ENGINEERING ASPECTS

OF

TRAFFIC ACCIDENTS

IN

ADELAIDE, SOUTH AUSTRALIA.

A.J. McLean, B.E. (Mech.), Adelaide, 1961.

A thesis presented for the degree of Master of Engineering of the University of Adelaide, based on work in the Traffic Accident Research Unit of the Department of Pathology of the University of Adelaide.

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CONTENTS

SUMMARY

This thesis describes the concept, development and organisation of a multi-disciplinary, on-the-spot survey of metropolitan road traffic accidents. The survey was financed by the Australian Road Research Board, directed by Professor J.S. Robertson of the Department of Pathology of the University of Adelaide, and conducted by G.A. Ryan, M.B., B.S., and myself.

408 accidents were attended in the Adelaide metropolitan area in the years 1963 and 1964. These formed a representative 12.3% sample of all traffic accidents to which an ambulance was called.

The causation and consequences of each accident were investigated in detail. A comprehensive photographic record was made by the author, and sketch plans were drawn. A check-list form and punch card code were developed for the recording of the engineering data. A system developed for rating vehicle damage is described.

The following results of the engineering aspects of this survey are summarised here:

Pedestrian Accidents: 19% of the total sample.* The young, the elderly, and middle aged inebriates were the three main groups involved.

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* These percentages refer to the type of accident and not necessarily to the types of vehicles involved. For example, some pedestrian accidents involve motor cycles, trucks, etc.

Risk of involvement was highest for elderly people.

The installation of pedestrian crossings and median strips may each reduce the frequency of pedestrian accidents by as much as one sixth.

The post-impact motion of a pedestrian, and the injuries he receives, depend largely on the shape of the front of the striking car and its speed on impact. The relationship between pedestrian injuries and certain detail features of vehicle body design is illustrated.

Pedal Cycle Accidents: 11%. These frequently involved a boy cyclist turning across the path of a car, not at an intersection. A cyclist was more likely to be struck from the rear at night than in the day.

The kinematics of the pedal cyclist/car impact are described.

Motorcycle Accidents: 14%. Most were at intersections and involved another vehicle turning across the path of the motorcycle.

Injuries to motorcyclists arose from both inertia loadings and direct impacts. Safety helmets complying with British Standard 2001 did not significantly reduce the incidence of concussion.

Truck Accidents: 3%. Most were collisions between a truck and another type of vehicle at an intersection.

Overhanging trays, exposed fuel tanks and lack of longitudinal restraint on door latches are among the design deficiencies noted.

Car Accidents: 47%. A collision with another car at an intersection was the most common type. Analysis of variance failed to show any significant relationship between impact geometry and injury severity or vehicle damage.

Single driver accidents were more often collisions with parked vehicles, trees or poles than rollovers without prior collisions.

The make and the year of manufacture are listed for the 553 cars in these accidents. The degree of vehicle damage, both sectional and overall, is related to speed on impact, and optimal damage scales are derived for these relationships. The cost of repair, when divided by the market value of the car, is shown to be closely related to the chosen scale for vehicle damage.

Damage to the interior of the car is listed, with specific reference to the steering wheel, instrument panel, rear vision mirror, and the front seat.

Safety glass for automobiles is discussed, with illustrated cases of damaged windscreens and side windows. Toughened glass windscreens were fitted to over ninety percent of these cars.

The incidence of severe to fatal injury was four times greater for the 3.4% of car occupants who were ejected. Ejection was associated more with spinning vehicles than with rollovers. 2.4% of the car occupants were wearing a seat belt. One twelfth of all car doors came open. Those door latches incorporating some form of longitudinal restraint failed half as frequently as others.

The average estimated travelling speed, for all motor vehicles, was 27 m.p.h. and, on impact, 20 m.p.h. Skid testing was used to estimate speeds in certain cases. Skidding in accidents is discussed in detail and illustrated. Skidding from braking was common on dry roads and depended greatly on the road surface.

Three-quarters of all car-to-car collisions were at or near intersections. One third of these intersections were controlled by traffic lights or a stop sign. Accidents at one particular signallised intersection are discussed in detail.

A methodfor calculating safe approach speeds at intersections is developed and compared with the method recommended by the American Association of State Highway Officers. The calculated safe speeds are compared with measured speeds at many intersections. Almost all of these measured speeds were higher than the corresponding safe speeds.

ACKNOWLEDGEMENTS

A survey such as this depends on the willing co-operation of many people. The St. John Ambulance Officers, notably Mr. H.G. Berry, and both staff and volunteer members rendered invaluable and essential support. Without the co-operation of the Ambulance radio controllers, under Corps Officer C. Scolyer, this survey would have been impossible. The Commissioner of Police (Brigadier J.G. McKinna), the Head of the Traffic Division (Inspector R.A. Wilson), the members of the Accident Investigation Squad under Sergeant S. Swaine, and all members of the police force contacted during this survey, gave Dr. Ryan and myself every possible assistance. The Commissioner of Highways, Mr. F.D. Jackman, and members of his staff, particularly Mr. A.K. Johinke and Mr. P.G. Pak-Poy, assisted us in the planning and execution of the survey.

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As this was a multidisciplinary study it is difficult to delineate clearly those aspects that are purely engineering. The planning of such a study also extends beyond one particular discipline. The role of Professor J.S. Robertson and particularly Dr. G.A. Ryan in the work presented in this thesis is emphasised and gratefully acknowledged.

This thesis is entirely my own composition and the work therein has not been presented for the award of any other degree in this or any other University.

A.J. McLEAN.

INTRODUCTION.

CHAPTER 1

1.1 Each year in Australia 3,000 people are killed and 60,000 injured on the roads. The very magnitude of these figures tends to conceal their meaning. The population of Australia is about 11,000,000. The mythical "average Australian" has one chance in 200 of being killed or injured on the roads in the next twelve months. Taking a lifetime view, based on three score years and ten, he has one chance in three. Yet again, each family of three or more people can expect that one member of that family will, sooner or later, be killed or injured on the roads. Road accidents have become perhaps the greatest public health problem in the Australian community.

1.2 Road accidents, however, are but one type of the range of events which we choose to call accidents. Particularly since the Second World War accidents have become more and more prominent as causes of death and injury. This increase is, in fact, only apparent. Developments in sanitation, of vaccines and of antibiotics have brought about a dramatic reduction in the incidence of deaths from infectious diseases. There has been no corresponding reduction in accident mortality. Therefore, particularly in the more developed countries, accident mortality has appeared to rise by remaining essentially unchanged in magnitude.

1.3 This is not to say that there have not been changes in the types of accidents. Faulkner (Ref. 1) has pointed out that "during the decade of the eighteen-fifties and even later a railroad passenger literally took his life in his hands ... An accident was considered an 'Act of God' rather than negligence on the part of the railroad". In the year 1888 some 5,693 persons were killed and 27,898 injured on the railroads of the U.S.A. (Ref. 2). With the adoption of safety devices such as the automatic vacuum brake and safer methods of operation, the hazards associated with rail transport have been greatly reduced. But as one hazard was being brought under control another, the road accident, was arising.

1.4 The substantially unchanged overall total of accidents has tended to encourage a fatalistic attitude. Even today it is not uncommon to hear certain types of accidents referred to as "Acts of God". Rolt, in his record of accidents on British Railways between 1840 and 1940, says "the pure 'accident' - the accident caused by fate alone - is rare on the railway" (Ref. 3; p.14). It is curious that this relic of determinism should linger on into what we are vain enough to call "this age of science". But, as Rolt indicates, comparatively few cases are now attributed to fate. He continues with an example of the modern scapegoat: "almost invariably human fallibility is responsible". This attitude is more commonly expressed by the phrase "people cause accidents".

1.5 The great bulk of road safety propaganda is aimed at the human operator. Unfortunately changes in human behaviour are difficult both to effect and to assess. Haddon et al (Ref. 4; p.2) have pointed out that "accidents remain the only major source of morbidity and mortality which many continue to view in essentially extrarational terms". This has had a deleterious effect on the study of accidents. Such work as has been attempted has rarely been more than mere tabulation. The study of accidents is considered in some way to be a "unique" field.

1.6 The lack of any systematic study has meant that such countermeasures as have been adopted have been based on "common sense". There has rarely been any detailed analysis either of the magnitude of the problem itself or of the effectiveness of any control. This is in marked contrast to the approach to other public health problems. The Salk polio vaccine, for example, was based on extensive knowledge of microbiology, laboratory experiment, and human testing. Despite this it was not endorsed for general use until extensive field evaluation had demonstrated its relative safety as well as its efficacy and cost.

1.7 There are many things which account for this difference in attitude. One of these is the way in which we choose to define an accident. An event is called an accident if it is both unexpected and also involves damage, be it to a person or an inanimate object. But not all types of unexpected damage are considered accidents. Physical damage, burns and poisonings may be accepted as such without question; but not damage due to biological agents. Today, disease is no longer assumed to be due to chance or fate. A polio sufferer would not be thought of as an accident victim. But the damage would have arisen from the unexpected ingestion of a polio virus, in much the same way as a child might have, accidentally, ingested a poisonous substance. The causal sequences would be almost identical.

1.8 This similarity continues into attempts at prevention. Selling milk in sealed bottles enables a physical barrier to be erected between harmful bacteria and the milk, and so prevents the bacteria from entering the body of the person who will drink the milk. Physical barriers, such as guards around moving machinery and insulation on electric cables, are used to prevent damage arising from "accidental" contact. These are not isolated examples. Almost all accident prevention measures have direct counterparts in the prevention of disease. Even attempts to modify human behaviour, so frequently attempted in accident prevention, have their place in the prevention of disease. Ensuring elementary personal hygiene is one example.

1.9 There is one further parallel between accidents and diseases that has rarely been recognised. Both road accidents and poliomyelitis are by-products of our modern civilisation. Both these modern epidemics have arisen in the twentieth century. They have both been largely confined to the more developed countries. Here the similarity ends. Whereas the effects of polio can now be prevented with any of the several vaccines that have been developed, both the incidence and the effects of road accidents continue to increase.

1.10 Even in the worst polio epidemic in the United States, the death rate from this disease was only 4% of the death rate from accidents over the same period. The Chief of the Research Grants Section, Division of Accident Prevention, U.S. Public Health Service, has estimated that "more than three hundred times as much money is currently being spent in the United States on medical research as on accident prevention research, despite the fact that accidents are the leading cause of death among those aged 1-34 and the cause of more than 45,000,000 injuries annually." (Ref. 4; p.4). The common assumption that accidents are either inevitable or caused by human behaviour has tended to delay progress in accident research.

1.11 In view of the many parallels that have been drawn between accidents and diseases it is well at this stage to look more closely at the methods that have been found successful in medical research. Haddon et al have pointed out that "every major (medical) research programme is to some extent interdisciplinary, the variety of disciplines reflecting the multiplicity of etiologic factors under investigation". (Ref. 4; p.4). When attempting to control an epidemic, it has been found necessary to study not only the victim but also his environment. Malaria is a case in point. Little progress was made until a painstaking study of the environment isolated the mosquito as the carrier of the disease. The approach applied to this and other epidemics has become known as epidemiology.

1.12 Gordon, writing in 1948 (Ref. 5), was the first to provide a conceptual framework which was applicable to the entire field of accident research. He noted that epidemiology has been successfully "extended from its original restriction to the communicable diseases to a broad application to mass disease of man; to cancer, diabetes, congenital anomalies and many others". He then went on to point out, with great significance for the future of accident research, "It is not so generally appreciated that injuries, as distinguished from disease, are equally susceptible to this approach, that accidents as a health problem of populations conform to the same biologic laws as do disease processes and regularly evidence comparable behaviour." He showed that it was possible to bring some degree of order into the seemingly chance events which lead up to accidents. Having done this, he showed that it was then possible to isolate individual parameters, assess their particular significance and also their interrelationships.

1.13 The basic ordering process of epidemiology recognises three main categories; host, agent, and environment. The host is the individual or structure affected by the accident. The agent is the factor which is the immediate cause of damage; an exchange of mechanical or thermal energy for example. An important sub-category is the vehicle, used in the general sense of the word, which carries the agent to the host. In the study reported in this thesis the vehicle is generally an automobile. The third category is the environment in which the accident occurs. In the case of traffic accidents, significant aspects of the environment may include traffic laws and social attitudes as well as the more obvious physical features of the road and traffic system. Without a general overview of the problem in this manner it is only too easy to neglect parameters and relationships which may be significant.

1.14 With the introduction of the methods of epidemiology the traditional emphasis on the chance aspect of accidents is being replaced by attempts to understand and prevent specific types of damage. This attitude is similar to that which is universally adopted in the study of infectious diseases. The nature and prevention of the disease, not the unexpectedness of its occurrence, is the point of concern.

1.15 There is a common tendency to attribute any given type of accident to one main cause. Road safety authorities, for example, have sometimes claimed that most road accidents were due to "excessive speed" or "inattentive driving". But it can be shown that most accidents are the result of many factors acting together in an extremely complex way. The problem then is one of identifying and assessing the significance of these many and varied factors. This is very difficult to do, even if all accidents of a given type can be studied. For this reason it is necessary to study the occurrence of these factors in the whole population. If it can be shown that any factor occurs more, or less, frequently among those involved in a certain type of accident than among those not involved, then this is an indication that the particular factor may be causally related to that particular type of accident. A study conducted in this manner is said to be a "controlled" study, and the non accident-involved group is called a "control" group.

1.16 Implicit in the above discussion is the assumption that the factors which may prove to be relevant are known in advance. This in turn requires an accurate knowledge of what actually happens in the phenomena to be studied. Research of this type has been termed the "natural history" phase of the development of any area of scientific concern. Haddon et al (Ref. 4; p.186) liken it to Darwin's observations in the field. They point out that "its essence is the open-ended observation and description of phenomena to discover variables which deductively seem to be of importance. Without continuing research of this type there can often be no assurance that variables more formally investigated have been realistically or wisely chosen." The engineering aspects of a study of this type are reported in this thesis. A representative sample of metropolitan road traffic accidents is analysed and the implications for the relevant branches of engineering are discussed.

HISTORICAL OUTLINE

CHAPTER 2

2.1 There have been comparatively few studies of traffic accidents at the scene, and those that have been attempted were all started within the last ten years. The initiative for these studies came, on the one hand, from persons responsible for treating people injured in traffic accidents, and on the other hand from groups already active in the study of accident frequencies. While hospital based studies were able to list the range of type and severity of road accident injuries they could not provide any information on the factors which led up to the production of the injuries. The study of the reports of road accidents was limited in two ways. The accuracy of the recorded information was not easy to assess; for example a police constable is reluctant to mention that an accident-involved driver has been drinking unless he is reasonably sure of securing a conviction. Also the amount of detail in official reports is rarely sufficient. This is not surprising in view of the extreme complexity of many traffic accidents. (Ref. 6).

2.2 The Road Research Laboratory in Britain began an on-the-spot study of road accidents in 1956. The unit consists of two regular members, an ex police officer and a medical student. Other members of the Vehicle Characteristics Section of the Laboratory occasionally go out with the team. Accidents occurring in the area between London Airport and Windsor are studied. This is largely a metropolitan area, but does also include two arterial roads, A4 and A40, and many minor rural roads. The team relies on telephone calls from local police units for information of accidents, and has attended up to 200 accidents per year. No attempt has been made to secure a representative sample of all accidents occurring in that area, and the unit is on call only during normal office hours. The work of this unit is described in References 7 and 8.

2.3 The main aim of this team's investigations has been to relate injury to vehicle design. Because the team has had no legally qualified medical practitioner working with it, it has had to rely on hospital reports for much of its information on injuries. It is obviously more desirable to have all injury assessments done by the one person, and for that person to have attended the accident at the scene.

2.4 Moreland (Ref. 9) developed a "Damage Index" to enable some estimation of accident severity to be made, based on damage to the vehicles involved. This Damage Index has theoretically 63 degrees of severity of damage. The laboratory has also investigated various methods of preparing plans of accident sites. Reference 10 discusses the stereo-photogrammetric analysis of road accident scenes. The unit is currently using a rapid and accurate method of vertical photography which it has developed. (Ref. 11.)

2.5 The main limitation on this study is imposed by the absence of any attempt to obtain an unbiased sample of accidents occurring over any given period. This greatly increases the difficulty in detecting and evaluating trends in particular types of accidents, and precludes the valid extrapolation of the results of these investigations to traffic accidents generally.

2.6 A second study of traffic accidents in Britain suffers from the same deficiency. The Automobile Association of Great Britain has been financing a study of road accidents in and around the city of Birmingham. The study has been performed by the Road Injuries Research Group of the Birmingham Accident Hospital, under the direction of Professor W. Gissane. The work of this team has been concentrated on injuries and injury causation, considering only the occupants of motor vehicles. Accidents to pedestrians, cyclists, and motor cyclists have not been investigated. This restriction makes it considerably more difficult to extrapolate from the recorded data to the whole body of accidents. Reference 12 is entitled "The nature and causes of major road injuries in and around a provincial city". Since pedestrians, cyclists and motor cyclists suffer the majority of serious to fatal injuries in such an area, a study based solely on car occupants is inadequate for the purpose of such a paper.

2.7 The Department of Transportation and Environmental Planning of the University of Birmingham commenced a road accident research project in 1965. The aims of this project are twofold: (1) To develop a technique for collecting information on all the various aspects of a traffic accident. (2) To describe in detail the characteristics of a representative sample of accidents within a chosen section of the city of Birmingham. The members of this team are all qualified research workers from a variety of disciplines. If a representative sample of accidents is in fact obtained, then the results of this project should be far more valuable than those obtained by either of the two groups whose work is discussed above.

2.8 Automotive Crash Injury Research of Cornell University is deservedly the best known road accident research group in America (Ref. 13). This work was initiated with funds from the Armed Forces Epidemiology Board. It is now financed by grants from the U.S. Public Health Service and the Automobile Manufacturers Association, in the ratio 3:2. Its data are obtained from highway accident reports by State Troopers in various States. Information on injuries is obtained from local medical officers. Each case must be an injury-producing accident involving only passenger cars. A field staff is constantly engaged on the training of State Troopers and Physicians to record the required data. As each case is received, the Analysis Branch of A.C.I.R. study the accompanying photographs and assess the severity of damage according to a six point scale, compared with the 63 point damage index of the British Road Research Laboratory. An assessment of survivability, based on the assumption that all occupants remain normally seated, is made by referring again to the photographs.

The direction of impact is noted and refers to the direction of the principal force and not necessarily to the area of impact on the car. A large staff is required to process the data from the 6,000 cases which come in to A.C.I.R. each year. Care is taken to reduce to a minimum the subjective content in the assessment of injury severity and vehicle damage. The subjective content of the former rating is about 10 per cent and of the latter 30 per cent.

2.9 Although A.C.I.R. works with derived data, attempts are made to minimise the deficiencies of the method, by training both the State Troopers and the physicians. Furthermore statistical methods have been developed to handle the many variables in the large number of cases. While their injury research work is continuing in this manner, an on-the-spot study of accident causes will commence late in 1966.

2.10 J. Stannard Baker of the Traffic Institute of Northwestern University at Evanston set up a three man team to conduct a detailed investigation of traffic accidents. This two year project began in 1958. The team consisted of a doctor, a psychologist and an engineer. None of these had any previous experience of accident investigation. Baker's intention in establishing this team was to select purposely people who were new to the work in the hope that they would come up with methods and/or results that others, including himself, had overlooked. According to Baker (personal communication) the team did not come up with any new ideas, nor did it function successfully as a team, there being a significant amount of personality trouble in the group. Also there was a marked tendency to equate a deficiency to a cause; to make their observations fit their predetermined conclusions. The emphasis in this project was entirely on case studies of individual accidents and no attempt was made to obtain a sample of any particular group of accidents. This severely restricted the value of this study in the wider sense. It did however make the task of the investigators very much easier, as the following quotation from Reference 14 indicates. "If individuals involved in an accident agreed to co-operate and if the accident did not involve commercial or certain other unfavourable circumstances, the team began to ask questions and make observations." Several other reports have been published on this project (Refs. 15, 16).

2.11 By far the most expensive and elaborate on-the-spot investigation yet attempted was based on the Department of Legal Medicine of Harvard Medical School. The programme involved research into fatal highway collisions, including pedestrian accidents, in the area of Boston. Finance for this project came from the U.S. Public Health Department and was $800,000 for the first five years. The project team consisted of a traffic engineer, a mechanic, and a psychologist, Moseley, as the principal investigator. Their work was supplemented by a much larger clinical team containing, among others, persons with such varied training as a pathologist, a sociologist, and an ethicist. The last named is more commonly recognised as a clergyman.

2.12 The original plan was to attend some one hundred fatal accidents each year. After four years operation only one hundred and thirty accidents had been attended, and no comprehensive report had been published. Detailed outlines of the procedures adopted by each member of the team were published in 1962, of which Reference 17 is an example. The great detail that each investigator went into was very impressive, but there were some significant gaps. For example no measurement was made of the skid resistance of the road surface, whereas elaborate measurements were made to determine the radius of curvature of a bend, and occasionally a light aircraft was chartered to enable aerial photographs to be taken to show the relative location of skid marks. Moseley emphasised the existence of homicide and suicide in the cases this team studied (Ref. 18). There appeared to be a very strong tendency for the members of this team to avoid the obvious fact in favour of the abstruse possibility. Despite the professed intention in the planning of this project to use the epidemiological concept, no attempt was made to obtain either a representative sample or a control group. Personal and organisational difficulties resulted in the termination of the research grant in 1964.

2.13 The remaining on-the-spot study of road accidents in America has been carried out by Huelke, Associate Professor of Anatomy, of the University of Michigan at Ann Arbor. This work has been essentially a part time study of injury causation in fatal automobile accidents (Ref. 19). No attempt has been made to obtain a representative sample.

2.14 These three studies, at Evanston, Boston, and Ann Arbor, are the only significant attempts that have been made to study traffic accidents at the scene in America. The only study elsewhere, apart from those mentioned above, has been that by Buttner and Friedhoff who investigated some 500 car accidents in Germany in 1957. Their published papers include a discussion on injuries to the drivers of forward control vehicles (Ref. 20), and injuries caused by contact with the windscreen (Ref. 21). There is no mention in these papers of the method of data collection, or whether any attempt was made to obtain a representative sample of accidents.

2.15 There have been, and are continuing, other projects related to traffic accidents. There is the well known work of Severy on controlled collision experiments at the University of California, Los Angeles. The three major car manufacturers in the U.S.A. and Mercedes in Germany have their own programmes of controlled crash testing. This work is also being developed at the Road Research Laboratory in Great Britain. General Motors Corporation, at their Michigan proving ground, have carried out many experiments on the role of highway surroundings in automobile collisions. Research workers in Sweden have been in the forefront of the development of seat belts for automobiles. Centres such as the Applied Psychology Unit of the Medical Research Council of Great Britain have for some time been working on human factors associated with traffic accidents. The work of Stapp in establishing limits of human tolerance to deceleration forces is perhaps the best known example of work in the field of biomechanics. The School of

Mechanical Engineering of Wayne State University in Detroit has an established research programme in biomechanics and has supplied much of the known data on human tolerance to impact.

2.16 The medical profession has approached this problem. There have been several hospital-based studies of injuries due to traffic accidents. Kulowski gathered together data relating to traffic accident victims admitted to the Missouri Methodist Hospital during the years 1949 to 1957 (Ref. 22). There have also been several studies based on post mortem examinations of persons killed in accidents. Gissane and Bull of the Birmingham Accident Hospital were active in this type of study before mounting the Road Injuries Research Group. Kamiyama has reported on two hundred autopsies of accident victims in the city of Tokyo (Ref. 23).

2.17 A similar study by Hodge was based on autopsies on virtually all road accident fatalities in the Adelaide area during 1960 and 1961 (Ref. 24). This study, based on the Department of Pathology of the University of Adelaide, and directed by Professor J.S. Robertson, was provided with information on the circumstances of the accident by the Accident Investigation Branch of the South Australian Police Department. It was found, however, that the amount of detail was insufficient to enable the production of individual and specific injuries to be reliably determined. Partly for this reason, and also in an attempt to obtain a more comprehensive and representative sample of traffic accidents, the Traffic Accident Research Unit was established by the Australian Road Research Board in the Pathology Department of the University. The composition and aims of this Unit are described in the following Chapter, and the final report was published in July, 1966 (Ref. 25).

2.18 Tonge et al have made a post mortem study, similar to that of Hodge, of traffic accident victims in Brisbane (Ref. 26). Jamieson and Tait have analysed a large amount of hospital-based data relating to 1000 consecutive admissions to hospital from 832 accidents in 1962 and early 1963 (Ref. 27). Some two years after the establishment of the Traffic Accident Research Unit, the National Health and Medical Research Council, together with the Department of Main Roads of Queensland and the Australian Road Research Board, established a similar Unit based on the Brisbane General Hospital and under the direction of the head of the Neuro-surgical Unit, Mr. K.G. Jamieson. The active work of this unit has been completed and a report is expected towards the end of 1966.

THE TRAFFIC ACCIDENT RESEARCH UNIT

CHAPTER 3

3.1 This Unit was established late in 1962 by Professor J.S. Robertson the Head of the Department of Pathology of the University of Adelaide. As noted earlier the work of Hodge (Ref. 24) in this department had shown the need for more detailed information on the circumstances of traffic accidents. Hodge's concern was primarily with injuries and injury production. He was legally empowered to perform autopsies on all road accident fatalities. His information on the circumstances of the accident, including whether the deceased was a pedestrian or car occupant etc., came from the specially trained police accident investigation branch. It was the methodological concept which limited this project, not the availability of data or lack of co-operation by public authorities.

3.2 The aim behind the establishment of the Traffic Accident Research Unit (hereafter referred to as TARU) was "to gather data in Australian conditions basic to the design of roads, traffic organisation and vehicles, by the objective study of medical and engineering aspects of injury-producing accidents". The investigating team consisted of G.A. Ryan, MB.BS., as medical officer and myself as mechanical engineer. Both investigators attended the scene of each accident. This minimised the need to rely on secondary sources of information. Furthermore the times that the team was on call were strictly regulated to ensure that the accidents attended were a representative sample of all accidents occurring during those times. It was thought that this was the most likely method to provide an accurate, integrated, and representative picture of traffic accidents.

3.3 It has since been realized that the disciplines of engineering and medicine, wide though they may be, do not cover all the significant features of the traffic accident situation. The later study directed by Jamieson has included a sociologist along with a medical officer and an engineer, thereby widening the scope of the investigation. As the work of TARU proceeded other restrictions became evident, chiefly in the method of sampling. These restrictions are discussed in the relevant sections following.

Planning of the Study

3.4 Perhaps the prime concern in the initial planning stage was to ensure that a representative sample of accidents was obtained. At this time no other research unit had been able to do this. Obviously the first step in any attempt to obtain a representative sample was to ensure that the team was notified of all accidents. There were two agencies that could do this; one was the police, the other the ambulance. An "ambulance definition" was adopted partly because the ambulance is notified quickly when an accident has occurred. The police may not be notified for some considerable time. It was feared that the ambulance would be called only to the more severe accidents. As it turned out, the team attended accidents ranging from fatalities to those involving little or no injury. Frequently

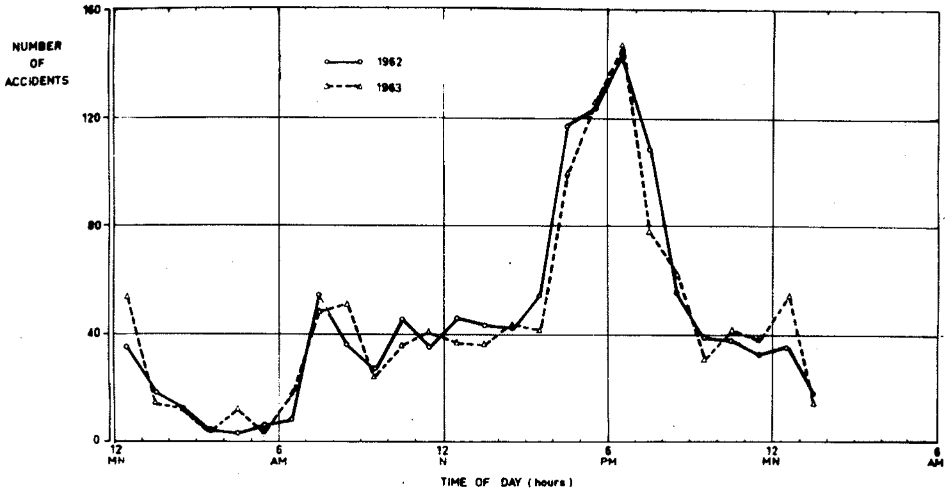


Fig. 3.1
Hourly distribution of accidents in Adelaide (1962).

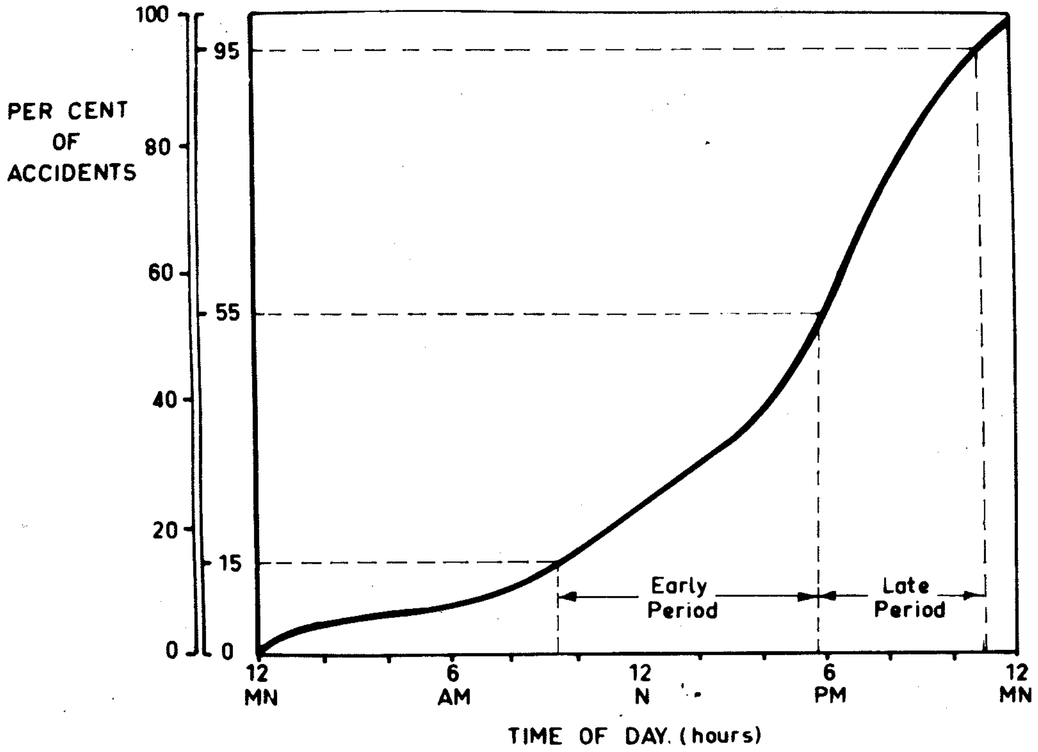


Fig. 3.2
Cumulative graph of accidents by time of day (Adelaide)

the ambulance is called when its services are not required. While a complete picture of traffic accidents must necessarily include those involving only property damage, an ambulance definition is not as restrictive as may be supposed.

3.5 The next step was to examine the ambulance records of vehicular accidents attended during the first six months of 1962. The area in which these accidents had occurred was arbitrarily divided into five regions. The number of accidents in each region was counted and further subdivided by day of week and time of day. Further analysis of these figures failed to show any significant relationship with region, time of day, or day of week. The six month period was also divided into the summer months of January to March and the cooler months of April to June. Once again no significant difference was found to exist between these two groups.

