories with currently low rates of road traffic accidents, and in which motorization is beginning to expand, have the opportunity to learn from the tragic experience of countries already highly motorized.

HUMAN LOSS

The size of the problem is indicated by the fact that, in 1957, in the 47 Member States of the World Health Organization that completed separate returns for motor vehicle accidents (Group BE47), [1] 102 552 people (79 810 of them males), in a total population of some 650 million, were killed in such accidents (World Health Organization, 1960). No records are available of the much larger numbers who were injured, many of them seriously and some permanently crippled or disabled. The present position is that well over 100 000 people are killed in road traffic accidents in the world annually and this number is increasing. The situation arises from man's own activities and amounts to the casualties of a moderate-scale war—*every year.*

The tragedy of road traffic accidents is that they particularly involve the young, perhaps the young and adventurous. Males aged 15-30 are especially involved; fatal accidents in this group represent not only tragic family losses but also a serious economic loss to the community, for their education and training have been wasted. In highly motorized countries, road traffic accidents are the commonest cause of death in

[1] Group BE47 of the *International Classification of Diseases* includes traffic accidents involving a motor vehicle and occurring on or off a public highway. Other road vehicle accidents are not included in this group. (See also page 20.)

this group. The total of potentially active and productive years of life lost through such accidents is enormous. Harris (1955) estimated that in Canada, among those children who reach their first birthday and who would normally survive to the present life expectancy of 70 years, the loss from road traffic accidents *each year* is more than 105 000 years of normal life expectancy. The estimated man-years lost in the United States in 1955 by persons aged 20-29 from motor vehicle accidents, compared with certain other causes, are given in Table 1. Among these young people, motor vehicle accidents account for a greater loss of potential life than any other single cause.

TABLE 1. ESTIMATED MAN-YEARS LOST FROM THE FIVE LEADING CAUSES OF DEATH, AGES 20-29, UNITED STATES, 1955*

Cause of death	No. of deaths		Man-years lost	
All accidents	12 646		634 498	
Motor vehicle accidents		8 401		421 460
Malignant neoplasms	2 765		136 629	
Diseases of heart	1 993		98 067	
Homicide	1 883		93 452	
Suicide	1 485		73 361	
All other causes	8 761		434 489	
All causes	29 533		1 470 496	

* Derived from U.S. Dept. of Health, Education and Welfare (1958) *Accidental Injury Statistics*, Washington, Government Printing Office.

The pattern of mortality from infectious and certain other diseases and from road traffic accidents is striking. Table 2 puts the mortality from such accidents and certain other causes into perspective and calls attention to the fact that in Canada, the United States, Austria, the Netherlands, Australia, and New Zealand, deaths from motor vehicle accidents in males in 1958 exceeded those due to tuberculosis (all forms), acute poliomyelitis, typhoid fever, diphtheria, and diabetes mellitus *added together*. Among females in these countries fatal road traffic accidents were fewer but were still prominent among the causes of death. It is evident that as a country becomes more highly developed and therefore more highly motorized, road traffic accidents assume an increasingly important part in national mortality.

Loss of life from road traffic accidents has increased to such an extent that in highly developed countries such accidental deaths exceed the combined deaths from all infectious and communicable diseases: in the United States in 1957, deaths at all ages from all infectious and

TABLE 2. NUMBER OF DEATHS FROM SELECTED CAUSES AT ALL AGES, 1958*

Country and sex		Tuberculosis, all forms (B1,B2)**	Acute poliomyelitis (B12)**	Typhoid fever (B4)**	Diphtheria (B8)**	Diabetes mellitus (B20)**	Motor vehicle accidents (BE47)**
Canada	M	667	20	0	3	822	2 665
	F	360	6	3	4	1 047	852
United States	M	8 943	163	11	36	10 961	27 492
	F	3 418	92	12	33	16 540	9 489
Israel (Jewish pop.)	M	64	28	1	3	23	112
	F	19	21	0	0	26	52
Ceylon	M	1 094	74	123	59	419	208
	F	805	58	91	65	239	50
Japan	M	21 744	135	30	306	1 222	6 996
	F	14 530	108	24	313	1 442	1 887
Austria	M	1 195	73	4	6	179	1 478
	F	565	40	9	8	341	379
France	M	7 591	96	17	19	1 938	6 306
	F	3 264	46	16	24	3 465	1 689
Netherlands	M	272	0	2	17	525	1 207
	F	210	0	0	9	1 092	326
United Kingdom	M	3 207	71	2	4	1 152	4 034
(England & Wales)	F	1 273	58	0	4	2 163	1 405
Australia	M	405	2	3	0	404	1 824
	F	133	2	2	1	711	507
New Zealand	M	89	0	0	0	102	273
(excl. Maoris)	F	49	5	0	0	171	80

* Data from World Health Organization (1961) *Annual epidemiological and vital statistics 1958*, Geneva.
** Indices refer to List B for tabulation of mortality in the WHO *International classification of diseases*.

communicable diseases were 24 256; those from road traffic accidents were 38,702 (World Health Organization, 1960).

The death rates per 100 000 population again reveal the major importance of road traffic accidents. The high death rates from such accidents compared with certain other causes, in males aged 20-24, in a group of highly motorized countries are shown in Table 3.

In the total field of health, not only mortality must be considered, but also the temporary and permanent incapacity resulting from road

TABLE 3. DEATH RATES PER 100 000 POPULATION, FROM SELECTED CAUSES, AMONG MALES AGED 20-24, 1958*

Country	Infective & parasitic diseases (B1-B17)**	Tuberculosis, all forms (B1, B2)**	Malignant neoplasms (B18)**	Cardio-vascular diseases (B22, B24-B29, A85, A86)**	Motor vehicle accidents (BE47)**
Canada	1.8	1.2	7.8	6.7	56.0
United States (all races)	2.8	1.3	11.6	10.1	72.5
German Federal Republic	4.5	3.2	10.5	6.4	77.9
Austria	7.1	4.3	11.4	6.1	102.2
Belgium	4.4	2.7	11.6	4.8	47.4
Denmark	0.7	—	10.9	5.5	36.3
France	6.0	3.9	11.3	6.0	40.7
Netherlands	1.7	0.7	13.2	3.5	28.5
United Kingdom: England & Wales	3.3	2.2	10.8	8.0	38.6
Sweden	2.7	2.3	13.5	7.7	28.4
Switzerland	2.4	1.8	17.1	4.7	60.0
Australia	1.9	0.3	11.8	13.3	82.6
New Zealand (excl. Maoris)	3.0	1.5	9.0	6.0	54.0

* Data from World Health Organization (1961) *Annual epidemiological and vital statistics 1958*, Geneva.

** Indices refer to List B for tabulation of mortality in the WHO *International classification of diseases.*

traffic accidents. For example, in Britain for every person killed there are 10-15 seriously injured and 30-40 who receive minor injuries (Great Britain, Ministry of Transport and Civil Aviation, 1960), and in the United States there are 35-40 persons disabled beyond the day of the accident for every death (National Safety Council, 1960).

ECONOMIC LOSS

In addition to the pain and suffering caused and the tragedy of death or permanent disability, a serious economic loss to the community arises from road traffic accidents. This is due to the actual costs of medical and surgical treatment, which tend to increase as techniques advance; to the loss of the services of the injured person; and to damage to property. The fact that many accident victims are in the younger age groups implies an enormous loss to the productive resources of a country. The American Medical Association found in a survey in 1955, for example, that accident cases of all kinds occupied 7 per cent of the total available beds in general and special hospitals, excluding mental and tuberculosis hospitals; the average hospital stay for each patient was 10.7 days; the actual cost of treatment of accident cases was estimated at $310 565 000. In the United States, the National Safety Council (1958) estimated that road traffic accidents caused wage losses of $1 550 000 000, property damage of $1 850 000 000, medical expenses of $150 000 000, and overhead costs of insurance of $1 750 000 000. These direct costs, omitting loss of production, amounted to some $5 300 000 000. In Japan (Japanese Police Board, 1954) the cost of property damage alone due to road traffic accidents in 1954 was 2 019 000 000 yen. (About 1000 yen equals one pound sterling.) According to *Trafik Kazarli 1957* (Turkey, Nafia Vekaleti, 1959) the cost of property damage due to road traffic accidents in Turkey in 1957 was 5 383 800 Turkish lire. (About 25 Turkish lire equals one pound sterling.)

But we are here concerned with health; and it is clear from what has been written above that road traffic accidents now constitute a public health problem of the first magnitude. It is a problem that appears likely to increase still further.

CHAPTER 2

EPIDEMIOLOGICAL FEATURES

The methods developed and adopted in the field of public health for the study and control of epidemic disease provide a useful framework for the study and control of road traffic accidents. Accidents may be interpreted as resulting from the total forces involved in the competition between man and his environment (Gordon, 1949), and the epidemiological method thus offers a scientific approach to the prevention of road traffic accidents.

It is useful to have a working definition of the term " accident ", and the following has been suggested: " An unpremeditated event resulting in a recognizable injury " (World Health Organization, 1957). A distinction should be made between accidents which cause damage to property alone and those which result in injury to persons. A study of road traffic accidents should cover the whole range of experience, from instant death to the narrow escape. A study of " near-accidents " might indeed provide useful information for the development of methods of prevention, but such a study has not yet been attempted and in the present state of knowledge it seems more practicable to concentrate on the improvement of statistics covering actual accidents.

Road traffic accidents do not happen by chance. The briefest study of the data reveals that different groups of the population are affected very differently by such accidents, as they are by disease. Accidents also differ in their geographic location, tending to occur more frequently at certain sites which may be designated as " black spots ", and differing in incidence between urban and rural areas. The incidence of road traffic accidents also varies with such environmental factors as time of day, day of the week, weather conditions, type of road design and surface, lighting and visibility. The severity of accidents, and the mortality resulting therefrom, may be affected for better or worse by the structural design of the vehicles involved.

In the study of epidemic infectious disease it is usual to consider three factors: host, agent and environment. For the study of road traffic accidents there are three analagous factors: the road user, the vehicle and the road. Epidemiological studies concern all three of these.

A simple hypothetical example of the way in which these factors may combine in accident causation is provided by the common type of accident in which a vehicle skids and collides with another vehicle. If the driver (road user) had entered the section of road concerned more slowly, the dangerous skid might have been avoided ; several factors operate in the driver, such as inattention, distraction by other events external or internal to him, and so on. But if improved tires had been fitted to the car (vehicle) or if a non-skid surface had been applied to the road, again the skid might have been prevented — and in the last instance by a factor quite apart from the driver himself. It is often said that most accidents are due to human factors, and, while this may be true in the sense that an improvement in human factors would have prevented many of them, yet an improvement in the vehicle or the environment, or both, would have presented the road user with a less hazardous situation and might also have been strongly preventive.

Epidemiological techniques are especially appropriate for the study of road traffic accidents because so many variables are involved in their causation.

The size of the population at risk of accident, according to sex and in age groups, must be known, in order that the incidence of accidents affecting different groups of the community may be calculated. In this way groups exposed to special risk may be found and measures for their protection considered. But the mere recording of numbers of accidents is of little use unless these numbers can be related to the sizes of the different groups exposed to risk. Recommendations for the recording of road traffic accident particulars on a national basis were made by the United Nations Economic Commission for Asia and the Far East in 1957, but the tables suggested give only gross figures. For the calculation of mortality rates, information to be collected should also include, for example, the category of road user killed (pedestrian, motorcyclist, etc.) and his age and sex, together with brief particulars of the accident itself — for example, collision of private automobile with pedestrian, and environmental circumstances such as time, season, weather and lighting. For studies of morbidity data, similar information should be collected for all accidents involving injury to a person; these may be somewhat arbitrarily divided into " seriously injured " and " slightly injured " groups.

Road traffic accidents do not usually have a single " cause ". Each individual accident is likely to have several causative factors. The effect of various factors must be isolated in order to assess their importance in causation and hence in prevention. The determining causes of a road traffic accident involving a motor vehicle reside in the driver-vehicle-environment complex as it varies during the short time leading up to an accident. The search for single causes of accidents is therefore likely to prove unproductive. Instead, a general conceptual framework is required, within which the different elements in accident situations can be evaluated and specific elements identified for analysis. This method of study makes possible the assessment of the relative importance of the contributing factors. One of the most important of these is the deleterious effect of alcohol on the performance of road users, described in Chapter 4.

Many countries publish annual statistical information about road traffic accidents. The total number of deaths occurring annually in motor vehicle accidents is also given for most member countries in the WHO publication *Annual Epidemiological and Vital Statistics*. This publication also gives annual death rates per 100 000 population according to sex and in five-year age groups. Motor vehicle accidents are given as Group BE47 (identical with the alternative Group AE138) of the *International Classification of Diseases* (World Health Organization, 1957 *a*). Under this classification of the external causes of injury or death, Group BE47 comprises Detailed List numbers E810 - E835 inclusive. These are as follows :

E810 Motor vehicle traffic accident involving collision with railway train
E811 Motor vehicle traffic accident involving collision with streetcar
E812 Motor vehicle traffic accident to pedestrian
E813 Motor vehicle traffic accident to pedal cyclist
E814 Motor vehicle traffic accident to rider or passenger of motorcycle in collision with non-motor vehicle or object
E815 Motor vehicle traffic accident to rider or passenger of motorcycle in collision with other motor vehicle
E816 Other motor vehicle traffic accident involving two or more motor vehicles
E817 Motor vehicle traffic accident to occupant of motor vehicle in collision with pedestrian or pedal cycle
E818 Motor vehicle traffic accident involving collision with animal or animal-drawn vehicle
E819 Motor vehicle traffic accident involving collision with fixed or unspecified object
E820 Motor vehicle traffic accident while boarding and alighting
E821 Motor vehicle traffic accident to rider of motorcycle without antecedent collision
E822 Motor vehicle traffic accident involving overturning in roadway
E823 Motor vehicle traffic accident involving running off roadway
E824 Other non-collision motor vehicle traffic accident
E825 Motor vehicle traffic accident of unspecified nature
(E826-E829 not used at present)
E830 Motor vehicle non-traffic accident to pedestrian (e.g., accident not on a public highway)

E831 Motor vehicle non-traffic accident to pedal cyclist
E832 Motor vehicle non-traffic accident to rider or passenger of motorcycle
E833 Other motor vehicle non-traffic accident involving two or more motor vehicles
E834 Motor vehicle non-traffic accident while boarding and alighting
E835 Motor vehicle non-traffic accident of other and unspecified nature

Certain other types of accident, such as streetcar accident to pedestrian (E840), other streetcar accident, except collision with motor vehicle (E841), accident to pedestrian caused by pedal cycle (E842), accident to rider of pedal cycle not involving collision with motor vehicle (E843), accident to pedestrian caused by other non-motor road vehicle (E844) and other non-motor road vehicle accidents (E845) are included in Group BE48 (all other accidents) and are therefore omitted from the group (BE47) of motor vehicle accidents. The E810 - E835 code can be further subdivided by the addition of a fourth digit to differentiate, for example, between accidents involving goods-transport and passenger-carrying vehicles.

It is an essential first step in road traffic accident prevention to obtain reliable epidemiological information. Adequate and accurate data provide the only satisfactory means of studying accident trends. Changes in the types of motor vehicle in common use may necessitate modifications in the information recorded. For example, the term "motorcycle" usually includes motorized bicycles, scooters and mopeds [1] along with the very high-powered machines; for the study of accident rates it is desirable to consider these different machines separately, for the rates of accidents involving personal injury are related to the size (i. e., cylinder capacity) of the machine (Scott and Jackson, 1960).

MORTALITY RATES FROM ROAD TRAFFIC ACCIDENTS

Mortality and other epidemiological studies of road traffic accidents may be undertaken at three levels: international, national and local.

Validity of international comparison of mortality rates

Annual mortality rates for 36 countries and territories for the years 1955-59 inclusive are given in Table 4, compiled from World Health Organization reports. The rates vary considerably, but a direct international comparison of rates is not practicable as traffic conditions

[1] Defined in the United Kingdom as two-wheeled machines having pedals and a motor not exceeding 50 cc cylinder capacity which may or may not be an integral part of the machine.

TABLE 4. DEATH RATES FROM MOTOR VEHICLE ACCIDENTS PER 100 000 POPULATION, 1955-59

Country or territory	1955	1956	1957	1958	1959
AFRICA					
Mauritius	10.2	13.7	12.8	11.9	12.2
Union of South Africa:					
White population	18.4	20.1	24.0	27.0	*
Asiatic population	16.8	15.0	18.1	17.6	*
Coloured population**	20.4	18.6	21.8	23.1	*
AMERICA					
Canada	19.5†	22.1	22.3	20.6	21.2
Colombia	8.0	7.8	7.9	9.0	8.6
Costa Rica	2.2	3.9	4.8	5.9	6.0
El Salvador	8.5	11.0	11.1	8.3	*
United States:					
All races	23.4	23.7	22.7	21.3	20.0
White	23.1	23.3	22.5	21.3	20.0
Non-white	25.7	26.8	24.7	22.1	20.3
Guatemala	5.7	5.6	6.9	7.3	7.7
Dominican Republic	5.4	1.1	1.3	3.4	*
Trinidad and Tobago	13.5	11.3	11.5	14.2	14.9
Venezuela (excl. tribal Indians)	††	11.8	13.7	20.6	21.6
ASIA					
Ceylon	2.7	2.5	2.8	2.7	*
Hong Kong	5.9	6.0	4.6	5.4	5.1
Israel (Jewish pop.)	3.9	6.7	10.1	9.2	*
Japan	6.7	7.4	8.6	9.7	11.9
Singapore	7.1	8.9	11.3	12.1	10.3
EUROPE					
German Fed. Rep.	23.6	24.5	23.6	21.7	24.8
West Berlin	13.1	16.1	12.9	11.0	13.0
Austria	9.6	20.6	28.7	26.4	29.0
Belgium	11.4	13.0	14.5	16.3	16.2
Denmark	15.1	14.5	14.5	14.6	17.7
Spain	5.2	5.9	5.5	*	*
Finland	10.6	11.8	12.5	12.3	14.1
France	18.6	19.0	19.3	17.9	18.8
Greece	3.2	4.3	4.9	5.4	5.7
Hungary	5.0	7.7	7.3	5.3	6.9
Ireland	7.5	8.8	6.6	8.3	8.6
Iceland	10.1	8.7	8.5	10.1	8.1
Italy	16.7	16.4	16.7	16.5	15.8
Norway	6.6	8.8	8.8	8.1	8.6
Netherlands	13.3	14.0	15.4	13.7	14.9
Portugal	7.1	6.9	6.6	7.7	9.5

* Data not yet available.
** Does not include Bantu.
† Excluding Yukon and North-West Territories.
†† Data not available.

TABLE 4. DEATH RATES FROM MOTOR VEHICLE ACCIDENTS PER 100 000 POPULATION 1955-59 (*cont.*)

Country or territory	1955	1956	1957	1958	1959
EUROPE *(cont.)*					
United Kingdom:					
England & Wales. .	11.1	11.3	10.9	12.1	13.3
Scotland.	11.6	10.8	10.9	11.6	11.8
Northern Ireland . .	10.5	9.7	11.5	10.0	11.9
Sweden	12.9	12.8	13.0	13.4	13.9
Switzerland	18.9	19.1	21.3	20.9	*
OCEANIA					
Australia	23.6	23.5	23.8	23.7	24.0
New Zealand (excl. Maoris)	15.6	14.4	16.1	16.5	13.9

* Data not yet available.

differ widely among the countries concerned. For example, the proportion of vehicles to miles of road (a measure of traffic density) varies considerably from country to country. The definition of mortality is the same for all countries in the *International Classification of Diseases*. In studying the statistics published nationally by police or transport departments, however, it is necessary to bear in mind that the definition of "mortality" varies. For example, in Belgium an accident is not classified as fatal unless death occurs at the site of the accident, while in the United Kingdom deaths occurring within thirty days after an accident are included in the fatal-accident statistics.

There are many other variables in international road traffic accident studies, such as the type of road, numbers of vehicles (sometimes including an unknown number of vehicles visiting from an adjoining country) and population differences. Comparisons of road traffic accident statistics between countries are therefore of limited value. It is important, however, that an attempt should be made to collect national data on a uniform basis, such as that suggested by the United Nations Economic Commission for the Far East (1957) referred to above. The information so acquired would be used to reveal favourable and unfavourable trends in individual countries, and the lessons thus learned would be available for application in other countries. Annual statistics of road traffic accidents, broken down in considerable detail, are published by the United Nations Economic Commission for Europe (*Statistics of Road Traffic Accidents in Europe*) for about eighteen European countries.

National mortality rates

Mortality rates are useful to indicate trends from year to year within a country, but the basing of fatalities on a denominator of total population is nevertheless of limited value. In addition to population changes, the number of motor vehicles has tended to increase rapidly in recent years in many countries. A somewhat more realistic picture is provided by relating the number of deaths (preferably also by age and sex) to the number of motor vehicles or the number of miles of road. Probably the most useful statistic is given by the relation between the number of deaths and the number of vehicle-miles travelled per annum. This mileage is obviously difficult to determine, but reasonably accurate estimates, based, for example, on fuel consumption, may be made by the methods described in *Road Research 1958* (Great Britain, Ministry of Transport and Civil Aviation, 1959*b*). In the United Kingdom, for example, the mortality in road traffic accidents per million vehicle-miles travelled was approximately 0.2 in 1938, falling to 0.1 in 1954 and showing little improvement since. In the United States in 1957 the mortality per million vehicle-miles was 0.06. There are obvious differences in the accident environment between the two countries, for example, in the relative mileages of open road. Although mortality per million vehicle-miles is one of the most useful statistics to indicate trends in mortality, it takes no account of such factors as increasing age of the population. No estimates are at present available of the annual mileages travelled according to age and sex of the driver.

In Table 4, the countries which showed a rising mortality from 1955 to 1958-59 were the Union of South Africa (white population), Costa Rica, Guatemala, Venezuela, Singapore, Japan, Belgium, Greece and Switzerland. In some of these countries there may have been increasing motorization from a previous relatively low level; with the exception of the Union of South Africa, Belgium and Switzerland, the mortality rates are comparatively low. In the United States the mortality rate showed a slight reduction during the five years under review. Perhaps increasing motorization with consequent congestion of traffic prevents people from behaving on the roads as dangerously as they might, but it seems unlikely that people are yet motorizing themselves into a state of safety. Other factors are probably responsible for this apparent levelling-off in accident rates. Further years of observation will be necessary before these results can be confirmed. It is possible, however, that a balance between man and the new element in his environment, the motor vehicle, is being reached, and that a mortality of roundly 20 per 100 000 per annum is the price of introducing the motor vehicle on a large scale (see Table 4), but there must be no complacent acceptance of such a view. The search for effective means of prevention of road traffic accidents continues, and the "optimum" level of mortality to be attained should be much lower than this.