3.6 All accidents occurring during these six months were then taken together and plotted against time of day. Figure 3.1, which includes all accidents the ambulance attended during the years 1962 and 1963, shows the very marked peak around 6 p.m. The similarity of the curves for the two years shows that this distribution is a relatively stable one. In order to make the best use of the available resources it was resolved to concentrate the survey on those times which would yield a reasonable number of accidents. The way in which this was done can be more clearly understood by reference to Figure 3.2 which is a cumulative

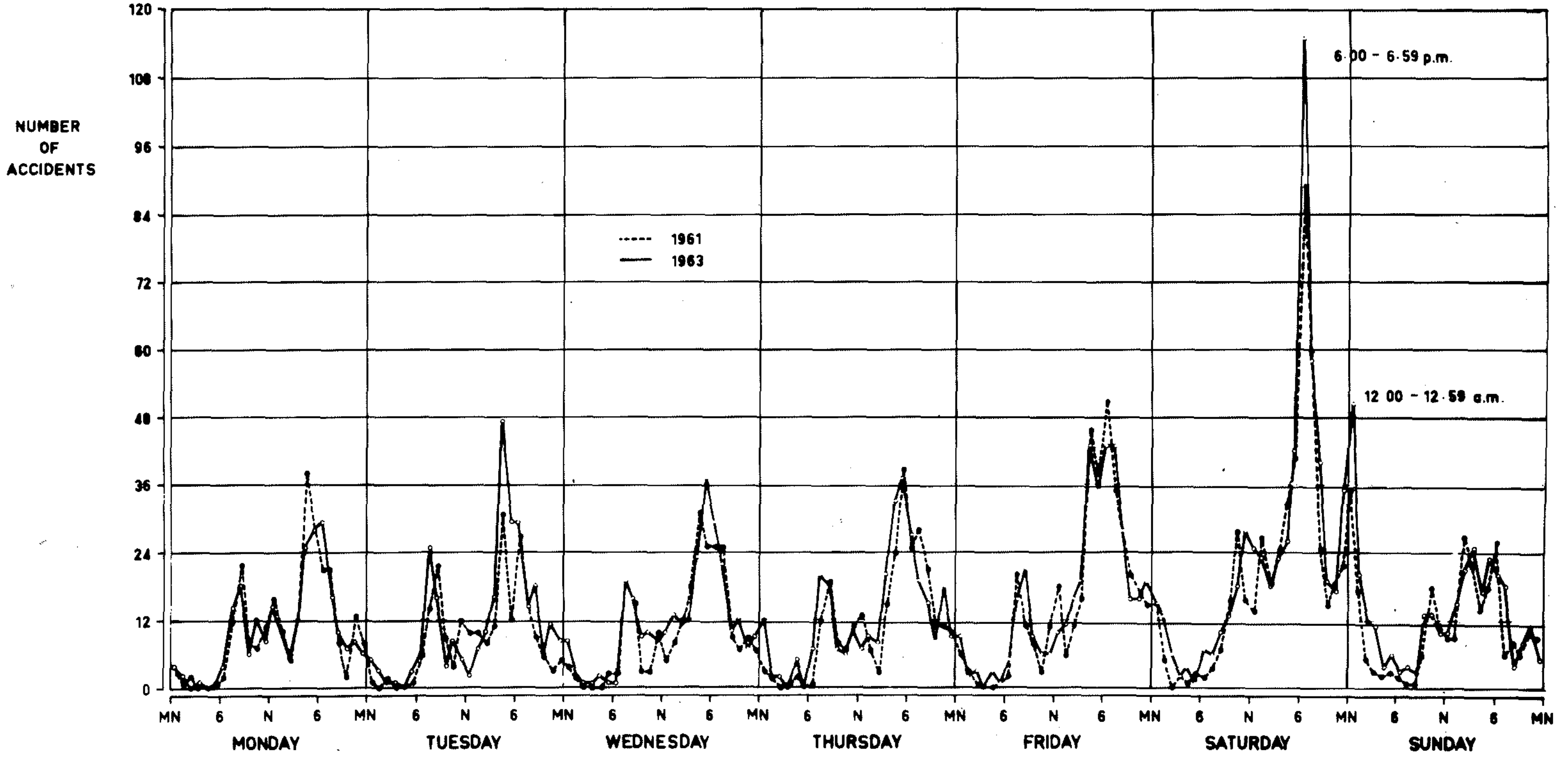


Fig. 3.3
Accidents by time of day by day of week (Adelaide).

frequency graph of accidents against time of day. Two working periods were chosen, each potentially covering forty per cent of the day's accidents. The early shift began at 10 a.m. and finished at 5.45 p.m. The late shift started at 5.45 p.m. and continued until 11 p.m. This meant that the period from 11 p.m. to 10 a.m. was not sampled at all. It was not until very late in the survey that the occurrence of accidents was plotted by time of day and day of week (Fig. 3.3). Then we saw that the second most frequent occurrence of accidents was very early on Sunday morning, a time outside our survey period. This point is emphasised here in the hope that subsequent studies will not make the same mistake.

3.7 As there was only one operational team, it was decided to study only alternate Saturdays and Sundays. After a short time, no work at all was attempted on Sundays. It was thought then that Sunday accidents would not differ appreciably from accidents on other days of the week. Figure 3.3 shows however that the frequency distribution of accidents is very different on a Sunday from that on week days. Omitting Sundays and every other Saturday produced another source of possible bias in our sample.

3.8 The final working schedule decided upon is shown in Table A 3.1 (Appendix). This schedule was based on a cycle of twenty weeks and was intentionally made as random as possible. In practice this proved to be a particularly tiring schedule, due mainly to the irregularity of working

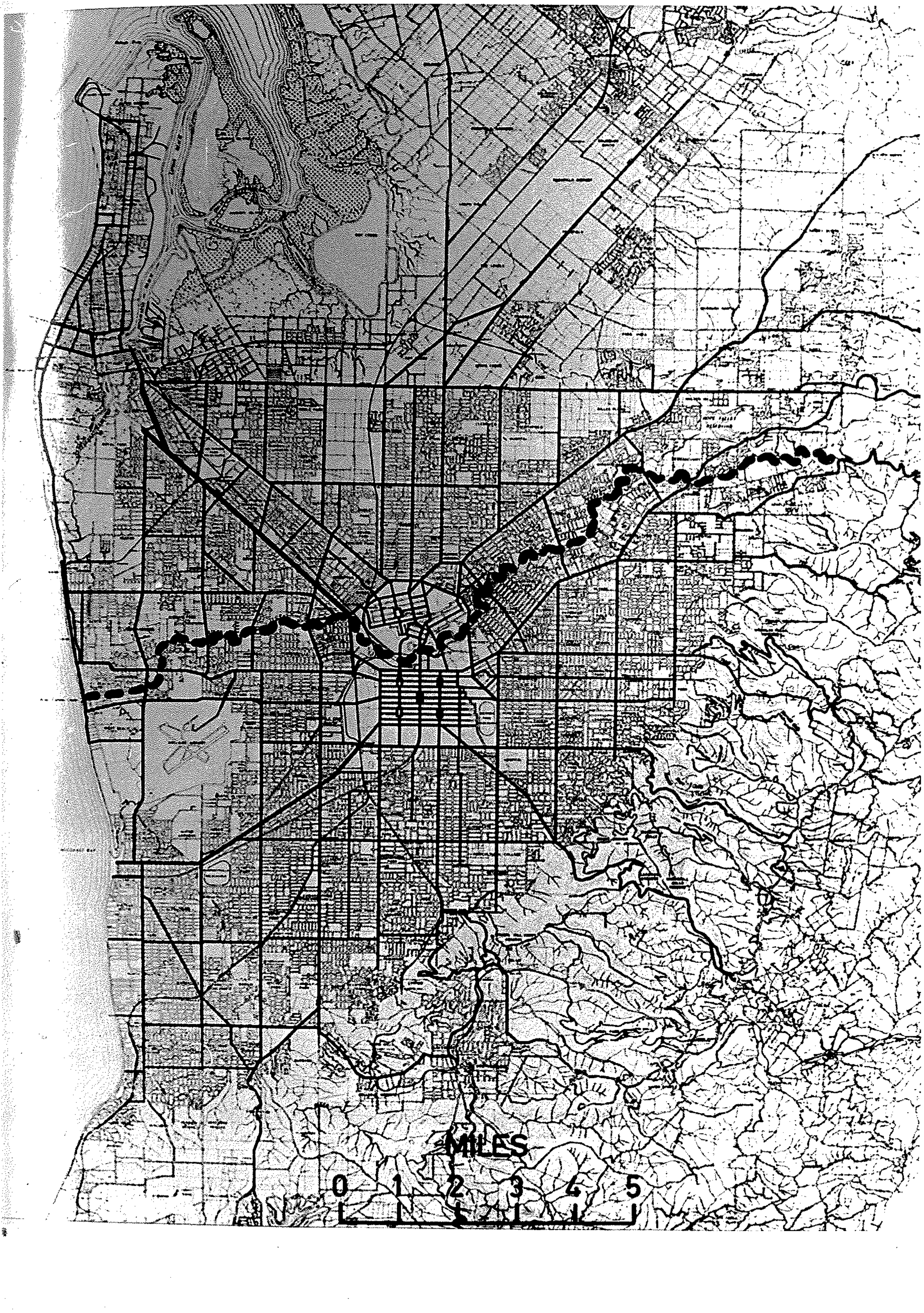


Fig. 3.4
Map of Adelaide showing 'busy' roads and the River Torrens.

hours. The centralised radio control of the St John Ambulance Brigade called us whenever an ambulance was despatched to a road accident during our working hours. We relied entirely on the radio operators for this information. During the first few weeks of the survey we were occasionally forgotten by the radio operator. After this initial period we were informed of virtually all accidents occurring. Without the ready and willing co-operation of these radio operators it would not have been possible to have obtained a representative sample of accidents.

3.9 This study was planned to concentrate solely on metropolitan traffic accidents. Consequently the area covered was entirely within metropolitan Adelaide. This city of 600,000 people is bounded on one side by the sea and on two sides by a low range of hills. It has a temperate climate. The city centre itself is centrally located on this coastal plain (Fig. 3.4). Elsewhere in this report comparisons have been made between the numbers of accidents occurring within the central city area and beyond it. This central area is in two parts, on either side of the River Torrens, and is bounded by park lands. The River Torrens forms the only natural barrier in the entire metropolitan area. The road layout is very simple, consisting almost entirely of long straight roads intersecting at right angles. An indication of the traffic volumes on the busier roads is given in Figure 3.5. Motor vehicle registrations in the metropolitan area increased from 188,000 in January 1963 to 203,500 by

Fig. 3.5
Relative traffic volumes in Adelaide.

the end of August 1964. This increase provides some explanation for the greater rate at which accidents were collected by the team during the second of these two years (Fig. 3.6).

3.10 Work on the roads began on January 22nd, 1963. The first 25 accidents attended were regarded as a trial sample and are not included in the body of accidents considered in this thesis. We soon realised that it was important to arrive at the scene of an accident as soon as possible and in any case within 20 minutes of its occurrence. Partly for this reason we attempted to cover only half of the metropolitan area during any one working period. The River Torrens, shown as a heavy broken line in Figure 3.4, was chosen as the dividing line. A random sequence was used to determine which area would be worked in any given period. We operated in this way until April 5th, 1963. Comparatively few accidents were attended and there were many periods in which we did not receive even one call.

3.11 Rather than continue working in this seemingly inefficient manner, we attempted to gain a clearer understanding of the probability of an accident's occurring in any one working period. We assumed that these accidents were random events both in space and time. We further assumed that the expectation of an accident happening was substantially constant. Figure 3.4 shows that this is scarcely a valid assumption, but we accepted it for this purpose and adopted a simple, rather than a modified,

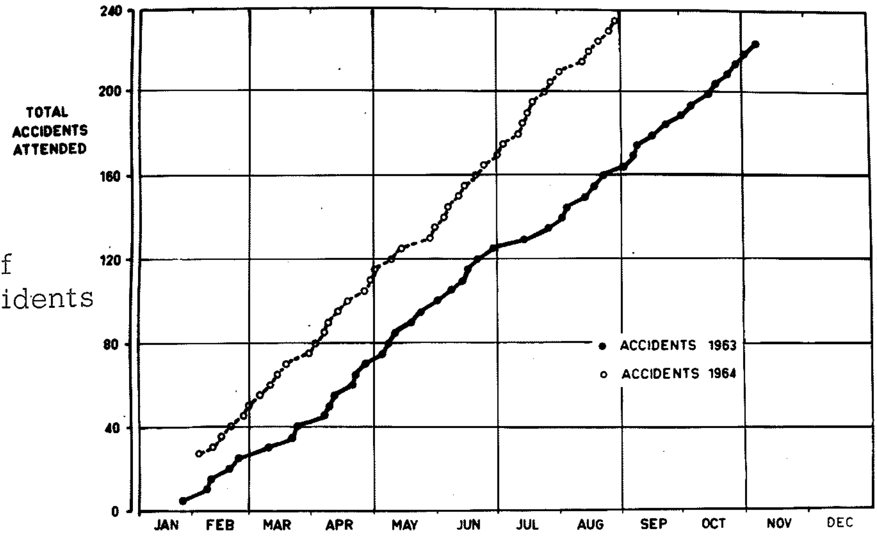


Fig. 3.6
Cumulative plot of attendance at accidents

Fig. 3.7
The vehicle with the author photographing skid marks.

Poisson distribution. The ambulance data used in these calculations are given in Table A 3.2. The results of the calculations are listed in Table A 3.3, and show that many working periods were likely to be unproductive. This confirmed our suspicions that, unless we modified our sampling method, we were unlikely to increase the rate at which we were collecting accidents.

3.12 Continuing with the assumption that the occurrence of a single accident was a random event, we went to the first accident reported in our working period and thereafter remained on that side of the river. This greatly reduced the number of unproductive working periods, and we operated in this way from Saturday, April 6, to July 20, 1963. We soon came to realise that the distances involved in covering one half of the city were almost as great as those which would be involved in covering the whole area. Furthermore it seemed foolish to ignore a readily accessible accident simply because it was on the wrong side of the river.

3.13 From July 21, 1963, we went to the first accident which occurred in any working period and thereafter to subsequent accidents in chronological order. Work on the roads continued until November 5, 1963. We then spent some three months evaluating and attempting to improve our working methods and also prepared an interim report (Ref. 28). Work on the roads began again on February 3, 1964, and continued until August 30 of that year. In the first of these two years we attended 201 of the 1,677 accidents which were reported to the ambulance. In the second year we attended 207 of a total of 1,626 accidents. The total is smaller in the second year because we were able to collect accidents at a greater rate and were therefore on the roads for a shorter period (Fig. 2). Our sample therefore increased from 11.9 per cent to 12.7 per cent. For the two years combined, our sample represents 12.3 per cent of the total number of 3,303 accidents. (Appendices A3.4 and A3.5.)

3.14 One remaining source of bias in our sample arose from the need to spend over an hour investigating most of these accidents. This time was not necessarily all spent at the scene. In most cases persons injured could be satisfactorily interviewed only in the casualty section of a hospital. This meant that at times of peak accident frequency, such as around 6 p.m., we were likely to miss some accidents which occurred soon after the first one that we attended. At other times we were able to attend very nearly all the accidents that happened. We purposely ended the early shift in the middle of the period of peak accident frequency in an attempt to minimise this disadvantage. Even so we were only able to attend about one accident in three at that time. There is a strong argument in favour of planning the working periods to provide an accident sample which is a constant percentage of the total for each hour of the day.

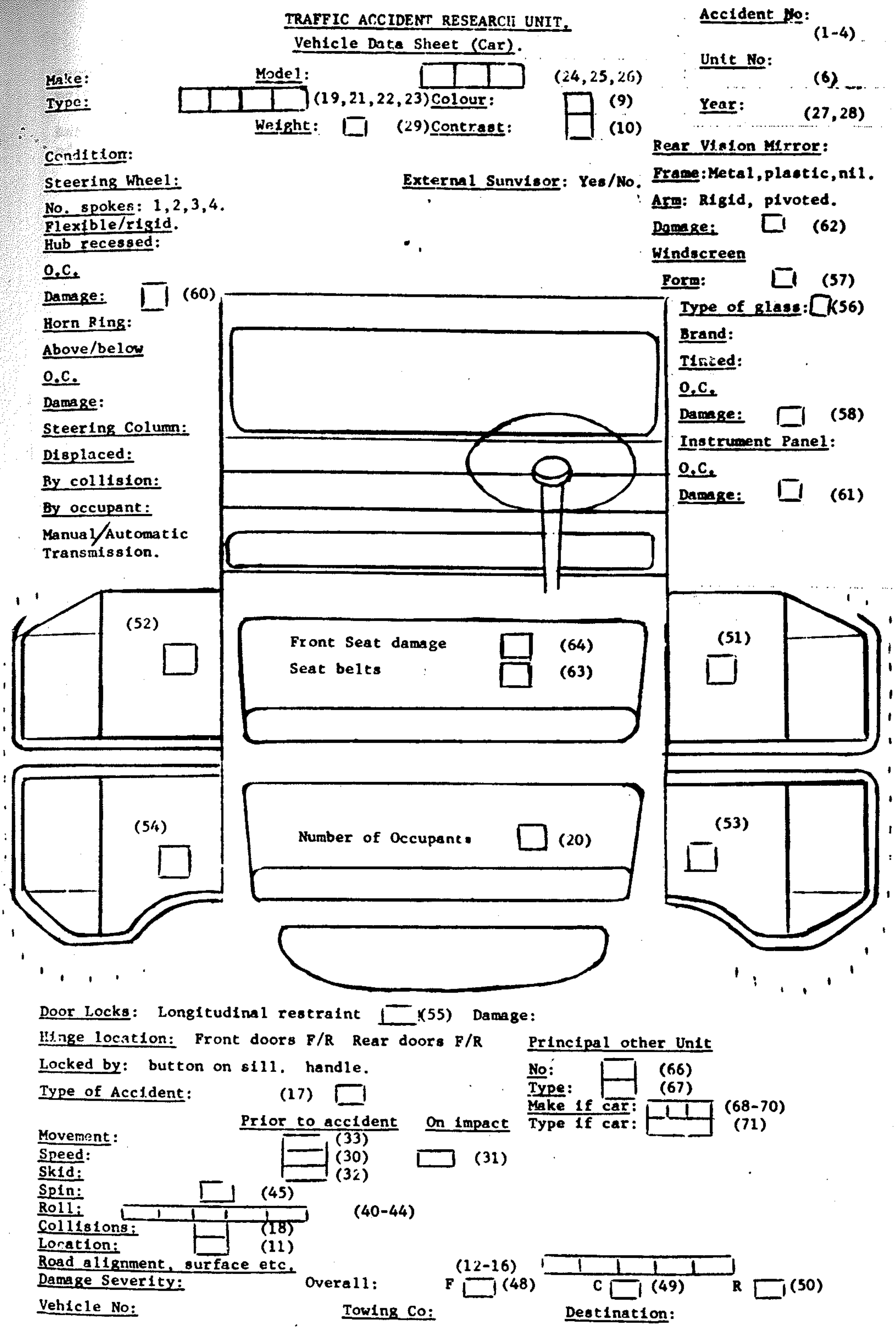
3.15 The possible sources of bias in this sample are therefore:

1. No accidents were attended between the hours 11 p.m. and 10 a.m.

2. After the first few weeks no attempt was made to attend accidents on a Sunday, and only alternate Saturdays were worked.
3. The sample obtained does not represent a constant proportion of the total accidents occurring for each hour of the day.
4. The percentage is lowest at times of peak accident frequency.

Equipment

3.16 One vehicle, a Ford Falcon Station Sedan, was used by the team. There were occasions when two vehicles would have facilitated the investigation of an accident, but there were also advantages in "housing" the team in one vehicle. A station sedan was chosen because it provided a large and readily accessible luggage area and also enabled a roof platform and an extendible ladder to be attached. The platform and ladder were used mainly to obtain better photographs of skid marks than was possible from ground level (Fig. 3.7). The vehicle was equipped with a two-way radio tuned to the ambulance frequency and the car was assigned an ambulance call number. A flashing amber warning light was attached to the roof. We were legally permitted to use this light only when stationary in a hazardous position or when moving at a speed of less than five miles per hour. Despite this warning light, many motorists failed to slow down when passing accident scenes. When working on the road we always wore white dust coats or white rain coats. We also found that, at night,



TRAFFIC ACCIDENT RESEARCH UNIT.

Vehicle Data Sheet (Car).

Accident No: (1-4)

Unit No: (6)

Make:

Model: ☐☐☐☐ (24,25,26)

Type: ☐☐☐☐☐ (19,21,22,23)

Colour: ☐ (9)

Year: (27,28)

Weight: ☐ (29)

Contrast: ☐ (10)

Condition:

Steering Wheel:

No. spokes: 1,2,3,4.

Flexible/rigid.

Hub recessed:

O.C.

Damage: ☐ (60)

Horn Ring:

Above/below

O.C.

Damage:

Steering Column:

Displaced:

By collision:

By occupant:

Manual/Automatic Transmission.

External Sunvisor: Yes/No.

Rear Vision Mirror:

Frame: Metal, plastic, nil.

Arm: Rigid, pivoted.

Damage: ☐ (62)

Windscreen

Form: ☐ (57)

Type of glass: ☐ (56)

Brand:

Tinted:

O.C.

Damage: ☐ (58)

Instrument Panel:

O.C.

Damage: ☐ (61)

(52) ☐

(51) ☐

Front Seat damage ☐ (64)

Seat belts ☐ (63)

(54) ☐

(53) ☐

Number of Occupants ☐ (20)

Door Locks: Longitudinal restraint ☐ (55) Damage:

Hinge location: Front doors F/R Rear doors F/R

Locked by: button on sill. handle.

Type of Accident: (17) ☐

Principal other Unit

No: ☐ (66)

Type: ☐ (67)

Make if car: ☐☐☐ (68-70)

Type if car: ☐ (71)

Prior to accident / On impact

Movement: ☐ (33)

Speed: ☐ (30) ☐ (31)

Skid: ☐ (32)

Spin: ☐ (45)

Roll: ☐☐☐☐☐ (40-44)

Collisions: ☐ (18)

Location: ☐ (11)

Road alignment, surface etc. (12-16) ☐☐☐☐☐

Damage Severity: Overall: F ☐ (48) C ☐ (49) R ☐ (50)

Vehicle No: Towing Co: Destination:

Fig. 3.8
Vehicle data check list devised by the author.

Estimated Cost of Repairs:

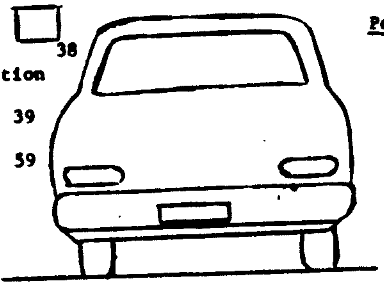
Time taken to complete repairs:

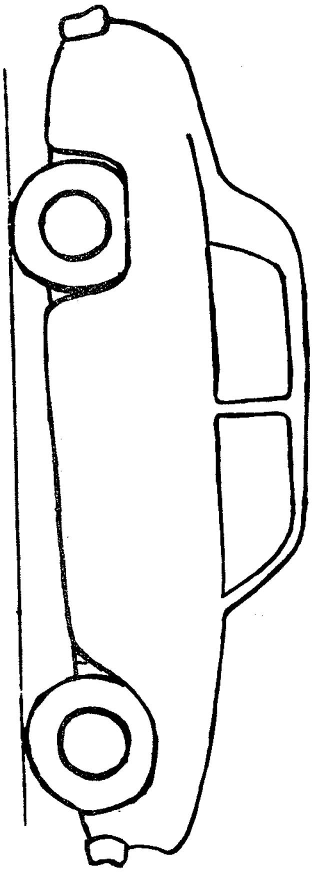
Permanent deformation at point of principal impact ☐ 38

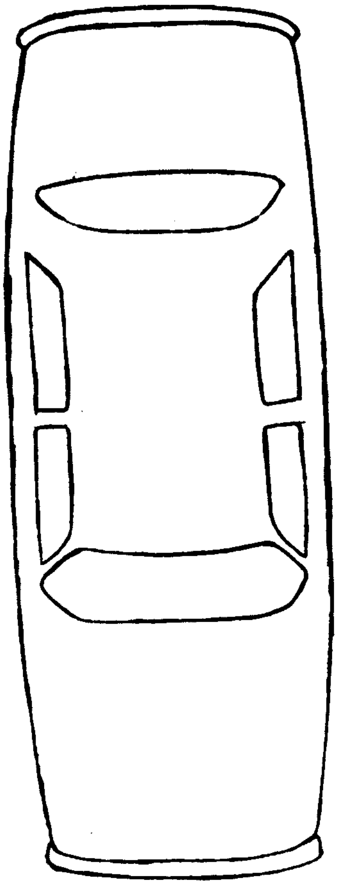
Region of maximum deformation of passenger compt. ☐ 39

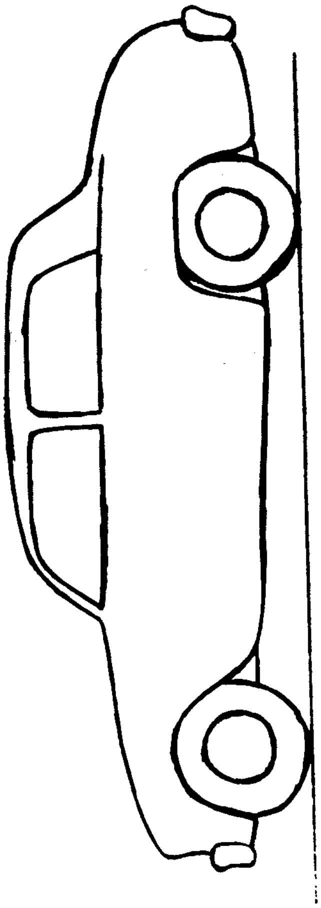
Damage to window glass ☐ 59

Petrol leakage:









Engine mounting damage

☐ 65

Tyres

46	47
☐	☐

Impact

34	35	36	37
☐	☐	☐	☐

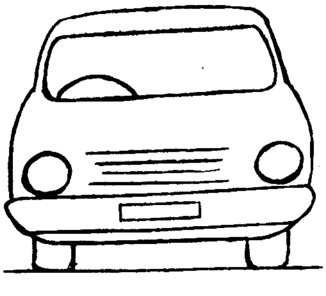


Fig. 3.9
Vehicle data check list devised by the author.

shining a torch directly on the white coat was more effective than waving a torch to warn approaching drivers of our presence on the road. We were insured against personal injury, but fortunately had no occasion to make a claim.

3.17 Photographic equipment consisted of a camera and electronic flash. The camera was a Zeiss Ikon Contaflex Super. This is a single lens reflex camera which was equipped with a standard, wide angle, and four close-up lenses. The flash gun was a Braun Hobby 160 Joule, having both full and half power settings. The flash unit itself was invariably used remote from the camera. Throughout the survey the film used was High Speed Ektachrome 160 A.S.A. Colour Reversal Film. This was initially chosen because of its wide speed range. In some cases the comparatively large grain of this film was found to be a disadvantage. With the assistance of the electronic flash the speed of the film is not of great importance, and it is suggested that a finer grain size film is to be preferred.

3.18 A series of forms were devised to assist with the recording of information at the scene. It was found desirable to have these forms designed to act as check lists. This both speeded up the recording process and also minimised the risk of omitting certain features altogether. The final form adopted is shown in Figures 3.8 and 3.9 which show both sides of the foolscap Vehicle Data form. Three other forms were also used, one general Accident Circumstances form which listed the vehicles involved in the accident and the number, age, sex and seated position of the participants. An Individual Participant form was completed for each person involved in the accident, and included information on the injuries sustained by the person. A further form was developed, as the survey proceeded, for pedestrians. It was found, as is discussed in Chapter 4, that many of the injuries sustained by pedestrians were closely related to the shape of the striking vehicle. This form was designed to facilitate the accurate recording of the location of a pedestrian's injuries.

3.19 Road distances were measured with a 'Trumeter' road measurer which has a wheel with a circumference of one yard. This proved to be sufficiently accurate for our purpose. In heavy traffic we were very often able to measure road widths with this measuring wheel when measurement with a tape would have been impossible. A six foot tape was used to measure the track of skid marks and of vehicles, and also to locate various points of the vehicles relative to both occupants and pedestrians. Engineer's chalk was used to mark the positions of the vehicles on the road, and also to define the position of skid marks more clearly. A simple protractor, consisting of two yard rules hinged together, was used to determine the angle of deflection of skid marks.

3.20 The temperatureof the road surface was obtained by use of a Dobbie Bros. surface thermometer. A Bacharach sling psychrometer was used to determine wet and dry bulb temperatures at each location. Tyre pressures were measured with a simple pressure gauge. A Heuer stopwatch graduated to a fifth of a second was used to time the phases of traffic lights and also, by timing vehicles over a known length of road, to estimate average traffic speeds.

3.21 A first-aid kit consisting mainly of sterile dressings and bandages was always carried in the vehicle. There were several occasions when we arrived before the ambulance and were able to be of some immediate assistance. We carried a hack-saw and a jemmy bar but did not have occasion to use either. In cases where a person was trapped inside a wrecked vehicle the equipment carried by ambulance, police, and notably, towing services, was sufficient. Probably the most frequently used item of our "emergency" equipment was a broom which the police frequently borrowed to sweep broken glass and small debris off the road.

3.22 Skid resistance of road surfaces was measured by locked-wheel skids with our own vehicle at the scene. Where conditions permitted these skids were made from a steady speed of 30 m.p.h. to a standstill. They were repeated until two runs gave skid lengths which were within ten percent of each other.

Method of Operation

3.23 On receiving a call from the Radio Operator we proceeded directly to the scene of the accident, generally arriving within ten to fifteen minutes.

This time could vary from less than five minutes to over twenty minutes, the variation being due to both distance from the accident and also traffic conditions at the time. Unfortunately peak-hour traffic both increased the time taken to reach an accident and also demanded that the scene be cleared as quickly as possible to allow traffic to proceed. This meant that we had to be prepared to start recording information as soon as we arrived at an accident scene.

3.24 On arrival the doctor located any injured persons and, if necessary, assisted the ambulance men. He then interviewed those participants who had not been taken to hospital. He recorded their accounts of the accident and also personal particulars such as age, sex, height, and weight. If they were car occupants their seated positions in the car were also recorded. Any eye witnesses who were still at the scene were interviewed. Their versions of what had actually happened often differed greatly from one person to another. We believe that this was mainly due to the very short time during which an accident can occur. Accurate recording of events occurring in such a short period can be extremely difficult. No names were recorded except for those admitted to hospital, and their names were removed from the records after they had been discharged.

3.25 Estimation of whether or not a participant had been drinking was based on our observation of his general behaviour and the smell of his breath. We had neither the equipment nor the authority to enable us to estimate blood alcohol levels in drivers and pedestrians. Towards the end of the survey we were able to use a simple breath alcohol indicator ("Alco Test"). The results we obtained from this indicator suggest that our estimation "had been drinking" was conservative, and therefore we had not detected all the drivers and pedestrians who were affected by alcohol. This should be remembered whenever the effect of alcohol is discussed elsewhere in this thesis.

3.26 My first concern on arriving at an accident was to record the general circumstances at the scene. I did this by taking a series of photographs which together showed the positions of the vehicles in relation to each other and to the general road layout. A great advantage of this method of recording information is that a series of photographs carefully planned will show virtually everything, not only those things which are obviously important at the time. In the confusion at the scene of an accident it is only too easy to forget to check whether all the street lights are on, or the positions of parked vehicles, to mention only two examples. I found it possible to obtain this information later when a comprehensive set of photographs was available for reference.

3.27 The positions of vehicles and skid marks were then marked with chalk on the road surface. This enabled us to leave the detailed drawing of a plan of the accident until after the scene had been cleared. In many cases we returned later to the scene of the accident to make more detailed measurement of skid marks and their location relative to the road layout. Environmental features were also recorded, whenever possible in a quantitative form, for example, ambient temperature and humidity, and road surface temperature. We recorded the type and condition of the road surface. A bitumen sealed road was classified into one of four categories as follows:

(1) A layer of bitumen or tar completely covering the aggregate.

(2) The aggregate exposed but flush with the layer of tar.

(3) The aggregate standing clear above the binding layer of tar, but not loose or ravelling.

(4) Aggregate above the surface of the tar, and ravelling.

3.28 Within the speed range encountered in these accidents we found that the stopping distance of a skidding vehicle depended mainly on the properties of the road surface. We therefore carried out skid tests with our own vehicle. This enabled us to check our estimate of the travelling and impact speeds of the vehicles involved in the accident. It should be noted that our speed estimates, based on statements from drivers, damage to the vehicles and motions of the vehicles, were commonly higher than the drivers' own estimates. Even so we suspect that our estimates may still have been conservative.

3.29 The make, model and registration number of each vehicle were noted and also the name of the towing service which removed the vehicle from the scene. If possible the vehicle was inspected for damage at the scene, but very often circumstances, such as heavy traffic, prevented this and the vehicle would then be inspected at the depot of the towing service or at a crash repair shop. Here again the amount of accurate information available decreased with time, except for certain details of damage which could only be determined after the vehicle had been partially dismantled. Inspection of the interior of the vehicle was guided by the known injuries the occupants received. We tried to assign a cause to each injury, but did so only when the relationship was readily demonstrated. We were also particularly concerned with damage to the interior of the vehicle caused by occupant contact but which was not associated with injury to the occupant. Whereas the "crash worthiness" of a vehicle becomes immediately apparent after an accident, its "road worthiness" is much more difficult to assess because many components can be damaged in the accident. A thorough examination for road worthiness would demand the complete dismantling of the already damaged vehicle. We had neither the authority nor the facilities to do this, and our assessment of road worthiness has been little more than to note the factors which were obviously significant in the causation of an accident.

3.30 After as much as possible had been recorded at the scene we followed the injured to the hospitals. There the medical officer was able to obtain more detailed information on those who had been injured. The patients were followed up until they were discharged from hospital.

3.31 I traced the vehicles to the crash repair shops, often a very time consuming task, for frequently a vehicle will pass through many hands before repair work is commenced. In many cases I was able to obtain the exact cost of repair and also the length of time taken to complete the repairs.

3.32 Both the medical officer and I attended the postmortems which followed fatal accidents. The medical officer was, by virtue of his detailed knowledge of the accident, frequently able to describe the mechanism of the production of many of the injuries. During his examination I was able to photograph the more significant and interesting of these injuries.

Definitions

3.33 The following general definitions are used in this report.

An injury-producing traffic accident:	One which involves a vehicle, occurs on a public road, and to which an ambulance is called.
Type of vehicle:	Car: includes car-type Station Sedans, Vans, Utilities.
	Light truck: includes forward control vans, small buses, jeep-type vehicles.
	Heavy truck: over two tons tare weight, bus, semitrailer.
	Car with trailer.
	Three wheeled car, or motor cycle with side car.

Fig. 3.10
Minor overall damage.

Fig. 3.11
Moderate overall damage.