There are interesting epidemiological features in the rate of increase of accidents as traffic increases. The relationship is not a simple one and varies with the type of accident. Accidents in which fixed objects are hit by motor vehicles increase in proportion to the number of vehicles, but accidents between two vehicles increase at a higher rate than the number of vehicles. The proportion of multiple-vehicle accidents to the total number of road traffic accidents increases as traffic increases. For example, in the United Kingdom the proportion of accidents involving three or more vehicles was 1.5 per cent in 1936-37 and 4.7 per cent in 1953. In Belgium, 46 per cent of traffic accidents were "non-collisions" in 1930 and only 19 per cent in 1950. In the United States, while the number of fatalities occurring from collisions of vehicles with fixed objects increased steadily from 720 to 1300 between 1930 and 1952, an increase of 80 per cent, the fatalities from collisions between two or more vehicles increased from 5880 to 14 100 over the same period, an increase of 140 per cent (Smeed, 1954). Again, the number of pedestrian casualties per motor vehicle decreases as the number of motor vehicles increases. Thus, between 1946 and 1953, the number of pedestrian casualties per registered motor vehicle was approximately halved in Switzerland, Sweden, the United Kingdom and Ireland. Pedestrian fatalities per million vehicle-miles travelled were also approximately halved in the same period in the United Kingdom, where these figures are available. During this period the total number of pedestrians killed annually increased in each of these countries.

Local studies

Local epidemiological studies, covering individual towns and districts, are mainly concerned with the plotting of accident sites and the recording of environmental data, such as character of road surface, data gleaned from site inspection, weather, time of day and categories of road user involved. The number of accidents and the population concerned are usually too small in local studies to render it worth while to undertake an investigation of such general factors as the relationship between age and accidents. At the same time, it is sometimes possible in the smaller area to extend the collection of information beyond the fatal and personal-injury accidents to include damage to property and thus widen the field of accident prevention. Because of the multiple circumstantial and environmental factors involved, studies of the sites at which individual accidents occur are likely to be of considerable value. Although in a particular accident it may be obvious

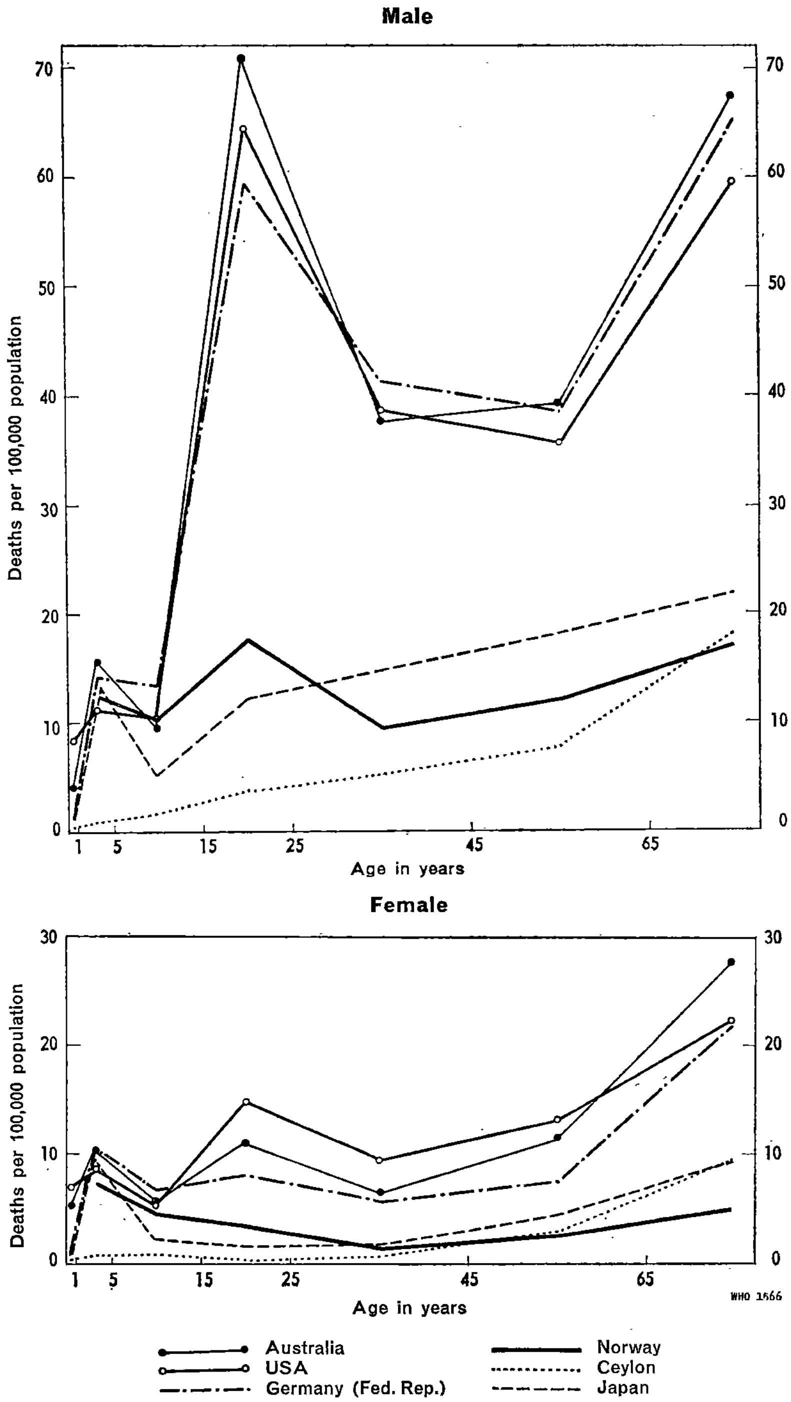
TABLE 5. DEATH RATES FROM MOTOR VEHICLE ACCIDENTS PER 100 000 POPULATION, BY AGE AND SEX*

Country	Males								Females							
	All ages	0**	1-4	5-14	15-24	25-44	45-64	65 & +	All ages	0**	1-4	5-14	15-24	25-44	45-64	65 & +
German Federal Republic †	39.3	1.0	14.0	13.1	59.2	41.0	38.6	65.1	8.3	0.6	10.1	6.8	7.7	5.2	7.3	21.8
Australia	36.7	4.0	15.5	9.8	71.0	37.7	39.1	67.2	10.1	5.1	10.1	5.5	10.9	6.3	11.3	27.8
United States	34.4	8.2	11.2	10.5	64.8	38.3	35.8	59.8	11.2	7.0	8.7	5.3	14.7	9.5	13.1	22.2
Switzerland	32.2	0.4	15.4	12.2	45.2	30.8	37.1	62.0	7.6	0.5	10.2	5.7	5.8	5.0	8.6	16.5
Canada ††	30.9	4.1	17.5	16.4	47.7	32.4	32.6	55.6	10.3	4.1	12.2	8.7	11.5	7.2	11.1	21.1
France	30.7	1.9	6.1	7.1	37.1	38.8	40.9	38.5	7.1	2.1	3.8	3.9	7.8	6.4	8.5	11.0
Italy	27.4	1.0	7.5	8.3	33.0	30.7	35.8	47.3	4.8	0.5	4.3	3.1	3.6	3.1	5.9	13.7
Denmark	23.0	0.5	13.7	9.0	33.2	17.2	26.0	56.2	6.6	0.5	7.6	4.2	5.1	2.7	8.2	19.3
Netherlands	21.7	0.7	12.2	11.5	19.0	20.0	28.5	57.4	6.0	0.5	8.6	6.1	5.2	3.7	6.6	11.1
Sweden	20.5	—	8.9	10.9	34.2	15.5	21.2	42.1	5.6	0.4	6.3	4.9	7.8	3.1	5.8	10.3
Finland	17.9	1.3	12.6	10.1	22.2	18.8	22.1	32.2	5.2	0.5	7.2	5.6	4.2	2.8	5.0	13.7
United Kingdom: England & Wales	17.2	0.8	8.8	7.5	30.6	14.8	15.0	37.1	5.5	0.9	6.1	3.3	4.5	2.4	4.8	16.6
Colombia	13.0	1.7	6.5	7.8	14.3	19.2	18.6	22.5	3.5	1.4	4.1	3.1	2.2	2.6	6.0	10.7
Japan	12.4	1.0	13.2	5.3	12.2	14.5	18.1	21.6	3.3	0.9	9.4	2.4	1.8	1.7	4.4	9.6
Norway	12.1	—	12.3	10.4	17.6	9.8	12.0	17.3	3.2	—	7.4	4.4	3.4	1.5	2.5	5.0
Ceylon	4.2	0.2	0.9	1.9	3.7	5.1	7.9	18.2	1.1	0.4	0.7	0.8	0.2	0.6	2.6	9.7

* Annual average of deaths, 1954-58; population, 1956.
** Age under 1 year: per 100 000 live-born.

† From 1958, including Saarland.
†† From 1956, including Yukon and North-West Territories.

FIG. 1. MORTALITY IN MOTOR VEHICLE ACCIDENTS IN THREE HIGHLY MOTORIZED AND THREE LESS MOTORIZED COUNTRIES, 1954-58



that a driver was blameworthy, nevertheless his apparent lack of care may have been associated with, and partially due to, environmental defects. For practical reasons, such inquiries can be undertaken only on a local basis. Detailed study frequently reveals the need for action at a particular site, for example, to provide guard rails for pedestrians, or to improve the lighting or road surface, or to introduce warning signs. Such local investigations, undertaken throughout a particular country and coordinated on a national basis, undoubtedly play a large part in the prevention of accidents. Local accident records also provide information about trends, using, for example, monthly records compared with a three-year moving average. Self-competition, supported by an informed and enthusiastic public opinion, is an important factor in road traffic accident prevention.

AGE AND SEX DIFFERENCES IN ROAD TRAFFIC ACCIDENT MORTALITY

National studies reveal differences in mortality rates from road traffic accidents according to age, sex, category of road user and some other factors. Little information is available in these respects for non-fatal accidents. Examples of death rates according to age and sex in sixteen countries are given in Table 5. These rates relate to all categories of road user taken together. There are considerable differences in mortality rates between different categories of road users, and some of these will be considered later.

In countries with high death rates from road traffic accidents there are peaks of mortality in the 15-24 and the 65-and-over age groups. In these countries the peaks are well marked for males and much less so for females, particularly in the 15-24 age group, as shown in the accompanying graphs. The high mortality from road traffic accidents among young men in the more highly motorized countries is striking (cf. Table 3). The mortality rates follow a remarkably similar pattern in the highly motorized countries — the German Federal Republic, Australia, and the United States, countries in which the proportion of vehicles to population is relatively high. The age-sex mortality pattern from road traffic accidents is much more consistent between countries than is, for example, mortality from tuberculosis: the graphs suggest that road accident mortality behaves as if it were following a biological or sociological law, the nature of which is as yet unknown, and which appears to be equally applicable in different parts of the world. A possible corollary to this is that preventive measures might be equally effective; close cooperation and coordination of preventive measures between the countries with high accident rates is clearly desirable.

Despite similarities in the graphs, in which all types of accidents are considered together, it seems possible that to study "accidents" as a whole may be like studying "disease" as a whole. Perhaps different types of accident should be distinguished and considered separately in the same way that individual diseases have been separated, but this is not possible in the present state of knowledge. The multiple environmental factors involved render such separation difficult, and until groups of accidents can be separated in which one, or perhaps two, causes assume a major role, this method of study does not appear likely to be productive. It is, of course, possible to separate accidents into groups according to such arbitrarily chosen parameters as "driver turning right", "accident at intersection" and so on, but these are superficial distinctions and are not related to true causation. Diseases cannot be distinguished from one another by such factors as "patient in bed", "temperature above/below 101°F", although the study of many such factors enables a "diagnosis" to be made. Diagnosis of disease depends fundamentally on causation, and the differential diagnosis of the various kinds of road traffic accidents on a causation basis is not yet practicable; but, as is shown later, useful groupings are possible—useful, because they show where action is needed.

In every country, taking all ages together, the mortality from road traffic accidents is from three to five times higher in males than in females. As might be expected, no difference is evident below the age of one year, but already at the age of 1-4 years males have a higher mortality. The male-to-female ratio at this age is remarkably similar in the four countries with the highest mortality rates (the first four listed in Table 5) — 1.38, 1.53, 1.28, and 1.51 to 1, respectively. At ages 5-14 the male-to-female ratio lies between 1.5 and 2 to 1, at 15-24 and 25-44 it becomes 4-8 to 1; at 45-64 it falls to 2-5 to 1, falling again slightly at age 65 and over (Table 5). The sex ratios are remarkably constant between countries in the age groups 1-4, 5-14 and over 65. Many of the fatalities at these ages occur to pedestrians, and it appears likely that the ratio of male to female pedestrian mortality is roughly the same in most countries.

CATEGORIES OF ROAD USERS IN ROAD ACCIDENTS

A further breakdown of national statistics provides pointers for preventive action, for example, by indicating vulnerable groups of road users who have an increased accident liability and towards whom specific preventive action should therefore be directed. Table 6 gives the numbers of persons killed and seriously injured in road traffic accidents in the United Kingdom in 1959 according to the main categories of road users.

TABLE 6. NUMBERS KILLED AND SERIOUSLY INJURED IN ROAD TRAFFIC ACCIDENTS, UNITED KINGDOM, 1959*

Age (years)	Motor vehicle drivers		Motor scooter & moped** riders		Motorcyclists		Pedal cyclists		All passengers		Pedestrians		Total	
	Killed	Seri-ously injured	Killed	Seri-ously injured	Killed	Seri-ously injured	Killed	Seri-ously injured	Killed	Seri-ously injured	Killed	Seri-ously injured	Killed	Seri-ously injured
0-4	0	0	0	0	0	0	7	23	34	389	209	1 700	50	1 112
5-9	0	0	0	0	0	0	25	446	19	560	177	3 292	221	4 298
10-14	0	18	0	2	1	1	114	2 338	15	701	79	1 437	209	4 497
15-19	30	523	24	831	312	5 424	92	2 502	195	3 464	48	787	701	13 531
20-39	340	5 725	133	2 819	628	9 027	111	2 042	417	7 646	158	1 942	1 787	29 201
40-49	136	1 958	33	741	77	1 158	91	1 028	108	2 052	127	1 283	572	8 220
50-59	123	1 279	35	617	68	759	107	1 086	129	1 856	277	1 996	739	7 593
60-69	57	510	23	203	28	197	111	627	125	1 107	462	2 391	806	5 035
70 & over . .	31	171	4	36	3	39	75	300	93	737	955	3 082	1 161	4 365

* Great Britain, Ministry of Transport and Civil Aviation (1960) *Road Accidents 1959*, London, H.M. Stationery Office,
** Two-wheeled machine having pedals and a motor not exceeding 50 cc cylinder capacity.

Some information is available about the kind of injuries which affect the different types of road users (see Cornell University Medical School, 1958 and 1959), but apart from specific research studies, the anatomic site of injuries received in road accidents is seldom recorded.

Pedestrians

The proportion in the different categories of road users killed and injured in road accidents varies considerably between countries. Thus accidents to pedestrians account for about 40 per cent of the fatal road accidents in the United Kingdom and about 20 per cent in the United States (the proportion is higher than this in United States cities); most occur in urban areas. The major cities of the world are endemic foci of pedestrian deaths. While this is true of the gross numbers, the death rate among pedestrians in the rural population is higher than for town dwellers. Thus, in Switzerland in 1953-57, the death rate of pedestrians in road traffic accidents was 5.0 per 100 000 in large towns and 6.5 in rural areas (World Health Organization, Regional Office for Europe, 1960). *Statistics of Road Accidents in Europe 1959* (United Nations Economic Commission for Europe, 1961) gives the numbers of pedestrians and other road users killed and injured in European countries.

The age distribution of fatally injured pedestrians is not even. The child pedestrian, from the age at which he begins to walk to the age of about 10, is at special risk; so is the elderly pedestrian from the age of about 65 upward. The death rate per million living is very high in pedestrians over 80 years of age: in the United Kingdom in 1957, the mortality per million living, for males over 80, was approximately 650 (compared with a pedestrian mortality of about 45 per million for the whole population); over 85 per cent of the fatalities in this age group were in pedestrians. Sex differentiation is also well marked at these higher ages: the mortality of females over the age of 80 in 1957 was much less, at approximately 210 per million living. Part of the high mortality in elderly pedestrians is due to the increased liability of an older person to succumb from an accident which a younger person might have survived. This is shown by the ratio of injured to killed pedestrians at different ages (Table 7). There is a steady reduction in this ratio with increasing age.

The total number of pedestrians injured is about 25 times the number killed; about six or seven pedestrians are seriously injured for every one killed. Minor injuries may not always be reported. There is a seasonal variation in pedestrian deaths; as might be expected, more deaths occur in the winter months with their longer hours of darkness. Pedestrian mortality is high, particularly in cities, at periods of peak travelling during working days.

TABLE 7. NUMBERS OF KILLED AND INJURED PEDESTRIANS AND RATIO OF INJURED TO KILLED, UNITED KINGDOM, 1958*

(a) Age (years)	(b) No. killed**	(c) No. seriously injured †	(d) No. slightly injured ††	(e) Column (c) / column (b)	(f) Column (d) / column (b)
0-19	527	6 855	21 784	13.0	41.3
20-39	161	1 752	5 984	10.8	37.1
40-59	405	2 918	7 808	7.2	19.2
60-69	407	2 115	4 087	5.2	10.0
70-79	564	1 994	3 171	3.5	5.6
80 & over	340	784	1 124	2.3	3.3

* After Great Britain, Ministry of Transport and Civil Aviation (1959) *Road Accidents 1958*, London, H.M. Stationery Office.

** "Killed" = Died within 30 days of a road traffic accident.

† "Seriously injured" = Injured so as to be detained in hospital as an "in-patient" or experiencing any of the following injuries whether or not detained in hospital: fractures, concussion, internal injuries, crushing, severe cuts and lacerations, severe general shock requiring medical treatment.

†† "Slightly injured" = Experienced a minor injury such as a sprain or a bruise.

In New York City pedestrian deaths amount to about 70 per cent of all road traffic accident deaths; in 1959, 515 pedestrians were killed in a total of 737 road accident deaths in the city. A study of the characteristics of the pedestrians killed in Manhattan from May to October inclusive, 1959, was reported by Haddon et al. (1960). This is the most carefully controlled study of fatal pedestrian traffic accidents that has yet been undertaken. Fifty pedestrians were fatally injured, and the control group consisted of four pedestrians for each fatality—the first four pedestrians stopped by the research team at the scene of the accident. The results showed that accidents tended to occur away from the main shopping and business areas; half occurred in the six hours preceding midnight, 73 per cent in the twelve hours beginning at 3 p.m., and the smallest number in the three hours ending at 9 a.m. Of those killed, 44 per cent survived less than six hours. Weather variations were not significantly associated with the occurrence of this group of accidents, but the study covered spring and summer months. The mean age of those killed was 58.8 years, of the control group 41.6 years; Haddon suggests that there may be both an age-associated risk of involvement and an age-associated risk of fatal outcome. The pedestrians fatally injured appeared to consist of two discrete groups, each with increased risk, namely, a group of the elderly who had been drinking alcohol a little or not at all, and a group of the middle-aged who had been drinking heavily.

Pedal cyclists

There is a relatively high proportion of pedal-cyclist deaths to total road traffic accident deaths among children, from about seven to fifteen years of age, and in elderly people, from the age of about fifty upward. The cyclist, like the pedestrian, is unprotected physically, except where special cyclists' tracks are used, and a severe degree of injury may follow even a minor collision with a motor vehicle. In the United Kingdom, about 700 pedal cyclists are killed every year (738 in 1959), forming approximately 11 per cent of the total road accident fatalities in that country; about 150 of those killed are under 15 years of age. For every cyclist killed, some 75 are injured, 15 of them seriously. The proportion of killed to injured cyclists rises with increasing age. Cyclists who ride in traffic are a special-risk group to which attention should be directed from the preventive point of view.

Motorcyclists

The motorcyclist is also relatively unprotected, and the more powerful machines are capable of very high speeds. In the United Kingdom in 1959, out of a total of 6520 road traffic accident deaths, 1128 (17.3 per cent) were in motorcyclists. In the United States only about 1 per cent of registered vehicles are motorcycles and they accounted for 1.3 per cent of the fatal accidents in 1957; the increased percentage suggests the degree of increased risk to motorcycle riders. Motorcycle deaths (passengers and pillion riders) affect the younger age groups most heavily; about 70 per cent of such deaths were in the age group 18-40 in the United Kingdom in 1959. The majority of deaths of motorcyclists affect males, and this accounts in part for the fact that in the more highly developed countries road traffic accidents are now the commonest cause of death in male adolescents and young adults. Motorcyclists and their passengers are about ten times more likely to experience fatal accidents than are the occupants of other vehicles, as Table 8 shows.

In the *International Statistical Classification of Diseases* (World Health Organization, 1957*a*) the term "motorcycle" is defined as including those with side-cars, as well as motorized bicycles, scooters and tricycles. *Statistics of Road Traffic Accidents in Europe 1957* (United Nations Economic Commission for Europe, 1959) gives the numbers of drivers killed or injured in European countries by age groups, for cycles without engine or with engine not exceeding 50 cc capacity, and for cycles with engine exceeding 50 cc capacity. With the considerable increase, particularly in some European countries, of

TABLE 8. DEATHS OF MOTOR VEHICLE DRIVERS AND PASSENGERS PER MILLION VEHICLE-MILES, UNITED KINGDOM, 1956*

Category of road user	No. of deaths	Millions of vehicle-miles travelled**	Deaths per million vehicle-miles
Motorcyclists (including 176 passengers)	1 250	4 500	0.27
Occupants of other vehicles . .	1 197	47 200	0.025

* Norman, L. G. (1960) *Lancet*, 1, 989.
** Chandler, K. N. & Tanner, J. C. (1958) *J. roy. statist. Soc.*, 121, 420.

TABLE 9. RATIO OF INJURED TO KILLED AT ALL AGES: MOTORCYCLISTS, CYCLISTS AND CAR DRIVERS, UNITED KINGDOM, 1958 *

Category of road user	No. seriously injured** / no. killed**	No. slightly injured** / no. killed**
Motorcyclists	14	36
Pedal cyclists	15	61
Drivers of cars and taxis	13	44

* After Great Britain, Ministry of Transport and Civil Aviation (1959) *Road Accidents 1958*, London, H.M. Stationery Office,
** "Killed", "seriously injured", and "slightly injured" used with same significance as in Table 7, p. 32.

scooters and mopeds,[1] separate records of accidents involving these vehicles should be collected. Figures are now published annually in the United Kingdom of the numbers of moped riders killed and injured in different age groups, but no estimates are available of the annual mileages travelled by these vehicles.