Type of vehicle (Contd.)	Motor cycle: includes motor scooters and motor assisted cycles.
	Pedal cycle.

<u>Rating of vehicle damage</u>

3.34 The following five point scale was used to assess and grade damage to the vehicles involved in these accidents.

Nil:	No damage
Minor:	From scratches to dents or deformation of the body of the vehicle - no structural damage.
Moderate:	Crumpling of the body of the vehicle - little or no structural damage.
Severe:	Structural damage, together with extensive damage to the body of the vehicle.
Extremely severe:	Extensive structural damage; general demolition of the vehicle.

3.35 For cars the above scale is applied separately to the front, the passenger compartment, and the rear sections of each vehicle. From these separate ratings an overall damage rating is obtained by taking the simple arithmetic sum of the numerical ratings given to these three sections, viz:

Degree of damage:	Numerical rating:
Nil	0
Minor	1
Moderate	3

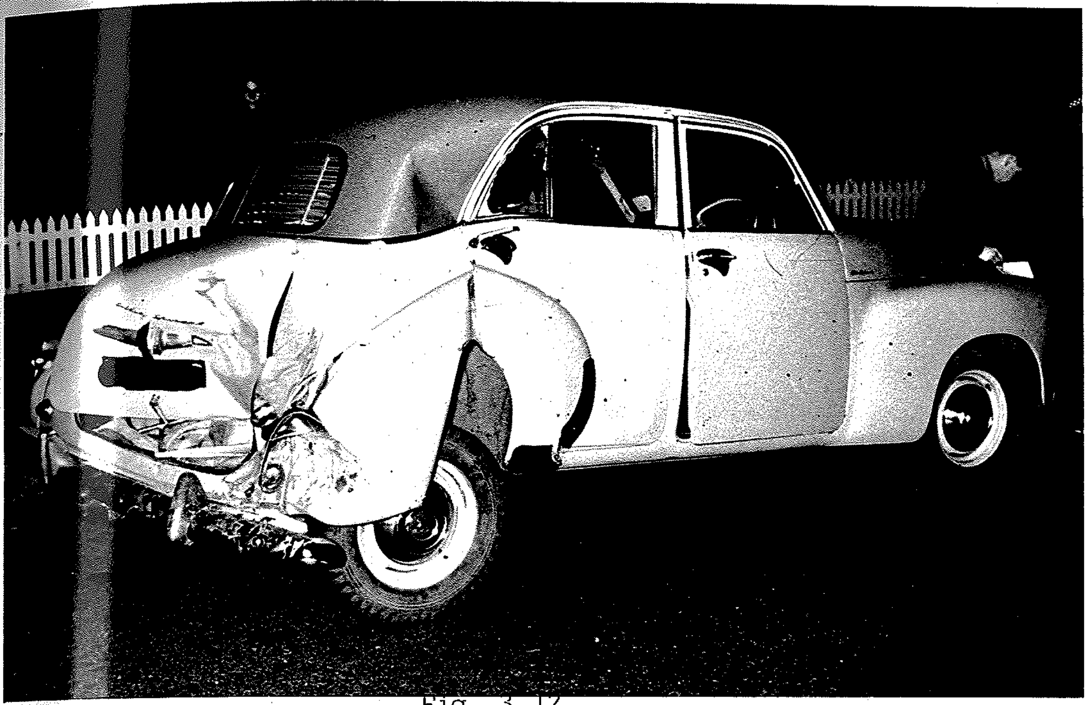


Fig. 3.12
Severe overall damage.

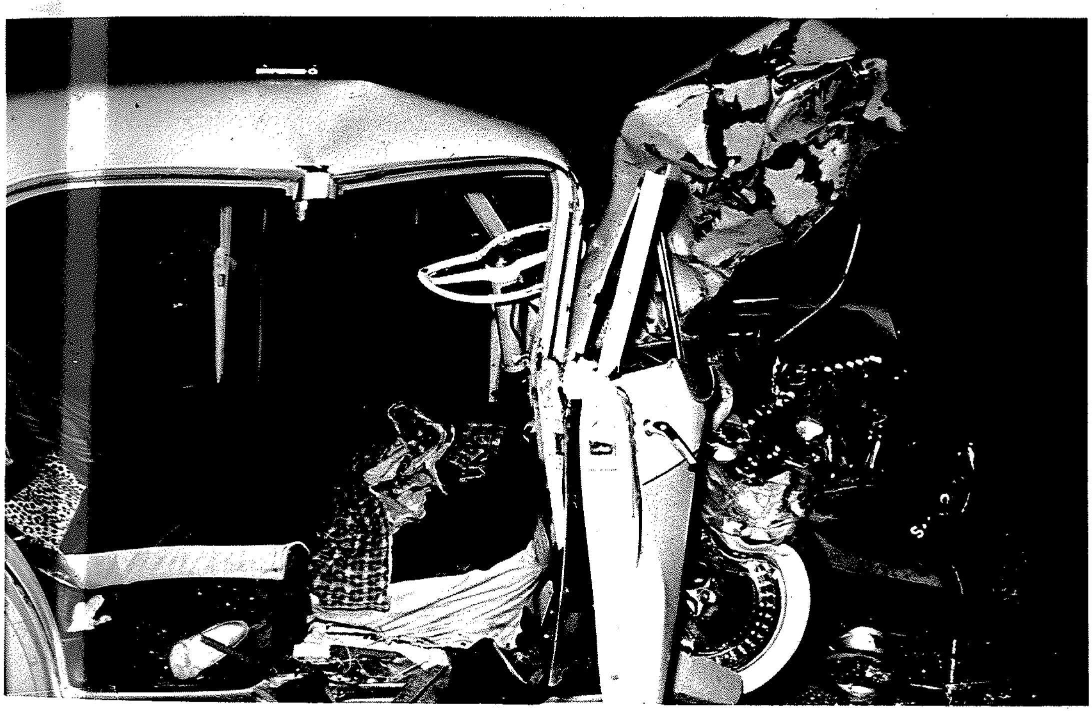


Fig. 3.13
Extremely severe overall damage.

Degree of damage (Contd.)	Numerical rating (Contd.)
Severe	7
Extremely severe	10

These overall damage ratings are then classified as follows:

Degree of overall damage:	Numerical rating:
Nil	0
Minor	1 - 2
Moderate	3 - 7
Severe	8 - 14
Extremely severe	15 - 30

Note that no attempt is made to give a greater weight to damage to the passenger compartment than to damage to the front or rear sections of the car. Compare this with the damage index devised by Moreland (Ref. 9). These damage ratings are illustrated in Figures 3.10 to 3.13.

3.36 For vehicles other than cars, including cycles and motor cycles, only an overall damage rating was used, along the lines of the scale given above for section damage for cars.

Rating of injury severity.

3.37 The degree of injury is divided into six grades which correspond approximately to the classification used by the automotive Crash Injury Research Unit of Cornell University in the U.S.A. These grades are:

Nil:	No injury.
Minor:	Bruises, abrasions, lacerations; "dazed" - no loss of consciousness.
Moderate:	Fracture of nose, hands, feet; concussion less than ten minutes; large lacerations; dislocations.
Severe:	Fractures of limbs; injury not endangering life.
Very Severe:	Injury endangering life.
Fatal:	Death within thirty days from any cause after involvement in a vehicular accident.

PEDESTRIAN ACCIDENTS

CHAPTER 4.

4.1 The pedestrian accident is unique in that, of all the various types of road traffic accident, it has been with us for more than a century. So too has the pedestrian's indignant cry that "Someone should do something!"

The Pedestrian's Complaint

> In spite of all order, justice, and decorum, we, the greater number of the Queen's loyal subjects, for no reason in the world than because we want money, do not share alike in the division of Her Majesty's high road. The horses and slaves of the rich take up the whole street; while we peripatetics are very glad to watch an opportunity to whisk across a passage, very thankful that we are not run over for interrupting the machine, that carries in it a person neither more handsome, wise, or valiant than the meanest of us. For this reason, were I to propose a tax, it should certainly be upon coaches and chairs; for no man living can assign a reason why one man should have half a street to carry him at his ease, and perhaps only in pursuit of pleasures, when as good a man as himself wants room for his own person to pass upon the most necessary and urgent occasion ....

> It is to me most miraculous, so unreasonable an usurpation as this I am speaking of, should so long have been tolerated. We hang a poor fellow for taking a trifle from us on the road, and bear with the rich for robbing us of the road itself....... The overseers of the highway and constables have so little skill or power to rectify this matter, that you may often see the equipage of a fellow whom all the town knows to deserve hanging, make a stop that shall interrupt the lord high chancellor and all the judges in their way to Westminster.
>
> SIR RICHARD STEELE, Equipages:
> The Tatler, 11th March, 1709/10.

4.2 A collision between a vehicle and a pedestrian is frequently regarded as a chance event, or the result of carelessness. Some attempts are made to prevent such collisions by separating pedestrians from vehicular traffic. The sidewalk is the ubiquitous example of this approach; pedestrian crossings and median strips are others.

4.3 Few attempts have been made to try to reduce the severity of the injuries sustained by a pedestrian in such a collision. It has been recognised that these injuries are frequently severe and some times fatal, but "surely this is inevitable if one is run over". This attitude displays both the traditionally fatalistic approach to accidents and an almost complete misunderstanding of the kinematics of this kind of collision. It is shown

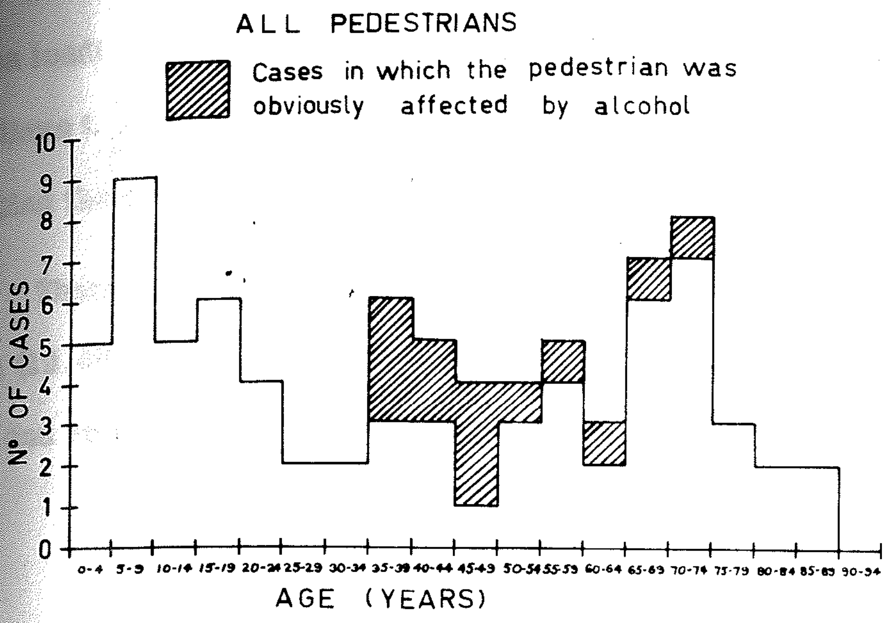


Fig. 4.1
Pedestrians (all accidents).

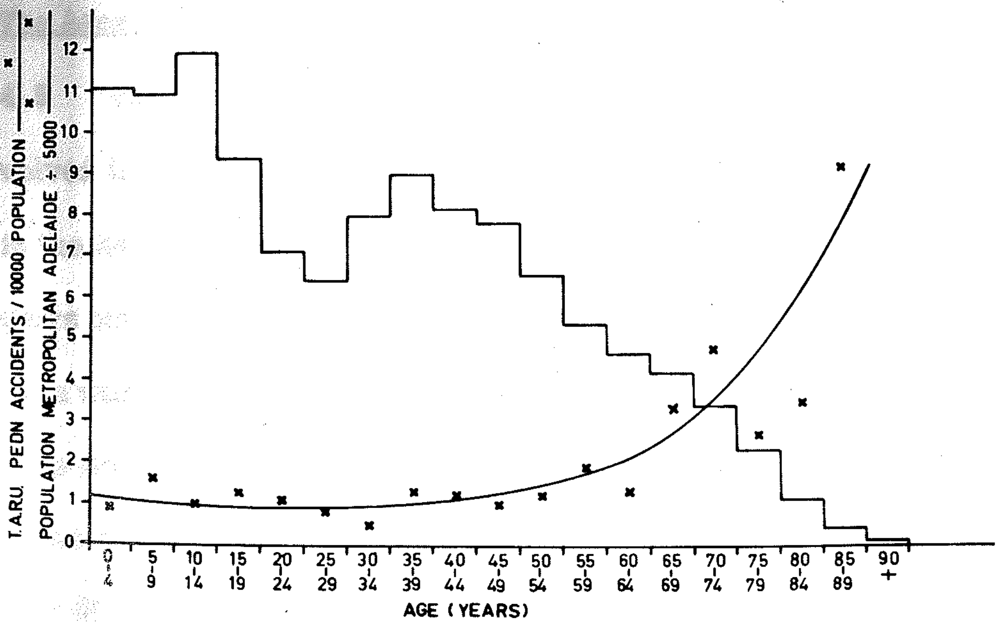


Fig. 4.2
Accident frequency by age of pedestrian.

below that the adult pedestrian is "run under", that his injuries are due to inertia loadings and not the "weight of the car", and that there is reason to believe that the severity of these injuries can be markedly reduced by changing the overall frontal shape of the car.

4.4 There were 79 pedestrian accidents in this sample of 408 accidents (19.4% of the total). Some of these involved more than one pedestrian and so there were 82 pedestrians in this series. Of these :

63 were struck by a car
7 were struck by a truck or bus
7 were struck by a motorcycle
4 were struck by a car with trailer
1 was struck by a pedal cycle

The Ages of Pedestrians involved in Accidents

4.5 Figure 4.1 shows the age distribution of all the pedestrians involved in these accidents. There are three main groups. The first is in the age range 5 - 9 years. The second, smaller, group at 35 - 39 years merges into the third group at 70 - 74 years. The youngest pedestrian was 3 years of age, the oldest 86 years. The age distribution for male pedestrians (Fig. 4.3) differs from that of females (Fig. 4.4). Up to the age of 50 years there are twice as many males as females involved; over 50 there are more females than males.

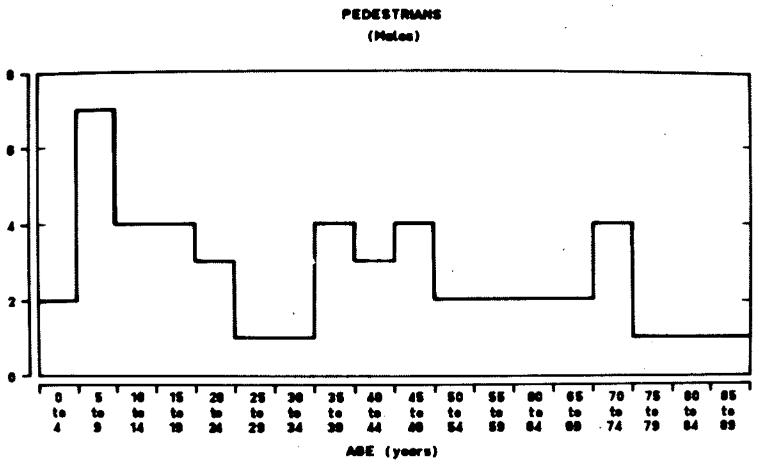


Fig. 4.3
Ages of male pedestrians.

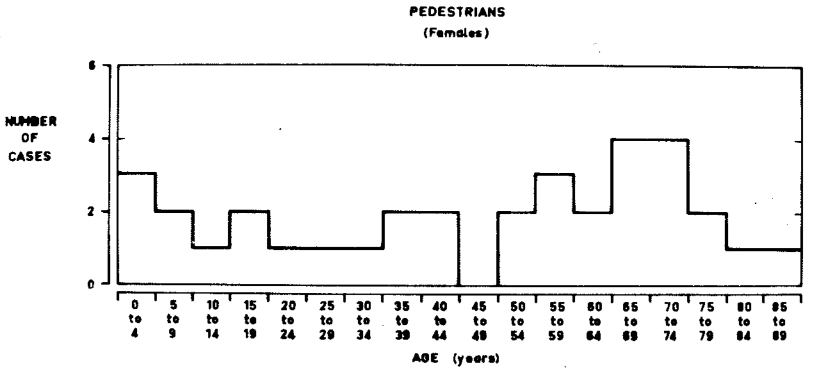


Fig. 4.4
Ages of female pedestrians.

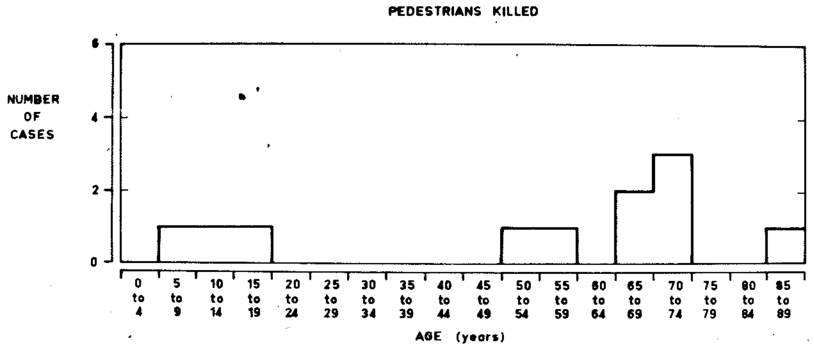


Fig. 4.5
Ages of pedestrians killed.

4.6 Figure 4.2 shows the age distribution of the population of metropolitan Adelaide. Superimposed on this is a curve showing the ratio between the number of pedestrian accidents in our sample and the number of people in each age group. The ratio has a minimum value at about the age of 25 years, and increases rapidly beyond the age of 60 years. This means that the risk, of being involved in a pedestrian accident, first falls slightly with increasing age, reaching a minimum in the years 20-29. It then increases gradually to the age of 60. From there the risk increases greatly with increasing age. The shape of this curve is similar to the J-shaped curve quoted by Haddon et al (Ref. 29) as representing the age-specific death rates of pedestrians in Manhattan.

4.7 The ages of those pedestrians who had obviously consumed alcohol before their accident, as indicated by the smell of their breath and their general appearance and behaviour, are shown on Figure 4.1. Between the ages of 35 and 64, 11 of the 28 pedestrians involved had been drinking. There were two female pedestrians who had obviously consumed alcohol. They were both in this age group.

4.8 Haddon et al found two discrete groups in their above-mentioned study of 50 fatally injured adult pedestrians in Manhattan. One consisted of the elderly who had been drinking little or not at all, and the other of the middle aged who had been drinking heavily. These correspond with the two older age groups in this study.

4.9 In Figure 4.1 the three peaks at different ages correspond to circumstances in which co-ordination and awareness of surroundings are impaired or not fully developed. In childhood and youth there is lack of experience in assessment of risks. In the age range 35 - 64, in which people should have accumulated experience in risk taking and its results, the faculties are dimmed by alcohol in almost half the cases. Over the age of 64 the processes of degeneration cause a slowing of both mind and body, increasing the risks involved in crossing roads.

4.10 Nearly one seventh of these pedestrians were killed. The fatalities, involving six males and five females, are concentrated in the very young and very old age groups (Fig. 4.5). Of the six pedestrians over 12 years of age who survived less than 12 hours, one had alcohol present in the blood at necropsy (0.150 mg %). One male aged six was not examined post mortem. The other four survived from three to eighteen days.

4.11 There are thus three main groups of persons involved in pedestrian accidents:

1. Young males less than 20 years old.
2. Males aged 35 - 59 affected by alcohol.
3. Males and females more than 64 years old - females outnumbering males.

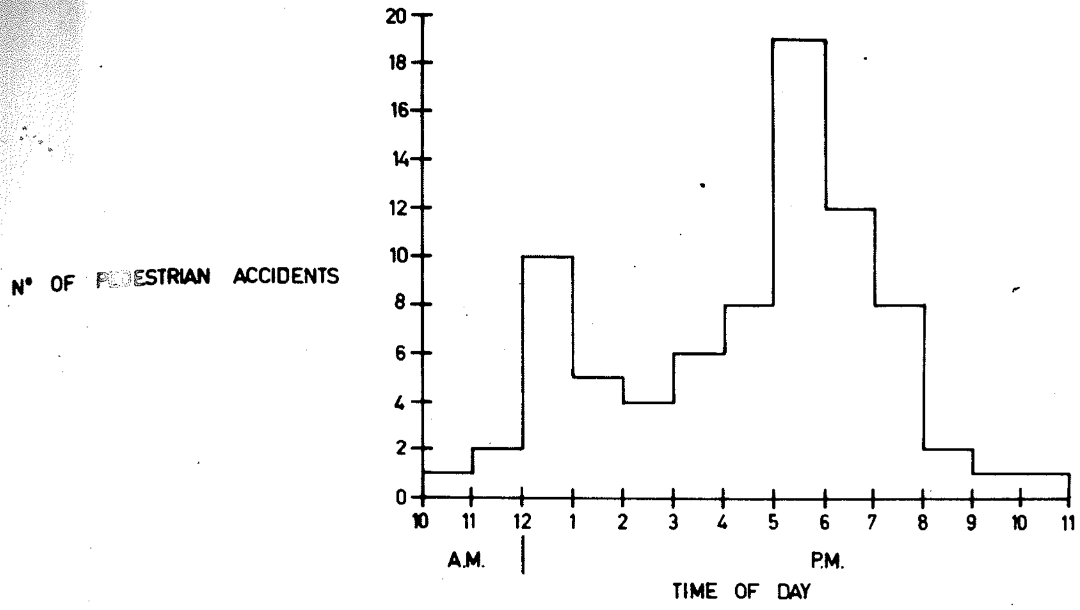


Fig. 4.6
Pesestrian accidents attended by time of day.

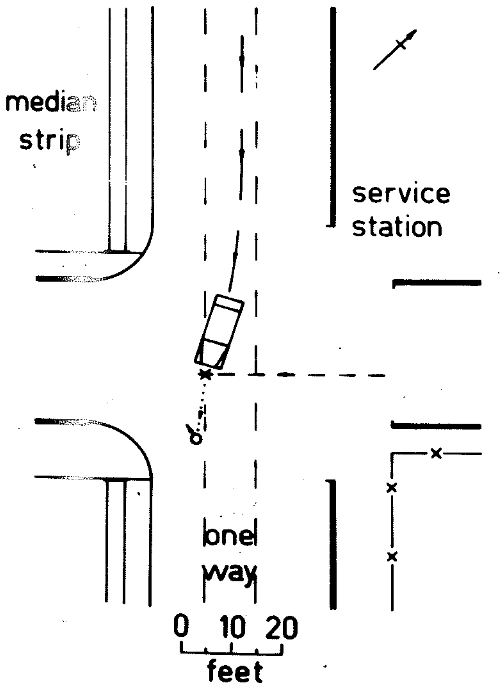


Fig. 4.7
Case 0177.

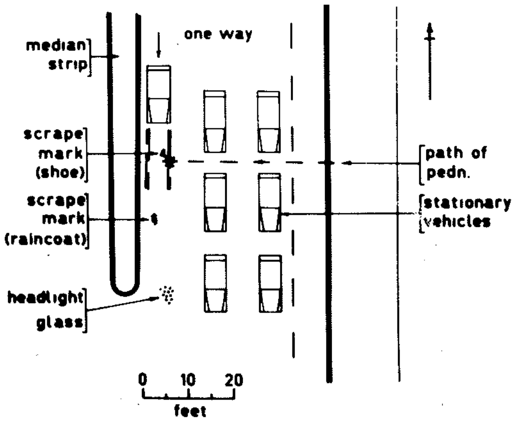


Fig. 4.8
Case 0317.

4.12 This is shown in Figure 4.6 for the hours between 10 a.m. and 11 p.m., this being the period during which we attended accidents. The histogram does not accurately represent the time distribution of all pedestrian accidents, for we were able to attend relatively more of the accidents occurring in the off-peak periods than in the peak periods (para. 3.14). Even so it can be seen that there are two peaks in Figure 4.6, one between 12 noon and 1 p.m. and the other between 5 and 6 p.m.

4.13 Children and elderly people were frequently involved in pedestrian accidents between noon and 4 p.m. Those aged between 10 and 70 years were more likely to be involved between the hours of 4 p.m. and 8 p.m. These groupings follow the times when these people are probably most often exposed to risk, i.e. on the roads.

Actions of the Pedestrian and the Driver before the Collision.

4.14 The movements and some of the actions of pedestrians and motor vehicle drivers are reported here. In each of the three cases in which there were two pedestrians involved only the elder of the two has been considered. This reduces the total number of pedestrians from 82 to 79.

4.15 The movements of both driver and pedestrian can be expected to be related to whether or not they saw the other party before the impact. In this regard there are three basic possibilities: the other party was not seen at all; he was seen, but too late to take effective avoiding action; he was seen in time to have taken effective avoiding action and yet a collision resulted.

What the Driver Saw

4.16 The second of the above three categories has been subdivided to distinguish between the case in which the driver saw the pedestrian at the last moment and was able to swerve or brake and the case in which he had insufficient time to attempt avoiding action. Examples of these four possibilities are listed below.

4.17 Driver saw the pedestrian : In the distance.

0177 A Holden FJ was travelling in the centre lane of a three lane divided highway. The driver saw a pedestrian starting to cross the road, from the left, at an intersection (Fig. 4.7). The pedestrian looked in the direction of the car and continued walking. The driver slowed. The pedestrian kept walking. Then the pedestrian "started" as if seeing the car for the first time, and hurried across the road. The driver of the car had begun braking by this time, swerved to his right and braked harder as the pedestrian hurried in front of him. The pedestrian was struck by the centre of the car and was thrown forwards as the car stopped. The pedestrian said he did not see the car until he was out in the middle of the road; then he did not know whether to jump upwards or forwards. The pedestrian was 84 and very fit but had a corneal opacity of his left eye. He sustained abrasions to the left forehead and the back of the left hand, and a bruise to the right calf.

4.18 Driver saw the pedestrian : Close, and did brake.

0200 A 49 year old male pedestrian came wandering out of a hotel across a main road. The 20 year old male driver of the car, a Ford Prefect, saw this pedestrian, braked, swerved to his right and just brushed the pedestrian with the left front head light and left side of the car. The pedestrian, who was drunk, sustained concussion and a small abrasion to the left side of his head.

4.19 Driver saw the pedestrian : Close, and did not brake.

0276 A 70 year old female pedestrian on a marked pedestrian crossing, at night, was struck by a Volkswagen at approximately 30 m.p.h. The driver of the car says that the pedestrian appeared from his left, apparently coming from in front of another car which was slightly ahead of him and on his left side. The pedestrian suffered compound fractures of right and left tibiae.

4.20 Driver saw the pedestrian : Not at all.

0234 A 59 year old pedestrian was struck by a Volkswagen travelling about 40 - 50 m.p.h. on an unlit road. The driver of the car did not see the pedestrian at all. He merely heard a bump, and then stopped and turned around to see what had happened. The pedestrian struck the left front mudguard of the car and dented the left front corner of the roof. He was killed, suffering extensive injuries to the thorax, spine abdomen and legs.

4.21 The number of cases in these categories are listed in the following Table.

TABLE 4.11

Driver saw Pedestrian	Braked before impact	Did not brake before impact	Not known if braked before impact	Total
In the Distance	11	3	-	14
Close	23	11	1	35
Not at all	-	13	-	13
Not known	2	3	12	17
	36	30	13	79

4.22 Considering only the cases for which all the information listed in Table 4.1 was known, it can be seen that the driver had an opportunity to take adequate evasive action in only 14 cases (23% of the total).

In 24 cases (39%) he did not have time even to attempt to take evasive action.

What the Pedestrian saw.

4.23 Many pedestrians were concussed and so unable to remember the events immediately preceding the impact. Using similar categories to the above yields :

TABLE 4.2. Pedestrian saw the vehicle:

In the distance	7
Close	11
Not at all	5
Not known	46
Not recorded	10
	79

4.24 Seven of the 23 pedestrians for whom this information is known or recorded saw the striking vehicle in time to take avoiding action and yet were hit. The other 16 pedestrians either saw the vehicle only when it was too late to take avoiding action, or did not see it at all. Examples of these situations are given below. There were also two pedestrians, not listed here, who were seen to 'start', as though seeing the car at the last moment, but who could not remember the accident.

4.25 Pedestrian saw the vehicle : In the distance.

0129 A 70 year old male pedestrian was struck by a Holden Station Sedan. The driver saw the pedestrian in the centre of the road, coming from her right. She sounded her horn and the pedestrian ran across in front of the car. She braked and swerved, striking the pedestrian with the left front corner of the car. The speed at impact was 21 - 30 m.p.h. The pedestrian said he saw the car in the distance but thought he had plenty of time to cross. He suffered abrasions to his nose and left knee.

4.26 Pedestrian saw the vehicle : Close.

0231 Collision between a pedestrian and an Austin A70. The speed of the car was 30 - 35 m.p.h. The driver saw the pedestrian on the left side of the road looking away from him. As she started to cross the road he sounded his horn, and then when he was very close she jumped out in front of him. He braked, swerved to the left and struck her with the right head light. The pedestrian said she looked both ways, did not see any traffic approaching, and suddenly saw this car nearly on top of her. The pedestrian, aged 37, suffered a comminuted fracture of the right hip, which was compound from within through a small laceration in the right groin and fractures of the right side of the pelvis. She also had an abrasion to the left knee, and a bruise of the bridge of her nose.

4.27 Pedestrian saw the vehicle : Not at all.

0381 A 57 year old woman crossing a wide road with a narrow median strip looked both ways, did not see any traffic, and was struck by a Ford Falcon coming from her right. She said she did not know where it came from. The driver of the car said the pedestrian stepped straight out without looking. The pedestrian sustained fractures of the right side of the pelvis and a bruise to the right calf.

4.28 Pedestrian Movements. Of these 18 pedestrians one was walking on the road with his back to the traffic when he suddenly heard a car behind him; and one was walking on the footpath when a car with a trailer backed into him from a parking area. Eliminating these two cases, the other 16, together with 7 who saw the striking vehicle in the distance, were crossing the road from either the right or the left as listed in Table 4.3. In this table the terms "from the right" and "from the left" refer to the direction of movement of the pedestrian as seen by the driver of the striking vehicle. (The two seen to 'start' before the impact are included in 'close'.)

TABLE 4.3.

Pedestrian first saw the striking vehicle:	Pedestrian crossing from: Left	Right	Total
In the distance	3	4	7
Close	8	3	11
Not at all	4	1	5
	15	8	23

4.29 Of those who first saw the striking vehicle in the distance, almost equal numbers were crossing from the right (4) and the left (3), while of those who first saw the vehicle when close or not at all, three times as many were crossing from the left (12) as from the right (4). Thus it would seem that a greater proportion of pedestrians crossing from the left side of the road failed to see the striking vehicle.

4.30 This result suggested that there may be more chance of there being an obstruction which obscures an approaching vehicle when the pedestrian is crossing from the left rather than from the right. Of the 76 pedestrians who were crossing the road when hit, 23 could not see the striking vehicle because it was obscured by a moving or stationary vehicle, e.g.:

> 0317 A 33 year old female pedestrian ran between stationary cars in the two left traffic lanes and was struck by a 1958 Ford Zephyr travelling down the outside lane. The pedestrian suffered a fracture of the right side of the pelvis and a fracture of the mid-shaft of the right tibia. (Fig. 4.8.)

4.31 In 19 of these 23 cases the pedestrian was coming from the left side of the road, and in only 4 cases was the pedestrian coming from the right. i.e. 41% of the 46 pedestrians coming from the left were obscured by a moving or stationary vehicle, and only 13% of pedestrians crossing from the right. Where there was no obstruction to vision the numbers of pedestrians struck, who were coming from the right and from the left, were approximately equal.

4.32 The relevant information for all 76 cases is listed in the following Table.

TABLE 4.4

	Pedestrian crossing from Left	Pedestrian crossing from Right	Total
Pedestrian crossing with back to traffic	2	2	4
Masked by stationary vehicle	13	2	15

Masked by moving vehicle	6	2	8
No obstruction to vision	25	24	49
	46	30	76

4.33 Vehicle Movements. The next Table shows the movements of the vehicles which were involved in the 27 cases where there was some obstruction of vision (23 cases where a vehicle obscured vision and 4 cases where the pedestrian had his back to the traffic).

TABLE 4.5.

Vehicle Motion:	Pedestrian crossing from: Left	Right	Total
Proceeding straight ahead	10	4	14
Proceeding straight ahead, overtaking	9	2	11
Turning left,	2	-	2
	21	6	27

4.34 In almost half (9 of 21) of the cases where the pedestrian was crossing from the left the striking vehicle was overtaking, e.g.

0356 A Holden FB sedan travelling at 35 m.p.h. moved into the centre of the road to pass a car travelling in the same direction. The driver suddenly saw in his headlights three females standing in the centre of the road, facing to his right. A 13 year old girl was struck by the right front headlight and thrown to the right. She suffered head injuries and a fractured right arm and died 12 hours later. The second woman, aged 23, was standing behind and to the left. She was struck by the centre of the bonnet, and suffered concussion and fractures of the face and right leg. The third pedestrian escaped injury. The driver did not brake before the impact.

4.35 In 11 of the 27 cases where vision was obscured the pedestrian was struck by a vehicle which was overtaking. Over three quarters of these pedestrians were coming from the left. Assuming that equal numbers of pedestrians cross from the right side of the road as from the left, which appears reasonable, it seems that pedestrians crossing from the left are struck more often than pedestrians crossing from the right. This may be because pedestrians crossing from the left are masked by moving or stationary vehicles more often than those coming from the right. Furthermore, vehicles which strike these pedestrians are often overtaking other vehicles. The overtaken car screens the pedestrian, crossing from the left in front of it, from the overtaking car.