Head injuries are the most common cause of death and serious injury in motorcyclists and moped riders. The ratio of numbers slightly injured to those killed is considerably lower for motorcyclists than for pedal cyclists, as might be expected for the higher speed and the apparently more dangerous vehicle (Table 9). Since the proportion of killed to injured rises with age, the age group 20-29 is considered separately in Table 10.

[1] For definition see footnote, p. 21.

TABLE 10. RATIO OF INJURED TO KILLED AT AGES 20-29: MOTORCYCLISTS, CYCLISTS AND CAR DRIVERS, UNITED KINGDOM, 1958 *

Category of road user	No. seriously injured** / no. killed**	No. slightly injured** / no. killed**
Motorcyclists	15	39
Pedal cyclists	23	107
Drivers of cars and taxis	15	49

* After Great Britain, Ministry of Transport and Civil Aviation (1959) *Road Accidents 1958*, London, H.M. Stationery Office.
** "Killed", "seriously injured", and "slightly injured" used with same significance as in Table 7, p. 32.

Table 10 shows the relatively high proportion of minor injuries affecting pedal cyclists, an observation which holds good in all age groups; obviously there is the added risk of fall from the machine itself. Tables 9 and 10 suggest that when car drivers are injured at all, they are nearly as likely to be fatally injured as are motorcyclists: the car body is not so protective as it appears to be. Most injuries to car drivers affect the chest (steering column) or head (windscreen and projections), and a high rate of serious and fatal cases is to be expected when these bodily areas are injured.

A detailed statistical investigation of accidents to young motorcyclists was undertaken in England and Wales in the summer of 1958 (Scott and Jackson, 1960). The method used was a mail survey of a sample of motorcycle owners of both sexes, requesting information about the type of vehicle and mileage driven; accident information was obtained from police reports. The results of this important study were summarized as follows:

1. Motorcyclists aged 16 appeared to have appreciably more accidents both per rider and per mile than those aged 17, but when account was taken of the differing riding (mileage) experience of the two groups and the different sizes of motorcycle they tended to ride, this gap vanished. (Sixteen was the youngest age at which a licence to driver a motorcycle was granted in England and Wales in 1958).

2. The same conclusion holds as the age range 17-20 is ascended. The older the rider the lower the accident rate, but in every case the difference could be accounted for entirely in terms of riding experience and size of machine. There was no evidence that age in itself had any effect on accident rates, but the survey did not prove that age had no effect.

3. Motorcyclists with less than six months' experience had about twice as many accidents, both per rider and per mile, as those with over six months' experience. After six months there was no appreciable sign of a continuing fall in the accident rate with increasing experience.

4. The more powerful the machine the higher was the accident rate. This trend was extremely marked if the accident rate was computed per rider: on this basis light motorcycles had six times the accident rate of mopeds, and the largest motorcycles had twice the rate of the light motorcycles. If the rates were calculated *per mile* the trend was still found but was much less marked.

5. The above conclusions were unaffected by the exclusion of accidents involving only slight injury, except that the advantage in favour of mopeds became even more marked. For the heavier machines a higher proportion of accidents were serious or fatal.

6. There was no difference in the accident rates, omitting cases of slight injury, between motor scooters and other motorcycles of the same cylinder capacity.

These conclusions are from the authors' summary. It will be seen that *length of experience* and *power of machine* (cylinder capacity) are the two most important factors in accidents to young motorcyclists. Although Scott and Jackson's investigation was concerned with the younger motorcyclists, they give tabulated information for motorcyclists of all ages. In the sample of 8594 owners of motorcycles, there were 40 over the age of 70, including one aged 80; these older men all owned vehicles of less than 250 cc cylinder capacity. The largest number of owners in the sample was at 21 years of age (340), after which the number declined steadily to 128 at age 50 and 61 at age 60.

Drivers of cars, commercial and passenger vehicles

These motor vehicle drivers may be considered from two epidemiological points of view: (1) the study of mortality and morbidity in drivers as "recipients" of accidents, and (2) the study of drivers as "causes" of accidents.

Drivers as "recipients" of road traffic accidents. Compared with pedal cyclists and motorcyclists, motor vehicle drivers appear to be relatively well protected by their vehicles against injury, but, as shown above, when injuries do occur, they are nearly as often fatal in car drivers as in motorcyclists.

In the United Kingdom in 1959, drivers of cars, commercial and passenger vehicles comprised 730 (11.2 per cent) out of a total of 6520 persons killed on the roads.

TABLE 11. DEATHS OF MOTOR VEHICLE DRIVERS* PER 1000 REGISTERED MOTOR VEHICLES, 1953-54

(a) Country	(b) Year	(c) Total motor vehicle accidental deaths†	(d) No. of deaths of drivers of vehicles†	(e) Registered motor vehicles per mile of road (excl. cycles and motorcycles)**	(f) Column (d) / column (e)	(g) Registered motor vehicles (thousands) (excl. cycles & motorcycles)†	(h) Driver deaths per 1000 registered motor vehicles
Belgium	1953	702††	103††	20	5.1	530	0.20††
	1954	811††	119††		5.95	§	§
Denmark	1953	488	83	10	8.3	242	0.34
	1954	636	100		10.0	289	0.35
United Kingdom	1953	5 090§§	390§§	28	13.9	3 892	0.10§§
	1954	5 010§§	405§§		14.4	4 272	0.09§§
Italy	1953	4 880	402	13	30.9	934	0.43
	1954	5 281	486		37.4	1 082	0.45
Sweden	1953	921	79	9	8.78	542	0.16
	1954	942	88		9.78	629	0.14

* Excluding motorcyclists.
† United Nations Economic Commission for Europe (1956) *Statistics of Road Traffic Accidents in Europe 1954*, Geneva (Document E/ECE/248).
** *Ann. Amer. Acad. polit. soc. Sci.*, Nov. 1958, p. 134.
†† Persons killed on the scene of the accident.
§ Unavailable.
§§ Persons dying within 30 days of the accident.

Table 11 gives the numbers of deaths of motor vehicle drivers (excluding motorcyclists) in five countries in relation to the number of registered motor vehicles per mile of road. It is evident from this table that the number of deaths of motor vehicle drivers is not closely related to traffic density or to the number of vehicles registered; when the United Kingdom is compared with Italy in Table 11, for example, the number of driver deaths is seen to be broadly similar, but the traffic density and number of registered vehicles are very different in the two countries.

The age distribution of drivers killed shows a peak in the United Kingdom below the age of 30. These are gross totals of the numbers killed; the annual mileage driven in the various age groups is unknown. There is, however, evidence that accident rates are higher among the younger and less experienced drivers (see below).

Serious injuries to drivers of cars and taxis in the United Kingdom are about 13 times, and slight injuries about 44 times, the number of road accident deaths among these drivers (Table 9). The number of slight injuries in all road traffic accidents appears to be increasing, possibly on account of more complete reporting of minor injuries.

Drivers as "causes" of road traffic accidents. The motor vehicle driver is not alone responsible for road traffic accidents. Responsibility, except perhaps in single-vehicle collisions with fixed objects and a few other instances, must often be shared among different categories of road user. But the motor vehicle driver holds the potentially lethal instrument in his hands, and driver responsibility is clearly of the first importance in road traffic accident prevention.

It is always difficult to compare accident rates among motor vehicle drivers, for the environmental conditions of each driver are different. His exposure to risk of accident depends on such factors as the type of vehicle, the distance driven, and whether driving is mainly by day or night, in town or country, in peak traffic hours or in quiet periods. Even under the apparently constant conditions of central London (England) bus routes, accident rates are three times as high on some routes as on others.

Nevertheless, the following factors are known to affect the incidence of accidents among drivers:

Age and experience. It is generally accepted that younger drivers have more accidents than the middle-aged, but few attempts have been made to separate the effect of age from that of driving experience. This is an important study and a difficult one, as experience obviously tends to increase with age. The United States accident records for 1959 (National Safety Council, 1960) relate the ages of drivers to their accidents (Table 12).

TABLE 12. PROPORTION OF MOTOR VEHICLE DRIVERS INVOLVED IN ACCIDENTS, BY AGE GROUPS, UNITED STATES, 1959*

Age group	Approximate no. of licensed drivers (thousands)	No. of drivers involved in accidents		Ratio of drivers involved in accidents to total number of drivers	
		Fatal accidents	All types of accidents (thousands)	Fatal accidents, per 1000 drivers	All types of accidents, per driver
Under 20 . .	6 000	5 350	2 340	0.891	0.390
20-24	9 400	7 700	2 700	0.819	0.287
25-29	10 700	6 150	2 540	0.575	0.237
30-34	10 500	5 300	2 020	0.505	0.192
35-39	9 700	4 200	1 840	0.433	0.189
40-44	8 700	4 100	1 620	0.471	0.186
45-49	7 600	3 600	1 450	0.474	0.191
50-54	6 600	2 700	1 120	0.409	0.169
55-59	5 200	2 100	860	0.404	0.166
60-64	3 900	1 800	610	0.461	0.156
65-69	2 600	1 350	540	0.519	0.208
70-74	1 800	950	200	0.528	0.111
75 & over . .	1 300	700	160	0.538	0.123
All ages . . .	84 000	46 000	18 000	0.548	0.214

* National Safety Council (1960) *Accident Facts 1959*, Chicago.

From Table 12 it will be seen that drivers under the age of 25 have a considerably worse accident ratio than that of all drivers taken together, both for fatal accidents and for all types of accident. The lowest fatal-accident ratios in Table 12 are those for drivers aged 55-59, which are less than half those for drivers under the age of 25. No figures are available of the mileages driven by drivers in the various age groups; if drivers under age 25 drove twice the distance driven by middle-aged drivers annually, their accident rates would be about the same. In the United States, in a large sample of Iowa drivers, Lauer (1952) studied accident rates by age and, after adjustment had been made for annual mileage travelled, found that drivers aged 16-21 still had rather more than twice the accident rate of those aged 38-65. Although this work has not been repeated, the evidence may be regarded as fairly clear that motor vehicle drivers under about the age of 25 have more than their share of both fatal and total accidents, and that the lowest accident rates are found in the age group 50-60.

TABLE 13. AVERAGE ANNUAL NUMBER OF ACCIDENTS PER DRIVER, LONDON TRANSPORT CENTRAL BUS DRIVERS, 1957-59*

Age attained in year of observation	Length of service as driver (years)				
	Under 4	4-8	9-13	14 & over	All service groups
Under 30 . .	2.508	1.772			2.478
30-39	1.917	1.224	0.849		1.557
40-49	1.624	1.012	0.873	0.694	1.126
50-59	1.443	1.057	0.908	0.667	0.894
60-64	1.434	0.947	0.996	0.660	0.786
Under 65 . .	1.940	1.097	0.900	0.666	1.230
65	X	0.907	0.894	0.790	0.828
66	X	0.900	1.077	0.678	0.770
67	X	0.757	1.212	0.761	0.794
68	X	1.300	1.684	0.739	0.826
69	X	X	X	0.724	0.819
70	X	X	X	0.846	0.876
65 and over .	1.538	0.946	1.063	0.750	0.811
All ages . . .	1.939	1.096	0.903	0.677	1.215

* Spratling, F. H. (1961) *Brit. Transport Rev.*, 6, 172.
X = Number of driver-years less than 10.

A study has been made of the accident experience of London Transport central bus drivers (Spratling, 1961). In the three years 1957-59, an average of 13 080 drivers had 15 898 accidents annually, or 1.215 accidents per driver per year. All reported accidents, however minor the damage caused, were included. The results are given in Table 13. These men were all professional drivers, who drove an average of 18 000 miles annually under broadly comparable conditions. Over 80 per cent had previous driving experience before entering training as drivers. Nevertheless, the relatively high accident rate in young and inexperienced drivers is striking: those under 30 with less than four years' service had nearly four times as many accidents as the best group, those aged 60-64 with 14 or more years' service. It was thought that accident-liable drivers might be discharged or leave in their early years to take up other work, but an investigation of wastage in relation to accident rates has not so far confirmed any effect of this kind. Although the effects of age and experience cannot be entirely separated, Table 13 does suggest that experience (the horizontal rows) has more effect than age (the vertical columns). A practical point is that the replacement of drivers over age 65, of whom there were about 450, by drivers under 30 would have considerably increased the number of accidents.

Much interest at present centres on the accident rates of elderly drivers, but there are no adequate statistics of accident rates of drivers over 70: such statistics as are available do not include figures of annual mileage driven. Table 12 suggests that in the United States the rates of drivers involved in fatal accidents begin to rise at about the age of 65, but the rates for all types of accident fluctuate after this age. It seems unlikely that the annual mileage driven increases as drivers age beyond 60. Häkkinen (1958) found no correlation between age and accidents in a detailed study of the personal and psychological characteristics of 1000 bus and tram drivers in Helsinki, Finland, in relation to their accident rates. The number of drivers concerned in this study was, however, relatively small, particularly in some of the age groups. It must be concluded that the information at present available about the amount and kind of driving performed by the elderly is insufficient to enable a proper evaluation to be made of their accident rates.

In some countries, insurance companies, before issuing a policy, sometimes require elderly drivers to submit a medical certificate of their fitness to drive. It may be presumed that the experience of the companies has been unfavourable with such drivers. The records of insurance companies, however, do not always provide satisfactory material for a study of road traffic accidents. There are several reasons for this (Johnson and Garwood, 1957): for instance, the insured car may be driven by different drivers at different times, and accident experience is not therefore confined to the elderly driver alone, since it is normally the car that is insured and not the driver. Nevertheless, bearing this difficulty in mind, some information about accident rates of elderly drivers might be obtained from a study of the claims records of insurance companies.

Sex of drivers. Contrary to popular opinion, there is little evidence to show whether male or female drivers are the more liable to accidents. This is the kind of problem that can be handled effectively by the methods of traffic-accident epidemiology. Beadenkopf et al. (1956) undertook a preliminary study of 208 men and 138 women drivers at Saratoga Springs, N.Y. When divided into age groups the numbers were too small to provide relative accident rates for men and women drivers, but some points in Beadenkopf's study identified unequivocal differences in driving experience and exposure to risk of accident. The exposure to road traffic accidents in number of miles driven per year for men was approximately six times that for women. Beadenkopf concluded that such variations as these offer strong argument for a critical examination of specific groups within the driving population as one phase in the search for hazardous drivers.

In 1959 in the United States, 68 male and 22 female drivers per 100 000 licensed drivers of each sex were involved in fatal road traffic accidents; 244 male and 144 female drivers per 1000 licensed drivers of each sex were involved in road accidents of all kinds. If Beadenkopf's observation in Saratoga Springs, that the mileage exposure of men drivers is six times that of women, is applicable throughout the United States, then the accident rates of women motor vehicle drivers there would appear to be disproportionately high.

In some earlier studies, Lauer (1952) analysed the reported road traffic accidents of men and women in Iowa (USA). After allowing for women holding only a quarter of the licences, and after estimating that they drove only about a tenth of the total mileage, Lauer found no real difference between the accident rates of men and women drivers. A curious finding was that men improved their accident records after about five years' experience whereas women showed an improvement after the first year. This observation has not been confirmed by other workers. Thus Lynette Shaw (personal communication, 1960) found that African drivers in the public transport service of Johannesburg had a learning period of about 200 days, after which an individual driver maintained his own level of accident frequency. The Johannesburg drivers were employed full-time in driving, and it seems likely that mileage driven rather than time is the more important factor in acquiring experience. From all these studies *experience* stands out as an important factor in accident reduction.

Viteles and Gardner (1929) studied the road traffic accident experience of groups of men and women taxi drivers and found that the women had fewer accidents than the men; but the groups were not evenly matched for previous driving experience. A study of motor vehicle drivers in Connecticut (United States, 75th Congress, 1938) suggested that accidents per driver were fewer among women than men, but differences in exposure to accidents could not be fully taken into consideration.

Until strictly comparable groups of men and women motor vehicle drivers can be studied, even the existence of any sex difference in their road traffic accident liability remains uncertain. There may be groups in the driver population among whom road traffic accident rates are abnormally high on account of such factors as inexperience, age, sex, or infrequency of driving, and epidemiological studies now being undertaken may lead to the identification of such groups, perhaps with quantitative identification of their increased risk. Only by means of such studies can groups of hazardous drivers be identified, towards whom specific preventive measures can be directed.

INCIDENCE IN URBAN AND RURAL AREAS

There are considerable differences in the incidence of different types of road traffic accidents between urban and rural areas. Thus pedestrian accidents are much more numerous in urban than in rural areas. In the central areas of large cities most fatalities affect pedestrians; the picture changes as the area becomes more rural, until in extremely rural areas most fatalities affect motor vehicle occupants. The most suitable index of study for a comparison of urban and rural road traffic accident mortality would probably relate pedestrian accidents to pedestrian population at risk, so far as this is ascertainable, together with vehicle mileage driven, for urban and rural areas separately. Studies of this kind have not yet been undertaken. Collisions between motor vehicles resulting in fatal injury are six or seven times more numerous in rural areas than in urban districts. Similarly, overturning, running off the roadway and collisions with fixed objects as causes of fatal accidents are much more common in rural areas. Four out of ten fatal accidents in rural areas in the United States in 1959 were non-collision accidents, due to such causes as running off the roadway. This may be associated with the higher speed of vehicles in rural areas.

SEASONAL PREVALENCE

In countries with well-marked seasons there are differences in the incidence of road traffic accidents at different times of the year. Thus in winter, fog, ice and snow lead to increased vehicular collisions, and longer hours of darkness are associated with higher accident rates affecting pedestrians. In the United Kingdom the highest adult pedestrian mortality occurs in December; the danger months for cyclists, motorcyclists and drivers of cars are December and January, with a peak also in August — the summer holidays — for motorcyclists. The pedestrian mortality of children of school age is lowest in December, January and February; their exposure to danger on the roads may be lessened during the long winter evenings when many remain indoors. These factors of seasonal variation must clearly be taken into account in any epidemiological study of road accidents. Studies undertaken for less than a full calendar year, for example, may be affected by seasonal bias.

INCIDENCE IN DARKNESS AND DAYLIGHT

It is generally accepted that accidents occur more frequently in hours of darkness than in daylight, but the numbers of road users exposed to risk in dark hours compared with daylight hours are unknown. Table 14 gives the numbers killed and seriously injured in the United Kingdom in 1959 in hours of darkness and in other hours.

TABLE 14. NUMBERS OF ROAD USERS KILLED AND INJURED IN DARKNESS AND IN DAYLIGHT, UNITED KINGDOM, 1959*

Category of road user	Hours of darkness		Other hours	
	Killed	Seriously injured	Killed	Seriously injured
Pedestrians:				
Under 15 years . .	66	770	399	5 659
15 years & over . .	1 126	5 358	929	6 410
Pedal cyclists:				
Under 15 years . .	15	264	131	2 543
15 years and over .	223	2 273	369	5 505
Riders of motorcycles, motor scooters and mopeds**	551	7 678	833	14 748
Drivers of other vehicles	331	4 367	399	6 085
All road users . . .	2 312	20 710	3 060	40 950

* Great Britain, Ministry of Transport and Civil Aviation (1960) *Road Accidents 1959*, London, H. M. Stationery Office.
** Two-wheeled machine having pedals and a motor not exceeding 50 cc cylinder capacity.

Larger numbers of all road users except adult pedestrians are killed in daylight hours. The larger number of adult pedestrians killed in hours of darkness may be associated to some extent with the consumption of alcohol (see Chap. 4). As much larger numbers of people use the roads in daylight, it appears that there is a considerably higher risk of accident in hours of darkness. Children under 15, both as pedestrians and pedal cyclists, are likely to be much less exposed to risk of accident during hours of darkness. The magnitude of the increased risk in hours of darkness is unknown, but an approximate computation made in the United States gives the national death rates per 100 million vehicle-miles as 10 in hours of darkness and 4 by day; in urban areas (affecting mainly pedestrians) these figures are 13 and 5 respectively. The death rate is highest in urban areas, where artificial lighting is, or should be, provided. Further evidence of the effect of darkness is provided by the effect of change in season. Thus, in the four hours 4-8 p.m. there is no darkness from May to July in the United States, and 21 per cent of the total deaths between these hours occur in those months; from November to January 75 per cent of this 4-hour period is dark, and 29 per cent of the deaths occur then (National Safety Council, 1958). A decrease in accidents has also been shown to occur during the hour lightened by the introduction of summer time; a corresponding increase takes place when summer time is abolished.

Night fatal accidents on main rural roads reach a peak rate between 2 a.m. and 4 a.m., according to a special study made by the United States Bureau of Public Roads. During these hours the rate was about 21 fatal accidents per 100 million vehicle-miles travelled, more than twice as high as it was from 9 p.m. to 11 p.m., during both of which periods it is dark throughout the year. From 6 a.m. to 6 p.m. the rate was below 5 fatal accidents per 100 million vehicle-miles travelled (National Safety Council, 1960). It is evident that the precise effect of dark and light hours upon road traffic accident rates cannot be quantified unless the exposure to risk of the road users during the two periods is known. The relative amounts of darkness and daylight must clearly be taken into consideration as an important variable in road traffic accident studies.

HOUR OF THE DAY AND DAY OF THE WEEK

In the United States the time of day with the highest accident rate is from 4 to 8 p.m.; this is because more people are travelling then than at other times. Records are available of the numbers of accidents and of fatalities, hour by hour, but until these can be related to a satisfactory denominator of number exposed to risk, they are of limited value. In the United Kingdom, studies have been undertaken of traffic accidents affecting various categories of road user, related to time of the day and day of the week, but again, no denominator figures are available. As would be expected, school-children have relatively high casualty figures on Mondays to Fridays between 8 and 9 a.m. and 4 and 5 p.m., compared with other times. Among adults, pedestrians have their peak incidence of accidents between 5 and 6 p.m.; pedal cyclists and motorcyclists have three peaks, 7 - 9 a.m., 12 - 2 p.m. and 5 - 7 p.m., all these on Mondays to Fridays, the times they are travelling between home and work, including the midday break. Drivers of cars and taxis have their accidents more evenly distributed, but there is a low peak between 5 and 6 p.m.

TABLE 15. PERSONAL-INJURY ACCIDENTS TO ADULT* ROAD USERS, BY DAY OF WEEK AND SEASON, UNITED KINGDOM, 1959**

Day	Pedal cyclists		Riders of motor-cycles, motor scooters and mopeds †		Drivers of cars & taxis		Pedestrians	
	Summer ††	Winter §	Summer ††	Winter §	Summer ††	Winter §	Summer ††	Winter §
Daily average, Monday to Friday inclusive	3 075	2 830	5 925	4 591	1 906	2 459	2 597	3 354
Saturday	2 798 (91%)	2 232 (79%)	8 330 (140%)	5 702 (124%)	3 331 (174%)	3 587 (146%)	3 741 (144%)	4 158 (124%)
Sunday	1 828 (59%)	1 073 (35%)	7 448 (126%)	3 167 (69%)	2 794 (146%)	2 834 (115%)	1 656 (63%)	1 652 (49%)

The percentages in parentheses indicate the ratio of the number of accidents occurring on Saturdays and on Sundays to the average daily number occurring on Monday to Friday inclusive (taken as 100).

* Persons aged 15 years and over.

** Great Britain, Ministry of Transport and Civil Aviation (1960) *Road Accidents 1959*, London, H.M. Stationery Office.

† For definition of "moped", see Table 14.

†† Summer is taken as April to September inclusive.

§ Winter is taken as October to March inclusive.

The effect of the day of the week, in summer and winter, on the incidence of road traffic accidents, is shown in Table 15.

The figures in Table 15 reflect travel habits: the pedal cycle is probably used to a relatively small extent on winter Sundays; the high accident rate to car drivers on summer Saturdays is noticeable. Although car drivers also have high accident rates on Sundays, pedestrians then have noticeably lower rates and are probably exposing themselves to danger on the roads much less than on weekdays, particularly in the winter months. Both high and low figures provide pointers to preventive action.

OTHER EPIDEMIOLOGICAL FACTORS

The number of road traffic accidents tends to be high at major holiday times, and allowance should be made for this where necessary in considering the incidence of accidents. Increased consumption of alcohol at holiday times may influence road traffic accident rates for the worse.

It is possible to analyse road traffic accident rates according to major faults shown in a driver or other road user, such as failing to give adequate signals or turning without warning, but the assessment of such faults is usually subjective and open to error. Records of this kind are useful as a guide to the nature of common faults and consequently for the development of educative and propaganda measures against such faults.

CHAPTER 3

CAUSATIVE FACTORS

There is usually more than one "cause" of any single road traffic accident. Causation may lie in three factors—road, vehicle and road user. It is often said that the road user is primarily responsible for accidents; if the road user always behaved correctly and within the limitations provided by good and bad road conditions and good and bad vehicles, accidents would indeed be few. The law prohibits certain types of risk behaviour. In some countries, such as the United Kingdom and New Zealand, there are also codes of recommended behaviour on the highway (e. g., Great Britain, *The Highway Code*).

The relative rarity of accidents emphasizes the need to maintain vehicle and road in good condition in order to provide good environmental circumstances when the occasional accident situation arises and thus provide the individual driver with a better chance of escape. Skidding, for example, is often given as "the cause" of an accident. The factors concerned in skidding include tire-tread condition (vehicle), road-surface condition (road), speed (road user), and behaviour of other road users, perhaps leading to sudden braking (road user and vehicle). In the United Kingdom in 1958, skidding occurred in 18 945 (9.4 per cent) of 201 851 accidents in summer (April to September) and in 21 977 (12.6 per cent) of 173 276 accidents in winter (October to March). In the United States in 1959, 19.6 per cent of all road traffic accidents occurred on wet roads. The development of relatively non-skid surfaces for roads has advanced considerably in recent years, and good, hard-wearing, skid-resistant surfaces are now available.

THE ROAD

There is a strong association between road traffic accident rates and the design, construction and surfacing of roads. The design of roads to provide the best traffic flow has led to the development of the new science of traffic engineering. Well-designed roads promote safety and reduce accident frequency. For example, the death rate per 100 million vehicle-miles on 19 United States turnpikes in 1959 was 2.8 compared with 7.4 for the corresponding rural state roads (National Safety Council, 1960). It is also known that three-lane roads are associated with higher accident rates than two-lane roads or dual roadways. In all countries, most roads, whether urban or rural, were not built for motor vehicle traffic but for very much slower-moving transportation. Thus in the United Kingdom the average widths of Class I and Class II urban roads are 29 and 25 ft, respectively; in rural areas the corresponding widths are 21 and 18 ft. Some 15 per cent of these roads are curved (under 3000-ft. radius) in urban areas and 20 per cent in rural areas. There is lighting on about 70 per cent of urban roads and about 8 per cent of rural roads (Great Britain, Ministry of Transport and Civil Aviation, 1959*b*). Roads designed for horse-drawn traffic are generally unsuitable for fast motor vehicles and are a contributory cause of accidents.

A great amount of research has been undertaken on the design, lighting and surfacing of roads, and it is now possible to design roads which are suitable for the amount of motor traffic likely to use them and which possess an inherently high degree of safety. The actual provision of good-quality, safe roads now depends almost entirely on the financial resources available. Research continues into various problems of the improvement of lighting, wear of road surfaces and maintenance. The beneficial effect on accident rates of improved lighting of roads, particularly in urban areas, may be considerable. It is not always remembered that many drivers (and many pedestrians) have defective eyesight, not of a sufficient degree to prevent their driving, and the combined effect of visual defects and poor lighting may produce an accident situation. The inadequate level of lighting, often with light and dark patches on the road, which is still found in many urban areas can be a menace to safety.

Climatic conditions probably influence the incidence of road accidents; 82 per cent of road accidents in the United States in 1957 occurred in clear or cloudy weather, 13 per cent in rain and 3 per cent in fog. No definite conclusion can be drawn from these figures, as data on mileage driven in each kind of weather are not available. It is known that deaths and serious injuries in road traffic accidents are reduced in severe fogs in Britain, owing no doubt to reduced speed and the presence of fewer vehicles on the roads.

In the design of roads, complete segregation of pedestrians from traffic, where such separation is practicable, reduces to vanishing point the risk of injury to pedestrians. Similar separate provision for cyclists also reduces the hazard to that category of road user.

THE VEHICLE

The proportion of accidents in which a mechanical defect or failure of a vehicle makes a gross and obvious causative contribution is small. For example, in the United Kingdom in 1958, only 7481 (2.5 per cent) out of 299 767 casualties in road accidents were considered by the police at the scene of the accident to be due to this cause; brakes, tires and steering had the most frequent defects. There is, however, reason to believe that vehicular defects are a factor in and contribute to a greater proportion of accidents than this. Thus, in the national vehicle-safety-check programme in the United States in 1959 (National Safety Council, 1960), one out of five passenger cars and one out of four trucks checked were found to be in need of maintenance attention for safe driving. The safety check was voluntary, and it is likely that, though the total number checked was large, these figures reflected the condition of better-than-average vehicles. Lights and brakes — two factors of great importance for safety — were the principal items needing attention on both passenger cars and trucks. In another study of vehicular defects in eleven states in the United States (National Safety Council, 1960), about two out of five vehicles tested were found unsafe; among individual states, four had vehicle rejections exceeding 50 per cent, and the highest was 72 per cent. Headlights led the list, being defective on 24 per cent of all vehicles; next in order of frequency were brakes, 17 per cent; rear lights, 15 per cent; steering, 10 per cent; glass, 5 per cent; and tires, 1 per cent.

In New Zealand there is compulsory testing of all motor vehicles, irrespective of their age, every six months. The vehicle owner pays a fee for the test, and about 40 per cent of vehicles are found to have defects, most of them readily remediable. The owner of a vehicle which is found to have a defect is required to have the vehicle retested within a stated time, and only in a few instances is it necessary to prohibit the owner from using the vehicle on the road until the defect has been remedied.

There are some curious differences in the statistics of vehicle defects in relation to accidents, which may be due to administrative procedures in recording and not to true differences. For example, in the United States (National Safety Council, 1958) 7.2 per cent of drivers involved in accidents were considered to have visual obstructions on the vehicle (e. g., rain, snow on windshield, other windshield obstruction, load on vehicle); in the United Kingdom (Great Britain, Ministry of Transport and Civil Aviation, 1959*a*) only 64 of 299 767 road casualties were considered to be due to this cause. This may be partly due to the fact that in the United Kingdom the records are maintained by the police, and such defects may be recorded only when prosecution is likely to follow.

Defects in such important safety factors as brakes, lights, tires and steering are evidently common. Even minor defects are important, for they may add to a driver's difficulties in a pre-accident situation. Although it is not possible to measure precisely the contribution of vehicular defects to road accidents, they probably play a considerable part in the pattern of causation of many accidents.

The driver of a modern vehicle sits in an atmosphere which may be fairly completely sealed from the outside air. Although several ventilation aids are available, he may not use them. The resulting warm and comfortable conditions may induce drowsiness. The ventilation of vehicles should be so designed as to produce the necessary air changes even when all the normal aids to ventilation are out of use. A defective exhaust system may lead to the escape of dangerous fumes into the interior of the vehicle.

The air intakes for car heaters and ventilators should be so positioned that they are well away from the exhaust of the next vehicle in front. If this is not done, dangerous quantities of carbon monoxide may be drawn into the vehicle while it is stationary in traffic. Gasolene-engine exhaust gases may contain up to 7% or more of carbon monoxide; a concentration of 0.01% of this gas in air is sufficient to cause symptoms in a short time.

These problems of vehicle design rest with the vehicle manufacturers, influenced by consumer demand. A higher standard of safety in the vehicle may mean a higher first cost, and manufacturers may not be able to reach this standard unless the public demands it and is willing to pay for it or is obliged to do so by legislation.

THE DRIVER AND OTHER ROAD USERS

The road user carries much of the responsibility for traffic accidents: the vehicle driver for the safety of others as well as himself, the pedestrian mainly for his own safety, while the passenger carries relatively little responsibility. The consumption of alcohol before going on the roads increases the incidence of accidents among all categories of adult road user; this important problem is dealt with in the next chapter.

Driving is a skill which requires training, and, like other skills, it can be maintained at a high level only by regular practice. The time usually required to train a London bus driver who has never driven before is 50 hours at the wheel, spread over at least four weeks. The average private car driver receives considerably less training than this before he drives on his own and proceeds to acquire experience. As has been shown, increasing experience is a major factor in accident reduction, for inexperienced drivers have high accident rates. Experience cannot be taught, but it can be guided. Studies of training methods for motor vehicle drivers have not been undertaken, but the inculcation of "defensive" driving techniques is important. It may be that "good", i. e., safe, drivers anticipate or in some other way avoid pre-accident situations.

The psychological problem in road safety is essentially one of vigilance. Vigilance is affected by environmental conditions; a practical application of vigilance studies lies in the teaching of anticipation, a very important quality for driving. The ease with which a driver's attention is diverted is important but difficult to measure. It is difficult to determine the degree to which a driver is absorbed in his driving by measuring his overt responses directly, but the spare mental capacity of drivers in a subsidiary task, such as an oral arithmetic test, can be measured. It is possible that a driver's behaviour could be adversely affected in this way, for example, by the use of a radio to listen to important or interesting information when he should be paying full attention to the road. No evidence is yet available, however, on the relationship, if any, between the use of car radios and road accidents. This is an illustration of how much needs to be done and of how little scientific methods have been applied to study the consequences of scientific development.

The average probable occurrences encountered while driving have been suggested by Platt (1958) to be as follows :

Observations	200 per mile
Decisions	20 per mile
Errors	1 per 2 miles
Near-collisions . . .	1 per 500 miles
Collisions	1 per 61 000 miles
Personal injuries . .	1 per 430 000 miles
Fatal accidents . . .	1 per 16 000 000 miles

The frequency of the first four of these events was based on general observations; of the last three, on published statistics.

Personal and emotional adjustments offer a more promising field of study of accident causation. The proposition that "a man drives as he lives" was originally put forward by Tillman and Hobbs (1949). They found that a high-accident group of taxi drivers contrasted with a low-accident group in showing marked intolerance for authority, aggression, an unstable home background and various aspects of antisocial behaviour. This lends support to the view that the personal characteristics of road users exert a considerable influence on accident rates.

TABLE 16. DEATH RATES PER 100 000 POPULATION FROM MOTOR VEHICLE ACCIDENTS, BY AGE, SEX AND MARITAL STATUS, UNITED STATES, AVERAGE 1949-51*

Age and sex		Single	Married	Widowed	Divorced
20-24	M	74	46	140	157
	F	13	9	55	43
25-34	M	62	32	146	134
	F	11	8	26	24
35-44	M	49	28	88	97
	F	7	8	20	22
45-54	M	51	29	68	93
	F	8	10	16	18
55-59	M	63	33	70	91
	F	10	13	16	19
60-64	M	70	37	75	109
	F	14	16	19	28
65-69	M	79	43	80	118
	F	17	18	19	23
70-74	M	98	49	91	150
	F	23	23	21	41
75 & over	M	121	65	98	199
	F	34	24	24	53

* United States Department of Health, Education and Welfare (1958) *Accidental Injury Statistics*, Washington, Government Printing Office.

A further example of the effect of "way of life" upon road traffic accident rates is given in Table 16, which shows a considerable variation at all ages in road accident mortality rates according to marital status. These rates are derived from a population basis, and the true exposure to risk in terms of mileage driven is unknown; caution in their interpretation is therefore necessary. Also, the relation between marital status and accidents may not be a direct one. For males, married men have the lowest rates, the rates increasing through the single and widowed until the highest rates are reached in the divorced group, which has a mortality about three times as high as the married. Differences for women are similar, but less marked at the higher ages.

Greater emotional instability has been found in a group of drivers who experienced repeated road traffic accidents compared with accident-free drivers. This could be cause and effect; it may be that in drivers who have repeated accidents, the accidents are but one expression of a faulty adjustment to the demands of life. This may appear as a desire for dangerous living; some people probably have more courage and less fear of death or injury than others. The view has also been expressed that many accidents are unconsciously motivated and serve certain personal needs; this view has not been tested in relation to road traffic accidents. The theory that "a man drives as he lives" may also apply to pedestrians: an aggressive person with marked intolerance for authority and many antisocial characteristics seems likely, on the face of it, to make an unsafe pedestrian, but this hypothesis has not been tested.

An analysis of the neuropsychological qualities used in driving and of the way in which they are applied to the driving task was undertaken by Ventra (1960), but few laboratory or experimental studies of the nature of the driving task have yet been undertaken. Emphasis is often placed on tests of reaction time in relation to accident prevention, but safe driving does not depend solely on quickness of reaction. At first sight it would appear that drivers with the shortest reaction times should be able to act most promptly in the moments preceding an accident and should therefore have fewer accidents than more slowly reacting drivers. That this idea may be misleading is suggested by the fact that drivers aged 18-25, who have the fastest reaction times, experience more accidents than middle-aged drivers. Young drivers give a better performance on psychomotor tests generally. It appears that as a man ages in the middle range, his reactions are slower, his hearing diminishes, his eye-hand co-ordination deteriorates — *but he becomes a safer driver*. This increased safety is probably due to experience which results in the avoidance of accident situations, a quality which appears to be better developed in the middle-aged than in the young. Avoidance of the accident situation depends on the degree of care exercised, on experience, on the important quality of anticipation, and perhaps on other factors as yet unrecognized.

Accident-proneness

Much prominence has been given to the idea that some persons, particularly drivers, are accident-prone. If such drivers could be identified it would be worth while to take special measures to attempt to reduce their accident liability. Unfortunately, although it has been widely publicized, the concept of accident-proneness has serious limitations. The theory of accident-proneness was originally based on the manner in which industrial accidents were distributed among members of groups of workers (Greenwood & Woods, 1919; Newbold, 1926). Individual workers did not experience the number of accidents that would have been expected had the accidents been distributed in a random way: too many workers had no accidents, and more workers had multiple accidents than would have been expected on a chance distribution. The theory was therefore proposed that individuals differ inherently in their liability to accidents. These original studies were conservatively presented, with full recognition of the limitation of the methods used. As McFarland et al. (1955) pointed out in a review of this problem, "the cautions voiced by the original workers were infrequently observed in much of the later work; hence a fiction of accident-proneness developed, which was compounded by fallacious reasoning and supported by inadequate or inappropriate statistical procedures." The present position of knowledge is that statistical evidence does not indicate clearly whether there are individuals who have a consistently higher accident liability than average. It is possible that, since such differences in accident liability have not become evident after considerable study, they are not likely to be large, even if further research should demonstrate their existence. The major difficulty in studying accident-proneness among motor vehicle drivers is to know the exposure to risk, i. e., the annual mileage driven and the conditions under which it is driven. Häkkinen (1958), in a study of bus drivers in Helsinki, found that individual drivers had an accident liability which remained constant in two successive four-year periods; the differences between individuals were not great. This work has been criticized by Smeed (1960) on the grounds that some of the methods used in the analysis are not satisfactory. Häkkinen was unable to find a reliable method of identifying drivers with high accident rates by means of laboratory tests; it is important to distinguish between knowing that such people exist and being able to identify them. Moore (1956) points out that it is surprising that such obvious advantages as good vision, short reaction time and high intelligence do not appear to correlate well with accident-immunity. There may be a simple explanation: gross deficiencies in these qualities may be rare among drivers, or a driver may be well aware of his defect and be able to compensate for it. He may not be at all aware of a temperament which predisposes him to accidents.

The existence of a permanent condition of higher-than-average accident liability among motor vehicle drivers therefore remains uncertain. On *a priori* grounds it may be argued that, if "a man drives as he lives", those who live dangerously may also be a menace on the roads. It is probably true that temporary states of accident-proneness occur, associated, for example, with emotional disturbances, but again statistical evidence is lacking and the case for the existence of temporary accident-proneness is based mainly on clinical observations of individuals. The assumption that, because a small proportion of drivers have a large proportion of all accidents, therefore some drivers are accident-prone, is fallacious. Thus, in the United States in 1957, some 22.5 per cent of drivers experienced 100 per cent of the personal-injury accidents; but in one hour of 1957, about 0.0025 per cent of drivers had 100 per cent of the accidents — the time period of exposure must be taken into consideration. The important problem is to know whether it is the *same* drivers who have accidents in successive periods. Also, on a chance distribution alone, accidents would not be equally distributed. Thus, for 500 drivers experiencing 300 accidents the chance distribution would be : 274 with no accidents, 165 with one apiece, 49 with two, 10 with three, and 2 with four or more; the average accident rate would be 0.6 accidents per driver, and two drivers would have—by chance alone —an accident frequency approximately seven times above average. And this chance distribution takes no account of extra mileage driven, perhaps in difficult circumstances. Evidently great care must be exercised before taking action in respect of drivers who have an accident record which is worse than average.

Whatever may be the truth about accident-proneness, it is certain that some drivers have repeated accidents while others have fewer than average. In the present state of knowledge it is probably best to use the term "accident repeater" and to define such a person as one who has more than a given number of road traffic accidents in a given time. Action may then be taken to examine the records of the driver concerned and if necessary the driver himself. The improvement or elimination of accident repeaters would obviously be effective in reducing the numbers of accidents, but if the repeater condition is temporary, a new crop of accident repeaters might be found in successive time periods. It is possible that a small group of "problem" drivers exists, but such a group has not yet been clearly identified.

Fatigue

It is commonly believed that as a driver becomes fatigued, he is progressively more liable to experience an accident. There is, however, no generally accepted definition of "fatigue". Early workers were concerned with muscular effort, physiological changes and a feeling of tiredness, and emphasized the importance of the accumulation of chemical products, such as lactic acid, in the production of fatigue. A more recent view is that fatigue is an outcome of frustration and conflict within the individual. Direct evidence about fatigue from motor vehicle driving is very limited. One source of fatigue may be the frustrations of the traffic situation, particularly in congested urban conditions. A paced task, of which driving in heavy traffic is an example, is known to be the most conducive to fatigue. Motor vehicle driving in itself does not produce the usual symptoms of physical fatigue unless it is prolonged for many hours. The onset of fatigue manifested on the psychological plane may be accompanied by such symptoms as unusual sensitivity to situations and to other people, and irrational stubbornness. These may be followed by a disintegration of attention, with the result that the driver responds to irrelevant stimuli at the expense of the relevant ones. These effects may be a function of the mid-brain "activation system" which controls the level of arousal from deep sleep through lighter levels to full wakefulness. It is not possible, on the present evidence available from psychological and accident studies, to decide whether, for example, the maximum of eleven hours of driving per day permitted for truck drivers in some countries should be changed.

Fatigue may be considered to arise at psychological, biochemical and neuromuscular levels, and of these the first is probably the most important from the point of view of road traffic accident causation. Vigilance decreases in an unchanging environment, and the lack of perceptual stimulation that may exist, for instance, on a monotonous trunk-road may induce drowsiness. While no detailed studies have been made of fatigue in relation to road accidents, it is known that in a proportion of accidents a driver was asleep, and it is assumed that fatigue may be a contributory factor in a larger number of accidents. For example, 3.8 per cent of drivers involved in fatal accidents in the United States in 1959 were recorded as having been asleep or fatigued at the time of the accident; and on nineteen turnpikes in the same year a driver was recorded as having been "asleep or sleepy" in 14.3 per cent of all accidents causing death, injury, or property damage over $100 (National Safety Council, 1960). Many "driver-asleep" accidents occur after the driver has been at the wheel only a few hours; McFarland et al. (1955) found that approximately 60 per cent of all long-haul trucking accidents occurred during the first three hours of driving. They concluded that, while hours of duty and hours since the last rest are important, more needs to be known about the off-duty activities of truck drivers as an additional complicating factor. Visual fatigue is known to occur after long hours of driving; it is sometimes manifested by hallucinations: a driver swerves to avoid an imaginary object that has no real existence. There is no satisfactory method of measuring fatigue; such methods as the measurement of the critical fusion frequency of flashing lights, of the tension levels of muscles above the eyes and of changes in reaction time have not given consistent results.

The proportion of all road traffic accidents which is due to fatigue in a driver is unknown. Gross fatigue recorded by the police at the time of the accident occurs in less than 1 per cent of road traffic accidents causing personal injury in the United Kingdom (Great Britain, Ministry of Transport and Civil Aviation, 1960), but the American turnpike figures quoted above suggest that fatigue is in reality a more common factor than this. Lesser degrees of fatigue, particularly affecting vision and vigilance, may be a contributory factor in many more accidents, a supposition that awaits confirmation.