4.36 However, there were 49 cases (of 76) where there was no obstruction to vision, but a collision resulted. 25 pedestrians were coming from the left and 24 from the right. These 49 cases in which there was no obstruction to vision can be subdivided thus:

TABLE 4.6.

Driver first saw pedestrian:	Pedestrian coming from: Left	Right	Total
In the distance	7	3	10
Close	9	11	20
Not at all	2	4	6
Not known	7	6	13
	25	24	49

4.37 Thus, in 26 of 49 cases the driver did not see the pedestrian until it was too late to avoid a collision, even though there was no obstruction to vision. 19 of these cases occurred at night. This points to the difficulty drivers have in seeing pedestrians at night.

4.38 The vehicle motions in these 26 accidents are set out in the following Table.

TABLE 4.7.

Vehicle Motion:	Pedestrian coming from: Left	Right	Total
Proceeding straight ahead	7	7	14
Proceeding straight ahead, overtaking	1	4	5
Turning right	2	3	5
Turning left	1	1	2
	11	15	26

4.39 It seems that where there is no obstruction to vision, vehicles travelling straight ahead hit pedestrians coming from the right and left

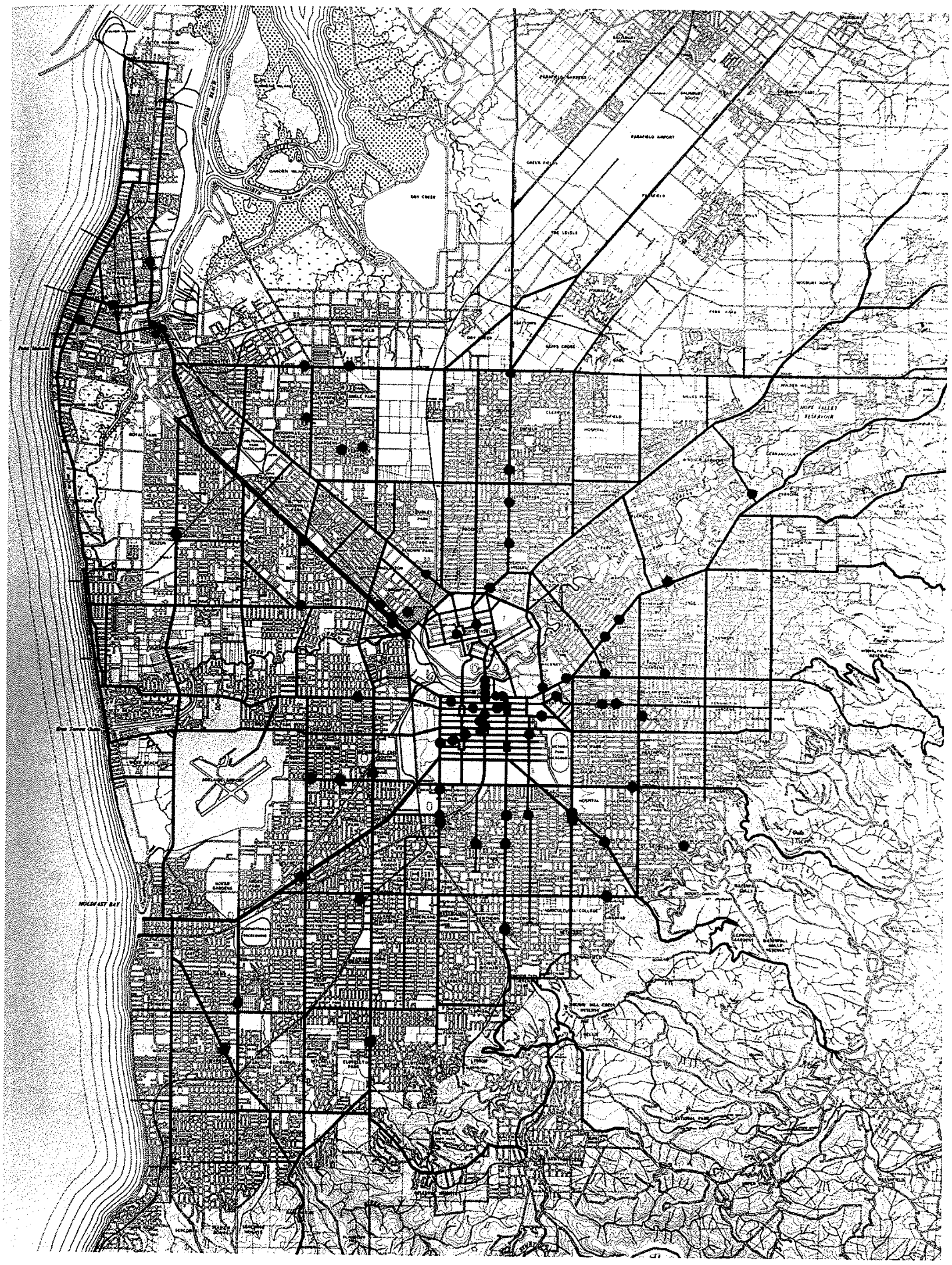


Fig. 4.9
The location of the pedestrian accidents in the TARU survey.

equally often. It therefore seems likely that the greater number of pedestrians in our sample who were hit coming from the left were involved because they were obscured from the driver for one reason or another, since, when there is no obstruction to vision, pedestrians crossing from the right and the left are hit equally often.

Pedestrians standing in the centre of the road.

4.40 It is a common sight to see pedestrians standing in the centre of a busy road, with their backs to one stream of traffic, waiting for a gap in the other stream to complete their crossing. There is a considerable risk attached to this procedure, as shown by the fact that 11 of the 76 pedestrians struck while crossing the road were "stranded in the middle". 6 of these pedestrians were crossing from the left and 5 from the right. It is clear that many of these particular accidents would not have occurred had there been a pedestrian refuge of some kind in the centre of the road.

The Effect of the Environment.

4.41 The locations of these pedestrian accidents are shown in Figure 4.9. Almost all occurred on busy roads In fact 72 of a total of 79 occurred on roads carrying more than 5,000 vehicles in 12 hours; the remainder occurred on minor side streets.

4.42 Almost half of the pedestrian accidents occurred very close to a shop or in a shopping area, as is shown by the following Table. A 15 m.p.h. speed limit past schools and the frequent use of traffic monitors

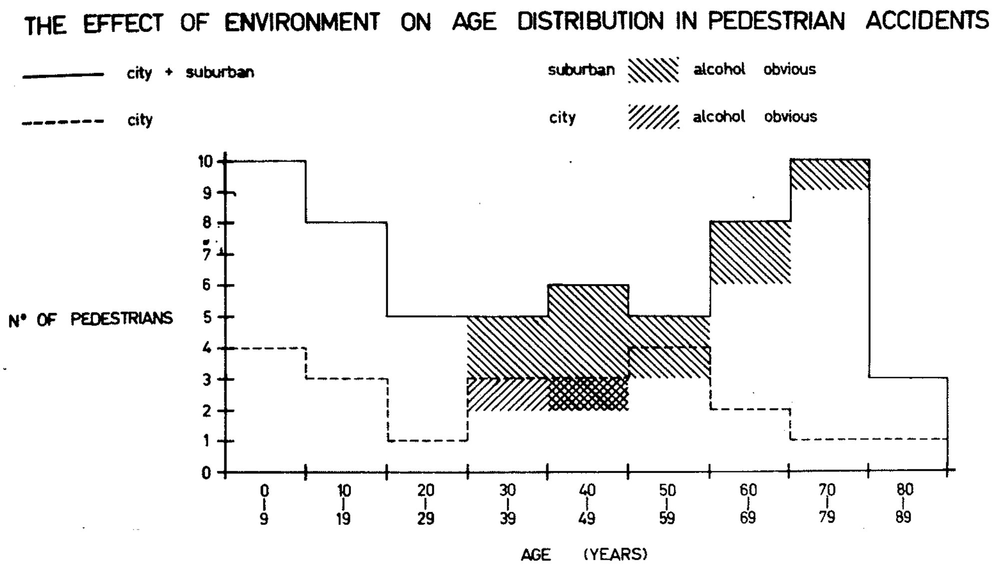


Fig. 4.10
Effect of environment on age distribution in pedestrian accidents.

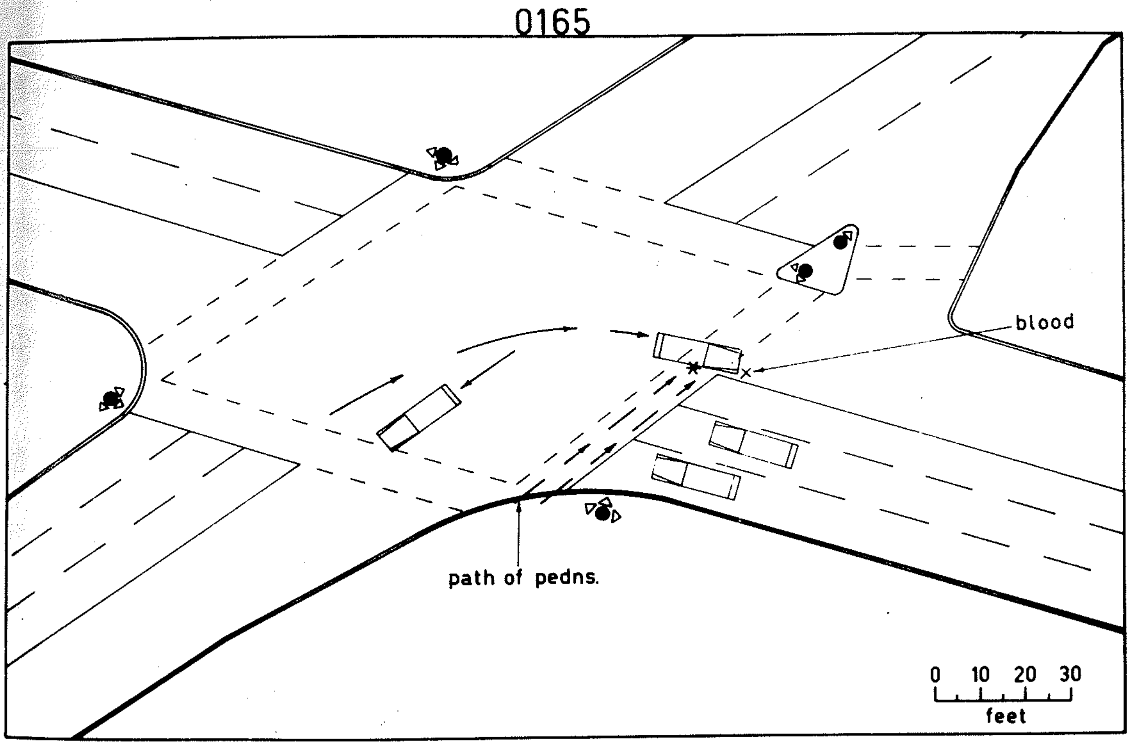


Fig. 4.11
Case 0165.

on school crossings may have limited the number of pedestrian accidents near schools. Accidents involving children occurred mainly away from schools and during weekends.

TABLE 4.8

Locality of Accident		No. of Accidents	% of total
Suburban	Shopping	34	43.0
	Residential	16	20.3
	School	4	5.1
	Industrial	5	6.3
City	Commercial	18	22.8
	Residential	2	2.5
		79	100.0

4.43 The age distribution of pedestrians involved in accidents, as shown in Figure 4.1, refers to the whole metropolitan area. When it is subdivided into city and suburban accidents there are marked differences between the resulting two age distributions (Figure 4.10).

4.44 The ages of pedestrians involved in accidents in the suburbs are distributed in a similar form to that shown in Figure 4.1. There are three main groups, children, middle aged males who had consumed alcohol shortly before their accident, and elderly people. By comparison the city distribution has a smaller proportion of children and elderly people. There are also only two city pedestrians who had been drinking; the other eleven cases all occurred in the suburbs. This variation between the two distributions may be a reflection of the fact that children and elderly folk are mainly walking across roads in the vicinity of their homes, which are in the suburbs. Most of the pedestrians in the city are transients who are there on business, and are therefore generally people between the ages of 20 and 60 years.

4.45 Pedestrian accidents in the city account for one quarter of all pedestrian accidents in the metropolitan area, whereas only one fifth of the remaining types of metropolitan traffic accidents occurred in the city. Although this difference is not statistically significant (Chi square = 2.46) and may be due to chance, it is a result that could be explained by the large numbers of pedestrians and vehicles on the city streets. It may point to a need for greater pedestrian protection in the city area, even to the detriment of vehicular traffic flow. The City of Adelaide has many wide streets without median or pedestrian refuges. One third of the pedestrian accidents we attended in the city might have been avoided had a median or refuge been provided.

Pedestrian Accidents at and near Intersections

4.46 The definition of an "intersection accident" has caused some difficulty. After some consideration it was decided that only those accidents which were influenced by the presence of an intersection would be called intersection accidents. This excludes cases in which a pedestrian - vehicle collision occurred where two roads intersected and one of the roads could have been ignored without affecting the course of the accident. Using this definition, there were 20 accidents at intersections and 59 accidents not at intersections, i.e. there were 20 accidents (25%) where the intersection played a part in the production of the accident. However, this does not tell us how many accidents took place within the boundaries of an intersection, regardless of whether the intersection had anything to do with the accident.

4.47 Also, it has been pointed out by the Road Research Laboratory in England (Ref. 30, p.84) that the area on either side of a pedestrian crossing is more dangerous than the crossing itself. It seemed likely that this would apply to intersections, for drivers of vehicles will be concentrating on the intersection and its traffic and they possibly will fail to observe pedestrians crossing close to the intersection. Therefore all the pedestrian accidents were classified thus:

1. At an intersection:- The impact point was within the extensions of the property alignments of the road at the intersection.
2. Within 20 yards of an intersection:- Before the vehicle reached the intersection, or "upstream",
3. Within 20 yards of an intersection:- After the vehicle had passed the intersection, or "downstream".
4. Not at intersection:- more than 20 yards from the boundaries of an intersection.

4.48 The results of this classification are shown in the following Table:

TABLE 4.9.

Location of Pedestrian Accident:	No. Cases	% of Total
At intersection	28	35.5%
Within 20 yards before an intersection	5	6.3%
Within 20 yards after an intersection	17	21.6%
Not at intersection	29	36.6%
	79	100.0%

4.49 There were three times as many pedestrians struck when crossing just past an intersection, than just before an intersection. It seems reasonable to assume that on the average as many pedestrians cross "upstream" of an intersection as "downstream", and the fact that three times as many pedestrians are struck within the 20 yards beyond an intersection as are struck within the 20 yards before an intersection means that vehicles are more likely to strike pedestrians beyond the intersection than before it. From the pedestrian's point of view, his greatest danger lies in the car approaching from the intersection.

4.50 The directions in which the pedestrians were crossing the road are shown in the following Table:

TABLE 4.10.

Pedestrian crossing from the	At Intersection	Within 20 yds of intersection.		Not at intersection.	Total
		Before	After		
Right	12	3	6	9	30
Left	16	2	11	17	46
	28	5	17	26	76

(3 not crossing)

There were twice as many pedestrians coming from the left as from the right, of those crossing after and not at an intersection. The numbers are more nearly equal for those crossing before and at intersections.

4.51 The distribution of these accidents by day and night is listed in the following Table:

TABLE 4.11	At Intersection	Within 20 yds. of intersection		Not at intersection	Total
		Before	After		
Day	15	3	7	20	45
Night	13	2	10	9	34
	28	5	17	29	79

4.52 Comparing accidents within the 20 yards after an intersection with the other 62 accidents shows that the ratio of day:night accidents is lower for the former group. Although the difference in numbers of accidents by day and night is not significant (Chi square = 2.2), this does suggest that the difficulties involved in seeing pedestrians at night are accentuated in the area just past an intersection.

4.53 The movements of the vehicles were as listed below:

TABLE 4.12

Vehicle Motion	At intersection	Within 20 yds of intersection		Not at intersection	Total
		Before	After		
Proceeding straight ahead	16	3	8	22	49
Proceeding straight ahead, overtaking	5	2	5	6	18
Turning Right	6	0	0	0	6
Turning Left	0	0	4	0	4
Not known	1	0	0	1	2
	28	5	17	29	79

In three of the four accidents involving left turns, the pedestrian was crossing from the left, and so the vehicle was coming from behind the pedestrian.

4.54 The area within the 20 yards after an intersection therefore seems to be more dangerous for the pedestrian than the corresponding area before an intersection. The 'downstream' area is the scene of proportionally more night accidents and also involves more left turning vehicles.

Vehicle Movements in Pedestrian Accidents by Day and Night.

4.55 Comparing movements of vehicles involved in pedestrian accidents by day and by night there seem to be relatively more vehicles involved while overtaking at night than in the day time.

TABLE 4.13

	Vehicle Proceeding Straight Ahead	Over-taking	Entering Traffic Lane	Turning Right	Turning Left	N.R.	Total
Day	31	9	1	3	2	0	46
Night	18	9	0	3	2	1	33
	49	18	1	6	4	1	79

4.56 The following Table shows how the reduced visibility at night affects the ability of drivers to see pedestrians before impact.

TABLE 4.14

	Driver saw pedestrian				
	In the distance	Close	Not at all	Not Recorded	Total
Day	14	16	5	11	46
Night	0	19	8	6	33
	14	35	13	17	79

Pedestrian Crossings

4.57 Seven of these 79 accidents happened at or within twenty yards of a controlled pedestrian crossing Only one of these crossings was entirely for the convenience of pedestrians. The accident at this crossing, which consisted of pedestrian-operated traffic lights, involved a boy who ran onto the crossing into the side of a car which had come from his right. Both the boy and the driver claimed to have had the green light.

4.58 There were three accidents at light-controlled intersections. One of these was caused by a driver who did not stop for the red light and hit, on the far side of the intersection, a boy crossing with the green light. Another involved a car turning right after slowing to allow a car to go by in the opposite direction. (Fig. 4.11.) The driver of the case car did not see two women crossing the road with the WALK sign until it was too late to avoid a collision. The pedestrians were concussed and unable to remember whether they had seen the car. The third accident involved a pedestrian running across the road in a rainstorm. The driver of the car which hit this pedestrian claimed that he was travelling with the green light; the pedestrian was concussed. The first of these three accidents happened at midday, the second at night, and the third late in the afternoon.

4.59 There were also three accidents within 20 yards of light-controlled intersections. These were all night-time accidents involving female pedestrians who were struck by vehicles leaving the intersection. In one case the vehicle was a bus which had come straight across the intersection and hit the pedestrian who was running across the road from the right. Another case was very similar, although the vehicle was a car and the pedestrian was crossing from the left in heavy rain. The remaining case also happened in heavy rain. The pedestrian, running across the road from the left, was struck by a van which had turned left at the intersection.

4.60 Four of these seven accidents were at night, and three happened in rain storms. These storms are not common in Adelaide and the occurrence of three of these seven accidents at such times suggests that pedestrians choose to risk their lives rather than get wet.

4.61 At the time of this survey uncontrolled pedestrian crossings ("zebra crossings") were not common in Adelaide. Some local authorities did provide unauthorised pedestrian crossing which were simply indicated by two parallel broken lines, 3 yards apart, painted across the road. The pedestrian had no legal right of way on these unauthorised crossings.

4.62 There were three accidents in which the pedestrian was using such an unauthorised crossing. One of these was at night in the rain. The full story of this accident is not known because the driver of the car refused to offer any information and left the scene before the police arrived. The other two accidents each involved a pedestrian who was crossing from the left in front of a slowly moving vehicle and was struck by a car overtaking this vehicle at the crossing. Both these accidents happened in fine weather, one at night, the other late in the afternoon. One additional case involved a car which passed a vehicle that had stopped for pedestrians on the unauthorised crossing, and then struck a pedestrian who was crossing from the left a few yards along the road beyond the marked crossing.

4.63 Apart from the one case for which the information is incomplete each accident on or near an unauthorised pedestrian crossing involved a car which was passing another vehicle that had slowed down to allow a pedestrian to cross the road. This suggests that these crossings, at which the driver is not legally required to stop, both confuse the motorist and give the pedestrian a false sense of security. The result may well be that such pedestrian crossings introduce additional hazards without removing those already present.

4.64 When initiating a programme for the protection of pedestrians it might seem reasonable to rely on accidents to indicate the most useful locations for pedestrian crossings. This survey has shown that not all pedestrian accidents are relevant to the provision of a crossing. For example, a child who has run onto the road and been hit by a car most probably would not have been influenced by the presence of a pedestrian crossing. A pedestrian who has had too much to drink and wanders carelessly across the road is unlikely to make use of a pedestrian crossing. Over one half of the pedestrian accidents in our survey but outside the central city area are in this category. This is a sufficient proportion to

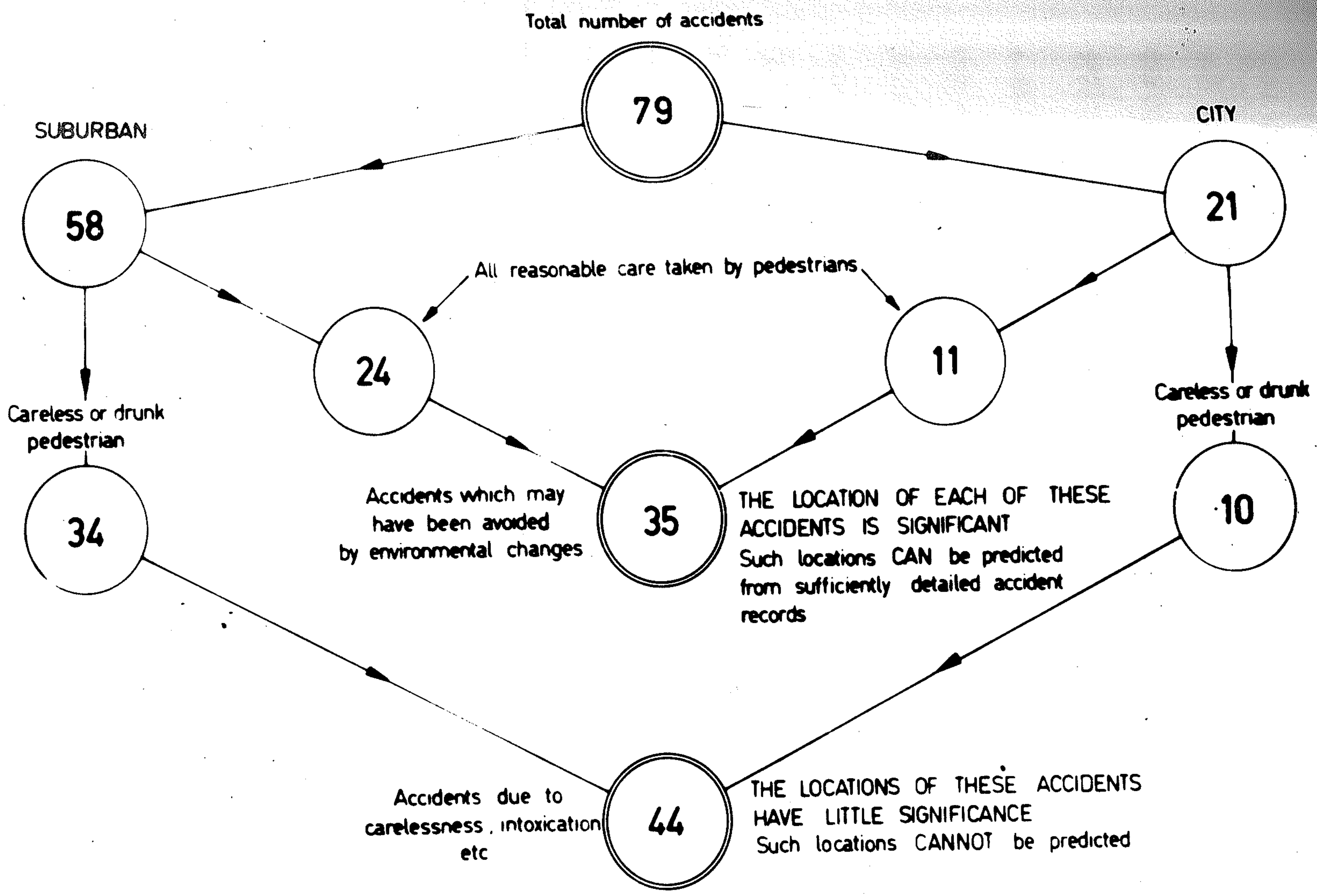


Fig. 4.12
The role of the environment in these pedestrian accidents.

give the impression that any pedestrian accident depends mainly on chance and not on the characteristics of the particular location. What then of the remaining accidents that cannot be attributed to carelessness on the part of the pedestrian?

4.65 Suburban accidents have been separated from city accidents in this analysis because the State Highways Department has recently completed a series of counts of pedestrian and vehicular traffic in the suburbs. (The Adelaide City Council is responsible for traffic management in the city proper.) Traffic conditions are among the many factors that must be considered before deciding whether or not to install a pedestrian crossing at any given location (Ref. 31). Responsibility for each pedestrian accident has also been assigned, as shown in Figure 4.12.

4.66 24 of the 58 suburban accidents and 11 of the 21 city accidents involved pedestrians who were taking care and yet were struck and injured by a vehicle. At 14 of the 24 suburban locations the flow of vehicles is such that few pedestrians would be likely to go out of their way to cross the road at a marked crossing. At the remaining 10 locations the volume of pedestrians and vehicular traffic is sufficient to suggest that a pedestrian crossing may be desirable. However, this does not necessarily mean that if crossings were in fact installed at these 10 places we could expect a reduction in accidents of up to one sixth (10 cases in 58). This would be the maximum reduction possible. In practice it would probably be less for many other factors are involved.

4.67 In fact accidents - or their absence - though very important are not the only criterion for the provision of pedestrian crossings. Ease, convenience and absence of anxiety for the pedestrian are also important. Just as it seems to be particularly dangerous to cross the road near but not at traffic lights or an intersection so it is likely to be more dangerous near but not on a pedestrian crossing. Under conditions of low traffic flows pedestrian behaviour may result in a pedestrian crossing introducing more hazards than it replaces, for pedestrians seem to study their own convenience rather than safety when crossing roads, and therefore are reluctant to walk even a short distance to the actual crossing unless heavy traffic makes it easier to use the crossing.

4.68 The above discussion is not to be taken as adverse criticism of the provision of pedestrian crossings, but rather as a warning that such a measure cannot be expected to be a "cure-all" for this problem of pedestrian accidents. The frequency of such accidents and the associated high injury and fatality rates do mean that even small reductions, such as would result from the installation of crossings, are very significant.

Travelling Speed and Speed at Impact.

4.69 The travelling speeds and impact speeds of all vehicles in the 79 pedestrian accidents are shown in the following Table.

TABLE 4.15

	Speed - m.p.h. - All Vehicles.							
	1-10	11-20	21-30	31-40	41-50	Reversing	Not recorded	Total
Travelling Speed	6	13	23	23	3	1	10	79
Impact Speed	13	22	21	12	3	1	7	79

This table shows that the mode of the travelling speeds is about 10 m.p.h. higher than that for the impact speeds.

The collision with the striking Vehicle.

4.70 In these accidents, pedestrians are injured in two ways, first by direct impact with the striking vehicle, and secondly by subsequent impacts with the road surface. The severity of the injuries will depend mainly on the shape and speed of the striking vehicle, since these determine the number and severity of the multiple impacts which follow the initial impact.

Pedestrians and Pedal Cycles.

4.71 There was only one collision between a pedestrian and a pedal cycle.

0167 A 60 year old woman walking from the right side of the road, diagonally, with her back to the traffic, was struck from behind by a pedal cycle ridden by a 16 year old boy who rode out of a gateway and turned on to the road without looking. The pedestrian suffered concussion and abrasions and a laceration to the right side of her head from contact with the road. She had a bruise on her right buttock which might have been caused by the bicycle.

Pedestrians and Motor Cycles.

4.72 Six of the seven collisions took place in daylight, the other at night. All happened more than 20 yards from an intersection. Six of the pedestrians were coming from the left and one came from the right. One pedestrian was masked by a moving vehicle and one by a stationary vehicle.

4.73 There were 5 males and 2 females involved. One 73 year old woman died of complications. She received fractured ribs and an oblique fracture of the left tibia. 5 of the 7 pedestrians suffered concussion and abrasions and bruises to the head; one received fractured ribs. Abrasions to the arms and legs nearly always occurred.

4.74 There were 3 fractures of the lower leg. Two of these were oblique, involving the ankle region. These indicate that the main fracturing force resulted from torsion combined with bending and compression of the tibia by the body weight. In both of these cases the pedestrian and the motorcycle were upright at impact. In the third case the motorcycle was sliding on its left side and the under surface of the engine, gearbox and frame struck the left lower leg of the pedestrian, producing transverse fractures of the type associated with direct impacts.

4.75 From this it would seem that when a motorcycle strikes a pedestrian, the front wheel goes to one or other side of the pedestrian's body. The headlight and handlebar strike the pedestrian at about buttock level,

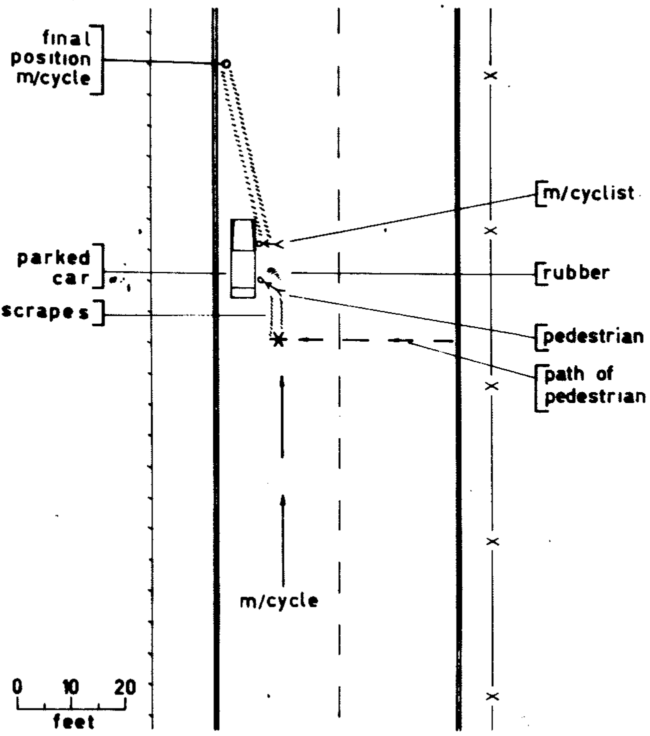


Fig. 4.13
Case 0424.

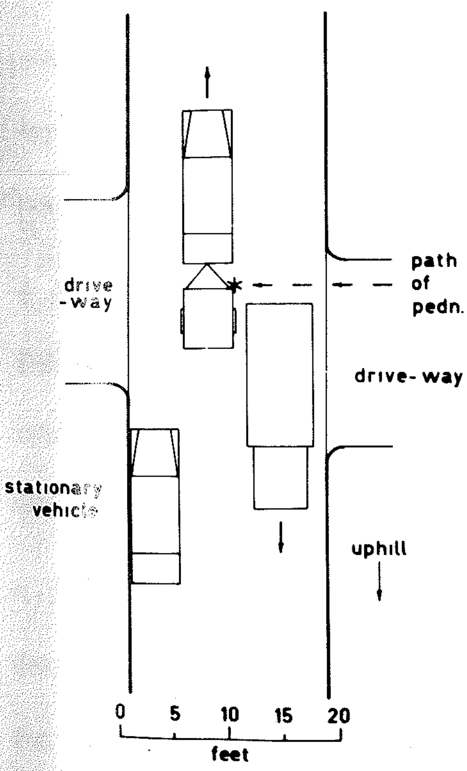


Fig. 4.14
Case 0092.

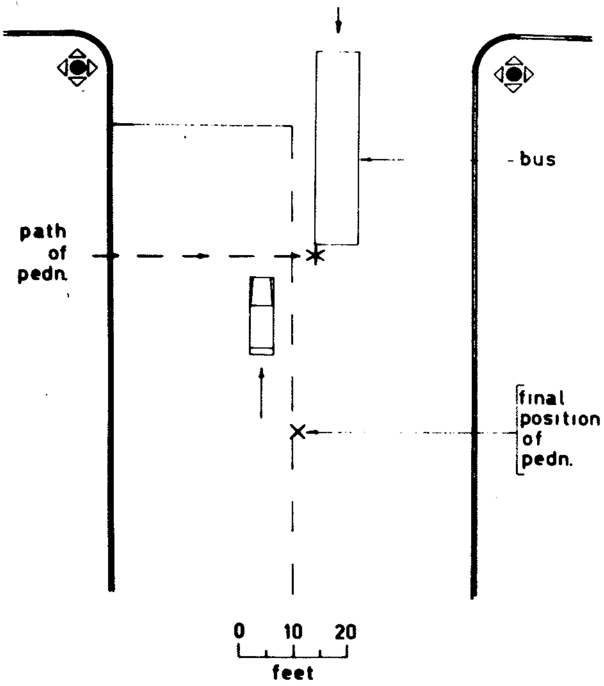


Fig. 4.15
Case 0389.

producing the torque which may produce an oblique fracture of the lower leg if the foot is fixed on the road. The foot may be fixed by body weight or perhaps by the front wheel of the motorcycle passing over it at the same time as the handlebars strike the buttocks.