Skill-fatigue may be of some importance in the causation of road accidents, but the part which it may play is as yet unknown. The concept of skill-fatigue was developed by Bartlett (1943) in aviation accident studies. This is a type of fatigue manifested by errors in highly coordinated action in which one movement must fit in with another, each being accurately timed to begin and finish without interference by others. Motor vehicle driving calls for skills of this kind, with persistent concentration. The driver responds to stimuli from a constantly changing environment and establishes for himself limits within which each separate stimulus may vary without requiring a response. In skill-fatigue these limits unconsciously widen, the standards followed by the central nervous system undergo deterioration, and the driver may think that performance is improving whereas in fact it is becoming progressively poorer (McFarland et al., 1955). At first the right actions tend to be performed at the wrong time, but later wrong actions are performed and gross errors are made. It seems at least possible that many accidents due to signals or warning signs being disregarded or not observed may in fact be due to skill-fatigue. A typical example, of a kind which many experienced drivers have observed in themselves, is that of a driver at night who "halts at an intersection where there is no traffic light and waits patiently for the green; then, 'pulling himself together', he dashes on, intent on the clear roadway ahead and deriving no meaning from the headlights he sees approaching from the side" (*Lancet*, 1957). Explanations of accidents in terms such as "lack of concentration", "absent-mindedness", "inattention" and "carelessness" are unsatisfactory because they suggest a cause without giving any insight into the way in which it might have operated to produce the particular accident concerned. These loose terms, which are commonly used, need to be split into meaningful component factors to be of value in the study of road traffic accident causation.

Speed

The speed of a vehicle is, or should be, entirely under the control of the driver. Proceeding at a speed that is excessive in view of the traffic conditions is a common contributory cause of accidents and one for which the driver must be held at least morally if not always legally responsible; it is a human factor in accident causation. In the United States (National Safety Council, 1960) excessive speed is the commonest of the recorded faults of drivers involved in accidents and was recorded in 31 per cent of all fatal road traffic accidents in 1959. In the United Kingdom in 1958 excessive speed was given as the cause of 11 500 accidents (7 per cent) involving personal injury out of a total of 165 832 accidents in which a driver or cyclist was regarded as contributing to the cause (Great Britain, Ministry of Transport and Civil Aviation, 1959*a*), but this proportion may be too small, as the reports are made by the police who are concerned with prosecution.

It is sometimes said that speed has little relation to road traffic accident causation, but it is probable that many accidents would not have happened at all if the vehicle(s) concerned had been proceeding more slowly in the first instance. The effect of speed may be considered in another way. If all vehicles were mechanically controlled to, say, a maximum speed of 5 m.p.h., fatal and serious accidents would be virtually eliminated. But such a price might be considered too high, in social and economic values, to pay for safety. In order to study precisely the significance of speed in the causation of accidents it would be necessary to know the numbers of vehicles proceeding at given speeds on a particular section of road, and the numbers at each speed involved in accidents. This information is not available. Again, it is sometimes said that vehicles proceeding at unduly slow speeds on main roads are a contributory cause of accidents, but there is no evidence available on this point. Until reliable evidence about the effect of speed has been obtained, the present view will continue to be that driving at a speed higher than is warranted by the traffic situation is a potent contributory factor in road accidents. It may be that vehicle engines and gear ratios are inappropriate to their task in cities. Judgement of what speed is safe rests with the driver; it is one of the few examples of the product of human factors that is relatively easy to measure. Public opinion also has an important part to play; for it should be the accepted view that a "good" driver means a *safe* driver, not the one who travels a particular distance in the shortest time. A social attitude encouraging competitive speeds is to be deplored.

It is not always realized that the distance within which a vehicle will stop after the brakes are applied increases with the *square* of the speed. If on a dry road a vehicle with excellent brakes, travelling at 30 m.p.h., will stop in 45 ft after the brakes are applied, at 60 m.p.h. this distance will become 180 ft—four times the braking distance at twice the speed. In an emergency stop, to these distances must be added the distance travelled during the reaction-time period, i.e., the interval before the driver actually applies the brakes (Great Britain, Ministry of Transport and Civil Aviation, 1959).

A study of speed in relation to injuries to the occupants of motor vehicles involved in collisions was undertaken by Automotive Crash

Injury Research (Cornell University Medical School, 1958). It was found that a steady increase in the frequency of dangerous and fatal injuries occurred as impact speed or travelling speed increased. The increases in these grades of injury were relatively small in the ranges up to 50-m.p.h. impact speeds and 60-m.p.h. travelling speeds. Of persons travelling below 60 m.p.h. (or impacting below 50 m.p.h.), 6 per cent sustained dangerous or fatal injuries, but of those travelling above 60 m.p.h. (or impacting above 50 m.p.h.), 17 per cent sustained such injuries. Many factors other than high speed operated to influence injury, such as ejection, seat area occupied and external site of crash impact. Even if it had been possible to control the travelling speeds to a maximum of 49 m.p.h., 60 per cent of the dangerous and fatal injuries to vehicle occupants would still have occurred. It was considered that dangerous or fatal injuries, when the travelling speed was less than 60 m.p.h., were influenced far more by the design characteristics of objects which the occupants might contact in the vehicle than by the speed at which the cars were travelling before the accident. But when travelling speeds were above 60 m.p.h., injuries were closely associated with speed *plus* interior design characteristics. These studies were not concerned with accidents to pedestrians.

SUMMARY

The relative importance of the following factors differs from one road traffic accident to another. In the total of all accidents it is seldom possible at present to assess the relative importance of individual factors in accident causation and prevention.

The road

Design, including visibility, curves, gradients, variations in width, adequacy for traffic flow, single or dual carriageways, intersection design, high-speed motorways, monotony
Separation of pedestrians from road traffic; special tracks for cyclists
Traffic signals and signs—legibility
Lighting
Surface—skid-resistance
Maintenance

The vehicle

Maintenance of efficiency, particularly of lighting, brakes, steering, tires and exhaust assembly
Ventilation
Interior design (in relation to causation of injury)
Visual obstructions affecting driver

The road user (all categories)

Adequate training
Experience
Consumption of alcohol (Chap. 4)
Vigilance
The " way of life " concept; " problem " drivers
Emotional instability and disturbances
Age, sex and marital status
Accident-proneness, persistent or temporary
Anticipation and avoidance of accident situations (" preventive " driving)
Fatigue and skill-fatigue
Visual efficiency
Physical and mental defects (Chap. 5)
Speed of driving in relation to traffic conditions
Reaction time

CHAPTER 4

ALCOHOL AND ROAD TRAFFIC ACCIDENTS

There is much evidence to indicate that alcohol consumption by a road user is a major factor in road traffic accident causation. This evidence comes from investigations made by research groups, the experience of the police and everyday observation. It has been shown many times that the drinking driver is particularly prone to accidents (e.g., Freimuth et al., 1958). In Perth, Australia, Pearson (1957) found that, of 218 fatal-road-accident victims, 86 (39.4 per cent) had an alcohol concentration of 100 mg per 100 ml of blood or more, and 53 (24.3 per cent) had 200 mg/100 ml or more. In Romania, Banciu and Diaconita (1957) examined 457 drivers with presumptive evidence of alcohol consumption, of whom 128 were involved in accidents. In a study of 98 alcoholic drivers, compared with the general population of Ontario (Canada), Schmidt and Smart (1959) found that the alcoholic drivers were involved in a significantly larger number of accidents per year and per mile driven. A study of 83 drivers killed in single-vehicle accidents, involving neither other vehicles nor pedestrians, revealed that 41 (49 per cent) had blood-alcohol levels of 150 mg/100 ml or more at death and a further 17 (20 per cent) had levels between 50 and 150 mg/100 ml (Haddon and Bradess, 1959).

The only controlled study so far made of pedestrian fatalities (Haddon et al., 1960) showed that 47 per cent of those killed had a blood-alcohol level of 50 mg/100 ml or above, a much higher proportion than in the control group of pedestrians not involved in accidents. The pedestrians fatally injured who were included in this study consisted largely of a group of middle-aged people who had been drinking heavily.

A person who is severely affected by alcohol may be physically incapable of driving a motor vehicle or may refuse to drive; one who is less affected but who is still obviously under the influence of alcohol constitutes a danger as a driver. Further, in subclinical intoxication, in which a person has consumed alcohol but shows no clinical signs whatever, his judgement as a driver may be impaired.

PROPORTION OF ROAD TRAFFIC ACCIDENTS DUE TO ALCOHOL

A considerable body of evidence has been collected on this important problem. Official statistics may underestimate the numbers of accidents due to alcohol where they are based on police reports, and the police may be reluctant to record that drink contributed to an accident unless there is a likelihood of prosecution following. Thus, in the United Kingdom in 1958, out of a total of 165 832 accidents in which drivers and cyclists were regarded by the police as contributing to accidents, in only 1102 (0.66 per cent) was the driver or cyclist regarded as being under the influence of drink or a drug. Among 25 292 casualties to pedestrians aged 15 years and over, in only 441 (1.7 per cent) was the pedestrian regarded as being under the influence of drink or a drug (Great Britain, Ministry of Transport and Civil Aviation, 1959*a*). There is evidence to show that a much higher proportion of road traffic accidents than this is associated with the consumption of alcohol by one or more of those concerned.

Thus Spriggs (1956) studied police reports of all fatal road traffic accidents in two English counties in 1953-55 and concluded that in 9 per cent there was a reasonable probability of intoxication and in a further 15 per cent there was suspicion of intoxication. Of the deaths after 10 p.m., 50 per cent were considered to be due to intoxication. In 1948 a coroner in the Midlands of England found that alcohol had been consumed by drivers or victims in 23 out of 108 fatalities (Jeffcoate, 1958). Jeffcoate examined police reports of fatal road traffic accidents occurring in three police districts. There were 352 accidents with 376 deaths: in 61 (17 per cent) of the accidents there was evidence from witnesses or pathologists that one or more of the people involved in the accident had recently been drinking alcohol; in 22 (6 per cent) of the accidents there was evidence that the equivalent of at least three pints of beer had recently been consumed by at least one of the persons concerned. Jeffcoate also found that in 46 (62 per cent) of the 74 accidents which occurred between 10 p.m. and 4 a.m., alcohol had recently been consumed by people involved. She concluded that alcohol had been consumed by one or more of the people concerned in from 10 to 25 per cent of all fatal road traffic accidents. Gerber (1954) measured the blood-alcohol concentration in 1755 victims of fatal road traffic accidents; all were over 15 years of age and died within 12 hours of the accident. Of these victims, 49 per cent had measurable amounts of alcohol in their blood (19 per cent with 200 mg alcohol or more per 100 ml, 26 per cent with 50 to 190 mg/100 ml, 4 per cent with 40 mg/100 ml or less). Three-fourths of the victims were pedestrians, 49 per cent of whom also had alcohol in their blood. Coldwell (1955) records that the National Safety

Council in the United States reported in 1953, on the basis of data obtained from 21 states, that 18 per cent of drivers involved in fatal road traffic accidents had been drinking and that 26 per cent of adult pedestrians involved in fatal accidents had been drinking. Coldwell concluded that alcohol is a contributory factor in at least 25 per cent of fatal road traffic accidents. In a study in southern Sweden (Coldwell, 1955), 36 (23 per cent) of 159 fatal road traffic accidents to adults were considered to be caused by alcohol; in Stockholm during 1945-48, 25.5 per cent of drivers involved in fatal road traffic accidents were found to have a blood-alcohol level of more than 50 mg/100 ml.

But the above studies deal only with numerator data. If, for example it were found that 25 per cent of drivers involved in accidents had been drinking and that 25 per cent of a random sample of drivers *not* involved in accidents had also been drinking similar amounts, the causative significance of alcohol would not be evident.

Three controlled studies have endeavoured to overcome this difficulty. In the United States, Holcomb (1938) measured the blood-alcohol level of 1750 drivers in Evanston, Ill. as a control group not involved in accidents and of 270 drivers admitted to hospital after accident. The results are given in Table 17. It will be seen that only 23 out

TABLE 17. TRAFFIC ACCIDENT HAZARD ASSOCIATED WITH VARIOUS BLOOD CONCENTRATIONS OF ALCOHOL, EVANSTON, ILL.*

(*a*) Blood-alcohol level (mg/100 ml blood)	(*b*) No. of drivers involved in accidents	(*c*) No. of drivers tested and not involved in accidents	(*d*) Column (*c*) reduced to a total of 270
Nil	144	1 538	237.3
Trace - 60	39	133	20.5
70-100	28	56	8.6
110-140	22	16	2.5
150 and over . . .	37	7	1.1
Total	270	1 750	270.0

* Holcomb, R. L. (1938) *J. Amer. Med. Ass.*, 111, 1077.

of 1750 drivers not involved in accidents (1.3 per cent) had a blood-alcohol level of 110 mg/100 ml or more, but that 59 out of 270 accident drivers (22 per cent) had this amount of alcohol in their blood. A blood-alcohol level of 110 mg/100 ml or above was therefore considered by Holcomb to increase a driver's liability to accident 17-fold. He considered that about 100 (37 per cent) of the 270 driver-accidents could be regarded as due to alcohol and would have been prevented if the drivers had not consumed alcohol. Holcomb's Evanston study has been criticized on the ground that his control and accident groups of drivers were not strictly comparable.

The second controlled study was conducted by Lucas et al. (1953) in Toronto: 423 drivers involved in accidents and 2015 non-accident drivers who passed the scene of accident supplied breath samples for later analysis in the Hazer Drunkometer or Greenberg Alcometer. The results are given in Table 18. Using Holcomb's method in the final

TABLE 18. TRAFFIC ACCIDENT HAZARD ASSOCIATED WITH VARIOUS BLOOD CONCENTRATIONS OF ALCOHOL, TORONTO*

(a) Blood-alcohol level estimated from breath analysis (mg/100 ml blood)	(b) No. of drivers involved in accidents	(c) No. of drivers tested and not involved in accidents	(d) Column (c) reduced to a total of 423
Nil - 50	328	1 839	386
50 - 100	30	109	23
100 - 150	17	39	8
150 & over	48	28	6
Total	423	2 015	423

* After Lucas, G. H. W. et al. (1953) In: *Proceedings of the Second International Conference on Alcohol and Road Traffic*, Toronto.

column of Table 18, the control group of non-accident drivers has been reduced to equal the number of drivers involved in accidents. Out of an equivalent total of 714 drivers whose blood-alcohol level was below 50 mg/100 ml, 328 (46 per cent) were involved in accidents; of 132 drivers whose blood-alcohol level was over 50 mg/100 ml, 95 (72 per cent) were involved in accidents, instead of the 66 expected if the two groups were equal in accident liability. Therefore 29 (30 per cent) of the drivers may be regarded as having been involved in accidents due to alcohol consumption out of the total of 95 drinking drivers (50 mg/100 ml or more) involved in accidents. These figures agree reasonably closely with those of Holcomb.

The third controlled study was undertaken by Vamosi in Bratislava, Czechoslovakia. His results are shown in Table 19; the figures show strikingly the increase in accident hazard as the level of blood alcohol rises, indicating that the chances of involvement in a traffic accident are 124 times greater for a person with a blood-alcohol level of over 150 mg/100 ml than they are for a person with only 30 mg/100 ml.

TABLE 19. TRAFFIC ACCIDENT HAZARD ASSOCIATED WITH VARIOUS BLOOD CONCENTRATIONS OF ALCOHOL, BRATISLAVA, CZECHOSLOVAKIA*

(*a*) Blood-alcohol level (mg/100 ml blood)	(*b*) No. of persons in accidents	(*c*) No. of persons tested and not involved in accidents	(*d*) Column (*b*) / column (*c*)	(*e*) Increase in chance of accident with increase in blood alcohol
30	123	370	0.33	1
100	89	37	2.4	7
150	82	8	10.0	30
Over 150 . . .	124	3	41.3	124
Total	418	418		

* From Vamosi, as reported by Elbel, H. (1960) *Ciba Symp.*, 7, 242.

Preston (1958), in a review of the literature, considered that about 500 deaths and 2000-3000 serious injuries would be prevented each year in the United Kingdom if people—drivers and pedestrians alike—did not go on the roads after drinking.

QUANTITATIVE RELATION OF ALCOHOL CONSUMPTION TO DRIVING SAFETY

The effects of small doses of alcohol on the efficiency of performance in a Miles motor-driving trainer were studied by Drew et al. (1958, 1959). The peak blood-alcohol concentrations from the doses given were approximately 20, 40, 60 and 80 mg/100 ml. It was found that the level of alcohol in the blood is a good indicator of the extent of impairment of performance. Urine and breath analyses were compared with direct blood analysis, and the results obtained with the Breathalyzer apparatus were regarded as good enough to warrant consideration from a practical point of view. Drew et al. found that errors in the performance of their subjects on the Miles trainer increased with increase in blood alcohol, amounting to about 16 per cent deterioration with a blood-alcohol concentration of 80 mg/100 ml. The average speed of all subjects taken together showed no significant change, but there were marked individual differences in speed after alcohol. Age, sex, previous driving experience and previous drinking habits—within the limits available—showed no relation to individual differences in response to alcohol. There were, however, interesting personality differences, giving some laboratory support to the concept that "a man drives as he lives".

Extroverts did not change either speed or control movements very much but showed large increases in error. Introverts, on the other hand, changed their speed considerably, though it was not found possible to differentiate between those who slowed down and those who speeded up.

In the Scandinavian countries and in 47 states of the United States, there is legislation making it an offence for a driver with a blood-alcohol concentration above a certain figure (50 mg/100 ml in Sweden, for example, and 150 mg/100 ml in the United States) to drive a motor vehicle. A British Medical Association report on the relation of alcohol to road traffic accidents (1960) lists the legislation and requirements in respect of biochemical tests, with the concentrations of alcohol accepted as evidence of impairment of drivers, in 25 countries. There is no doubt whatever that, in spite of individual variations in performance, a person with a blood-alcohol concentration of 150 mg/100 ml or above is unfit to be in charge of a motor vehicle.

The performance of drivers in an actual driving task after taking alcohol was studied by Cohen et al. (1958). Three groups of bus drivers were given the task of judging whether they could drive between two posts and then actually undertaking the drive. It was found that the performance of the drivers, as well as their judgement, progressively deteriorated as they consumed more alcohol. An important finding was that the trustworthiness of a man's judgement of his driving skill was impaired after even a small quantity of alcohol, producing a blood concentration lower than 50 mg/100 ml.

The conclusion is inescapable that the consumption of alcohol is responsible for a considerable number of road accidents. In all these studies there has been no mention of the additive effects of alcohol and drugs. The consumption of barbiturates or tranquillizers together with alcohol may be disastrous in a road user and particularly so in a motor vehicle driver.

The British Medical Association report (1960) on the relation of alcohol to road accidents published, *inter alia*, the following conclusions:

"In a high proportion of accidents in which pedestrians have received fatal injuries it has been found that the victim has taken alcohol; relatively low concentrations of alcohol in the tissues cause a deterioration in driving performance and increase appreciably the likelihood of accident; clinical examination in the absence of biochemical tests is neither sufficiently sensitive nor reliable enough to detect deterioration in driving performance of this degree. A clinical examination is, however, an essential part of the examination of persons suspected of driving vehicles under the influence of alcohol, since it is the only way of detecting physical illness and the presence and extent of any injury. A substantial reduction in the number of accidents caused by alcohol has been achieved in countries where it has been made an offence to drive a motor vehicle when the concentration of alcohol in the tissues is in excess of a certain level. A concentration of 50 mg of alcohol in 100 ml of blood while driving a motor vehicle is the highest that can be accepted as entirely consistent with the safety of other road users. While there may be circumstances in which individual driving ability will not depreciate significantly by the time this level is reached, the committee is impressed by the rapidity with which deterioration occurs at the blood levels in excess of 100 mg/100 ml. This is true even in the case of hardened drinkers and experienced drivers. The committee cannot conceive of any circumstances in which it could be considered safe for a person to drive a motor vehicle on the public roads with an amount of alcohol in the blood greater than 150 mg/100 ml. "

The World Health Organization Expert Committee on Alcohol (1954) reported:

" Taking into consideration (1) the investigations performed in recent years on the effect of alcohol on different functions in laboratory experiments, (2) the results of statistically designed practical tests on drivers, air pilots, etc., and (3) the statistical evidence from the few adequate studies existing on alcohol and road accidents, the inference cannot be avoided that at a blood alcohol concentration of about 50 mg/100 ml a statistically significant impairment of performance is observed in more than half of the cases examined. "

CHAPTER 5

MEDICAL FACTORS IN CAUSATION

A number of common medical conditions may have a causative relation to road traffic accidents, though they are responsible for only a small proportion of the total of such accidents.

The clinical assessment of fitness to drive vehicles has been described in detail by the American Medical Association (1959) in a handbook for physicians; and the Association has published a bright little booklet for patients, entitled *Are You Fit to Drive?* The British Medical Association (1954) and the World Health Organization (1956) have also published guides for physicians on assessing fitness to drive motor vehicles.

DISEASE AND ROAD ACCIDENTS

Acute diseases, particularly at their onset, may affect the safety of drivers and other road users. No information is available about the number of accidents caused in this way.

Chronic diseases may increase the accident risk of road users, especially in motor vehicle drivers who suffer from disabilities which may cause a sudden loss of consciousness, impaired concentration or defective eye-hand co-ordination and reaction to traffic conditions.

Table 20 shows the disabilities (excluding the influence of alcohol) found in drivers and pedestrians involved in accidents in the United States in 1959. As shown in this table, 1.2 per cent of all drivers involved in accidents (2.4 per cent of those involved in fatal accidents) had defective sight or hearing or were suffering from illness or other medical defects. Of the pedestrians involved in accidents, 3.4 per cent (7.7 per cent of those in fatal accidents) were similarly affected.

In the United Kingdom in 1958, in 992 (0.6 per cent) out of 165 832 personal-injury accidents, a motor vehicle driver or cyclist was considered by the police at the scene to be suffering from illness or physical defect of a degree sufficient to be a contributory cause of the accident (Great

TABLE 20. PHYSICAL CONDITION OF DRIVERS AND PEDESTRIANS INVOLVED IN ACCIDENTS, UNITED STATES, 1959*

Condition	Drivers				Pedestrians			
	Fatal accidents		All accidents		Fatal accidents		All accidents	
	Per cent of conditions	Per cent of drivers	Per cent of conditions	Per cent of drivers	Per cent of conditions	Per cent of pedestrians	Per cent of conditions	Per cent of pedestrians
Illness	6	0.4	7	0.2	5	0.4	6	0.2
Defective eyes	6	0.4	7	0.2	23	1.8	26	0.9
Defective ears	2	0.1	2	<0.05	13	1.0	12	0.4
Other defects and conditions	24	1.5	24	0.8	55	4.5	55	1.9
Asleep or fatigued	62	3.8	54	1.5	Not recorded for pedestrians			
All conditions	100	6.2	100	2.7	100	7.7	100	3.4

* From National Safety Council (1960) *Accident Facts 1959*, Chicago.

Britain, Ministry of Transport and Civil Aviation, 1959*a*). Separate records were not maintained for pedestrians.