4.76 After the impact with the front of the motor cycle, the pedestrian falls to the road, almost invariably striking his head and sustaining concussion, abrasions and lacerations as he rolls down the road. The motorcycle rider falls with the machine, generally sustaining abrasions to his bony prominences. In one case (Fig. 4.13) the motorcyclist braked and skidded before impact. The motorcycle struck the pedestrian while sliding on its side, and the motorcyclist, who was wearing a helmet, almost simultaneously fell off and struck his head on the side of a parked car. He suffered concussion.

4.77 In summary; pedestrians struck by motorcycles suffer bruises to the upper thigh and buttocks and fractures of the lower legs caused by the machine, and head injuries caused by impacts with the road. The rider of the motorcycle generally suffers minor injuries from his fall to the road.

4.78 The vertical number plate on the front mudguard required by law in South Australia seemed not to cause more than minor injuries, for it bends out of the way if struck with any force.

4.79 There seems to be no obvious explanation for the failure of pedestrians to see motorcycles. Presumably, if they had seen the motorcycle there would not have been an accident. It may be that the motorcycle is smaller and therefore harder to see than a car, and when seen is closer. All except one accident happened in daylight, and only in two cases was there any obvious obstruction to vision. In one other case, the pedestrian was crossing the road diagonally with his back to the motorcycle which struck him. Unfortunately, most of the pedestrians were concussed and were unable to remember whether they saw the motorcycle before impact.

Pedestrians and Trucks.

4.80 We have included in "trucks", heavy utilities, trucks of all sizes, buses and vans. There were four male and three female pedestrians involved. They ranged from a boy of 5 to a woman of 85. There were two rather unusual cases:

0187 A man of 28 was seen to walk on to the road from the right of a Fargo utility. As the utility approached the man suddenly seemed to hunch himself down and charged into the front of the utility with his left shoulder. The driver of the utility braked and swerved to try to avoid a collision. The speed at impact was 11-20 m.p.h. The pedestrian struck the right front corner and headlight of the utility and was thrown forwards onto the road. He suffered concussion and fractured ribs on the left side. He was very depressed, and on psychiatric investigation was found to be psychotic.

0237 An inebriated 61 year old male staggered into the left side of a fire engine, which was travelling very slowly at the time. One of the crew leaned out and pushed him off. Whereupon he fell down, dislocating his right shoulder and sustaining concussion.

In the other accidents -

> Two pedestrians were looking to the left as they stepped into the road, and were struck by buses coming from their right.
>
> One pedestrian ran across in front of cars coming from her right and was struck by a bus coming from her left (Fig. 4.15).
>
> A small boy ran diagonally onto the road from in front of a parked truck, with his back to the Land Rover which hit him.
>
> A Commer Van turning left at traffic lights in heavy rain struck a woman coming from the left, just past the corner.

In these cases it seems that none of the pedestrians looked in the direction from which the vehicle was coming. Presumably, if they had looked, they would have seen the vehicles, which were all fairly large, and perhaps not tried to cross the road just then.

4.81 The injuries received were rather more severe than those sustained by pedestrians struck by motor cycles.

> 0126 An 85 year old woman died of cerebral complications 3 days after she was struck by a Volkswagen Kombi Van. Her other injuries were fractured right ribs, a compound fracture of the right forearm and a disruption of an intervertebral disc in her cervical spine.

This was the one death among the 7 pedestrians struck by trucks.

4.82 All the pedestrians suffered concussion, mainly through striking the road. One received a fractured skull from the front of a Commer Van. Three pedestrians received fractured ribs, one with damage to the lung. These three were struck respectively by a Leyland bus, a Fargo utility and a Volkswagen Kombi-Van, at speeds between 11 and 30 m.p.h., and these injuries were directly caused by the fronts of the vehicles.

4.83 Three of the five injuries to the lower limbs were caused by the striking vehicles. The door hinge on a Volkswagen van lacerated the thigh of an 85 year old woman, the bumper and grille on a Commer van produced bruises on the calf and hip in a 69 year old woman, and a 55 year old woman had her left femur fractured when struck by a Leyland Bus.

4.84 The pedestrian struck by a truck or bus is likely to suffer severe injuries; those to the body being caused by the direct impact, and those to the head from being subsequently thrown to the road.

Pedestrians and Cars with Trailer.

4.85 In two of the accidents involving cars with trailer the pedestrians were struck by the trailer. In the first, a 3 year old girl ran out from behind a truck into the right side of a trailer drawn by a utility travelling in the opposite direction at 11-20 m.p.h. (Fig. 4.14). She sustained concussion, and abrasions to the back and arms. In the other case, a 22year old man was backing a trailer, piled high with empty packing cases, out of a parking area and knocked down an 88 year old man, who passed completely under the trailer and halfway down the car. The pedestrian sustained many abrasions from the road surface and the under parts of the car and trailer, but was otherwise unhurt.

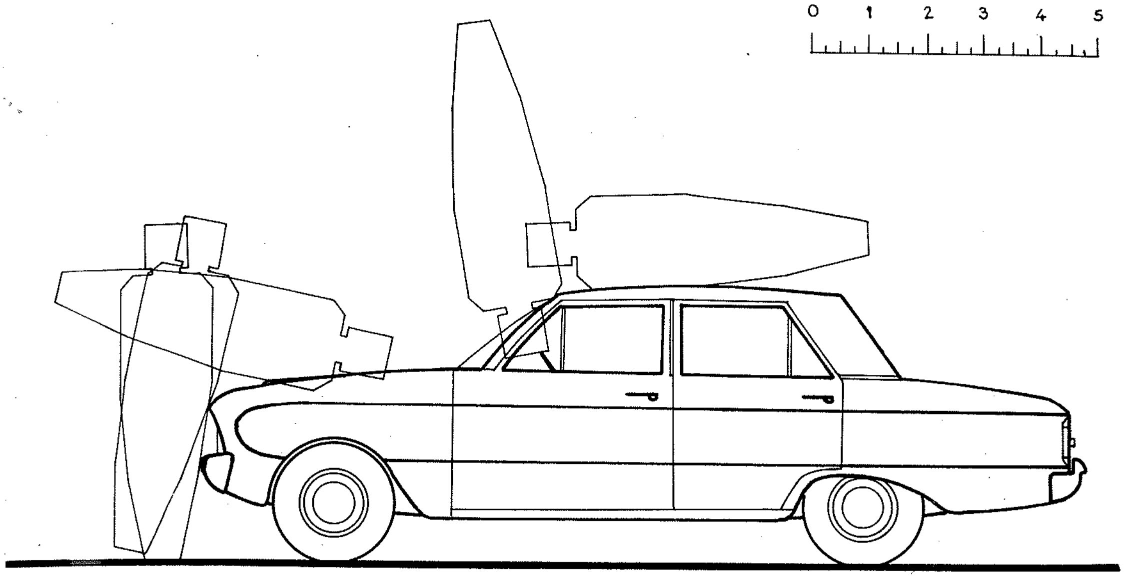


Fig. 4.16
Movements of an adult pedestrian struck by a Ford Falcon sedan.

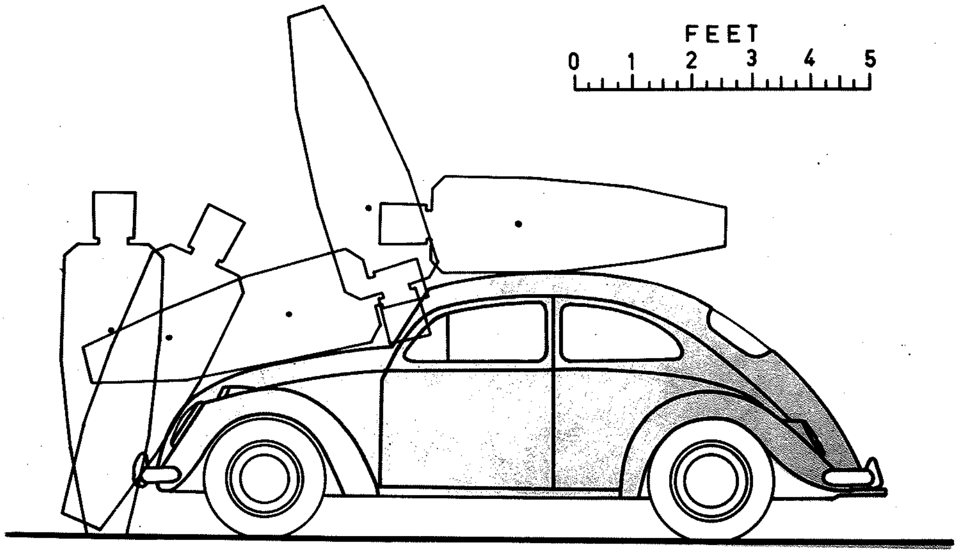


Fig. 4.17
Movements of an adult pedestrian struck by a Volkswagen.

4.86 In the other two cases the pedestrian was hit by the front of the car. A 3 year old girl ran across the road from the right and was struck by the front of a Holden FJ utility drawing a trailer and passed under both utility and trailer, suffering a few abrasions on the way. In the fourth case, another 3 year old girl ran out from between parked cars into the left head light of a Ford Zephyr, which was towing a trailer at 11 - 20 m.p.h. She sustained lacerations of the face and concussion.

Pedestrians and Cars.

4.87 There were 60 accidents, involving 63 pedestrians and 61 cars. On 3 occasions one car struck two pedestrians; and one occasion one pedestrian was struck by two cars.

4.88 It has been seen that pedestrians when struck by motorcycles and trucks suffer head injuries from striking the road, and injuries to the rest of the body from direct impact with the striking vehicle. This pattern is seen again in pedestrians who are struck by cars.

4.89 Contrary to common belief, pedestrians are not 'run over' by cars but are 'run under'. The adult pedestrian, when standing or walking and struck by a car, is thrown in the air. This is because the pedestrian's centre of gravity is above the top of the bonnet of the car, and when the pedestrian's legs are knocked from under him his trunk stays approximately in the same place. Children, and small adults, whose centre of gravity is below the top of the bonnet, are thrown forwards at impact with the car

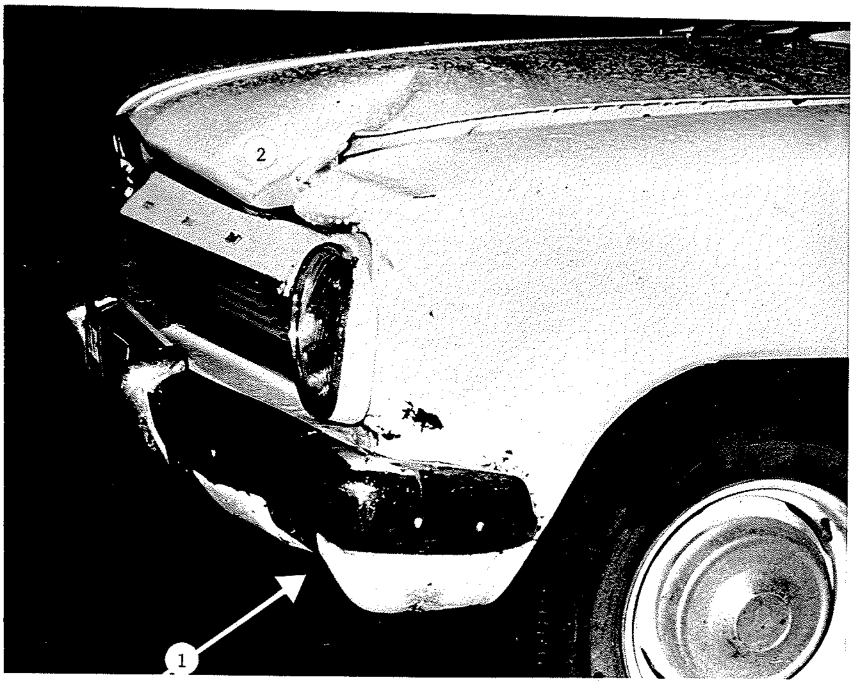


Fig. 4.18
Case 0105: Holden EJ versus pedestrian. Numbers show first and second impact points.

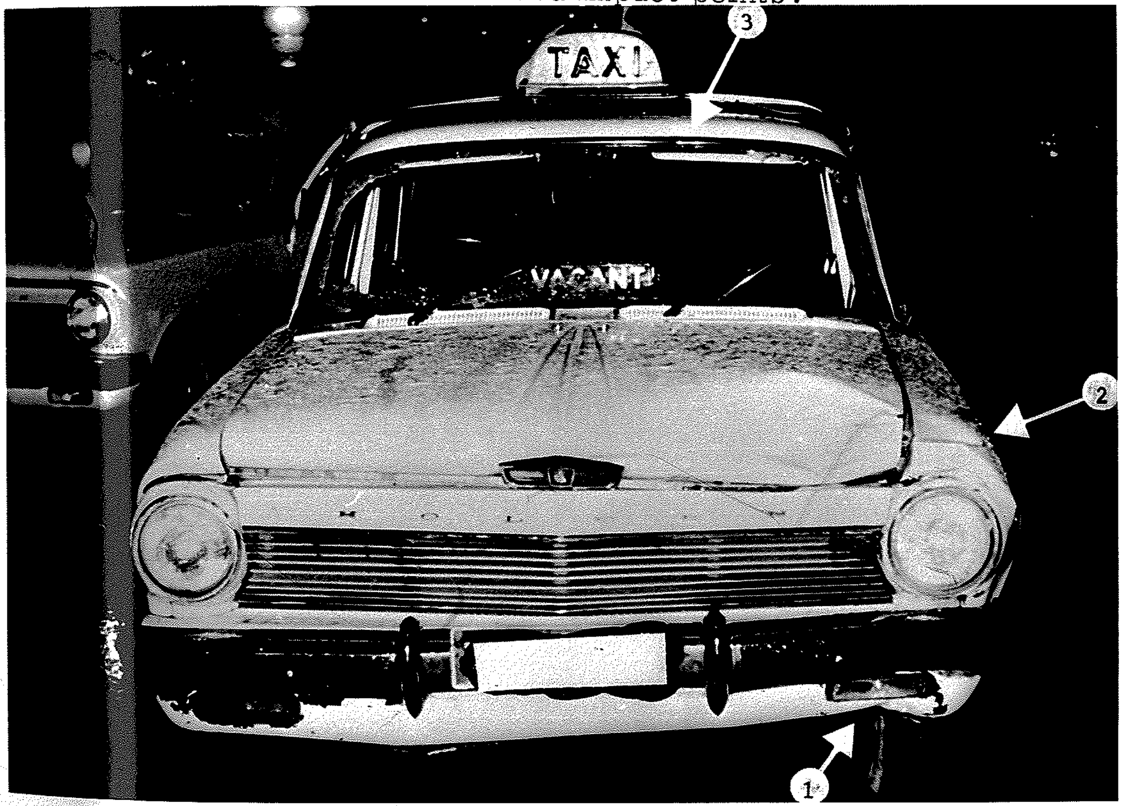


Fig. 4.19
Case 0105: Holden EJ versus pedestrian
Note: 1 (First impact) smear on bumper, dent in metal beneath bumper.
2 (Second impact) dents in edge of bonnet and headlight.
3 (Third impact) broken windscreen, small dent in surround.

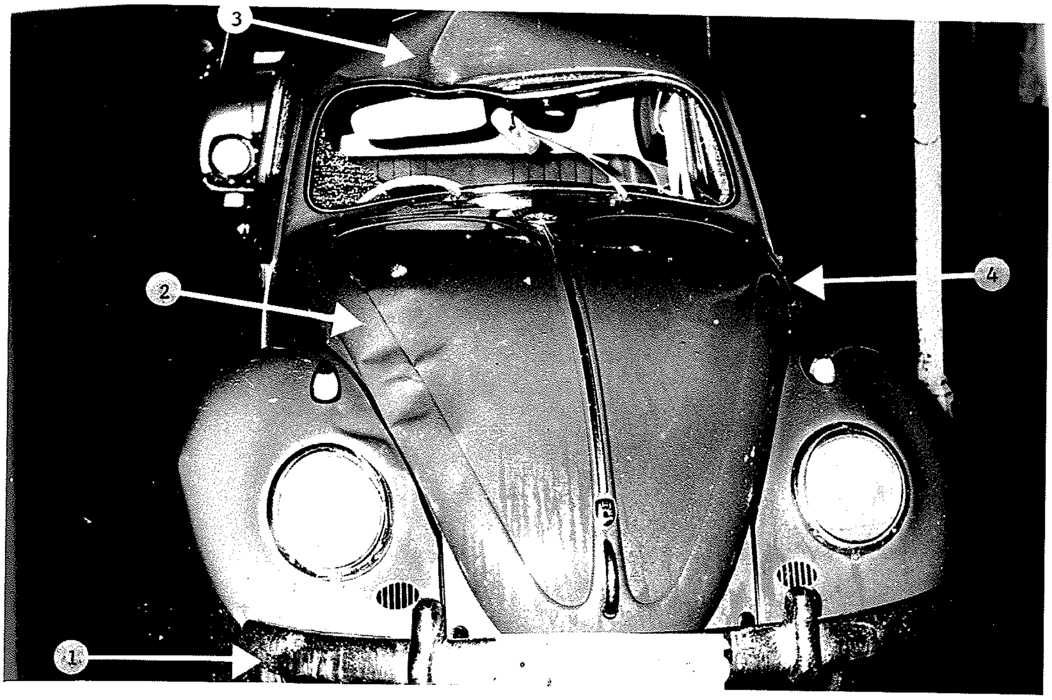


Fig. 4.20
Case 0414: Volkswagen versus pedestrian (See notes below).

Fig. 4.21
Case 0414: Volkswagen versus pedestrian. Arrow shows dent 5 in. deep in roof, produced by the impact of the pedestrian's head (third impact point).

Note: 1 Smears on bumper, which is pushed back against mudguard.
2 Dent in bonnet and mudguard caused by pedestrian's hip.
3 Dent in roof and broken windscreen caused by pedestrian's head.
4 Radio aerial pushed forwards as pedestrian slid off roof onto road.

in much the same way as the adult is pushed forwards when struck by a bus. There is of course a possibility of being "run over" but this would seem to be when a body is actually lying on the road, e.g. after an accident, and is then struck by a car.

Movements of the pedestrian during impact.

4.90 The sequence of events when a car strikes a pedestrian is as follows: (Assuming the pedestrian is an adult and standing with one side towards the car): (Figs. 4.16, 4.17) The initial impact is from the bumper bar which strikes the lower leg. The effects of this impact for a given vehicle speed depend partly on the amount of body weight this limb is supporting at impact, and partly on the limb's own inertia. Almost at the same instant, but slightly later, the leading edge of the bonnet (hood) of the car will strike the hip of the pedestrian. The pedestrian then rotates about this secondary impact point until his head and chest strike the bonnet, windscreen and/or the windscreen surround. The higher the impact speed the further back along the car this third impact point will be (Figs. 4.18 to 4.21).

4.91 At still higher speeds the pedestrian now rotates about his head and shoulders, i.e. the third impact point. This can result in either a fourth impact with the car or in the car passing under the pedestrian who then falls to the road. On this fourth impact with the car the pedestrian's legs strike the rear of the roof of the car. From this point, if the car does

Fig. 4.22
Case 0414: Volkswagen versus pedestrian. Dent in rear of roof was probably produced by impact of pedestrian's legs (fourth impact point).

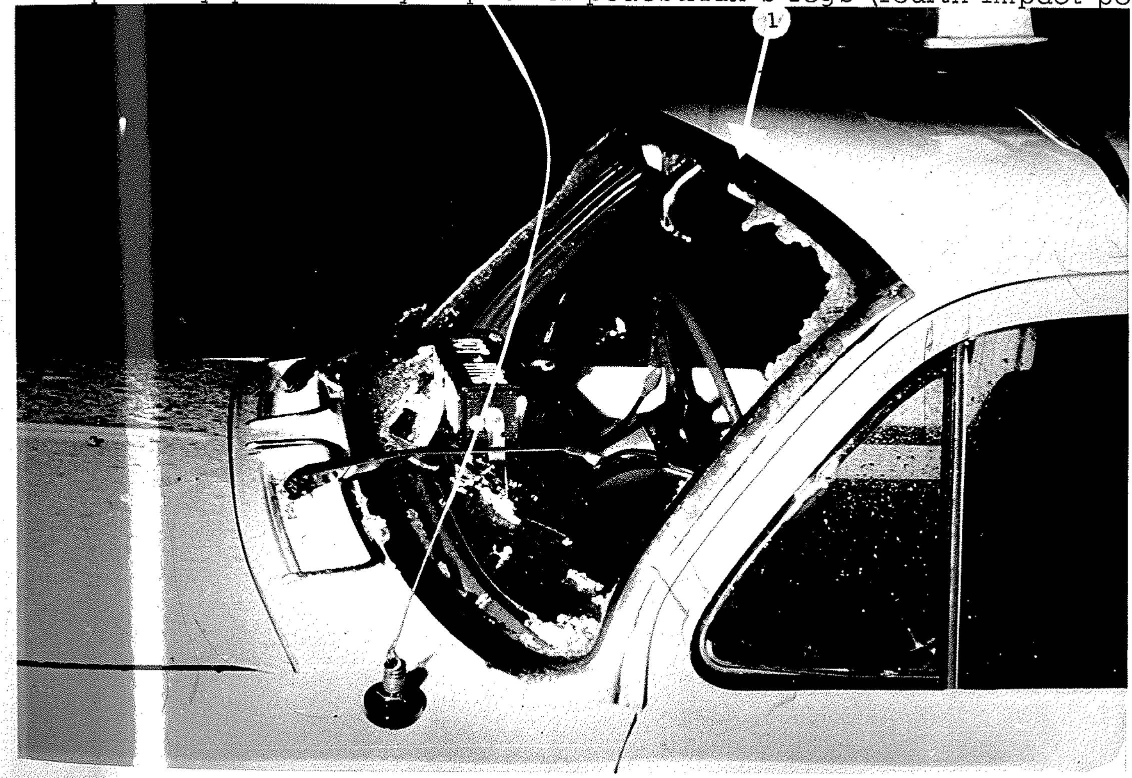


Fig. 4.23
Case 0105: Holden EJ versus pedestrian. Arrow shows third impact point.

not slow down, the pedestrian, who is now travelling almost at the speed of the car, will fall to the road, either behind or on one side of the car (Fig. 4.22).

4.92 If the driver of the car should suddenly brake, the car will then slow down at a much faster rate than the pedestrian, who tends to continue forwards with undiminished speed, sliding over the roof and bonnet and then falling to the road in front of the car. He finally comes to rest after sliding and rolling along the road.

4.93 From this it appears that the pedestrian is subjected to a series of impacts to different parts of his body, culminating in a fall to the unyielding road surface from a height of between 3 and 5 feet, at a speed approximating the then travelling speed of the car.

4.94 This sequence of multiple impacts was worked out by observing characteristic marks on the car made by the pedestrian during his passage over it. There are dents, or brush marks in the dust on the bumper, headlight rims, and the edge of the bonnet. These often correspond with the injuries on the pedestrian's legs and hips. Dents, brush marks and scratches on the top of the bonnet indicate where the trunk and head hit. There may be grease marks from the head on the windscreen and surrounds; or if the windscreen is broken, there may be hair and skin on the jagged glass fragments retained in the frame. (Figs. 4.23; 4.29.)

4.95 The driver was often able to recall part of the motion of the pedestrian on impact. Witnesses outside the vehicle could say little more than that the pedestrian was thrown into the air.

Comparison of Injury Potential of Makes of Cars.

4.96 Obviously little can be done to alleviate injuries caused by being thrown along the road. The first publication which suggested that any substantial reduction might be achieved in the injuries caused by the car was based on this survey (Ref. 32).

4.97 There may be some shapes of the fronts of cars which are less likely to injure pedestrians than are other shapes. For example the Volkswagen 1200 has a gently sloping front compared with that of the Ford Falcon. Is the Volkswagen 1200 kinder to pedestrians? To seek an answer to this a study was made of all pedestrian accidents in the following category, viz: The striking vehicle was a passenger car and the point of impact was across the front of the car only, that is, excluding cases in which the pedestrian was brushed by the side of the car, and we also excluded pedestrians under the age of 15 years. This last exclusion was made to ensure some order of consistency in the height of the pedestrians. As noted above, children, being shorter than adults, are thrown forwards by the car rather than upwards. This left 32 cases from the total sample of 79 cases. In one of these 32 cases two pedestrians were struck by the same vehicle. One of these two was a child and was therefore excluded. It is unlikely that the fact that two pedestrians were struck by the one vehicle will have

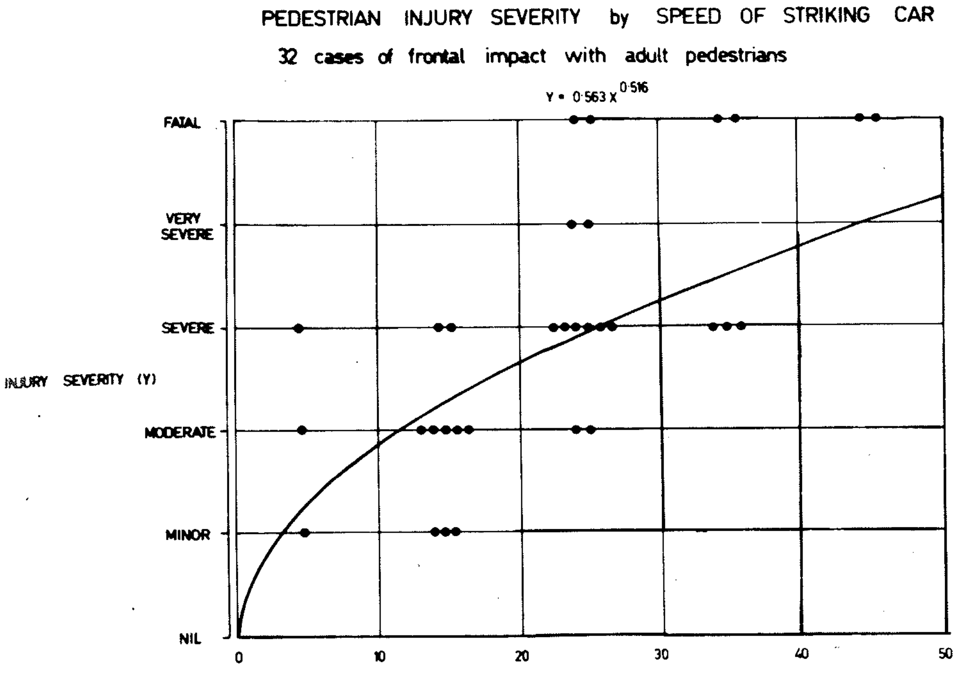


Fig. 4.24
Pedestrian injury severity by speed of striking car: 32 cases of frontal impact with adult pedestrians.

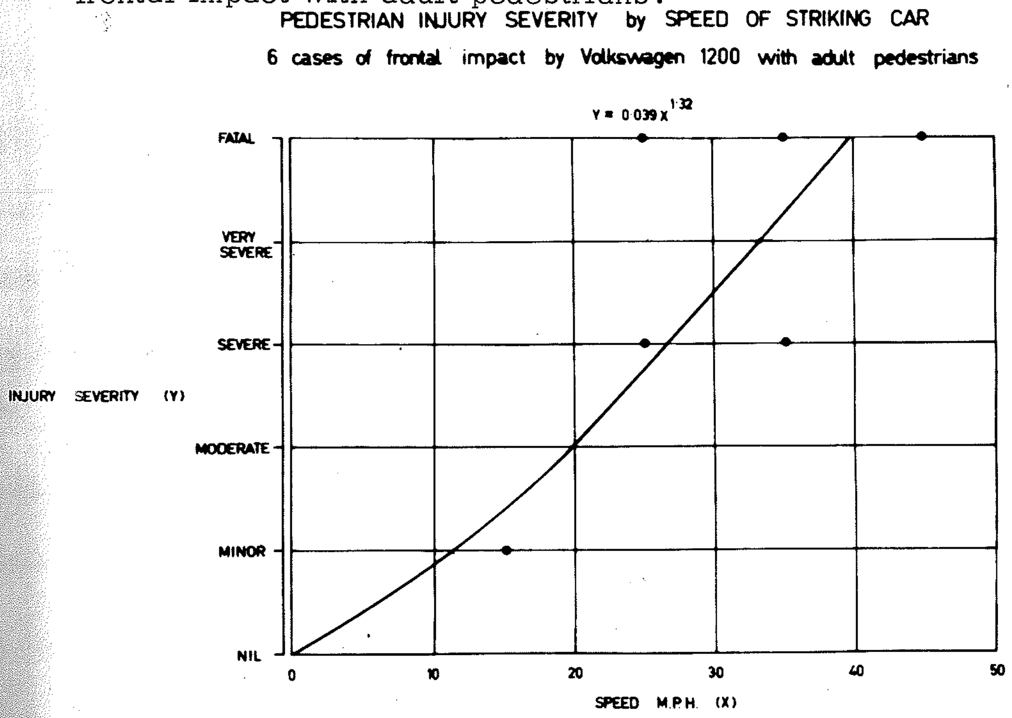


Fig. 4.25
Pedestrian injury severity by speed of striking car: 6 cases of frontal impact by Volkswagen 1200 with adult pedestrians.

had any significant effect on the injuries sustained.

4.98 Care has been taken to ensure that the injury severity assigned to each pedestrian relates to the injuries due only to impact with the car. This has resulted in the reduction of some injury ratings from "fatal" to "very severe", in cases when death has been primarily due to causes other than injuries sustained in the accident.

4.99 The 32 cars have been grouped according to the shape of the front of the car. This also means grouping according to make and model. The only models that occur often enough in these 32 cases to be considered as a group are the Ford Falcon and the Volkswagen 1200. This has enabled the comparison of the injury potential of these two models, the fronts of which are of very different shapes. Logarithmic regression analyses were performed to find the line of best fit and also to test for significant variations of form. Rating injury severity in five stages from minor through to fatal and grouping speeds in 10 m.p.h. intervals the curves shown in Figures 4.24; 4.25; 4.26 result. The whole 32 cases taken together show the expected increase in injury severity with increase in impact speed (Fig. 4.24).

4.100 The curve for the Falcon and the VW 1200 have significantly different slopes, (see Appendix A 4.1). The injury-producing potential of the Falcon is moderate at even very low impact speeds, but does not increase greatly with increasing speed up to the end of the range covered by our

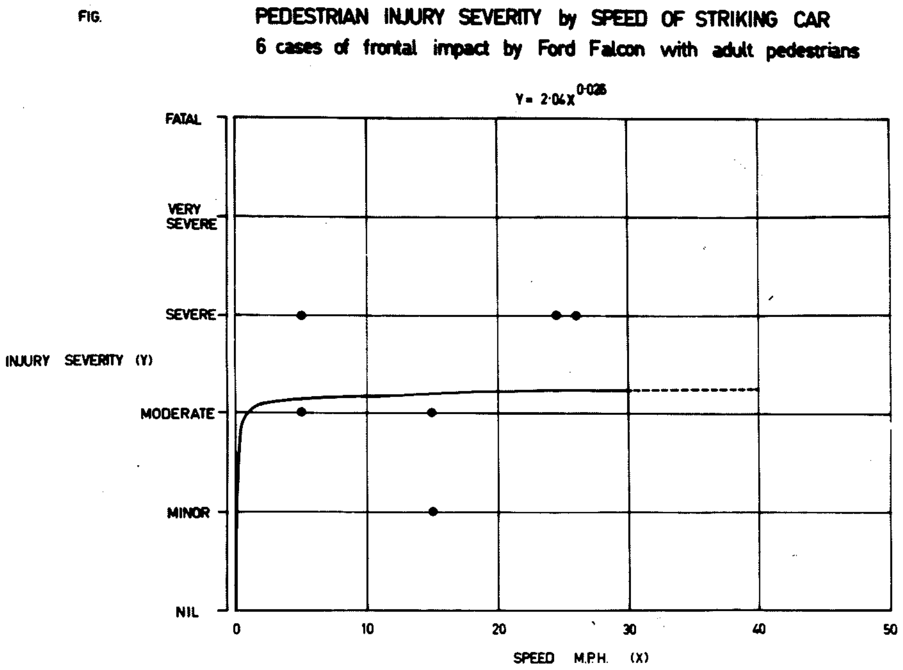


Fig. 4.26
Pedestrian injury severity by speed of striking car: 6 cases of frontal impact by Ford Falcon with adult pedestrians.

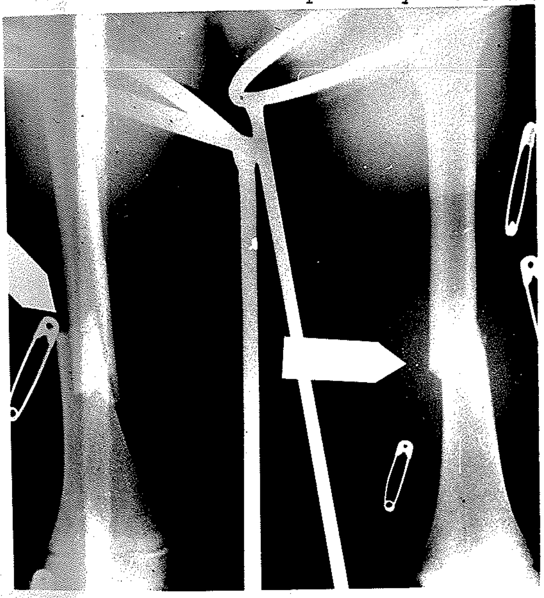


Fig. 4.27
Case 0131: X-ray showing fractures of both femurs.