In the German Federal Republic in 1957, drivers hindered by ill health and bodily defects accounted for 0.25 per cent of road accidents (Elbel, 1960), but Elbel points out that the statistics were supplied by the police, who have not the medical technique necessary to establish a diagnosis. Elbel considered that many individuals responsible for accidents not only failed to report mental or physical defects but did everything they could to cover them up; he concluded that about 2 per cent of road accidents were due to such defects.

It is clear that a small but important number of road traffic accidents are associated with disease or physical defect in motor vehicle drivers or other road users. The prevention of this group of accidents is of particular medical interest.

Another approach to this problem is to compare the proportions of mental and physical defects found in comparable groups of accident repeaters and accident-free drivers.

This was attempted by the ENO Foundation (1948) in a study of the personal characteristics of accident repeaters. Physical defects did not appear to differ between the two groups, except for visual defects. No significant differences were found in systolic and diastolic blood pressure between the two groups. In agreement with other similar studies, considerable emotional, personality and "way of life" differences were found between accident repeaters and the accident-free. At the Medico-Psychological Institute for Traffic Safety in Stuttgart (*Zbl. Verkehrs.-Med.*, 1958*a*) a comparison was made between 200 reputedly "normal" drivers and 126 others, each of whom had been involved in at least three accidents. There were rather more medical findings (e.g., restricted sensory perception; internal organic, orthopedic-surgical and neurological conditions) in the accident-repeater group, and again the psychological findings (affectivity disorders, reduced mental capacity, and psychomotor disturbances) were much more prominent among the accident repeaters.

In assessing the fitness of an individual to drive, account must be taken of his exposure to risk. Thus, a person who drives for eight hours a day has a much greater chance of developing a disability while driving than one who drives for only an hour or two weekly.

Following are three illustrative examples of the influence which medical disorders may have on the occurrence of road traffic accidents.

Epilepsy

Nothing is known of the number of accidents caused by epilepsy in a road user; examples have been reported from time to time, but evidence of the occurrence of a seizure preceding an accident is rarely found. This may be due to concealment or to the transitory nature of the seizure. The general term "blackout" which, in a driver, accounts for some accidents, may cover some cases of epilepsy. Many published papers refer to epilepsy in a driver as a cause of road traffic accidents, but it is probable that only a small proportion of accidents are due to this cause. Nevertheless, the total loss of control of the vehicle which may result when a driver experiences an epileptiform seizure is likely to lead to a serious accident.

The observations which follow relate to idiopathic epilepsy of major or minor type. Until about 1948 it was generally held that a person who had at any time suffered from epileptic fits should be refused a driving licence. In recent years a more liberal view has prevailed in respect of private car drivers. The American Medical Association (1959) considers that epileptic patients who are not receiving medicaments and who have been free from seizures for at least two years may be allowed to drive private cars but not commercial or passenger vehicles. The Association recommends that such patients should be advised not to take any alcoholic drinks for at least 24 hours before driving, and not to drive for more than six hours in any day; driving at night may be dangerous because photic stimuli from approaching headlights may precipitate a seizure, and emotional stress should be minimized by avoiding driving in peak hours. The present practice in the United States regarding the granting of driving licences to epileptics varies from state to state. In 18 states licences are granted on the basis of medical control of seizures; in others an interval of one to three years' freedom is required. The effectiveness of these procedures in accident prevention is not known. It is probable that epilepsy in its various forms is an occasional cause of motor vehicle accidents. The responsibility for avoiding the hazard appears to lie primarily with the epileptic driver himself, to some extent with the authority which issues driving licences (when the disability is known), and with the medical practitioner when the driver seeks advice regarding his condition.

Cardiovascular disease

Ischemic heart disease (myocardial infarction) accounts for about a third of cases of loss of consciousness when driving a motor vehicle (Norman, 1960). Such cases are rare; there was one instance in every 280 million vehicle-miles travelled in London Transport. In 5 out of 14 cases, the driver did not have sufficient warning to stop his vehicle; in 3 of these a collision resulted. The frequency of such cases depends on the incidence of ischemic heart disease in the population, which is related to age. If the London experience of three to four cases of loss of consciousness while driving, due to myocardial infarction, per 1000 million vehicle-miles applies generally, some 2000 such cases would be expected to occur in the United States annually and 200 in the United Kingdom. In some of these cases the driver would have sufficient warning to stop the vehicle, and a collision might be expected to result in about a third of them; perhaps 700 collisions annually in the United States and 60 in the United Kingdom. If these approximations are correct, these accidents form some 5-10 per cent of those in which it is recorded that a driver was taken ill. At present it is not possible to predict the occurrence of myocardial infarction in most cases, and the prevention of accidents by the removal of the drivers concerned in advance of their infarction is not practicable.

It has been shown (Morris et al. 1957) that the risk of a second coronary episode may be about ten times as high as the risk of a first. For this reason it is generally recommended that a man should not drive passenger-transport vehicles after he has been found to have ischemic heart disease (*Med. J. Aust.*, 1959; American Medical Association, 1959; British Medical Association, 1954). It is generally considered that people who have made a good recovery from myocardial infarction, or whose attacks of angina pectoris are mild and infrequent, may be advised that they may continue to drive private cars. In such cases there is an increased risk of accident, but the increase is believed to be small and acceptable. If further research enables the degree of risk to be measured, its acceptability may need to be reconsidered.

Little is known of the relation, if any, between road traffic accident rates and the blood pressure of motor vehicle drivers. Occasionally an accident occurs in which a driver loses consciousness from a cerebrovascular accident and is then found to be suffering from high blood pressure. Comparative studies of accident-repeater and accident-free groups of drivers have not revealed any differences in blood-pressure measurements, but at very high levels of blood pressure there is an increased risk of accident due to sudden loss of consciousness. This condition may affect any type of road user and is obviously likely to be more dangerous in motor vehicle drivers than in, for example, pedestrians. The difficulty is to assess the point at which a raised blood pressure becomes unacceptably hazardous; there are no accident statistics to help here, and the decision must be made on clinical grounds. A full discussion of this problem is given by Norman (1960).

Diabetes mellitus

No studies have been made of accident rates in diabetic drivers compared with non-diabetics. Such evidence as is available does not suggest that there is any increased accident risk in drivers of private motor vehicles. Drivers of heavy commercial vehicles and passenger-transport vehicles, because of the heavy nature of their work, often on shift duties, are generally advised to change to other work when they are under treatment with insulin or oral hypoglycemic agents, because of hazards which may affect drivers suffering from hypoglycemia (low blood sugar). Drivers of any kind of motor vehicle whose diabetes is controlled by diet alone do not run this risk and are safe to continue their work so far as their diabetes is concerned.

The Italian Diabetic Association drew attention (*Zbl. Verkehrs.-Med.*, 1958) to the exceptional rarity of road accidents due to hypoglycemic states and considered that the accidents caused by diabetes might be regarded as altogether insignificant. Elbel (1960) refers to an investigation of 70 000 road traffic accidents in which only two appeared to be due to diabetes, with two further ones doubtfully due to this condition. In a study of some 20 000 road traffic accidents, Elbel (1960) found only one that was due to hypoglycemia.

It is clear that hypoglycemia resulting from treatment of diabetes is a rare cause of road traffic accidents, forming an insignificant proportion of the total accidents. Suitable medical advice to private car drivers and the exclusion of drivers of heavy commercial and passenger-transport vehicles who are undergoing treatment with insulin or oral hypoglycemic agents appears to be all that is necessary to deal with the problem of diabetes in relation to road traffic accidents. About 1 per cent of the general population of some countries is diabetic, and the safety of the individual diabetic as a driver has to be considered in each case.

IMPAIRMENT OF HEARING

Little is known about the accident liability of deaf or partially deaf drivers. Deafness would appear to be a handicap to a pedestrian, but there are no statistics of accident frequency in the deaf. Nevertheless, many opinions have been expressed, most of them suggesting that road traffic accidents are no more frequent among deaf drivers than in those with normal hearing. Macfarlan (1937) considered that the deaf are generally safe drivers and that presumably they are cautious and alert because they are aware of their handicap. Elbel (1960) refers to United States statistics which show that, among 3000 deaf drivers, the percentage involved in accidents was only 0.14, compared with an over-all average among all motor vehicle drivers of 3.9 per cent. In Pennsylvania, deaf drivers broke all safety records over a period of two years, registering one accident per 600 deaf drivers.

It is obviously possible to master traffic situations in spite of deafness; although good hearing is an undoubted asset to a driver, it is by no means essential. Deafness may be associated with other disorders, and it is imperative to ascertain the cause of deafness in each individual case. In some cases hearing may be more acute in traffic than in a quiet room. If hearing is unequal on the two sides, the sense of direction may be impaired, as there is difficulty in locating the position of a source of sound. Little benefit is to be expected from the use of hearing aids, because of extraneous noises, variability in the instrument, and mechanical defects which may develop and also because of difficulty in locating a sound.

Until comparative studies have been undertaken of accident rates in the deaf and in those with normal hearing, the significance of deafness must remain unknown. At present there is no evidence on which to suggest that deafness in motor vehicle drivers contributes at all to the total of road traffic accidents. Deafness would appear to be more likely to be a hazard to a pedestrian.

EYESIGHT AND ROAD ACCIDENTS

Several studies have been made in the United States of the relation between visual acuity and road accidents. Lauer et al. (1939), using two different tests of visual acuity, found that higher acuity was associated with fewer accidents. Brody (1941) found that 4 out of 26 accident repeaters had an acuity of less than 20/30 in the better eye and 20/50 in the worse eye. A comparison of a group of accident repeaters with a group of accident-free drivers undertaken by the New York Center for Safety Education indicated that drivers with poor visual acuity were more likely to be involved in accidents than drivers with good acuity (Smeed, 1953). Fletcher (1942) found that the proportions of drivers who failed tests of visual acuity were 1 per cent for drivers with good accident records and 5 per cent for drivers with poor records. Miles (1956), in a study of lighting and visual requirements for road safety, gave the incidence of poor visual acuity in drivers involved in accidents as about 5 per cent. Defective vision is also a hazard to pedestrians and other road users. The proportion of road accidents which is directly due to defective vision in a road user is not known. It is, however, evident that defective vision, depending on the degree and kind of the defect, may add to the difficulties of a driver or pedestrian and is likely to be a contributory cause in a proportion of road accidents. The various recommended minimum standards of visual acuity for motor vehicle driving have been somewhat arbitrarily chosen, and there are other factors concerned besides distant visual acuity alone. In a study of the personal characteristics of groups of accident repeaters and accident-free drivers, the ENO Foundation (1948) found that depth perception and ocular-muscle balance were better in the accident-free group, as was the ability to see simultaneously with both eyes. There was no difference between the two groups in visual fields or in rate of dark adaptation. Davey (1958), found that of 1534 private-car drivers who consulted opticians, 5 had a visual acuity in both eyes together, *with glasses*, of less than 6/18—less, that is, than any generally accepted standard of safe vision. Of those who sometimes drove without their glasses, 26 had a visual acuity (without glasses) below this standard. Defective colour vision has not been shown to be associated with any increased liability to road traffic accidents and, unless in special circumstances, does not seem to be in any way a factor in accident causation.

No data are available about the accident experience of one-eyed drivers. Many one-eyed persons acquire judgement of distance and have the ability to drive private cars safely. Schwarz (1939) found that one-eyed drivers had a higher prevalence of accidents at intersections and that these accidents were often on the side *away* from the defective eye; apparently the driver turns his head to compensate for the loss of visual field on his blind side. On the other hand, the German Federal Republic Society of Opticians (Elbel, 1960) considers that the incidence of road traffic accidents among one-eyed drivers is no more than the average. Cole (1959) found that 5.27 per cent of patients referred for sight testing had unilateral amblyopia, and this condition may be of some importance in the causation of road traffic accidents in all types of road user. Good eyesight is of obvious importance for safety, but the problems of the ophthalmologist extend beyond the case of individual eyesight to include some of the basic principles of traffic safety, such as dazzle. Antidazzle screens sometimes form part of the design of a motorway. The use of polarized light in headlights to prevent dazzle has not yet proved satisfactory. The provision of coloured windscreens or coloured eye-glass lenses forms an obstruction to vision and reduces the safety margin. Even eye-glass frames fitted with wide opaque side-pieces may be dangerous, as they obstruct lateral vision. The problems of ophthalmology in relation to safety are many and important.

DRUGS AND THE ROAD USER

All types of road users, including pedestrians, will obviously be rendered unsafe if they use the roads after consuming narcotic or hypnotic drugs in sufficient amounts. Drug addicts, at least during the active phase of their addiction, should not drive motor vehicles. In addition, performance as a driver of a motor vehicle may be adversely affected by many drugs which are in common use today, many of them obtainable without a doctor's prescription. The extent to which the consumption of drugs contributes to the causation of road traffic accidents is unknown. Accidents in which a road user was noticeably under the influence of a drug are certainly uncommon, but the desirable clinical effect of mild sedation or the attempt to induce peace of mind by chemical means may be accompanied by adverse effects on an individual's driving ability. No laboratory studies on drugs and road traffic accidents, comparable with those on alcohol, have so far been published.

There are now in common use powerful drugs which can lower the blood pressure, affect the personality and alter the blood chemistry, and any of these effects may adversely affect the patient's performance and safety as a motor vehicle driver. It is the duty of the doctor who prescribes a drug that may be dangerous to a driver to inform his patient of the possible dangers of driving after taking the drug. The patient cannot be expected to know the possible effects and side-effects of the drug he has been given; he may not even know its name.

Hypnotics, sedatives and tranquillizers should be prescribed with caution for drivers. The side-effects of antihistaminics vary considerably, and Miller (1957) suggests that patients taking these drugs should not drive until they have established by trial that they do not experience significant side-effects. Patients taking ganglion-blocking agents (used to lower blood pressure) should generally be advised not to drive, but other hypotensive drugs are probably safe if they do not produce postural hypotension. The central-nervous-system stimulants, of which amphetamine is probably the most often prescribed, temporarily increase alertness and efficiency; but large doses may induce headache, agitation, irritability and impaired concentration, which would make it unsafe to drive a motor vehicle. Nevertheless, an investigation by the Food and Drug Administration of the United States uncovered a "dope ring" which was illegally selling amphetamine sulfate tablets as "benny pills", "copilots" or "stay-awake pills" to the trucking industry in 1953-55. Fatigue and depression normally follow the initial stimulation. Miller (1957) suggests that long-distance truck drivers may be particularly exposed to this hazard and recommends that if the dosage of amphetamine does not exceed 10 mg, a driver may be permitted to prolong driving for a period of not more than two hours; the drug should not be repeated on the same day. This suggests that amphetamine may be fairly extensively used; but in the interests of safety, drivers should probably be discouraged from taking any such drugs at all.

CHAPTER 6

PREVENTION: PRESENT PRACTICE AND FUTURE PERSPECTIVES

Because there are many causative factors involved in road traffic accidents, it is difficult to assess accurately the effectiveness of any particular preventive measure directed specifically against one of them; other factors may have varied during the period of observation and produced a change in accident rates. That an effective reduction in death *rates* can occur is illustrated by the facts that, in the United States, the road traffic accident mortality rate declined steadily from 17.9 per 100 million vehicle-miles driven in 1925 to 5.9 in 1957 (Baldwin, 1955, and National Safety Council, 1959); and in the United Kingdom, mortality per 100 million vehicle-miles declined from 22.2 in 1938 to 9.6 in 1959. The total numbers killed annually in road traffic accidents have not changed much in highly motorized countries in the past 25 years. In the United States there were 36 369 fatalities in 1935 and 37 800 in 1959; in the United Kingdom 6502 persons were killed in 1935 and 6520 in 1959. But there is indeed no reason for complacency. The reduction in the death rates per 100 million vehicle-miles driven is due to the great increase in the number of motor vehicles that has taken place during the period under review; since 1935 in the United Kingdom, for example, the number of motor vehicles has doubled and the number of motorcycles trebled. It is tempting to assume that these reductions in death rates were also partly due to accident-prevention measures, but there were so many other factors involved, affecting the road, the vehicle and the road user (as to category, age and sex, for example) that this assumption may not be correct. Nevertheless, there are numerous instances in which it is highly probable that a particular preventive measure was effective.

PRESENT PRACTICE

The road

In 1952 in the United Kingdom, pedestrian fatalities fell by over 10 per cent; this was the year in which the "zebra" pedestrian crossings were introduced. Turnpikes, main highways and controlled-access roadways show lower accident rates than do ordinary highways without controlled access (Baldwin, 1955): for all roads and streets in the United States the road traffic accident death rate in 1959 was 5.4 per 100 million vehicle-miles travelled; on 19 modern turnpikes it was 2.8; and on the New Jersey Turnpike, an outstanding example of modern highway design, it was only 1.5. There are innumerable specific examples where the widening of a narrow section of road, the building of an overpass (flyover) or underpass, or other road improvements have reduced the number of accidents occurring at particular sites. Twenty-two such examples, with photographs and diagrams of the improvement in road layout, were given by the British Road Federation in 1952. Improvement in road lighting has also been shown to reduce the numbers of accidents at sites where comparable accident rates before and after the improvement have been obtainable. For example, on eight main roads near London, there were 97 night and 246 daytime accidents; over a corresponding period after street lighting had been improved, there were 83 night and 299 daytime accidents, a reduction of night accidents while accidents in daylight were increasing (Tanner and Christie, 1955). A summary of numerous examples of accident reduction when street lighting was improved was given in *Revue Internationale de la Circulation et de la Sécurité routière* in 1956. As far as pedestrians are concerned, complete segregation from the highway is possible in some areas and is a very effective accident-prevention measure. Such separation may be possible on main highways and in some city shopping and business areas.

The vehicle

It is difficult to obtain specific examples of a reduction in accident rates which can reasonably be attributed to changes in the design or construction of vehicles. Improved visibility for the driver is a feature of present-day vehicle design and may be presumed to reduce accident risks. Studies of the effectiveness of safety belts in preventing casualties have verified the importance of their role in injury reduction, as shown in Table 21; the use of safety belts produced a 60 per cent reduction in all grades of injuries and in injuries graded moderate to fatal. These results were confirmed in a study of highway accidents in California by the Automotive Crash Injury Research Team (Cornell University Medical School, 1960). The California study also showed that, in cars fitted with safety belts, only one-third of the installed belts were actually being worn by the occupants at the time of an accident. The Automotive Crash Injury Research team has also shown that the removal of dangerous projections from the interior of the vehicle

TABLE 21. EFFECT OF SAFETY BELTS IN REDUCING INJURY TO OCCUPANTS OF CARS*

Type of injury	Per cent of occupants with injury	
	Safety belt not used	Safety belt used
All grades	75.5	29.9
Grades moderate to fatal	23.0	9.2

* From Cornell University Medical School (1957) *Automotive Crash Injury Research, annual report,* New York.

contributes considerably to the reduction of injuries affecting occupants of motor vehicles. It is generally agreed that the removal of sharp and dangerous projections from the exterior of vehicles reduces the injuries to pedestrians involved in collisions with motor vehicles. Improvements of motor vehicles in these respects are the responsibility of the manufacturers, who will be moved by public opinion and consumer demand.

Good maintenance of motor vehicles is the responsibility of the owners of the vehicles and should be a factor in reducing road traffic accidents. In 1949, twelve states of the United States required periodic inspection of vehicles, and in these states the motor vehicle death rate per 100 million vehicle-miles was 5.9 compared with 7.2 in states not requiring inspection (United States, Committee on Motor Vehicle Administration, 1949). There were, however, other factors involved, and the extent to which this difference was due to the vehicle-inspection programme could not be determined. So far as injuries received by car occupants in accidents are concerned, an investigation in the United States in 1956 (Cornell University Medical School, 1957) showed that occupants of new-model (1956) cars sustained nearly 30 per cent fewer dangerous or fatal-grade injuries than a corresponding group of occupants of older cars. This decrease was due largely to a reduced frequency of ejection from the vehicle, but improvements in interior design were probably also concerned.

The road user

Improved performance by road users is probably the most important factor in accident prevention. There are already several examples of specific improvements which have produced a reduction in accidents. The evaluation of the results of *training* of drivers is one of these.

Glanville (1954) reported the results of twelve studies of the results of driver training, given in Table 22. The training was undertaken as part of the regular curriculum in high schools. Trained drivers appear to have fewer accidents than untrained ones, but as McFarland et al. (1955) point out, it is not entirely certain whether the better records are wholly due to training or whether they may also reflect other differences, such as motivation, between the two groups.

TABLE 22. ACCIDENT RATES OF UNTRAINED AND OF TRAINED DRIVERS, UNITED STATES*

Training status	Exposure in driver-months	Number of accidents	Accident rate per 1000 drivers per month	Ratio of accident rates of untrained to those of trained drivers
Men and boys:				
Untrained	123 865	979	7.9	1.8
Trained	61 818	265	4.3	
Women and girls:				
Untrained	42 581	110	2.6	2.2
Trained	62 272	72	1.2	

* Glanville, W. H. (1954) *J. roy. Soc. Arts*, 102, 496; original data from American Automobile Association, *Research Report No. 39*, July 1953.

The results of training of high-school pupils in motor-vehicle driving appear to be equally satisfactory elsewhere. Thus Thorndike (1951) reports a comparison of the accident and traffic-violation records of high-school students in Cleveland, Ohio who had taken the driving course with those of students who had not taken the course. A significantly larger number of the untrained group experienced accidents in the period covered, although there was no difference in the number of traffic violations for the two groups. Thorndike also gives the results of a study of 2200 graduates of high schools in the state of Delaware. Half of these students had taken a driver-training course, half had not: during the period studied, 22.9 per cent of the untrained students were involved in road traffic accidents as against 5.1 per cent of those trained.

The evaluation of the results of retraining accident repeaters is more difficult, as there is a natural tendency for the number of accidents experienced by these drivers to regress towards average in a subsequent observation period. However, Thorndike (1951) reports a 60 per cent reduction of accidents following retraining of a group of 400 accident repeaters; the accident experience of a comparable control group, not retrained, remained unchanged. Similar results were reported by Shellow (1926) and by Slocombe and Brakeman (1931).

An example of the effectiveness of *legislation* covering road users in the prevention of road traffic accidents is provided by those countries and states in which there is legislation making it an offence for a driver with a blood-alcohol concentration above a stated amount to drive a motor vehicle. When the state of Tennessee, in the United States, introduced mandatory blood-alcohol tests for drivers in 1956. associated with surprise highway checks by the police, there were 16 per cent fewer fatalities than in 1955. During the same period 40 other states of the United States showed an increase in traffic fatalities.