Fig. 4.28
Case 0276: X-ray showing fractures of both tibiae.

data, viz. 30 m.p.h. The injury-producing potential of the Volkswagen 1200 is almost directly related to the impact speed. The information shown in Figures 4.25 and 4.26 can be expressed thus: (1) Below 20 m.p.h. a Falcon is more likely to injure a pedestrian seriously than is a Volkswagen 1200; (2) in the speed range 20-25 m.p.h. the injury producing potential is the same for each of these two cars; (3) above 25 m.p.h. the Volkswagen 1200 will probably cause more serious injuries than the Falcon. In fact, Figure 4.25 suggests that the VW 1200 will usually inflict fatal injuries at impact speeds greater than 40 m.p.h. It is emphasised that Figure 4.26 should not be taken to mean that a Falcon will not also inflict fatal injuries at similar speeds.

4.101 The differences between the two cars in producing injuries are most apparent at low speeds and depend on the dimensions of the vehicles and of the pedestrian. When a standing adult pedestrian is struck by a VW 1200 the initial point of impact is the bumper, which strikes below his knees. The impact point is a considerable distance below his centre of gravity, which is about the height of his navel. At low speeds his legs are pushed from under him, and his trunk and head rotate downwards, striking the bonnet. If his height and the speed of the car are great enough, he will strike his head and shoulders on the relatively unyielding area of the car body around the windscreen.

4.102 However, if the same pedestrian is struck by a Falcon there are important differences in his movements. The initial impact point is again the bumper. But now the bumper is higher, close to the knee joint itself. Almost simultaneously the pedestrian is struck on the hip by the front edge of the bonnet. This second and higher impact point is only just below the centre of gravity of the pedestrian. At low impact speeds he is pushed forwards bodily by the car, falling to the road. This series of movements is markedly different from that produced by impact with a VW 1200, where the pedestrian falls back on the car.

4.103 At higher impact speeds a pedestrian, when struck by a VW 1200, will strike his head on the windscreen and roof, causing severe injuries. The higher impact speed will also cause severe lower leg injuries. When a pedestrian is struck by a Falcon at the higher speeds he suffers severe lower leg injuries (from the bumper) and severe injuries to the pelvis (from the front of the bonnet). He is not pushed forwards on to the road, but his trunk and head rotate towards the car and strike the top of the bonnet, the point of impact of the hips and front of the bonnet acting as a pivot. The pedestrian's head does not strike the windscreen, for the distance from the front of the bonnet is greater than the length of his trunk and head.

4.104 At still higher speeds both the Volkswagen and cars of a similar shape to the Falcon hurl the pedestrian upwards, allowing him to be struck by the area around the screen and even by the roof of the car (Figures 4.19; 4.20; 4.21). The pattern of injuries to the pelvis and lower limbs is as described above, but severe head injuries become common. In these cases it is exceptional for the pedestrian to survive.

4.105 The primary concern here is not with a quantitative assessment of the data presented. Rather it is an attempt to show that the shape of the front of the car determines the nature and severity of injury to a pedestrian for a given impact speed. It is not enough merely to demonstrate this variation. With a larger amount of data it would be possible to describe the frontal shape of a car that will inflict minimal injuries when it strikes a pedestrian.

The Effect of Detail Vehicle Design on Pedestrian Injuries.

4.106 The above discussion relates to the overall frontal shape of a car. Most of the attention that has been given to the injury potential of cars striking pedestrians has been confined to small fittings such as bonnet mascots. In this series of accidents few injuries to pedestrians could be directly attributed to a bonnet mascot or external rear vision mirror. There were some cases of accessory hoods over headlamps which came into contact with a pedestrian. Despite the sharp appearance of these fittings we found that they tended to crumple, and caused minor injuries. We did find some cases of lacerations caused by broken headlamp glass.

4.107 Apparently innocuous features of the frontal design of cars can have a very marked bearing on the severity of the injuries sustained by

Fig. 4.29

Case 0316: Dodge versus pedestrian

Note: 1 (First impact) dents and smears on bumper.
2 (Second impact) dent in bonnet and grille.
3 (Third impact) dent in centre of bonnet produced by the impact of the pedestrian's elbow.

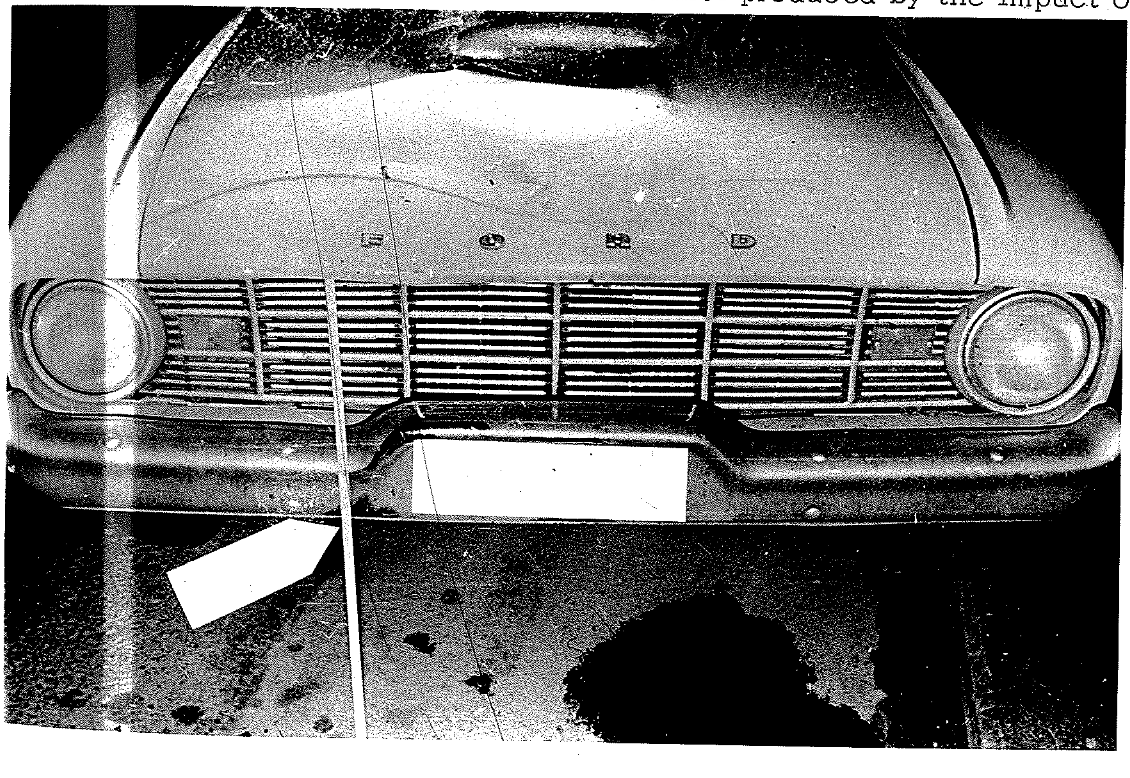


Fig. 4.30

Case 0131: Brush marks on bumper bar (arrow) from impact with pedestrian's legs. Dents in bonnet produced by pedestrian's head and trunk.

a pedestrian. Figure 4.30 shows a 1962 Ford Falcon sedan which struck a nine year old boy at a speed of over forty miles per hour. The boy sustained fractures of both femurs. (Fig. 4.27.) The shape of the bumper bar was changed on later models of this car. (Figure 4.32.) The car shown in this figure struck an elderly man. The smaller radius of the leading edge of the bumper bar on this model very nearly severed the legs of the pedestrian (Figure 4.31).

4.108 While bonnet mascots and detail fittings to the front of a car may certainly aggravate the injuries a pedestrian receives, the extreme severity of the majority of pedestrian injuries tends to conceal the effects of such objects. Apparently less dangerous styling features, such as the change illustrated in Figure 4.32, have far more influence on the severity of a pedestrian's injury. It is emphasised again, however, that a major reduction in the severity of injuries to a pedestrian is only likely to be achieved by a radical redesigning of the overall frontal shape of the car.

Mechanics of Bone Fractures.

4.109 The X-rays shown in Figures 4.27 and 4.28 show clearly the nature of the fractures to the legs of two pedestrians. It was found that it was possible to predict, from the known circumstances of the accident, the nature of these fractures to a fairly high degree of certainty. Similarly a careful study of such fractures affords a considerable amount of information regarding the direction of the impact. This can be extremely useful in

Fig. 4.32
1965 Ford Falcon after collision with pedestrian. (This accident was attended by the author in the year following the TARU survey.) Note the modification to the shape of the bumper bar (compare with Fig. 4.30) which resulted in the injuries shown in Figure 4.31.

Fig. 4.31
Pedestrian's legs almost completely severed by bumper bar shown in Figure 4.32.

indicating the attitude of the pedestrian when struck by the car. For example it can provide evidence to suggest whether the pedestrian was crossing from the right or from the left. It is also possible, from the shape of the fracture, to determine whether or not the broken bone was bearing any axial load at the time of the impact. This in turn can indicate whether or not the pedestrian was standing still or walking or running.

4.110 The height of the fracture can also be closely related to the height of the bumper bar of the car. This can be done with sufficient accuracy to determine whether or not the driver of the car was braking at the time of impact. When braking, of course, the front of the vehicle is lower. Furthermore the general pattern of the pedestrian's injuries can either support or dismiss the possibility of the striking car being of a certain model. For example a Volkswagen is unlikely to cause fractures of the pelvis, which are almost inevitable when the striking vehicle has a more conventional frontal shape such as a Ford Falcon.

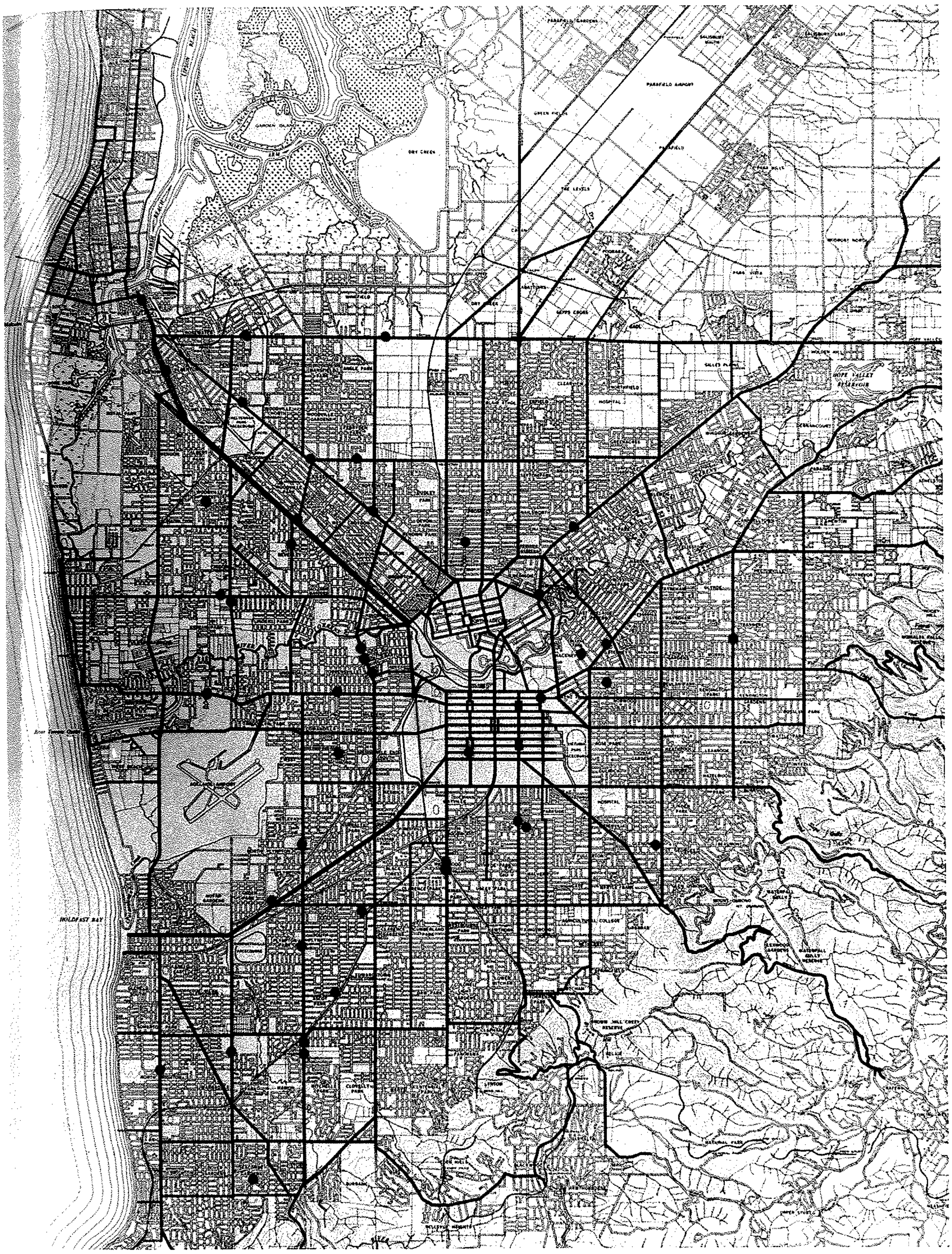


Fig. 5.1
Location of bicycle accidents.

PEDAL CYCLE ACCIDENTS.

CHAPTER 5

5.1 Pedal cyclists were involved in 44 (11%) of the 408 accidents covered by this survey. The locations of these accidents are shown in Figure 5.1 and were, with two exceptions, all in the suburbs. One other accident, a collision between a child's tricycle and a semi-trailer, is not included in these 44 cases.

Ages of Cyclists involved in these Accidents.

5.2 The age distribution of these cyclists is shown in Figure 5.2. More than half of them were less than 20 years of age. Almost all the cyclists were males, there being only four females in the 44 cases. This histogram does not represent the relative degrees of accident liability for each age group. There is no information available on the age distribution of all cyclists in the metropolitan area, or on the length of time each age group spends cycling on the road. Without this information it is not possible to calculate a cyclist's risk of being involved in an accident. The inability to calculate these risks of involvement, of which this is merely one example, bedevils all serious quantitative studies of accidents.

Time Distribution.

5.3 Almost half of these accidents happened in the two hours between 4 p.m. and 6 p.m. (Fig. 5.3). This suggests that well over half of all injury-producing pedal cycle accidents in the metropolitan area occur

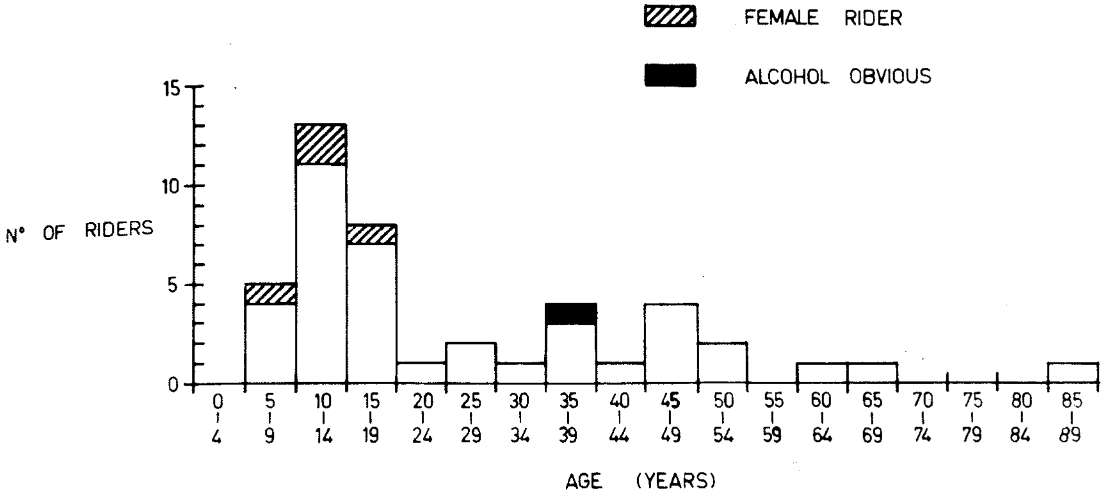


Fig. 5.2
Number of pedal cycle accidents by age of rider.

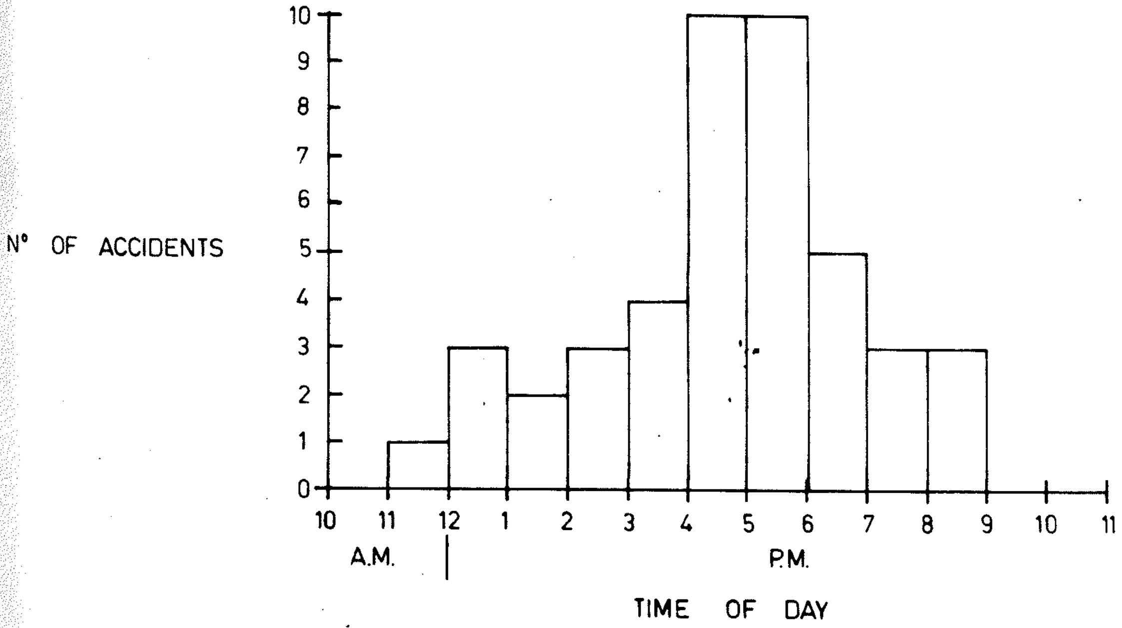


Fig. 5.3
Number of pedal cycle accidents by time of day.

during these two hours, because our sample contains a higher proportion of off-peak period accidents than of those that happened at peak periods. This time distribution of accidents is much the same for each week day. The next Table shows that we attended many more accidents involving a cyclist on a Friday than on any other day. Statistical tests show that this bias towards Fridays could be due to chance.

TABLE 5.1

	No. of Cycle accidents involving a second vehicle	No. of other types of accidents	Ratio $\frac{\text{Cycle accidents}}{\text{other types of accidents}}$
Monday	5	43	12:100
Tuesday	6	50	12:100
Wednesday	8	65	12:100
Thursday	6	61	10:100
Friday	15	74	20:100
	40	293	

Chi square = 2.8 ($p_{0.05}$ = 11.1)

(Note: 4 non-collision cycle accidents are not included here.)

Day and Night.

5.4 Just over a quarter of these 44 accidents happened at night, and involved mainly adult cyclists.

TABLE 5.2

Age of Cyclist	Accident happened by Day	Night	Total
Under 15 years	16	2	18
Over 15 years	16	10	26
	32	12	44

Chi square = 4.0*.

5.5 This relationship between the age of the cyclist and accidents by day and by night leads on to two features of pedal cycle accidents which became very obvious to us as the survey proceeded. Daytime accidents to pedal cyclists very often resulted from a child cyclist suddenly attempting a U-turn or a right turn in front of a following car. Night time accidents were usually a consequence of the driver not seeing the cyclist who was riding along at the side of the road.

TABLE 5.3

Party initiating events which resulted in a collision	Accident happened by Day	Night	Total
Driver of striking vehicle	9	7	16
Cyclist	19	5	24
	28	12	40

Chi square = 2.4 ($p_{0.05}$ = 3.8)

5.6 Whether or not a driver sees a cyclist at night will depend largely on how well the cyclist contrasts with his background. On a poorly lit road this contrast is first achieved by the tail light on the bicycle. The next stage comes when the headlights of the car illuminate the cyclist who is then visible against a dark background. Unfortunately, with dipped headlights, the vehicle is often too close to the cyclist to avoid a collision at this stage. With improved street lighting the situation may, curiously enough, become worse, unless the lighting is very good indeed. If the background is not dark, but rather poorly illuminated, a tail light on a bicycle will no longer show up clearly. Similarly the headlights of the car, as they bear on the cyclist, may diminish the contrast between the illumination on the cyclist and that of the background lighting so that for a short time all contrast may be lost and the cyclist blends into the background. By the time the car is close enough for its headlights to illuminate the cyclist strongly a collision is almost inevitable, at present day traffic speeds. It is not surprising therefore that eleven of the twelve night-time pedal cycle accidents were under lighting which is considered, perhaps mistakenly, to be "good".

TABLE 5.4

Type of Street Lighting	No. of cases
Incandescent	1
Mercury Vapour	3
Sodium Vapour	7
Fluorescent	1
Total number of night-time accidents	12

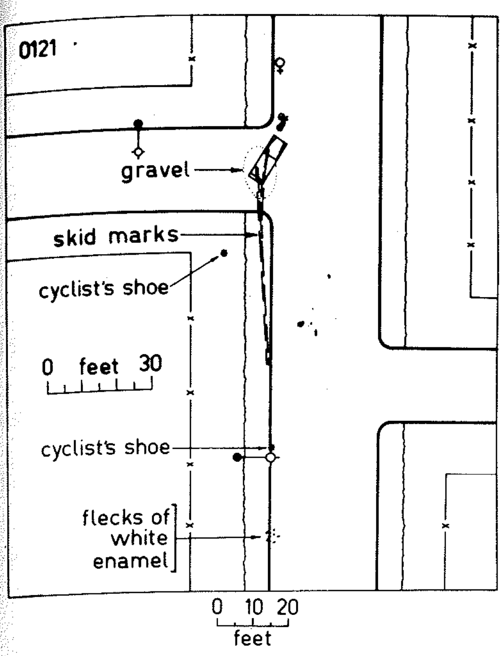


Fig. 5.4
Case 0121.

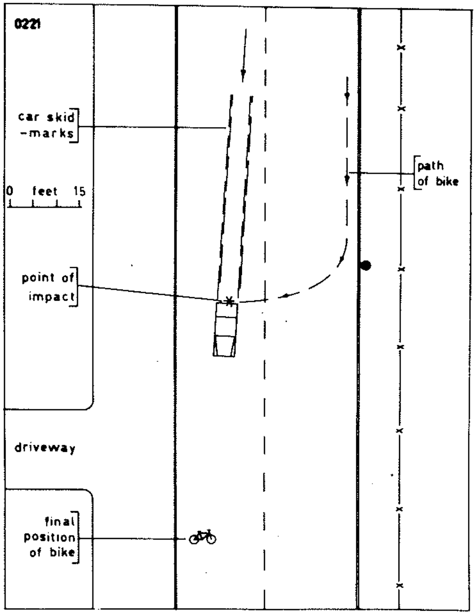


Fig. 5.5
Case 0221.

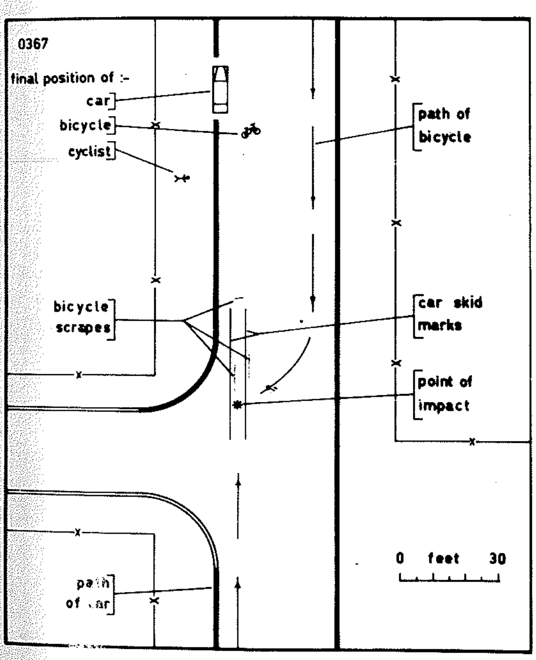


Fig. 5.6
Case 0367

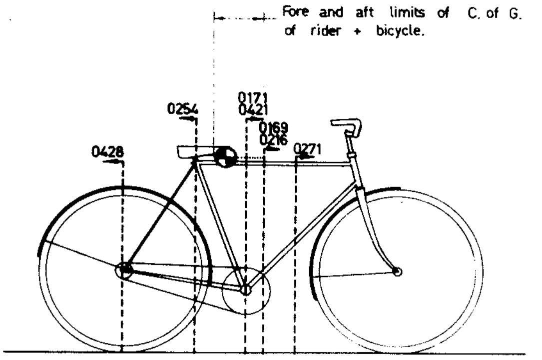


Fig. 5.7
Position of centre of gravity of rider and cycle and points of impact for cases shown.

5.7 There is a tendency for local government authorities to try to reduce the considerable costs of street lighting by increasing the spacing between lights. It seems probable that a better approach would be to illuminate a few roads to the recommended standard, leaving others almost without illumination, than to attempt to cover a great length of road with sub-standard lighting.

5.8 There were five accidents where the cyclist was struck from the rear while riding on the left side of the road, i.e. the driver did not see the cycle. Four of these occurred at night, e.g. case 0121 (Fig. 5.4).

> 0121 A 15 year old girl riding a bicycle was struck from behind by a Holden F.E. panel van. She was thrown up on to the bonnet of the car, striking the windscreen. Some threads of green wool from the cyclist's cardigan were found caught on the ends of some lengths of wood which were carried on the roof rack and projected forwards overthe bonnet.
>
> The driver did not brake until he was about 8 yards past the presumed point of impact. The car then skidded for 30 yards, and as it stopped the cyclist was thrown from the bonnet on to the ground, coming to rest 7 yards in front of the car.
>
> The cyclist sustained concussion and abrasions to the left side of the neck and back, and extensive abrasions to both buttocks and the inner side of both legs.
>
> The driver of the car - a 43 year old man - was appreciably affected by alcohol. He was not injured.

Alcohol.

5.9 The other three night-time accidents of this type all involved drivers who had obviously been drinking. Indeed, of the 40 drivers whose vehicles collided with cyclists, these four were the only ones who had obviously been drinking, and in each case they should have been able to avoid the collision. In these 44 accidents there was only one case in which a cyclist had obviously been drinking (Fig. 5.2). It is probable that the number of drivers who had obviously been drinking is a conservative estimate of the number who actually were affected by alcohol. Therefore, to sum up this paragraph: one tenth of these accidents involving a cyclist and a motor vehicle might have been avoided if the driver of the motor vehicle had not consumed alcohol a short time before driving.

Movements of Cyclists

5.10 As is shown in the following table, two movements predominate, viz: proceeding straight ahead, and turning right.

TABLE 5.5

Motion of Cyclist	Age of Cyclist (years)		Total
	Less than 15	15 or over	
Proceeding straight ahead	1	15	16
Turning Right	9	6	15
'U' turn	3	1	4
Entering traffic lane	3	-	3
On cycle track at cross-over of a dual highway	-	1	1
Crossing roadway not at an intersection	-	1	1
Total:	16	24	40

5.11 It is interesting to regroup this table into those cyclists who were proceeding straight ahead and those who were changing direction. Two thirds of those changing direction were less than 15 years old. Most of these were turning right, or attempting a 'U' turn. The next table compares the behaviour of cyclists less than 15 years and 15 years and over.

TABLE 5.6

Motion of cyclist involved in a collision	Age of Cyclist (years) Less than 15	 15 or over	Total
Proceeding straight ahead	1	15	16
Turning right, 'U' turn, entering traffic lane	15	7	22
	16	22	38

(Note: two cases not in the above categories)

Chi square = 12.1** (after Yates correction).

5.12 The commonest pedal cycle accident was that involving a young boy cyclist who turned right, across the path of a car travelling in the same or the opposite direction, without looking or signalling. Most drivers do not seem to be aware of the fact that cyclists can and do turn right suddenly, without signalling e.g. 0221, 0367.

0221 A 13 year old boy cyclist turned right from the left hand kerb and crossed the path of a Morris Elite sedan which was travelling in the same direction. The driver of the car said that he was travelling at 30 - 35 m.p.h. when he saw the bicycle come from the left side of the road. He

Fig. 5.8
Case 0367: blood smears on roof of car.

Fig. 5.9
Case 0367: bicycle which was struck by the car shown in Figure 5.8.

swerved to the right and braked, but the bicycle kept turning in front of him. The car then struck the bicycle on the centre of the right side of the latter. The windscreen of the car was broken. The rider of the bicycle sustained concussion and abrasions and a small laceration to his chin.

The car skidded for 20 yards which, in this case, indicated a speed of more than 40 m.p.h. before the driver started braking (Fig. 5.5).

0367 A 12 year old boy cyclist turned right from a main road into a side street. He was struck by a Holden EJ sedan which was travelling in the opposite direction along the main road. The Holden was being repaired and had most of the front grille and bumper bar removed. The speed at impact was between 30 and 40 m.p.h. The cyclist sustained a compound fracture of the left tibia caused by the impact from the front edge of the bonnet, separation of the pubic symphysis and sacro-iliac joints and a laceration of the anterior wall of his rectum. The cause of these injuries is obscure. He sustained concussion and abrasions to the left side of his face, possibly from striking and breaking the windscreen of the car. His legs swung upwards as his head hit the windscreen and he slid along the roof of the car and then fell to the ground, in soft mud at the roadside, as the car braked to a halt. (Figs. 5.6, 5.8, 5.9.)

Movements of Striking Vehicles.

5.13 The movements of the striking vehicles are set out in the following Table. 28 of the 35 cars were proceeding straight ahead. 7 vehicles were overtaking, and 5 turning right.

TABLE 5.7 **Type of Striking Vehicle X Motion on Impact**

	Car	Motor Cycle	Truck	Total
Proceeding straight ahead	28	-	-	28
Proceeding straight ahead and overtaking	5	1	1	7
Turning right	2	1	2	5
Totals:	35	2	3	40

5.14 The next table relates the movements of the cyclists to those of the striking vehicles. This shows that most (70%) of the striking vehicles were proceeding straight ahead, while 55% of the cycles were changing direction at the time of collision.

TABLE 5.8

Motion of Pedal Cycle	Motion of Striking Vehicle: Proceeding Straight Ahead	Proceeding Straight Ahead and Overtaking	Turning Right	Total
Proceeding straight ahead	11	2	3	16
Turning right	11	3	1	15
Entering traffic lane	3	-	-	3
'U' turn	3	1	-	4
On cycle track	-	-	1	1
Crossing roadway	-	1	-	1
Totals:	28	7	5	40

Location of these Accidents.

5.15 Seventy percent of these collisions occurred at or near intersections. The table shows the location of these accidents according to the participant who may be considered to have initiated the movement which resulted in a collision. The group of nine cyclists who initiated collisions away from intersections represents those cases in which the cyclist either turned right, attempted a 'U' turn, or entered a traffic lane without first ensuring that the road was clear. Of the three cases in which there was no collision, i.e. the cyclist "fell off", two occurred away from intersections and the third at an intersection.

TABLE 5.9

Persons initiating accident	Location of the Accident At intersection	Within 20 yards	Not at intersection	Total
Cyclist	13	2	9	24
Driver	11	2	3	16
Total:	24	4	12	40

5.16 The reason for a large proportion (24/40) of these accidents occurring at intersections may be that drivers have many things to look for at an intersection. At an intersection the driver must attempt to sum up the situation very quickly. This means that he will be looking for obvious vehicles such as cars, trucks, etc. The cyclist, who is not as easy to see as a car, may well be not noticed, and a collision result. The drivers were asked whether or not they saw the cyclist before the collision. The results of these questions are shown in the following table. The large number of drivers who did not see the cyclist at an intersection until it was too late to avoid a collision (15/23 = 65%) tends to support the above explanation. Perhaps the point to be emphasised here is that the cyclist should not assume that the driver has seen him, particularly at or near an intersection.

TABLE 5.10

	Location of the Accident		
	At or within 20 yards of an intersection	Not at an inter-section	Total
Driver saw the cyclist in the distance	8	6	14
Driver did not see the cyclist until immediately before the impact, or not at all	15	4	19
	23	10	33

5.17 A similar table has been drawn up to show the same information for the cyclist. Unfortunately there is a large number of cases in which the cyclist's injuries left him with no recollection of the events leading up to the collision. A high percentage (69%) of cyclists at intersections did not see the striking vehicle. This is despite the fact that they travel at much lower speeds than cars and have excellent visibility.

TABLE 5.11

	Location of the Accident		
	At or within 20 yards of an intersection	Not at an intersection	Total
Cyclist saw the striking vehicle in the distance	4	2	6
Cyclist did not see the striking vehicle until immediately before the impact, or not at all	9	3	12
	13	5	18

Non-collision Cycle Accidents

5.18 The three non-collision accidents in our sample all resulted from some object suddenly locking the front wheel of the bicycle. In one case it was the generator which was dislodged and became locked in the spokes of the front wheel. Another case resulted from a loose front mudguard catching on the tyre and locking the wheel. In the third case a fishing rod carried by the rider slipped from his grasp and became entangled with the front wheel. In each case the rider sustained concussion from striking his head on the road.