The crash helmet for motorcyclists, the importance of which was first emphasized by Sir Hugh Cairns in 1940, affords an important example of personal protection which is effective in reducing head injuries and therefore fatalities, provided the helmets are of satisfactory construction.

Many other measures which have been applied to the prevention of traffic accidents have undoubtedly made an effective contribution, but it is difficult to obtain statistical evidence of their effectiveness. This is due to the difficulty of studying in isolation the effect of one factor selected from among many, when at the same time changes may have taken place in the effect of the many.

Emergency medical care

Efficient accident services, promptly available, may in some instances save lives and more frequently may prevent the worsening of injuries received in road traffic accidents. Accident services, more speedily available in cities than in rural areas, therefore play an important part in the prevention and reduction of mortality.

Modern accident surgery can make a valuable contribution; prompt and efficient treatment by an experienced surgical team considerably increases the patient's chances of recovery in many cases and shortens the period of incapacity in most. These factors are also of considerable economic importance. The causes and treatment of orthopedic injuries in road traffic accidents are described by Kulowski (1960). In major cities it is relatively easy to organize the rapid removal of casualties to an emergency surgical team at particular hospitals where special units for accident surgery are provided. In rural areas there may be great distances between the site of an accident and the nearest surgical team, but a well-organized casualty service can still do much to promote recovery from injuries received in road traffic accidents. Such a service would include, among other facilities, first-aid treatment, ambulances distributed at strategic points, and arrangements for attendance of medical practitioners at the scene of accidents when required. Modern rehabilitation measures for injured victims form an essential part of the casualty service.

FUTURE PERSPECTIVES

The prevention of mortality and injury from road traffic accidents is essentially a public health problem. Public health departments in all parts of the world have dealt, and continue to deal, effectively with epidemic and communicable disease, using orthodox techniques of preventive medicine and epidemiology. More than 100 000 persons are killed and many more are injured in road traffic accidents throughout the world annually, and the attention of public health departments everywhere should be directed towards the prevention of this new epidemic. Medical care and rehabilitation are already in hand, albeit some improvements in these may be necessary. But what of prevention? Community thinking should be reoriented in the direction of the question "Is there such a thing as a road traffic accident for which no one is to blame?" Criteria for legal liability are fairly clearly established, but a high standard of personal moral responsibility is also necessary. The public conscience should be so developed that every individual automatically *thinks* preventively about road traffic accidents. This is a problem of health education.

Owing to the multiplicity of factors operating in the causation of road traffic accidents, it is unlikely that there can be any single preventive measure adequate to produce effective minimization of accidents. The complete prevention of all road traffic accidents which result in death or serious injury seems at the present time an impossible ideal. But the problem is a relatively new one, having arisen on a large scale only in the past half-century, and new and effective measures are needed to combat it. No one can tell at present what is the minimum number of road traffic accidents causing personal injury that can be achieved in any given community; but it is certainly much smaller than present-day figures.

Administrative measures

The multiplicity of the circumstantial and environmental factors concerned in the causation of accidents suggests a need for multiple preventive measures. Preventive action involves the co-operation of experts in many fields, and in particular highway and traffic engineers, town planners, automobile manufacturers, medical practitioners, psychiatrists and psychologists, teachers, public relations and publicity experts, police and enforcement officers, and representatives of the public. One of the first and most important steps in prevention is to bring all these individuals together as a single-minded team for the purpose of *preventing* road traffic accidents in their area. Public administrators would take the lead in this undertaking. Responsibility for prevention should be vested in the team, operating as a road accident prevention committee, preferably with statutory duties for this purpose. In many areas, voluntary committees have already made a useful contribution.

At present in many countries and territories there is a division of local administrative and legal responsibility for the prevention of road traffic accidents among numerous authorities. This leads to confusion and the lack of any well co-ordinated system or method of handling road traffic accident prevention as a specific problem. Local accident investigation should include, as a routine, site inquiries, personal inquiries and vehicle investigation. The establishment of a statutory body, charged with the prevention of road traffic accidents, might be considered, at least on an experimental or research basis in one or two areas. Such a body would be able, at the very least, to draw lessons from current accidents for application in prevention. Instead of many bodies with a partial interest, *one* authority, such as the public health department, should be clearly responsible for the prevention of road traffic accidents.

A reduction in road traffic accidents is unlikely to take place suddenly as the result of any one action, but the steady and continued application of many measures, perhaps small in themselves, over a long period, may be the most effective approach to prevention.

In order to assess the effectiveness of any preventive measures adopted, it is essential to maintain an adequate system of records in each area, so that trends in accident frequency may be observed, for example, from year to year. A system of accident reporting which is uniform throughout the area and as accurate as possible should be adopted. A uniform classification should be used, such as that of the *International Classification of Diseases* (1955 rev. ed.) published by the World Health Organization. Uniform definitions of road traffic (motor vehicle) accidents are described in a publication of the United States Department of Health, Education and Welfare (1956). Each country and territory keeping adequate statistics of road traffic accidents maintains a central recording system, with records kept in a form suitable for analysis by modern methods for handling large masses of data. In smaller localities particulars of individual accidents involving personal injury should be recorded and, where suitable, spot maps maintained to indicate the occurrence of accidents at particular sites, leading to the application of any necessary preventive measures at the site. In studying statistics from different sources, differences in the base should be kept in mind. For example, some countries (e. g., England & Wales, Scotland, the United States) compile accident statistics on a *de facto* population basis, including tourists and excluding people travelling abroad; others (e. g., Austria, Denmark, Germany, Norway, Switzerland) classify deaths from accidents on the basis of residential population.

The road

Those who consider that the faults of human nature are incapable of much improvement believe that the greatest potential for increased safety lies in better roads. It is the purpose of the highway-design engineer to ensure that an increasing volume of traffic is able to move expeditiously and safely on new and improved roads. Many highly developed countries have inherited narrow and winding roads which are quite unsuitable for motorized vehicular traffic. Half a century ago the design need was "to get out of the mud, first with dustless and later with paved surfaces. Width was sufficient if two vehicles could squeeze by one another... the problem of the motorist was not how fast he could reach his destination, but whether he could get there at all" (Holmes, 1958). Highway engineers are now able to design roads which are adequate to meet all reasonable safety requirements; no doubt further road research will enable design (and surfacing) improvements to be made, but sufficient knowledge already exists to enable those responsible to provide roads with a high degree of safety. The problem has become an economic one, and in many cities the cost of providing adequate roads is prohibitive because of the expense of clearing away existing buildings in order to widen the roads. A new road built today may be in existence for many years ahead, and it is necessary in planning such roads to estimate traffic needs in, say, fifty or more years' time. Such estimates are notoriously likely to go astray, but the attempt should be made, and the road planned, on the basis not of present but of future traffic requirements. Here, particularly, countries which are developing into the motorization era can profit by the building difficulties which have bedevilled traffic movement and safety in highly motorized countries, especially in cities. Perhaps the city of the future will have very wide roads, with rigidly controlled pedestrian crossings or subways, and very tall buildings with ample parking stations. The modifications of existing roads which become practicable from time to time within economic limitations present interesting problems for the traffic engineer, particularly from the safety aspect. The engineer recognizes that design must be fitted to the physical and mental capabilities of motor vehicle drivers, as well as providing the highest practicable traffic flow. The design and positioning of direction and warning signs continue to receive detailed consideration. It has been shown that turnpikes, motorways, *autobahnen*, and *autostrade*, the wide dual carriageways without side turnings between cities, have a reduced incidence of road traffic accidents compared with rural roads generally. For accident prevention in intercity traffic it is becoming clear that roads should be built of adequate width, with restricted access, dual carriageways, and overpass (flyover) junctions; there should be no railroad crossings, no stop signs, no traffic lights. At the same time, speed should be restricted to moderate and realistic levels, and speed limits strictly enforced. Curves and gradients should be limited to safe values, and pedestrian traffic entirely segregated. Separate lanes, with their own access, should be provided for cyclists where they are numerous enough to justify such provision.

In cities there is rarely an opportunity for redesign on a large scale, but the centres of Rotterdam (Holland) and Coventry (England), which were largely destroyed in the Second World War, have been reconstructed: a central shopping area has been provided with wide pavements for pedestrians and no vehicular traffic. These are examples of the scope which is possible in town planning to provide city areas with a high degree of safety. Most improvements must necessarily be on a smaller scale, with street widening, channelization at difficult intersections, schemes for improved lighting, and the provision of underpasses and overpasses when the opportunity arises. Throughout urban areas the segregation of pedestrians from motor vehicle traffic — for example, by the provision of guard rails at the pavement edge — is a safety measure which should be extended.

The traffic engineer, who occupies a key position in the road traffic accident prevention team, is fully aware of the techniques at his command and of their value in promoting road safety; his activities are normally limited only by the amount of money available for highway improvements, which is decided by each community.

The vehicle

There are two aspects of vehicle design that are important for safety: accident prevention and injury prevention.

Accident prevention. This covers features which are pertinent to the efficiency and comfort of the driver and hence reduce his liability to incur accidents. These include such items as wide window areas of visibility, seating design, the location and design of electric switches, and location and ease of visibility of instruments. For example, Fosberry (1958) described methods of measuring and improving visibility from the driver's seat. Motor vehicle design features in relation to safety were studied by McFarland and Moseley (1954), who described a procedure for evaluating vehicles in terms of human requirements. They gave design specifications, particularly for trucks and buses, which would accommodate at least 90 per cent of all drivers in comfort. The incorporation of these data in vehicle design leads to an increasingly effective integration of man and machine, with increased efficiency and safety of operation. Riding comfort has some value as a safety factor, but insufficient attention has so far been paid to seating design. Schneider (1960) has proposed a seat designed to overcome tiredness in the muscular system of the back. In Schneider's design, the seat cushion is constructed in two parts and the seat and the backrest follow the anatomic shape of the spine and pelvis, local pressures being reduced. An important feature for comfort is that the seat surface should be made of a porous material.

The maximum speed of vehicles, and of their acceleration, could be physically restricted between any prescribed limits by imposing design limits on the manufacturers. Such restrictions may have to be considered if the high incidence of road traffic accidents continues. If speeds were controlled to a maximum of 49 m.p.h., for example, 40 per cent of the dangerous and fatal injuries to vehicle occupants in the United States would be prevented (Cornell University Medical School, 1957).

Much attention has been paid to the design of vehicle headlights so as to avoid glare, but there is still room for improvement, particularly in the servicing and maintenance of vehicles already on the road. The use of polarized light in headlights, discussed by Jehu (1956), is not yet sufficiently advanced for general use. Adequate ventilation is important for safety, particularly in cold weather when the interior of the vehicle may be warmed without sufficient changes of air.

Although a relatively small proportion of accidents appear to be due to vehicular defects, a high standard of maintenance is clearly desirable. A driver who is momentarily at fault is likely to have a better chance of recovery with an efficient vehicle than with one in which the brakes or steering are faulty. When tests are undertaken, as has been shown in a previous chapter, the commonest defects found are in brakes, lighting, tires and steering. The compulsory testing of vehicles at intervals of six months or so, irrespective of the age of the vehicle, would undoubtedly reduce the incidence of such defects. In addition, owners of vehicles, knowing that such tests were to take place, would be likely to maintain their vehicles in good condition so as to meet the test requirements. There should also be a regular check of the exhaust system, leaks in which may result in the accumulation of dangerous fumes within the vehicle.

Injury prevention. The second safety aspect of vehicle design is concerned with the reduction of the degree of injury when an accident occurs. This involves (1) the elimination of projections and sharp cutting edges from the exterior of the vehicle in order to reduce the extent of certain injuries in the event of collision with, e.g., a pedestrian, and (2) the design of the interior of the vehicle in such a way as to reduce injury to the occupants in the event of collision. The latter project has been studied particularly in the work of the Automotive Crash Injury Research team undertaken at Cornell University Medical School (1958). It was found in this research that in many collisions involving serious injury, one or more of the occupants were ejected from the vehicle. Ejection multiplies fivefold the risk of being killed. The frequency of ejection from the vehicle after collision differs in different countries; it is less common in Britain than in the United States, for example. Head injury is the main cause of death among vehicle occupants, due mainly to impact against the windscreen, roof, dashboard and steering column; the steering column is also liable to cause serious chest injury. The actual kinematics of crash injury were demonstrated by experimental front-end crashes of cars containing life-size dummies. Films of these experiments showed the front-seat occupants thrown forward and upward, hitting their heads against the windscreen, roof or dashboard. Rear-seat occupants were flung upward and forward against the roof or even the windscreen and were frequently sprung back into the rear seat, all within a few milliseconds. It was clearly demonstrated in this research that the injuries sustained by vehicle occupants in an accident are determined largely by the structure of the vehicle, in particular its interior structure and the relationship of the occupants to the interior. According to J. C. Lane (personal communication), an improvement in the design of door latches, to reduce the chance of ejection, reduced the percentage of occupants ejected from 11.9 per cent to 6.1 per cent, with a corresponding reduction in the percentage of occupants suffering dangerous or fatal injuries from 9.3 per cent to 6.6 per cent.

The Cornell work also provides the main data on which the introduction of safety belts has been based. To be effective, the belt must be firmly fixed to the floor and must cross over one shoulder at least. So fixed, it will, in the event of accident, prevent ejection of the occupant from the vehicle and reduce the kinetic energy with which the head or chest strikes an object in the vehicle. In many accidents that are now fatal, the decelerative forces are within the physiological limits for survival; a human being, properly restrained, can withstand high decelerative forces without injury, but sudden stopping at a speed of 15 m.p.h. can cause death if the momentum of the head is not checked.

Under these conditions, if a fixed object 1 cm square is struck by the skull, a puncture fracture results (De Haven, 1944).

The hub of the steering wheel should be recessed for safety to move it farther away from the driver's chest and reduce the likelihood and the severity of injury. The rim and spokes of the steering wheel should be carefully designed so as to support and decelerate the chest before the hub area is contacted. A steering column which will yield on sudden pressure is an additional safety measure. In some cars dashboard padding is provided, but conclusive evidence of the value of this is not yet available; sponge-rubber padding is inefficient, and special energy-absorbing padding, made of low-density plastic foam, should be used. The elimination of all sharp projections and knobs is also an important feature of interior design.

The design of motor vehicles in such a way as to include maximum safety factors is a problem for the manufacturers. Public demand is most important, as it affects the salability of new motor vehicles, and available methods of educative propaganda could usefully be employed in leading the public to demand a high standard of safety in new vehicles. The manufacturer's task is to provide a vehicle of structural strength and mechanical reliability, so designed that misuse is both less likely and less harmful; but the manufacturer can only encourage and facilitate safe driving.

A large proportion of the serious and fatal injuries to vehicle occupants are head injuries, many of which would have been rendered much less serious if an efficient safety cap had been worn. A safety cap suitable for use by motorists has been designed by Gissane (1959).

In the design of two-wheeled vehicles, particularly motorcycles, metal bars (" crash bars ") fixed low down on the outside of the vehicle reduce to some extent the likelihood of injury to the driver's legs in the event of an accident.

The road user

The main scope for effective prevention of road traffic accidents lies with the road user. A steadily improving standard of performance by road users would reduce the accident toll correspondingly. No single measure is likely to be effective in itself, and continuing efforts are needed in many sectors, as new generations of road users grow up and need to acquire safe habits and techniques.

Education. Safety education should start with very young children, who should be taught how to behave as pedestrians in modern road traffic. Such education must be the responsibility of the parents until the child attends school. Safety education of parents by modern techniques, using radio, television and the press, is therefore important here. Public health authorities also have a part to play in the instruction of the pre-school child and the parents in road safety. The young child with a small bicycle or tricycle should not be allowed to ride it in road traffic. Children under the age of fifteen who ride bicycles are particularly liable to road traffic accidents. In congested urban traffic it may be wiser for the child not to ride a bicycle at all; where there is less danger, the child should be taught how to control the vehicle competently before he is allowed on the road and should also be taught the principles of riding in traffic, good habits of road safety and a good traffic sense. Such instruction, promoted by public health authorities, may be given in schools and reinforced by demonstrations, for example, by the police. A child living in a modern city needs to acquire a good road sense at an early age if accidental death or injury is to be avoided. Here again, good co-operation between the various authorities concerned is essential in order to obtain the best results, and the procedure must be continuous as successive generations of children take to the roads. The importance of road safety training of children cannot be overestimated.

Education in road safety in fact continues through life into old age, when pedestrians are especially vulnerable. An important aim of road-safety education is to improve the driver-pedestrian relationship. Certain safety rules should be impressed on pedestrians at an early age, such as the importance of facing oncoming traffic and of wearing some white object at night so as to be clearly visible to motorists. Exhortation to particular groups of road users, such as motorcyclists or car drivers, may be undertaken through the usual propaganda media of posters, radio, television, leaflets and the press. Views differ as to the display of horror and tragedy in this way, but the more horrific posters may bring home effectively the possibly tragic results of a few moments' carelessness. Such propaganda should be reinforced at certain holiday times, for example, before Christmas Eve in some countries, when it is known that the incidence of accidents increases. In France, an " accident-free day " has been held annually; such a campaign undoubtedly brings home to road users the fact that they themselves have the opportunity to reduce the number of road traffic accidents. The planning and execution of a road-safety campaign in Denmark and its results were described by Duurloo (1957).

In many countries a code of safe behaviour on the roads, covering all categories of road user, has been published; in the United Kingdom, for example, the *Highway Code* is well known and applicants for driving licences are required to state that they have read the *Code*. Such codes of behaviour go far beyond the legal requirements, and if they were acted upon by all road users at all times they would undoubtedly reduce the incidence of road traffic accidents very considerably.

Training. The training of motor vehicle drivers is of the greatest importance. Before being allowed to drive on the public roads unaccompanied by an experienced driver, the learner should have a thorough grounding, not only in the technique of handling the vehicle, but also in behaviour on the road and in safety. The training period before a driving licence is first obtained should be spread over a period of several months, although it may be less when training is given full-time. Whether driving a motor vehicle is regarded as a privilege or as a right, no one should be permitted to drive until he has shown himself competent. This implies that every driver should be required to pass a test of ability before being granted a licence; the test should be an adequate test of competence in handling the vehicle and of behaviour on the road. Even more important than a driving test, however, is the method of training drivers. Driver training could usefully begin with older schoolchildren, as it does in some countries. There should be a prolonged period of training, with a prescribed number of hours of both theoretical and practical tuition, preferably in government-controlled or licensed driving schools. Where there is a system of tests of drivers before licences are issued and the driver-training schools are not adequately controlled, there is a danger that the schools may emphasize teaching of the techniques for passing the test rather than the techniques of safe driving. The training of an adequate number of approved driving instructors to a high standard is essential. It is far better to train drivers adequately before they go on the road in the first place than to try to effect improvement later by such methods as the withdrawal or suspension of licences, a penalty which may operate very unevenly. Training should include practice in driving in traffic, at night, and on modern motorways, together with the recognition of emergency situations. For example, in an analysis of bad-weather accidents on the Pennsylvania Turnpike, it was observed that driving practices often precipitated skidding or prolonged it; training in the dangers and prevention of skidding is required. Blotzer et al. (1954) found that important factors in the causation of these accidents were inexperience in preventing skids and in handling skidding vehicles, and lack of training in this aspect of driving. Drivers should be taught how to drive *defensively*—that is, not only to avoid accident situations, but also to allow for a wide margin of error on the part of other road users. This concept of safe driving is opposed to the common practice of expecting other road users always to do what is right. It should not be made unduly difficult to obtain a driving licence, but no one should be licensed until a high standard of proficiency has been acquired, with practical training. It is probable that at present the standards for driver training in all countries are lower than is desirable. A considerable improvement in driver training might well be an effective step forward in accident prevention.

The training of motorcyclists presents a special difficulty as they cannot normally be accompanied by an experienced driver. It has been shown (page 36) that two of the major factors in accidents to motorcyclists are inexperience and size of the machine (cylinder capacity). Compulsory training of learner-motorcyclists *off the roads*—for example, on school playgrounds or on tracks specially constructed for the purpose—followed by a proficiency test before learners are allowed to use the roads would be a useful measure of accident reduction. Experience should be gained in conditions of safety. Such compulsory training would not be costly in relation to the cost of the present large number of accidents to inexperienced motorcyclists; most of these are young men, whose loss to the community means the loss of their education and many productive years of life. Motorcyclists should be allowed to drive the heavier machines only after they have had experience with lighter ones. The wearing of crash helmets by motorcyclists is a useful measure of injury prevention.

Certain practical advice can usefully be given to drivers from time to time, for example, weather reports with information on difficult or dangerous road conditions. Such matters as the prevention of fatigue while driving should be called to the attention of drivers: the need for adequate rest periods before driving, the advisability of resting for a few minutes every two hours or so on a really long drive, and the importance of getting out of the vehicle and walking round for a short time when drowsiness develops. These measures should be taught in driver training and mentioned again from time to time in educative propaganda.

Licensing of drivers. The licensing of drivers is an important area for the reduction of road traffic accidents. It has already been mentioned that the requirements for obtaining the initial licence should be strengthened. Provisional licences are sometimes issued to drivers under instruction, but such drivers (except motorcyclists) should not be permitted to drive unless they are accompanied by a fully licensed driver.

Limited or restricted licences may be issued, for example, with speed restrictions, or requiring the wearing of spectacles; this is a useful safety measure in particular circumstances. Drivers with certain physical disabilities may be licensed to drive only a vehicle with modified controls or a special type of vehicle for disabled persons. A compulsory medical examination (in addition to any eyesight test that may be given) before the issue of a private-car driving licence is sometimes advocated; in most countries a driver of a public-transport vehicle must undergo medical examination initially and periodically. Bearing in mind the large numbers of licences issued and consequently the numbers of medical examinations that would be required, together with the relatively few accidents that are associated with organic disease detectable at a routine examination, it may not be practicable in some countries to require medical examination before the issue of licences to drive private cars. The applicant for a driving licence to drive any kind of motor vehicle should be given at least a simple eyesight test, perhaps by an optician, and should be required to sign a declaration of health, information being particularly required about " blackouts ", fainting attacks, epilepsy, giddiness, diabetes, heart disease and some other conditions. The applicant should be asked whether he has *ever* suffered from these conditions, not whether he is suffering " at present ", because he may —incorrectly—regard himself as cured if, for example, he is an epileptic who has not experienced an attack for some time. The application forms of those who are suffering from declared disease or infirmity should be scrutinized by a medical practitioner in the public health department, who would arrange for a medical examination in doubtful cases. It is preferable for such examinations to be made by an independent medical examiner in view of the difficulties that might arise, in the event of certification of unfitness, between the driver-patient and his usual medical attendant. A medical examiner so appointed would also be available to examine drivers on other occasions when doubt arose as to medical fitness—for example, by court order. Licences should not be issued for too long a period without renewal; chronic illnesses which may affect driving can develop within a relatively short period, and if licences are issued for more than a year there should be an annual declaration of physical fitness. It is probable that there should be medical examinations, perhaps annually, of drivers at the higher ages, 70 and above, in order to detect the development of chronic and degenerative conditions that may adversely affect driving performance, although it must be admitted that little evidence is so far available about the accident rates of these elderly drivers. Good eyesight is of obvious importance for safe driving, and defects found at routine eyesight examinations, which might usefully be undertaken periodically, would usually be correctible with spectacles; in suitable cases the licence would be endorsed to the effect that the driver must always wear his glasses when driving. In a few instances where the vision could not be corrected to a safe level the driver would not be permitted to drive and the licence would be refused or revoked. In such cases there should be provision for an appeal. Eyesight examinations can be undertaken far more rapidly in most cases than a full medical examination, so the time required for large numbers of examinations should not present a difficult problem.

General. When motor vehicle drivers have been trained and have received their licences, continuing educative measures should be brought to their attention, aimed at maintaining and improving their level of performance. In addition to the usual propaganda techniques, a form of advanced driving certificate might be an incentive to improving skill; in Great Britain such a certificate is obtainable after examination and test from the Institute of Advanced Motorists.

The issuance to every driver of a personal accident record, in which would be entered particulars of all accidents involving injury to a person in which he was concerned, would be a strong incentive to drivers to avoid accidents. An official body, presumably the police, would be responsible for ensuring that accident particulars were correctly entered in the driver's record book. Since some drivers have considerably more accidents than others, even on a chance distribution, and since there are great variations in mileage driven, such an accident record should not be used in evidence against a driver in any alleged offence. Such records might, however, be of some value in identifying accident repeaters. Duplicate records would need to be maintained by the authority concerned, in case of loss.

In urban areas and particularly in major cities, speed restrictions are commonly imposed on vehicle drivers. Where such restrictions are considered to form an essential part of road safety, it is important to ensure that they are strictly enforced. In these densely populated areas, accidents affecting pedestrians are common, and legislation to restrict the movements of pedestrians could also be an important measure of road safety. Thus, if pedestrians were permitted to cross roads only at recognized and clearly marked crossings where they had priority, there should be a reduction in pedestrian accidents. This legislative procedure should be regarded only as the first step in the important principle of segregating pedestrians from road traffic.

Penalties applied to road users may operate unevenly, particularly for drivers. The suspension of a driving licence may be a triviality to an occasional driver but a disaster to a man whose livelihood depends on driving. Nevertheless, the withdrawal of a driving licence for a short period of two or three weeks might sometimes be a useful and salutary penalty; considerable discretion should be available to courts of law to suspend licences for short or long periods, and greater use might perhaps be made of such powers. An increase in penalties for offences is, however, not likely to be so effective a deterrent as an increased probability of detection. Unfortunately the nature of driving offences and the relative paucity of enforcement officers are such that there is a fair chance of " getting away with it " unless an accident results. In these circumstances, education in road-safety measures offers one of the most promising possibilities for accident prevention.

It is essential that public opinion should hold widely and strongly to the view that safety is more important than speed. Education in road safety through the many propaganda media now available deserves active support from both voluntary and official circles. Exclusive reliance on legal enforcement is not likely to be adequate by itself; in fact, it should be regarded only as a last resort when other persuasive measures have failed. The strengthening of public opinion in the direction of safety needs to be pressed, and pressed continuously. The creation and development of a social climate which is conducive to the cultivation of good road manners should be a natural effort for a cultured community of mature citizens. Good manners are life-saving on the roads.

Both for accident repeaters and for drivers who are found guilty of traffic offences, a "traffic clinic" such as those in Detroit and in the state of New Jersey in the United States may be of considerable value. The detection and treatment of those suffering from medical, visual, and psychological conditions and the withdrawal of licences from those who cannot be rehabilitated are useful measures of accident prevention. In these and in some other places, traffic offenders are required to attend a course of lectures, a procedure that may be of some value in improving the performance level of drivers who have shown themselves to be inadequate.

Finally, there is the difficult question of education and legislation regarding the consumption of alcohol by a driver. As discussed in Chapter 4, it appears likely that some 25 to 50 per cent of road traffic accidents are associated with the consumption of alcohol and would probably not have occurred if the road users concerned had not been drinking. In most countries it is an offence to drive (in some, to be in charge of) a motor vehicle while under the influence of alcohol to such an extent as to be incapable of proper control of the vehicle. This usually means clinical intoxication, and, as has been shown, a driver's performance and safety begin to deteriorate considerably before intoxication is clinically evident. In Norway and Sweden it is an offence to drive a motor vehicle when the alcohol content is 50 mg per 100 ml of blood or above, and in the United States, when the blood-alcohol level is 150 mg/100 ml. Tests may be made after accidents or at other times, generally using breath-exhalation methods, which are considered to give a reliable indication of the amount of alcohol in the blood stream. The knowledge that such tests may be made is likely to be of preventive value as a deterrent to drivers. There can be no doubt that if no motor vehicle drivers ever drove when their blood-alcohol level was 50 mg/100 ml or more, there would be a reduction in accidents, and legislation to this end might therefore be an effective accident-prevention measure. Such legislation has so far been applied particularly to motor vehicle drivers, who hold the safety of others in their hands, but it is equally applicable to cyclists—indeed, possibly more so because of the balancing required when riding on two wheels. The judgement of a pedestrian may also be affected by the consumption of alcohol, and it is known that many pedestrians fatally injured had previously been drinking considerable amounts. Here the better method of prevention lies in education and propaganda, with frequent reminders, particularly before public holidays.

CHAPTER 7

NEED FOR FURTHER INVESTIGATIONS AND RESEARCH

Road traffic accidents in large numbers are of comparatively recent origin in the more highly developed countries and are only beginning to be a problem in the less highly developed. At this early stage preventive measures should be generally easier to apply, and it is therefore very important that the lessons painfully learned by highly motorized countries should be made fully available and applied whenever practicable in countries where motorization is developing.

An investigation should be undertaken of the direct and indirect cost of road traffic accidents. Such an economic study would provide information on which to base expenditure in the different fields of research. Apart from the saving in human life, pain and suffering, an estimate could be made of the potential economic results of certain investigations. The economic incentives to safety, both personal and under insurance-company schemes, merit further study to see whether they could be strengthened.

As in many public health fields, research on road traffic accidents in most of the highly motorized countries has not been centrally co-ordinated. Consequently research has been undertaken, without a clear-cut over-all programme, by many independent groups including, for example, government-sponsored units, universities and voluntary bodies. This freedom to develop spontaneously but haphazardly may be desirable in certain research fields, but in road traffic accident research the first essential would appear to be the development of a planned programme on a national basis. This essential administrative step would enable available resources to be applied where they are most needed. Overlapping of research on the same problem and dissipation of effort would be avoided. At the same time, by bringing together as a team the research workers in the road traffic accident and some related fields, a considerable stimulus would be given to research on traffic-accident prevention. There is some international co-ordination for exchange of views, results and ideas, and such international exchanges should be strengthened. The first research measure needed is therefore an administrative one in order to make the best use of the research workers and facilities available.

It is surprising that, although air and rail accidents are normally fully investigated as to causation, similar inquiries are seldom held in respect of road accidents, even where there is more than one fatality. Consequently, little of a factual nature is known about the causes of road traffic accidents. Inquiries are, of course, made in fatal accidents in some countries by such authorities as the coroner, whose duty it is to ascertain the cause of death, and by the police, who consider prosecution in cases of infringement of the law. But no one authority is normally charged with the duty of investigation of road accidents with a view to prevention.

It is important but often difficult to try to measure the effectiveness of any measures adopted for the prevention of road traffic accidents. The following paragraphs give examples of areas in which research is needed; the list is not complete and many other projects will need to be developed.

THE ROAD

Research in respect of roads is actively pursued at the present time but could usefully be intensified in some sectors. The physics of skidding, for example, in relation to tire design and type of road surface merits further exploration, as skidding is a common occurrence in accidents. The search for road surfaces with improved skid-resistance and durability should be continued.

Traffic-engineering techniques and traffic-flow studies should be pursued largely from the safety angle in order to design highways with the highest safety factor—vehicle speed and traffic flow in themselves being secondary considerations, although these three factors are correlated.

The comparison of accident rates, based on exposure to risk (vehicle mileage travelled), on newly constructed motorways and on other main roads can usefully be continued in order to investigate design features associated with variations in the incidence of accidents. The design of motorways in such a way as to avoid monotony, with its risk of loss of vigilance, should be studied.

Research on the lighting of different types of roads, to provide lighting which is efficient, economical and conducive to safety, should continue to be actively pursued. Studies of traffic signs, signals, warning devices and other information displays should be undertaken in relation to the human factors that enter into their interpretation.

As a large proportion of accidents involve pedestrians, research is needed into the practicability, economics and effectiveness of various methods of segregating pedestrians (and possibly cyclists also) from motor traffic.

THE VEHICLE

An investigation is needed of the ventilation and microclimate in modern enclosed cars, in relation to the possible development of drowsiness and fatigue.

Studies of the biomechanics of road accidents should be strengthened. The few studies so far undertaken have given useful results and should be extended. Further investigation might be made, for example, into the physical distribution of injuries sustained in road traffic accidents by different types of road user; the distribution of injuries of differing severity should also be studied.

Research is needed on the effect on various body tissues of the kind of impact arising in road traffic accidents. The more serious and the fatal injuries to motor vehicle drivers appear to be principally those to the head and chest; improved "packaging" of drivers and passengers to reduce injury to these parts is a problem of research in vehicle design. Crash-protection studies of different vehicle designs should be undertaken. An investigation of the stresses which can be supported by the head, chest and other parts should be undertaken, for example, on the cadaver; variations due to age, body build, sex and mode of load application would need to be considered. Crash-injury research should be continued and broadened so as to ensure a complete and effective exploration of the generic aspects of injuries resulting from road traffic accidents. Studies of vehicular damage in relation to personal injuries should provide pointers for improved design. A clearer picture of injury patterns and of the most common combinations of injuries needs to be delineated. Such data would be useful to medical accident services and would help to develop an integrated approach to the treatment of trauma from road traffic accidents.

The effectiveness of different types of safety belt should be evaluated, and new protective devices, such as safety caps for motorists, should be studied as they are introduced.

The strengthening of the vehicle and the introduction of such features as hydraulic shock-absorbing bumpers (fenders) might usefully be investigated.

The use of electronic systems to control vehicle movements is unlikely to be of practical value in the foreseeable future, although limited experiments have been undertaken. Electronic equipment, installed under or along the road and in the vehicle, can furnish information to the driver as to road conditions ahead, the position of his vehicle on the road, and the presence and position of other vehicles; it could reduce the likelihood of collisions between vehicles through control of their speed and headway. Such provision would be enormously expensive and is unlikely to be installed on any large scale.

THE ROAD USER

Social studies of the different types of road user, regarding their possession of factual information about road accidents and safety, beliefs, attitudes towards traffic and safety measures, and attitudes towards other road users would provide useful information for the training of, for example, schoolchildren and motor vehicle drivers and would indicate weaknesses towards which safety-propaganda campaigns should be directed. An evaluation should be made routinely of the effectiveness of any general safety campaign.

Research is needed on the motivational aspects of safety and risk. Safety education often tends to be weak in this respect, as its motivations are usually negative and tend to have singularly little impact. Research into this aspect would need to be a detailed market-research type of activity, taking narrow segments of the population whose motivations towards safety may be entirely different. With such motivational information about, for example, teen-age motorcyclists and first-car motorists, it would be possible to develop educational programmes directed to those narrow groups of the population, rather than the grape-shot type of propaganda which is commonly used.

A detailed study of a sample of road traffic accidents should be undertaken. In view of the large numbers of accidents it would be practicable to study only a relatively small sample. This proposed research would include, for example, a detailed account of the activities during the preceding twenty-four hours of the road users concerned, particularly in respect of previous rest, meals, alcohol and drugs, together with eyesight and medical examinations. Details of the driving training and experience of any drivers concerned would also be obtained. A complete study of the occurrence of the accident itself would be included, together with the events immediately preceding it, particularly the behaviour of the road users concerned. Such studies, undertaken in full detail in respect of a relatively small number of personal-injury accidents, should yield results of considerable value as a guide to the training of road users and for educative propaganda in accident prevention. Researches of this nature would probably be best undertaken by a team of social workers; it would be essential to make it clear that the apportionment of blame would not be attempted, at least from a legal point of view.

Operational research on the behaviour of drivers and other road users is a neglected field which might be expected to yield results of considerable preventive value. Field studies of different types of risk-taking behaviour, irrespective of the actual occurrence of accidents, would be of much interest. For example, a study of driver and pedestrian behaviour at a sample of pedestrian crossings would give information which might be applied in legislation, education and propaganda, and in respect of individual items such as the quality of maintenance of crossings and the ease or difficulty with which they can be identified under different climatic and lighting conditions. Objective studies of overtaking on bends, behaviour at traffic lights and actual speed in relation to speed restrictions and the occurrence of accidents are examples of the type of research which should be continued and developed in this field. A study of trends in road-user behaviour would provide useful information regarding particular items requiring emphasis in the safety-propaganda campaigns.

More factual information about accidents should be recorded in order that certain research studies may be pursued. For example, drivers who have repeated accidents cannot usually be identified unless their accidents occur in the same police area; the age, sex and driving experience of drivers involved in accidents to others are not normally recorded. Such personal particulars of the road users concerned in personal-injury accidents should be recorded at a central office, at which accident repeaters would be identified. Comparative studies of accident repeaters and accident-free groups, already undertaken to some extent, should be extended to cover a wide range of psychological, emotional, medical and visual characteristics. Should individual motor vehicle drivers be identified who appeared to have considerably more than their fair share of accidents, it might be a useful research measure to establish a clinic for investigation and rehabilitation of such individuals, as has been undertaken at some centres in the United States. No penalty would be involved if no offence had been committed, and it should not prove too difficult to secure the co-operation of the individuals concerned. An essential part of this research would be to examine the subsequent accident records of rehabilitated drivers in order to study the effect of the procedures adopted.

As a separate research inquiry, adequate samples of drivers of different types of motor vehicle might be invited to record their mileage annually, so that a study could be made of their accident rates per million vehicle-miles travelled. Such studies would provide information of value about the accident rates of elderly drivers, which, if they proved to be high, would lead to preventive action—for example, additional tests or medical or eyesight examinations above a certain age. It might be that the accident rates of inexperienced drivers and drivers with little recent experience would prove to be high. When research investigations have revealed the facts in these respects, preventive action will need to be considered. Until the facts are known, preventive action tends to be based on opinions which may or may not be correct. Similar inquiries would provide information regarding sex differentiation in accident rates of drivers; here again, if any considerable differences were found, preventive action would be possible in respect of the higher-accident-rate group by means of education and training. The records made available in these investigations would be used for a study of accident-proneness, and in due course, when sufficient data had been collected, it should be possible to ascertain whether motor vehicle drivers can be identified who have a permanent condition of accident-proneness. If such drivers could be identified, investigation of the cause of the condition would be undertaken with a view to the institution of remedial measures, such as additional training. The community might be faced with a decision on whether to withdraw licences, temporarily or permanently, from accident-prone drivers, and a quantitative knowledge of the extent of accident-proneness would be helpful in making such a decision.

Further field studies are needed of the relation of alcohol consumption to the incidence of road traffic accidents, using control groups of road users not involved in accidents, as in the studies of Holcomb (1938), Lucas (1955), and Vamosi (quoted by Elbel, 1960) in respect of drivers, and of Haddon et al. (1960) for pedestrians. It has been clearly established that the consumption of alcohol by road users is responsible for a considerable proportion of road traffic accidents, but it is important that these studies should be pursued in order to assess quantitatively the causative relation of alcohol to road traffic accidents—that is, to determine the proportion of accidents that would have been prevented if the road users concerned had not consumed alcohol. The need for strengthened legislative and educative measures could then be assessed. Similar studies have not been undertaken in respect of drugs. Laboratory research is needed on the effect on driving efficiency and safety of many drugs in common use, using, for example, the method of study employed by Drew et al. (1958) for alcohol; the existence of idiosyncrasy and personal variation in the effects of drugs would need to be taken into consideration. The drugs most likely to be concerned are sedatives, hypnotics, antihistaminics, central-nervous-system stimulants (amphetamine and its derivatives), hypotensives and tranquillizers. Field studies of the influence of drugs as possible causative factors in road traffic accidents would perhaps best be undertaken as part of the intensive study of a sample of accidents, referred to above.

Research should be undertaken into the effects of different forms of fatigue on driving skill and safety, both in the laboratory and on the road, in order to determine the extent to which fatigue is a causative factor in road traffic accidents.

The objective measurement of driving skill, both in the laboratory and in the field, presents practical difficulties, but pilot studies of techniques have been made by Shaw (1957), and research will no doubt continue to develop. Laboratory studies of the nature of the driving task would provide information about the qualities required for safe driving. Assuming that these qualities, once identified, can be taught, the work of the psychological laboratory would be applied in driver-training schools. Experience, for example, cannot be taught, and the driver should acquire whatever experience is necessary—and only a specially conducted investigation will show how much this is—under conditions of safety. Studies should be undertaken, for example, to determine how much mileage must be covered in a given time in order for a driver to lose the high accident liability due to inexperience. It is often said that a new driver is relatively safe because he is aware of his lack of experience, but that after he has driven a few thousand miles he thinks he is experienced and tends to become involved in accident situations; after further mileage, adequate experience and consequent safety as a driver have been acquired. Only careful investigation will reveal the truth of this suggestion. Such investigations should also reveal the accident liability of people who drive only occasionally, or who drive after a lapse of some months or years.

Laboratory studies are likely to be of use in improving the method of training as well as its content. Research is needed on the effectiveness of different training methods in relation to subsequent safety on the road; research, that is, on the validation of the driver-training curriculum. In some countries tests are given to drivers before they obtain a driving licence; the content and the reliability of these tests in relation to future performance should be studied.

There is need for an analytical study of certain qualities required in motor vehicle driving, such as anticipation; many of these qualities can at present be approximately named and described but cannot be quantified and their relative importance assessed. If crucial personal qualities required for driving could be identified and if certain people were found to be lacking in these qualities, the elimination of such people from driving would then have to be considered.

Research is needed on the relationship between certain medical disabilities and the safety of road users. Epilepsy, for example, can be a considerable hazard. Accidents in which epilepsy appears to have been causative are rare, and the most practicable approach to research on this problem is through clinics attended by epileptics. In a study of 126 epileptic patients, of whom about 50 adults would have been expected to be motor vehicle drivers, Pond and Bidwell (1960) found 19 who were driving. Information is needed also regarding the relationship to road safety of diabetes, raised blood pressure and coronary artery disease, particularly in motor vehicle drivers. Studies should be undertaken of the driving records of patients suffering from these and other conditions. As there is no information available about the accident rates of deaf drivers and of those with orthopedic disabilities, an investigation might be made as soon as the exposure to risk (annual vehicle mileage) of such drivers could be compared with control groups. There is, however, no evidence to suggest that such drivers have high accident rates, and research on this problem would not need to be given high priority. An investigation of the eyesight and hearing of injured pedestrians might be of some value; but many people are reluctant to admit such defects. Drivers should undoubtedly be taught to expect to meet pedestrians with visual, auditory and locomotor defects.

Few studies have been made of eyesight in relation to road traffic accidents, and nothing is known of the extent, if any, to which minor defects of vision contribute to the causation of accidents. In the course of the study of a sample of motor vehicle accidents referred to above, the vision of road users concerned would be tested and information gained regarding any relationship that might exist between defective vision and accidents. The obstruction of lateral vision by wide side-pieces of spectacle frames might, for example, be of importance. Investigation of accident repeaters in comparison with accident-free groups of road users, particularly motor vehicle drivers, would also provide information regarding visual capacity. The investigations so far made have been on relatively small groups, and such research would be worth undertaking on a scale sufficient to give statistically reliable results, as many visual defects are correctible. The advisability of endorsement of driving licences to the effect that glasses must always be worn when driving might need to be considered. In this connexion, the role of visual acuity, lateral vision (visual fields), depth perception, muscle balance and perhaps visual and perceptual reaction time would need to be considered.

SUMMARY OF RESEARCH NEEDED

General

Investigation of the economic aspects of road traffic accidents and of incentives to safety

Administrative co-ordination of research

The road

Continuation and strengthening of research on the design, surfacing (particularly in relation to skidding), lighting, and traffic flow of roads

Studies of the practicability, economics and effectiveness of the segregation of pedestrians (and cyclists) from motor traffic

Comparison of accident rates on different types of road for different categories of road user

Studies of traffic signs, signals and warning devices in relation to the human factors affecting their interpretation

The vehicle

Studies of ventilation and microclimate in vehicles in relation to the development of drowsiness and fatigue

Strengthening of research on the biomechanics of injury

Studies of the effects on body tissues of impacts produced by accidents

Improved " packaging " of vehicle occupants and studies of interior safety features in design of vehicles

Crash-protection studies on different types of vehicle

Investigation of the stresses which can be supported by various parts of the body in relation to the load applied

Continuation and development of crash-injury research

Studies of the effectiveness of safety belts in injury prevention

Vehicle-design studies, e.g., strengthening of body construction, fitting of hydraulic bumpers (fenders)

The road user

Detailed investigation of a sample of road traffic accidents, including a personal study of the road users concerned in respect of such factors as previous driving experience and events leading up to the accident

Operational research on the behaviour of road users

Field studies of risk-taking behaviour and of driver-pedestrian relationships

Identification and study of accident repeaters, with follow-up studies of any rehabilitation procedures adopted

Objective studies of driving skills and of the qualities required for safe driving

Investigation of the effectiveness of different driver-training methods

A study of the value of driver-testing procedures

Studies of the accident rates (per million vehicle-miles driven) of drivers of different types of vehicle according to age, sex and experience

Further studies of the relation of alcohol to accidents

Investigation of the existence of any relation between drug consumption and accident occurrence

Investigation of the relation of medical conditions and of defective vision to accident occurrence

Studies of fatigue in relation to accidents

Studies of protective devices, such as safety caps for motorists, in relation to injury prevention

CONCLUSION

An important need is for the collection, summarizing and distribution of research findings, both nationally and internationally. The research projects discussed above do not form a complete list, nor is any one project discussed in detail, but sufficient indication has been given of the many fields in which research is needed. This multidisciplinary approach to the problem of the prevention of road traffic accidents necessitates a high degree of co-operation and team-work by all authorities concerned.

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