Collision with a Pedestrian.

5.19 This case has also been presented in Chapter 4.

0167 A boy aged 16 rode his bicycle out of the driveway of a house, turned left into the road and looked over his left shoulder to talk to a friend on the footpath. When he looked ahead he saw a pedestrian walking with her back to him. He shouted a warning and after the impact the cyclist and the pedestrian fell to the road. The pedestrian suffered concussion and abrasions to the right side of the face. The cyclist was not injured.

Collisions with other Vehicles.

5.20 These accidents consisted of:

35 collisions with cars
3 collisions with trucks
2 collisions with motorcycles.

Pedal cycle v. Motor cycle.

5.21 Both of these collisions seem to have been glancing impacts, and the injuries to both parties were caused mainly by hitting the road.

0343 The rider of a motorscooter swerved to his left to pass a car turning right from the centre of the road. He brushed a pedal cyclist travelling in the same direction. The pedal cyclist, male - 35, sustained concussion from striking his head on the road. The rider of the scooter fell from his machine but was not injured. His breath smelt faintly of alcohol.

0413 A motorcycle, turning right at an intersection at night, struck a 12 year old boy on a pedal cycle. Both riders fell off, each hitting his head on the road. The motorcyclist, who was not wearing a protective helmet, received concussion and facial abrasions. The cyclist received an abrasion on his forehead.

Pedal Cycle v Truck.

5.22 Two of the pedal cyclists rode into the sides of trucks which were turning right across their path. These were both daytime accidents and the drivers of the trucks saw the cyclists, but thought they had time to cross in front of them. One of the drivers said "If the cyclist had slowed down he wouldn't have run into me". This cyclist struck his head on the front corner of the tray of the truck and suffered concussion. The other case was similar to this.

> 0136 A cyclist struck the tray of a truck which had turned right, in front of him, across the cycle track on the median of a divided highway. He received facial abrasions and a fractured left forearm. His breath smelt of alcohol. One month previously he had been knocked off his bicycle and had suffered a fractured skull.

5.23 In the third case the cyclist turned in front of the truck:

> 0419 An 8 year old girl riding a small pedal cycle turned right, across the path of a heavy utility which was about to overtake her. The driver braked hard and the truck had almost stopped when it struck the right side of the cycle, pushing the cycle and rider on to the road. The rider suffered concussion, probably from striking the road, and abrasions to the right leg, probably from the impact with the truck.

<u>Pedal Cycles and Cars</u>.

5.24 There were 35 collisions between cars and pedal cycles. When struck by a car the pedal cyclist, like the pedestrian, has no protection from the impacts with the car and subsequently with the road. The impact geometry of these 35 pedal cycle/car collisions was as follows:

Side of bicycle to front of car		24
Rider fell on bonnet	14	
Rider slid down the side of the car	7	
Rider thrown diagonally across bonnet	3	
Rear of bicycle to front of car		5
Rider fell on top of bonnet	4	
Rider's movements not known	1	

Front of bicycle to front of car		3
Rider fell on bonnet	1	
Rider slid down the side of the car	2	
Front of cycle to side of car		2
Position of cycle not known		1
		35

5.25 24 of the impacts were on the side of the bicycle, and in two-thirds (14) of these impacts the rider fell onto the bonnet of the striking car. The motion of the rider depends largely on the initial point of impact by the car on the cycle. The position of the centre of gravity of the rider and cycle is shown in Figure 5.7. This was located for a 5 feet 8 inches high, 140 lbs. weight male seated on a cycle having wheels 28 inches in diameter and a seat height of 35 inches. The fore-and-aft position of the centre of gravity varied according to the stance of the rider. If he sat normally, the centre of gravity was located near the front of the seat; while if he remained seated but leant forwards over the handlebars the centre of gravity moved forwards seven inches (Fig. 5.7). With the rider normally seated the centre of gravity of rider and machine together was 33 inches above the ground, which was just below the saddle height of 35 inches.

5.26 At 33 inches above the ground the centre of gravity of a cyclist together with his bicycle is close to the top of the bonnet of a car of conventional frontal design. This means that, if a cyclist is assumed

Fig. 5.10
Case 0160: impact of front of car with side of bicycle. Arrows indicate marks made by (1) handlebar on left headlight of car,
(2) the seat of the bicycle and the rider's hip on the top of the bonnet.
(3) the rear axle of the bicycle on the right bumper overrider.

Fig. 5.11
Dent in roof of car made by bicyclist's head. Note hair stuck to chrome strip.

to be rigidly attached to his machine, when struck from the side by a car, rider and cycle will be pushed sideways away from the car.

5.27 However, this assumption that the rider and cycle act as one rigid body is only acceptable at very low impact speeds (less than 10 m.p.h.). The rider is, of course, not rigidly fixed to his bicycle, even though he is astride it, and the two are readily separated on impact. Rider and cycle must therefore be considered separately, and the post-impact motion of each canbe derived by relating the point and direction of the impact to the positions of their individual centres of gravity.

5.28 An impact from the side, at the height of a car bonnet, will strike the rider on the hip and will cause the cycle to be pushed away in front of the car, while the rider will be rotated about his centre of gravity, his head moving towards the car. The rider's legs, being below the top of the bonnet of the car, will be pushed forwards and thus assist in rotating his trunk towards the car. The distance back from the front of the car that the rider's head strikes is determined largely by the speed of the car at impact. With increasing speed, the rider strikes successively the top of the bonnet (Fig. 5.10), the windscreen, and at higher speeds still, the roof just above the upper edge of the windscreen (Fig. 5.11). The height of the rider's trajectory will also be affected to some extent by his position, e.g. seated, or standing on the pedals, and by his stature.

5.29 After striking the car, the rider then falls to the road on one or either side or behind the car. If the car stops quickly the cyclist may be projected on to the road in front of the car. There need not be contact between the rider and the striking car in all cases. There were 3 cases of impact between the front of the car and the side of the cycle where the rider passed diagonally over the bonnet of the car, without touching it, landing directly on the road.

5.30 In the above 17 cases the centre of gravity of the cycle and rider was struck by the front of the car. There were a further 7 cases of impacts on the side of the cycle, in which the centre of gravity of the cycle and rider was beyond a corner of the front of the car. The cycle and rider pivoted about the corner of the car and slid down the side of the car to the road. Fig. 5.7 shows the positions of these impacts.

5.31 There were five cases in which the cycle was struck from the rear. A small amount of the energy of the impact is dissipated, resulting in damage to the cycle, before the cyclist receives a direct impact. At speeds above 30 m.p.h. this effect appears to be of little benefit to the cyclist, who has not been accelerated significantly when struck by the windscreen and adjacent structures.

5.32 The head-on collision, of which there were three, is very similar to the rear impacts discussed above. The cycle absorbs some of the force of the impact, but the rider is still exposed to the direct impact

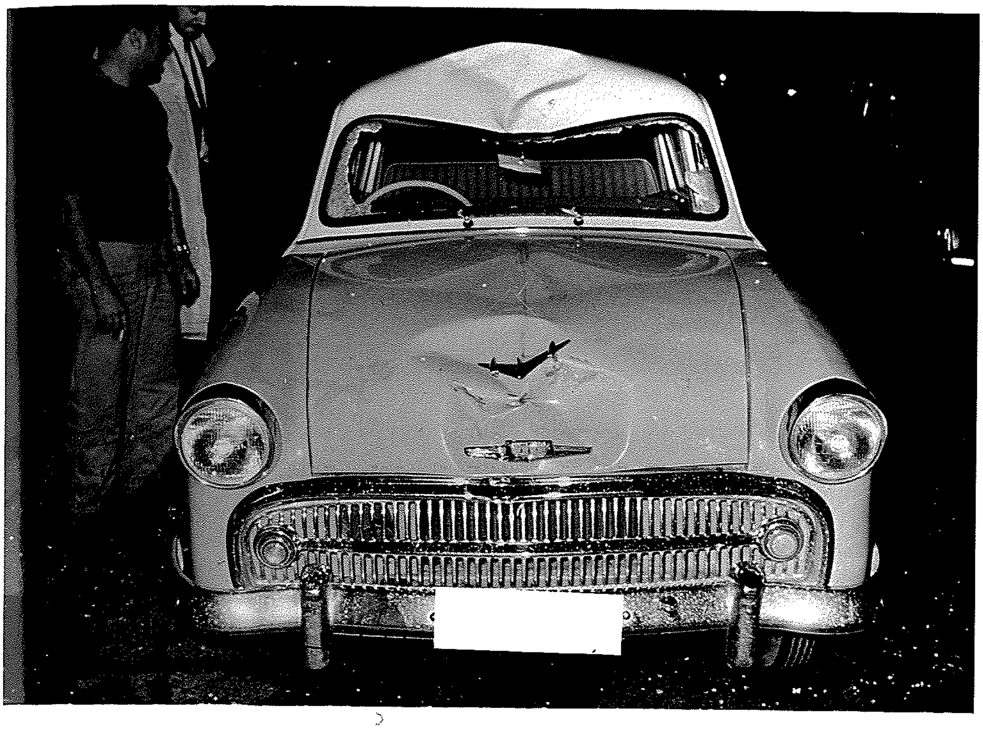


Fig. 5.12
Head-on collision between car and bicycle. Dent in roof made by rider's head.

Fig. 5.13
Bicycle which collided with the car shown in Figure 5.12.

with the windscreen area (Figs. 5.12; 5.13). Because the cyclist usually travels at a much lower speed than that of the striking vehicle, the relative speed on impact is of the same order for both types of collisions.

5.33 In three cases there was insufficient information available to determine what happened. In a further two cases the cyclist struck the side of the car.

5.34 All except two of the car-cycle impacts were with the front of the striking car. The trajectory of the cyclist depends on the speed of the car and the position of the bicycle across the front of it. The rider may fall in front of the car, or be thrown up on to the bonnet, windscreen or roof, subsequently falling on to the road; or slide down the side of the car on to the road. Therefore, like the pedestrian, the pedal cyclist suffers multiple impacts with the car and with the road. Consequently, the pedal cyclist also suffers multiple, and frequently severe, injuries.

MOTOR CYCLE ACCIDENTS

CHAPTER 6

6.1 This sample of 408 traffic accidents in metropolitan Adelaide contains 66 motorcycle accidents i.e. 16% of the total. This proportion increased in the two years of the survey, from 14% in 1963 to 18% in 1964. This may be a chance variation although it has been suggested (Ref. 33) that as motorcycles become a smaller fraction of the total traffic so the risk of a motorcycle being involved in a traffic accident increases. In South Australia, motorcycles were 4.15% of all registered motor vehicles in 1963 and 3.48% in 1964. Many motorcycle accidents arise from other vehicles turning into the path of the motorcycle. In these cases the drivers, seeing the road to be clear of cars, proceed to turn, not realising that a motorcycle is much more difficult to see than a car. Of course if there were many more motorcycles than cars on the roads car drivers would be accustomed to looking carefully for a motorcyclist when checking that it is safe to proceed. As it is today, drivers can almost assume, as many do, that only cars need to be watched for, because smaller vehicles are so few.

6.2 This section deals with accidents to motorcycles, motorscooters, and one motorcycle and sidecar. Unless otherwise stated "motorcycle" includes motorscooters. Motorcycles and motorscooters are not always obviously exclusive categories. An open-frame machine such as a

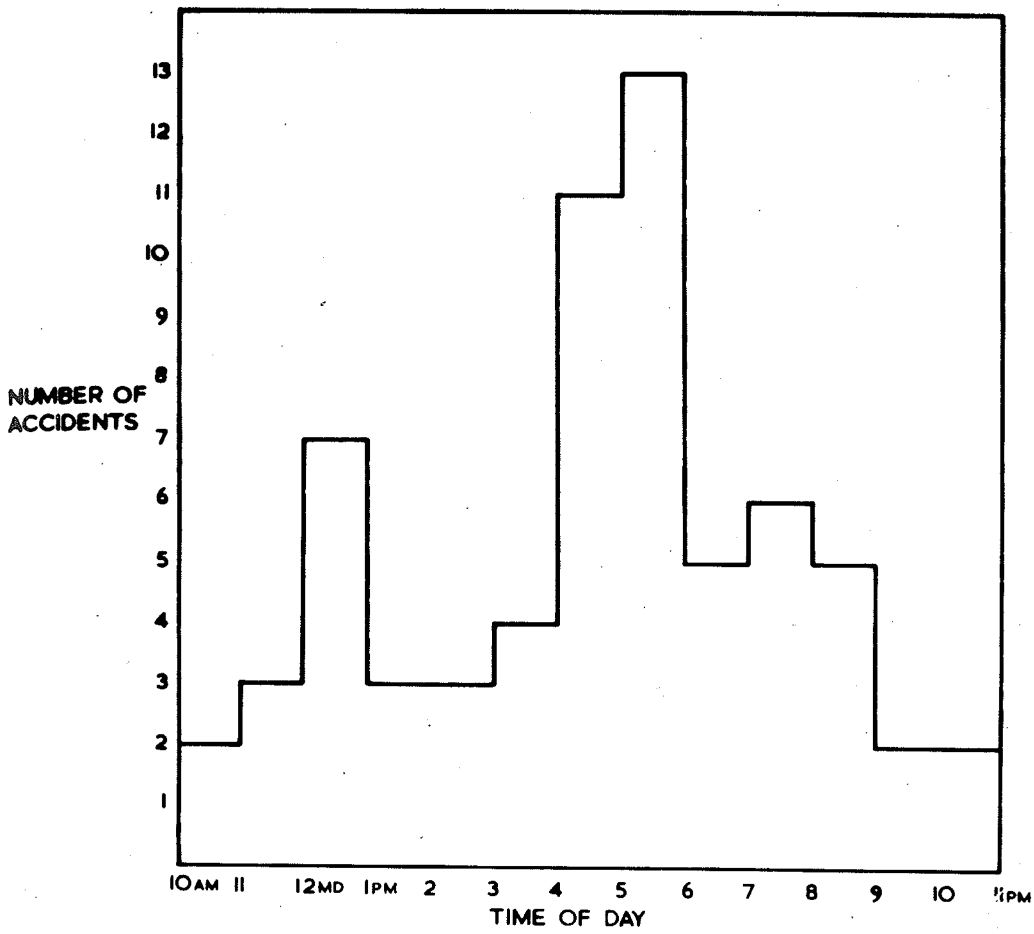


Fig. 6.1
Total motor-cycle accidents by time of day.

Fig. 6.2
Time distribution of
motor-cycle accidents

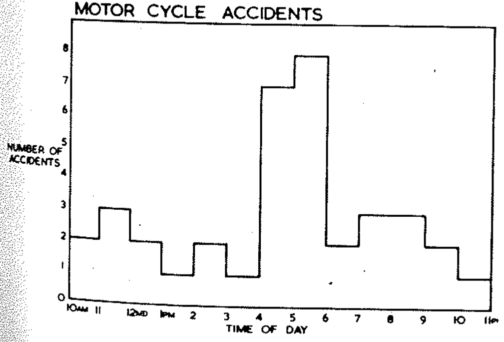
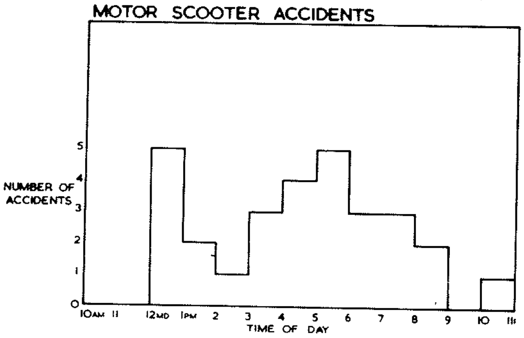


Fig. 6.3
Time distribution of
motor-scooter accidents.



Honda Cub has been classed as a motorcycle because the rider's foot rests on a peg, not on a flat plate, and his lower leg can be trapped against the machine in the event of an impact from the side.

6.3 One case, accident number 0026, has been considered as two separate accidents to make subsequent analyses clearer.

> 0026 A motorscooter, ridden by a 38 year old man with his nine year old daughter on the pillion, began to swing from side to side of a ridge along the edge of a newly laid road surface. A heavy load on the luggage carrier may have prevented the rider from regaining control and he and his passenger eventually fell off, both sustaining abrasions. A car following closely behind this scooter braked suddenly to avoid hitting it and was struck in the rear by a second motorscooter which was unable to stop as quickly as the car. This second scooter skidded sideways on braking and slid in under the back of the car. This rider was not injured.

By considering these two scooters to be involved in separate accidents, viz. one single vehicle accident (0026A) and one collision between a motorscooter and a car (0026B) the total number of motorcycle accidents is increased to 67. Please note, however, that when making comparisons such as that at the beginning of this section the original definition is used, viz: this whole series of events constitutes one accident.

Time Distribution

6.4 Over two thirds (45/66) of these accidents happened in the daytime. The previously noted peak of traffic accidents around 6 p.m. is very pronounced in this group of motorcycle accidents. Fig. 6.1 shows

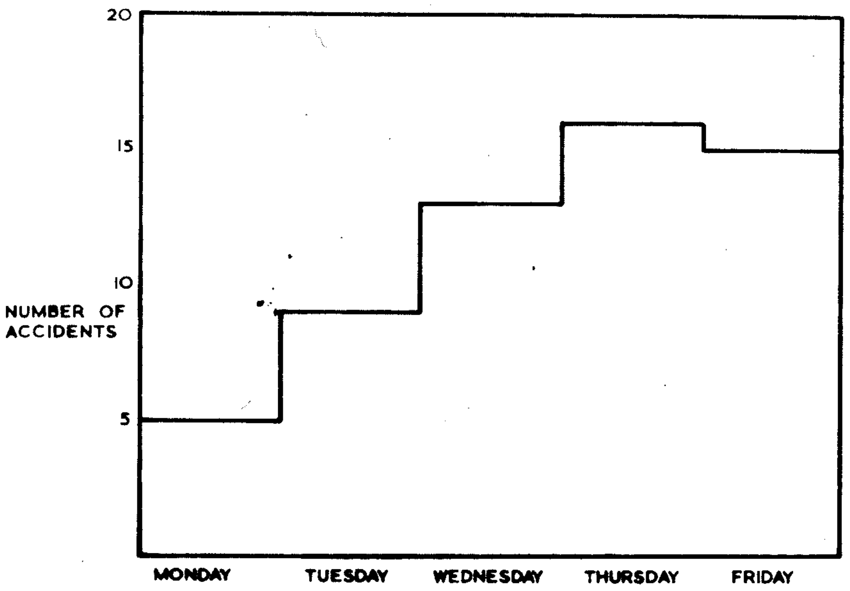


Fig. 6.4
Total motor-cycle accidents by day of week.

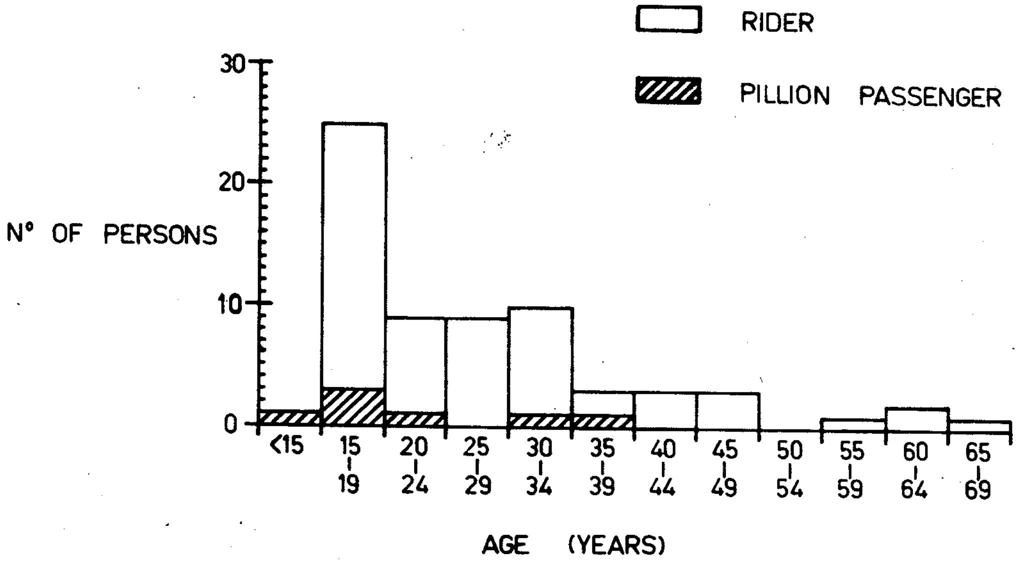


Fig. 6.5
Age distribution of motor-cycle riders and pillion passengers.

the time distribution of accidents in this survey. The histogram shows that over one third (24/66) of these accidents happened in the two hours between 4 p.m. and 6 p.m. When reduced into two histograms, one for motorcycles and the other for motorscooters, this peak becomes very much more pronounced for motorcycles (Fig. 6.2) but is suppressed in the case of motorscooter accidents (Fig. 6.3). There is also a slight peak during lunch hours (12 p.m. - 2 p.m.) and the evening peak continues, although diminished, to between 8 p.m. and 9 p.m. The differences between the two distributions may be due to chance. As noted earlier in this thesis, the sampling method was biased towards periods of low accident frequency. These peaks in the distribution are therefore much less marked than is actually the case.

6.5 The distribution of motorcycle accidents by day of week shows that the number increases from Monday to Thursday (Fig. 6.4). The accidents collected on Saturdays and Sundays are not shown here, because very few Sundays and only alternate Saturdays were sampled. This increase in the number of accidents through the week is shown also in the calls ambulances received to traffic accidents. A similar trend is shown in the total figures for this survey but is much more marked in the case of motorcycle accidents.

Weather Conditions

6.6 The motorcycle, being a single track vehicle, relies on the stabilizing effect of its rotating wheels to enable the rider to balance his machine. When either or both wheels are locked by the brakes it is extremely difficult for even a skilled rider to maintain control. Similarly when cornering, skidding can be very hazardous for the motorcyclist because both his directional control and the stability of his machine are affected.

6.7 Because of these dangers associated with skidding, and the obvious relationship between reduced skid resistance and wet roads, motorcycle accidents would be expected to be closely related to weather conditions. It comes as a considerable surprise therefore to find that only one of these accidents occurred when it was raining and only three on wet roads. Of these three accidents the condition of the road surface was significant in two cases. These two accidents both involved a car turning across the path of a motorcycle. Each rider braked hard and his machine, one a heavy motorcycle, the other a scooter, skidded and slid sideways into the car. The scooter rider sustained bruises and abrasions. The motorcyclist was not injured. Both were wearing safety helmets.

Tyres

6.8 The following Table does not show any significant relationship between the condition of the tyres on motorcycles and the incidence of skidding. In these 67 accidents 13 cases were recorded in which a motorcycle skidded when braking.

TABLE 6.1

	Condition of tyres			
	Good	Poor	Not Recorded	Total
Skidding when braking	6	5	2	13
No skidding observed	28	14	12	54
	34	19	14	67

6.9 Of the three categories of motorcycles, viz. motorcycles over 200 c.c., under 200 c.c., and scooters, we found that light motorcycles appear to be less susceptible to skidding while braking than the heavier machines and scooters.

TABLE 6.2

	Motorcycles		Scooters	Total
	Heavy	Light		
Skidding while braking	7	-	6	13
No skidding observed	16	13	24	53
	23	13	30	66

6.10 There are two possible explanations here; one is that the lighter, less powerful motorcycles may not have been travelling as fast as the heavier machines. This is largely true in this sample of accidents as the following Table shows:

TABLE 6.3

Travelling speeds	Motorcycles Heavy	Motorcycles Light	Scooters	Total
Up to 20 m.p.h.	3	4	4	11
20 m.p.h. and over	15	6	18	39
Speed not recorded	5	3	8	16
	23	13	30	66

The other possible explanation is that the brakes on the lighter motorcycles do not lock the wheels as easily as do those on the heavier machines.

Age Distribution

6.11 There were 67 riders (of whom 60 were males and 7 females) and 7 pillion passengers (of whom 3 were males and 4 females). There were no riders less than 16 years old, (16 years is the minimum age for holding a driving licence). One pillion passenger, a girl, was 9 years old. The histogram (Fig. 6.5) shows that more than half of these riders were less than 24 years old.

Helmets and age of rider

6.12 A total of 21 riders and one pillion passenger were wearing safety helmets. In the following Table the number of riders in each age group wearing helmets is compared with the total number in each group.

TABLE 6.4

	Age of Rider (in years)						
	15-19	20-24	25-29	30-34	35-69	N.R.	Total
Wearing helmet	7	4	5	5	0	0	21
No helmet	18	5	4	5	13	1	46
	25	9	9	10	13	1	66

Those in the group of youngest riders may not have been willing to buy a helmet. Those over the age of 34 years presumably did not consider that the risk of injury justified the expense and inconvenience of buying and wearing a helmet.

Type of machine and age of rider

6.13 The age distribution of motorscooter and motorcycle riders is shown in the following Table.

TABLE 6.5

Age of Rider (in years)	Motorscooter	Motorcycle	Total
15 - 19	9	16	25
20-29	8	10	18
30-69	12	11	23
Not recorded	1	-	1
Total	30	37	67

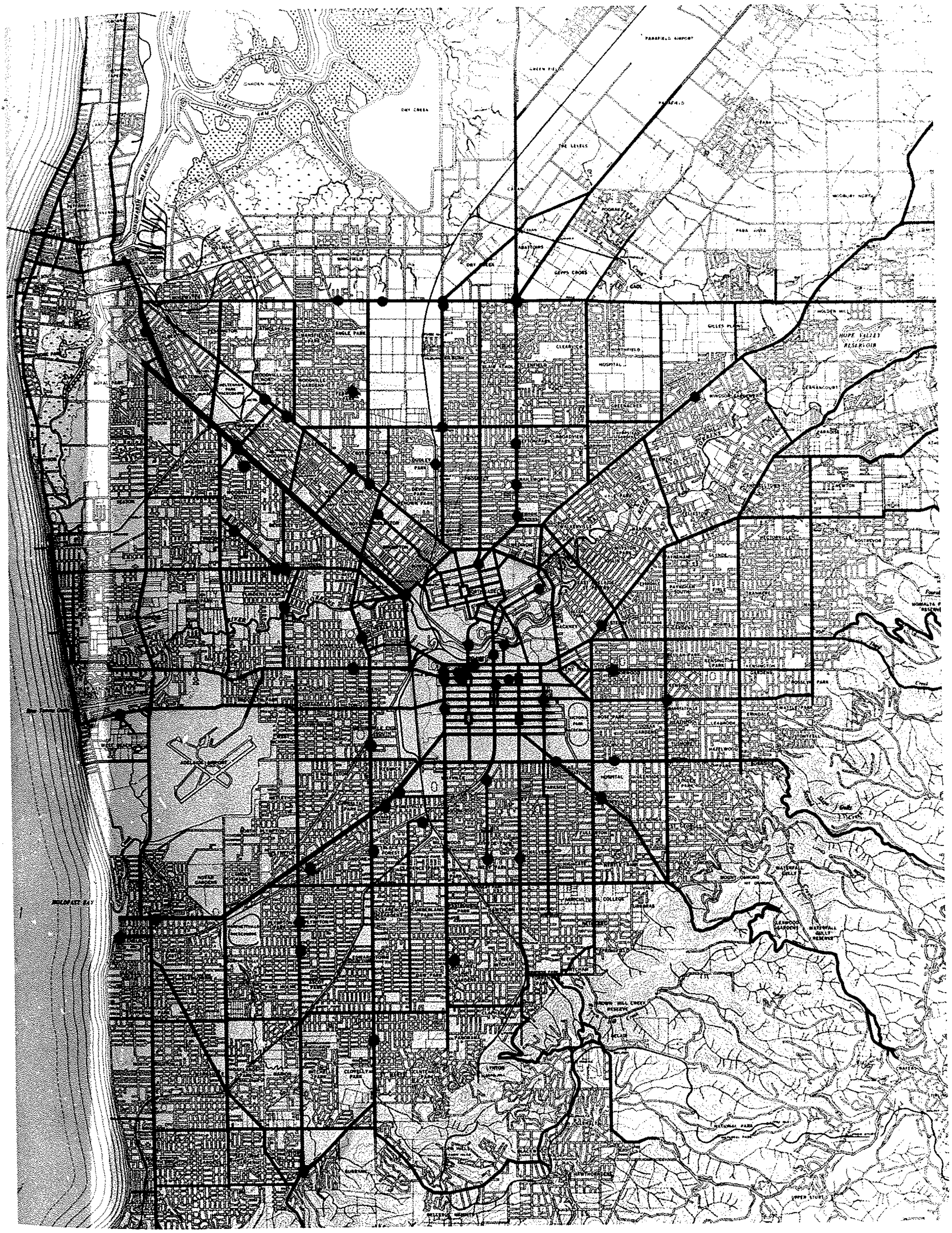


Fig. 6.6
Location of motor-cycle accidents.

6.14 The 67 motorcycle accidents can be divided into groups as follows:

	No. of cases
Collision between motorcycle and car	47
" " " " pedestrian	7
" " " " truck	4
" " " " pedal cycle	2
" " " " train	1
Motorcycle alone	6
Total:	67

(Accident 0026 is counted in two categories)

Collisions with cars and trucks make up 76% of all motorcycle accidents. The accidents involving a motorcycle alone consist of two cases of collision with a fixed object, and four cases where the motorcycle and rider fell to the road without striking any other vehicle.

Locations of these accidents.

6.15 The location of each of these accidents is shown in Fig. 6.6. The accidents are distributed more evenly between the central city area and the suburbs than is the case for pedal cycle accidents. Note that nearly all of these motorcycle accidents happened on busy roads.

6.16 The locations of these accidents with respect to intersections are shown in the following Table.

TABLE 6.6

Collision of motor cycle with ...	Not at inter-section	At inter-section	Within 20 yards before inter-section	Within 20 yards after inter-section	Total
Car	9	32	4	2	47
Truck	0	4	0	0	4
Pedestrian	3	1	0	3	7
Pedal Cycle	0	2	0	0	2
Motorcycle alone	2	1	2	1	6
Train		Not applicable			1
	14	40	6	6	67

6.17 The collision between a motorscooter and a train occurred at a level crossing, and so is not classified in the Table. 40 (61%) of the other 66 accidents happened within an intersection, 12 (18%) happened within 20 yards of an intersection, and 14 (21%) more than 20 yards from an intersection. One of the 7 pedestrian accidents happened at an intersection, the rest took place some distance away from the intersection.

Vehicle Movements.

6.18 There was a marked difference between the movements of these motorcycles and those of the cars with which some of them collided. 79% of the motorcycles were travelling straight ahead and only 8% were changing direction at the time of the collision. By contrast with these figures, 70% of the cars which collided with motorcycles were changing direction.

Types of Motorcycle Accidents.

6.19 There were six accidents in which the motorcycle was the only vehicle involved. In each case the motorcycle was proceeding straight ahead. There were two cases of collisions with fixed objects, and four cases of falls when the rider lost control of his machine.

6.20 In two cases the motorcyclist was forced to swerve to avoid a vehicle turning into his path, and in so doing fell from his machine. In the first case (0037) a 25 year old male riding a B.M.W. motorcycle was forced into the left hand kerb by a semi-trailer which turned on to the dual highway from the median. The motorcycle scraped along the kerb, still upright, until it struck a 6 foot high pile of bricks stacked on the footpath level with the edge of the kerb. The left side of the rider and the motorcycle struck the edge of the pile of bricks. The rider, who was wearing a crash helmet, suffered concussion, lacerations of the left eyebrow and left cheek, a fractured collarbone, chest injuries, and a comminuted fracture of the left knee-cap, all produced by the impact with the pile of bricks.

6.21 In the second case (0197) a 19 year old female riding a motor-scooter swerved and braked to avoid a taxi which turned sharply across in front of her. The scooter fell on its side and slid down the road.

The rider suffered concussion, an abrasion to the left cheek, a laceration of the back of the top of the skull, a fracture of the right collar bone and abrasions to hands, hips, knees and ankles.

6.22 In one of the two cases where a motorscooter struck a join in the road surface and the rider lost control, the rider and scooter struck a steel and concrete utility pole. The rider suffered concussion (0321). In the other case (0026), the scooter had a large parcel on the carrier at the rear as well as a pillion passenger. The scooter and load fell to the road, rider and passenger suffering abrasions.

6.23 In the fifth case (0182), a 19 year old male, unlicensed and testing his unregistered motorcycle, braked on loose gravel. The cycle skidded, fell on its side and slid into a concrete kerb. The rider suffered concussion and bruises on the left temple, left shoulder and over his hip.

6.24 In the last of these cases (0303) a woman, approximately 30 years old, was stationary on a motorscooter at traffic lights when she was seen (and heard) to open the throttle wide and to let the clutch out suddenly. The scooter reared up in the air slid into the next lane and the rider fell off. She was unconscious for approximately five minutes after the incident, and on recovering she was very unco-operative. The story is very suggestive of an epileptiform fit.

<u>Motorcycles and Pedestrians</u>.

6.25 The circumstances of these accidents have already been described in Chapter 4. The riders of the motorcycles all fell off following the collision. They all sustained abrasions and bruises to their extremities and in two cases they sustained concussion. One rider wearing a crash helmet struck his head on the side of a parked car as he fell to the road after impact with the pedestrian (case 0424). The other rider, who was not wearing a helmet, struck his head as he fell to the road. Only one of these accidents was at night, whereas over two fifths of the total number of pedestrian accidents happened at night. This may be due to chance, but it is possible that an approaching motorcycle is more noticeable at night, when its headlight is on, than in the daytime.

Motorcycles and Pedal cycles.

6.26 There were two of these collisions. Both have been considered in the chapter on pedal cycles (Chapter 5). In one case the motorcyclist suffered concussion and abrasions to his face, and in the other the motor cyclist was unhurt. These collisions are rather akin to collisions with pedestrians in that the fall to the road, rather than the collision itself, causes injury to the motorcyclist.

Motorcycle and Train

6.27 The one death among motorcyclists occurred when a 47 year old man stopped at a level crossing to allow a train to go past on the track furthest away from him. He then moved on to the closer track and was struck by a diesel railcar travelling in the opposite direction, as he tried

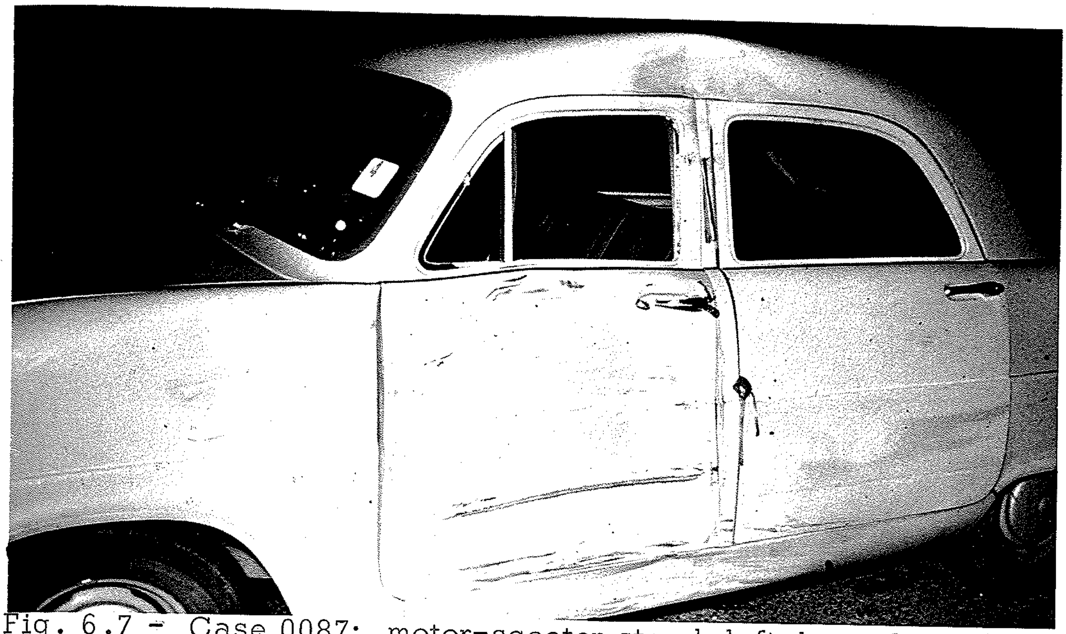


Fig. 6.7 - Case 0087: motor-scooter struck left door of car. Damage around centre post caused by impact of rider's head.

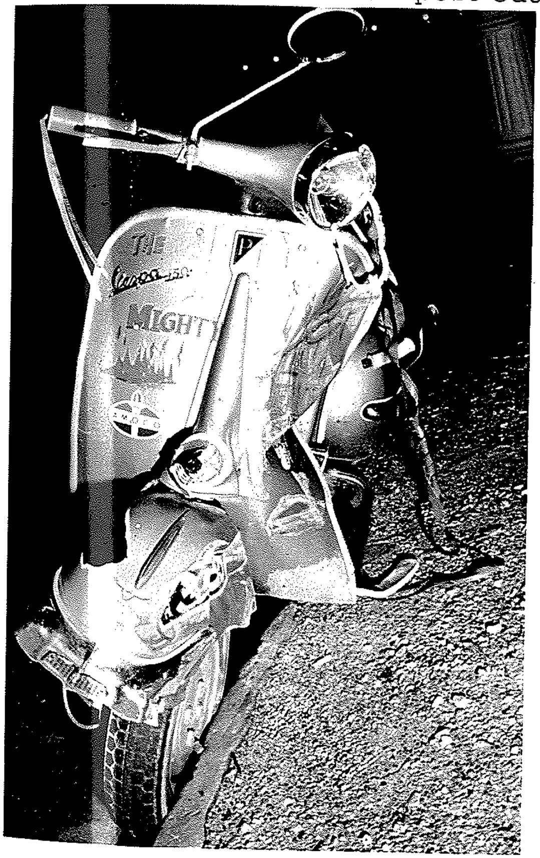


Fig. 6.8
Case 0087: motor-scooter struck car shown in Figure 6.7.

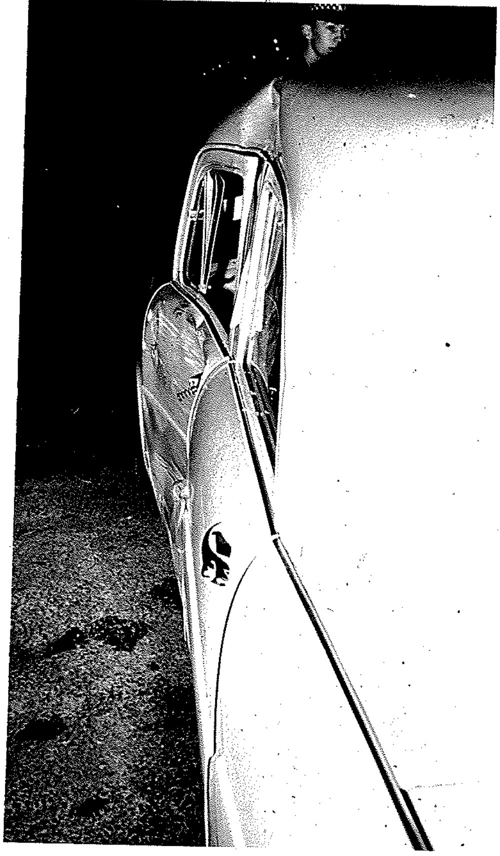


Fig. 6.9
Case 0087: deformation of car produced by the impact of motor-scooter and rider.

to push his machine back off the track. The warning signals were operating at the time. The front left corner of the railcar struck the right side of the rider's head causing extensive fracturing of his skull.

Motorcycle and car.

6.28 Reference has already been made to the high proportion of these collisions in which the car was changing direction (paragraph 6.18). The movement of the car is therefore taken as the basis for the following discussion of these collisions.

Cars turning right

6.29 This category comprises a third of all motorcycle accidents in this survey. The alarming feature of this type of accident is that there is very little that the motorcyclist can do to avoid such a collision. Thirteen cases involved a car turning right across the path of a motorcycle approaching on the same road.

> 0087 This accident happened in the city just before dusk on a fine clear day. A youth on a motorscooter struck the left side of a car which had been coming towards him and had turned right, across his path, at a traffic-light-controlled intersection (Fig. 6.10). The scooter rider's head struck and shattered the glass of the left front door of the car (Figs. 6.7, 8, 9). The jagged edges of the glass remaining in the frame caused extensive lacerations of the left side of the base of his neck and left shoulder. The impact with the centre post fractured his lower jaw and left collar bone. A safety helmet protected his scalp from abrasions, but he was concussed. The elderly male driver of the car received only small lacerations from fragments of glass from the broken window.

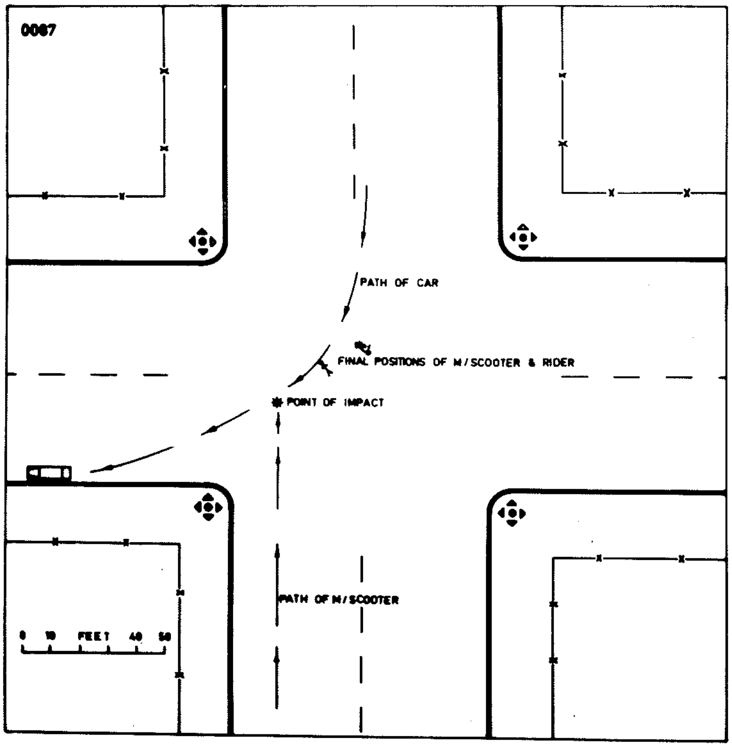


Fig. 6.10
Case 0087.

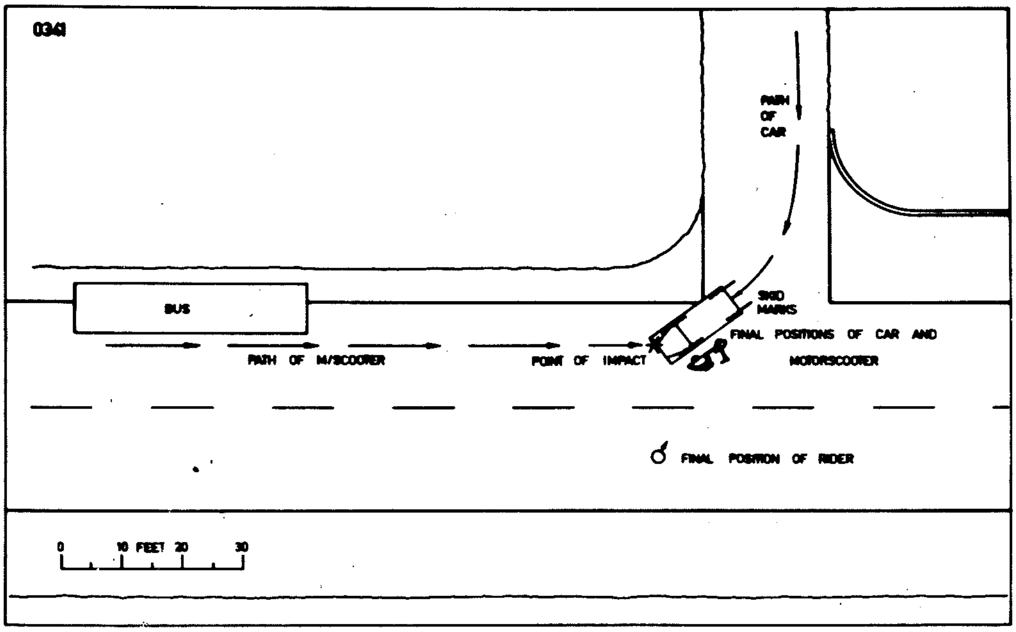


Fig. 6.11
Case 0341.

6.30 All of these 13 accidents involved passenger cars. Five cases were at traffic-light-controlled intersections. At one of these (O'Connell Street and the Main North Road), the layout of the lights is confusing and tends to give the turning driver the impression that he has the right to turn whereas in fact he has to yield to oncoming traffic. At one other location (West Terrace and Currie Street) during peak traffic periods the West Terrace traffic has a split green phase; that is the southbound green phase is shorter than the northbound. This has the effect that a driver who is facing south waiting to turn right, sees his light change to red and completes his turn, unaware that the northbound traffic still has the green light.

6.31 By contrast with the motorcycle collisions with pedestrians, which were nearly all in the daytime, these accidents involving cars turning right were equally divided between day and night.

TABLE 6.7

	Day	Night	Total
Cars turning right - Motorcycle approaching	6	7	13
Other motorcycle accidents	40	14	54
	46	21	67

Chi square = 3.5 ($p_{0.05}$ = 3.8)

6.32 The above result conflicts with the suggestion made earlier that it may be harder to see an approaching motorcycle in the daytime than at night. This sighting will obviously depend on many factors, among them the nature of the background behind the motorcycle. If, at night, it is a dark background, with no other lights apart from the headlight of the motorcycle, it should not be difficult to see the machine approaching. If it is only one of many lights the headlight could easily be overlooked. It seems that, at all times, drivers should look first for motorcyclists, then for other vehicles, before completing a turn to the right. The following Table shows that while the motorcyclist usually saw the car approaching in the distance, the car driver usually saw the motorcyclist only just before the collision.

TABLE 6.8

	Participant saw the other vehicle				
	In the distance	Close	Not at all	Not known	Total
Motorcyclist	8	3	0	2	13
Car Driver	3	6	3	1	13
	11	9	3	3	26

Grouping together "close" and "not at all": Chi square = 3.5 (after Yates' correction). $p_{0.05} = 3.8$.

6.33 It might be suspected that the motorcyclists who are involved in this type of accident were travelling unusually fast, this making it difficult for the car drivers to judge their speed. Our data do not support this suspicion. The average travelling speed for the twelve cases for which we were able to obtain information is less than 30 m.p.h.

6.34 In a similar category, there were ten cases in which a car turned right from one road and hit a motorcyclist travelling towards the intersection along the other road.

> 0341 The middle-aged male driver of a car proceeded with a right hand turn from a side street, despite the fact that his view to his right was obscured by a bus which was taking on passengers. A motorscooter suddenly came past the bus from his right and struck the right front corner of the car (Fig. 6.11). The rider of the scooter said he saw the car appear from behind the bus with the driver looking to his left. Although he tried to stop he was unable to avoid the collision with the car. He sustained a fracture of his left tibia. He was wearing a safety helmet.

6.35 This occurrence of a stationary vehicle obscuring a driver's view is repeated in three other cases in this group of ten accidents. The motorcyclist usually saw the car long before the driver saw the motorcyclist.

TABLE 6.9

	Participant saw the other vehicle:				
	In the distance	Close	Not at all	Not known	Total
Motorcyclist	5	4	-	1	10
Car driver	-	7	2	1	10
	5	11	2	2	20

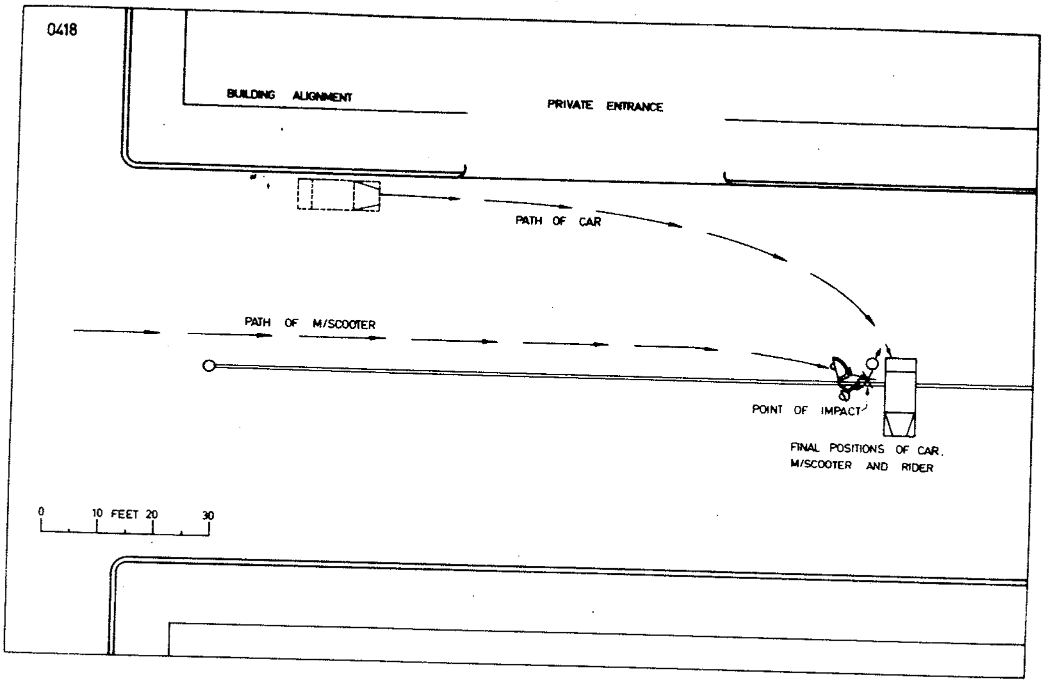


Fig. 6.12
Case 0418.

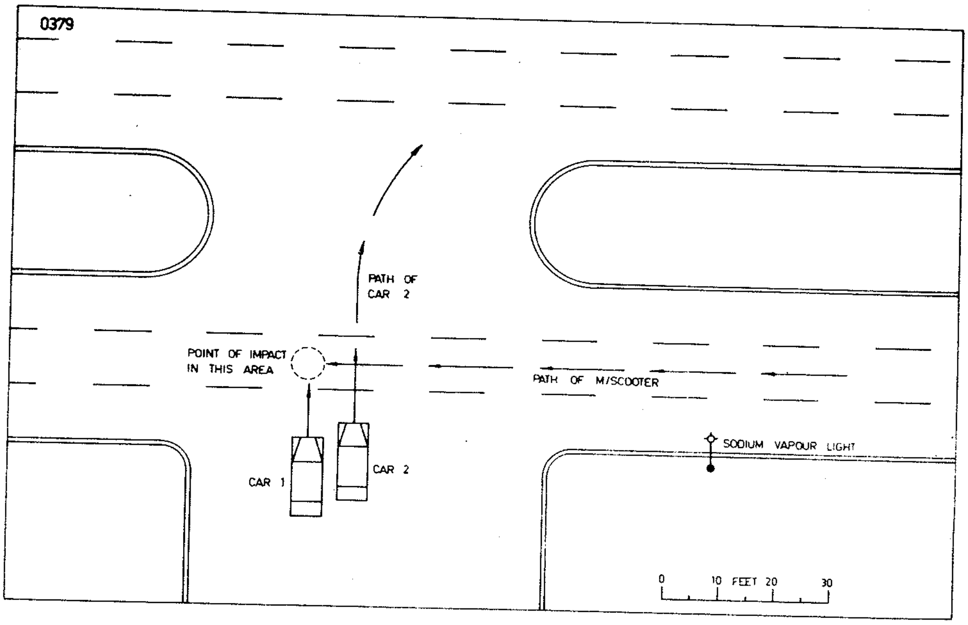


Fig. 6.13
Case 0379.

6.36 The average travelling speed of these motorcyclists is slightly higher than in the previous group, but is still below 30 m.p.h. Seven of these ten accidents happened in the daytime, none of them at light-controlled intersections. In each case the car was turning from a side road into a through road. There is no noticeable distinction between motorcycles and scooters in these 23 accidents. This is not surprising, for the performance of the cycle has little bearing on such accidents. In 20 cases there was virtually nothing that the motorcyclist could have done to avoid the collision.

Cars performing 'U' turns.

6.37 There were seven cases involving cars which struck a motorcyclist while attempting a 'U' turn from a parked position alongside the kerb. Six of these seven accidents happened in the daytime. The types of motorcycles involved were four scooters, two light motorcycles, and one heavy motorcycle.

0418 The driver of a Holden sedan, ranked on the left side of a road 70 feet wide, looked both ways before starting a 'U' turn. He saw a motorscooter some distance away behind him, but thought that he had time to turn in front of it.

The rider of the motorscooter said that the car suddenly made a 'U' turn in front of him without any warning (Fig. 6.12). His machine struck the right rear wheel of the car and he hit his face onthe right rear corner of the roof. He was concussed, and also fractured his right cheekbone and some teeth. Damage to the infra-orbital nerve resulted in partial loss of feeling in the right side of his face. His left hand and both knees were bruised.

6.38 Once again there is very little that the motorcyclist can do to avoid a collision of this nature. Both motorcyclists and car drivers saw each other with equal frequency. It seems likely that the car drivers underestimated the speed of the motorcycle and also the time needed to complete a 'U' turn.

TABLE 6.10

	Participant saw the other vehicle:				
	In the distance	Close	Not at all	Not known	Total
Motorcyclist	3	2	-	2	7
Car driver	3	3	-	1	7
	6	5	-	3	14

The average travelling speed for these motorcyclists is high, being between 30 and40 m.p.h., but this is not beyond the range of speeds that a driver should allow for when turning across the path of an approaching vehicle.

6.39 There is one other accident similar to those in this group. A driver moved off from a ranked position to turn right into a side street and was struck by a motorscooter which he had not seen coming up behind him.

Collisions at intersections.

6.40 In these 8 accidents both the motorcycle and the car were proceeding straight across the intersection.

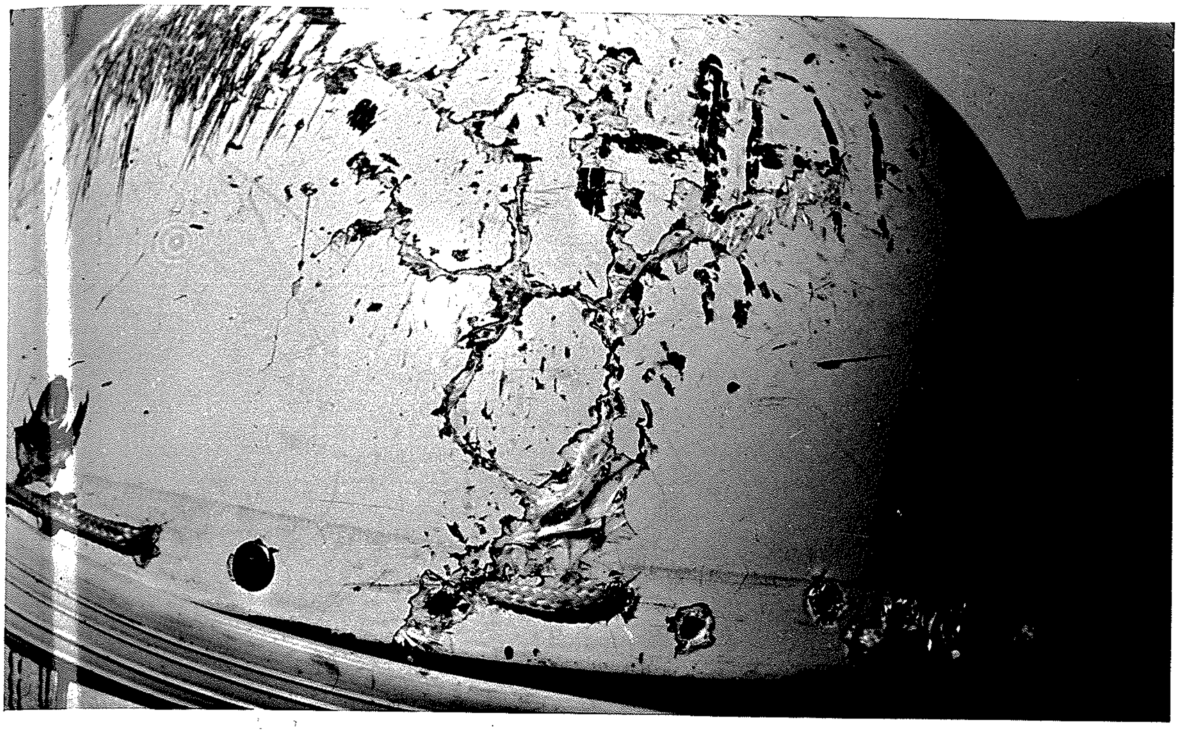


Fig. 6.14
Note fracture lines in shell of helmet.

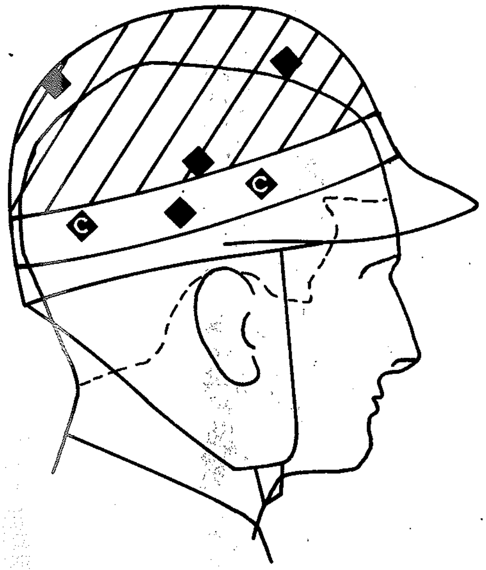


Fig. 6.15

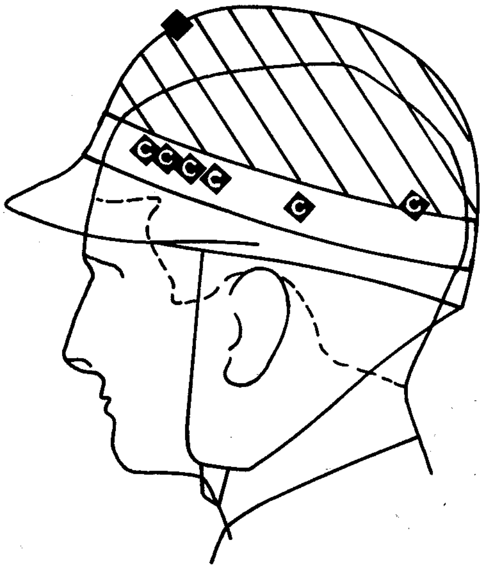


Fig. 6.16

Cases in which a helmet was worn, showing the position of impacts in relation to the shell of the helmet and the protective padding. The cross-hatched area indicates the extent of the padding. 'C' indicates an impact causing concussion.

0379 The young driver of an old light car moved off to cross to the median of a divided highway as the car alongside him on his right started to move off. In fact this car allowed a motorscooter to pass along the highway from the right. The driver of the case car could not see the motorscooter approaching and continued to move forwards striking the scooter (Fig. 6.13).

The young scooter rider, who was wearing a safety helmet, sustained bruises to his left leg. The pillion passenger, who was not wearing a helmet, sustained concussion in addition to bruises.

6.41 This example of a driver moving off because the car alongside him on his right starts to move is one of the manoeuvres which we have found commonly to result in an accident.

6.42 There was little difference between the motorcyclists or the drivers as far as awareness of the approach of the other vehicle was concerned.

TABLE 6.11

	Participant saw the other vehicle:				
	In the distance	Close	Not at all	Not known	Total
Motorcyclist	-	4	-	4	8
Car driver	1	4	3	-	8
	1	8	3	4	16

Three quarters of these were daytime accidents.

6.43 In two cases a vehicle was travelling unreasonably fast for the particular situation. By "unreasonably fast" we mean, in one case, any speed above 5 to 10 m.p.h. on entering the intersection, which had a blind corner. In the other case the car driver was, at a speed of over 50 m.p.h., inviting a collision with any unfortunate person who emerged from a side street without first looking rather a long way up the road to his right.

Rear end collisions.

6.44 Of the three accidents of this type two resulted simply from the motorcyclist running into the back of a car which had stopped because the vehicles ahead of it had stopped. In the other case the car skidded to a stop to avoid a fallen scooter rider and a motorscooter following closely behind the car was unable to avoid running into the back of it.

Car turning left across path of motorcycle

6.45 Two cases of a similar nature resulted from cars turning left, one into a private entrance, the other to park. By turning left from near the centre of the roadway they each cut across the path of a motorscooter which was travelling in the same direction but keeping further to the left side of the road.

Miscellaneous motorcycle accidents.

6.46 The remaining five motorcycle accidents are all different from each other and from those listed above. There are some similarities however:

(a) A sideswipe collision between a motorcycle and an overtaking car.

(b) A rider on a heavy motorcycle making a 'U' turn when unable to see beyond a van double-ranked behind him. He was struck on the side by a car.

(c) A motorcyclist turning right at a roundabout on a divided highway saw one car yield to him and proceeded to turn, only to be struck by a second car which did not stop. Confusion regarding the right of way rule at such a location may have been a significant factor in this accident.

Motorcycles and Trucks

6.47 There were four collisions with trucks. Two occurred at the same light-controlled intersection (Gepps Cross).

One of these accidents (0239) involved the familiar manoeuvre of one participant, in this case the motorcyclist, moving off when the traffic lights turned green even though he could not see past a car alongside him on his right. A truck approaching from the road on the right had entered the intersection just before the amber phase of the lights. The amber phase was not long enough to allow the truck to clear the intersection before the lights changed to red, and simultaneously to green for the motorcycle. The scooter struck the left side of the truck, which was travelling at little more than 20 m.p.h. The rider suffered an abrasion of the right lumbar region with a fracture of the right tenth rib, probably from impact with the tray of the truck, and bruises and abrasions of both thighs. The pillion passenger suffered abrasions to the lumbar region and a laceration of the right knee. Both the rider and his pillion passenger were wearing safety helmets which showed signs of having struck the road surface.

6.48 In the other case (0376) a motorscooter ran into the right side of the cab of a truck which was still crossing the intersection after the light had changed to red. The rider was wearing a crash helmet, but sustained concussion with signs of cerebral irritation, bruises to the left shoulder and right buttock, and abrasions to both knees and the left lower leg.

6.49 In another collision (0147) a motorscooter swung wide while turning left at a corner and, while still heeled over to the left, struck the front of a truck travelling in the opposite direction. The rider's right leg struck the bumper bar of the truck producing a fracture of the right tibia and fibula.

6.50 The fourth collision (0178) was between a van, which did not stop before entering a main road, and a motorcycle. The motorcycle struck the left front door of the van and the rider, a male aged 18 years, suffered a laceration of the right forehead and abrasions to both hands. The cause of the injuries could not be accurately determined.

6.51 While it may be obvious in the above descriptions, it should be re-emphasised that the motorcyclist very often is the "victim" in the causation of these accidents. In only 15 of these 67 cases could the motorcyclist reasonably be expected to have been able, by his own action, to avoid the accident.

Design Standards for Safety Helmets

6.52 The number of riders wearing helmets has been presented in paragraph 6.12. Including pillion passengers also, the number wearing helmets is 22 out of a total of 74 riders and passengers, or a 'wearing rate' of 30%.

6.53 A detailed comparison of the circumstances of these accidents failed to show any very pronounced reduction in injury severities that could be attributed to the wearing of safety helmets. This is not to say that there were no obvious benefits in certain cases, e.g.:

> 0376 A Ford Falcon car moved off from a stop sign and hit a motorscooter ridden by a 30 year old man. The rider was thrown from his machine and slid along the road, finally striking his head on the edge of a median strip. The helmet he was wearing was shattered at the main point of impact (Fig. 6.14). He sustained concussion and bilateral fractures of the squamous temporal bones of the skull.

Other studies have assessed the effectiveness of safety helmets (Ref. 34). Foldvary and Lane (Ref. 35) showed that the introduction of legislation making the wearing of safety helmets compulsory in the State of Victoria had reduced the fatality rate for motorcyclists.

6.54 Close study of both the point of impact to the head and consequent injury in each relevant case among these motorcyclists suggested two factors that are not adequately allowed for in the present Standard for safety helmets (Ref. 35). The points of impact in those cases in which helmets were worn are shown in Figures 6.15 and 6.16. Those impacts which caused concussion are marked with a 'C'. The energy-absorbing lining of a helmet made to the above Standard is shown by the cross-hatching.

6.55 It can be seen that very nearly all of the impacts which caused concussion were in fact located below the energy-absorbing lining. This obviously defeats one of the main purposes of these helmets, to absorb the energy of the impact before it reaches the brain. A more demanding Standard, that for racing motorcyclists' helmets (Ref. 36), does specify a more enveloping helmet covering the ears and lined throughout with energy-absorbing material. The second factor to appear is also related to the speed at impact. B.S. 2001 demands a test impact equivalent to that of a 10 lb. mass falling through a distance of 9 feet. The head weighs about 10 lbs. and so this test is roughly equivalent to a direct head impact resulting from a fall from a height of 9 feet, neglecting the weight of the remainder of the body. Most of the impacts shown in Figures 6.15 and 6.16 were at speeds greater than 20 m.p.h. But an impact at even 20 m.p.h. is equivalent to a 'free fall' impact from a height of 14 feet, far beyond the test height of 9 feet.

6.56 It is therefore recommended that B.S. 2001 should be revised to incorporate a higher test impact level, with the point of application of the test impact being in the temporal region. This presupposes a more enveloping helmet, similar to that specified by B.S. 1869.

TRUCK ACCIDENTS

CHAPTER 7

Definition of Vehicles listed as 'Trucks'.

7.1 In this section on truck accidents all heavy vehicles and also some light commercial vehicles are considered. This wide range of vehicles has been reduced to two somewhat more homogeneous groups by classifying each vehicle further as either a 'light truck' (up to 2 tons tare weight) or a 'heavy truck' (over 2 tons tare weight). The arbitrary limit of 2 tons has no basis other than being a reasonably convenient value which divides the total number of vehicles into two groups of approximately equal numbers (27 light trucks, 35 heavy trucks).

7.2 Further subdivision into specific types of 'trucks' e.g. light vans, heavy utilities, buses, etc. is only done when this has some relevance to any particular accident. The justification for having a separate category for all these vehicles is that they are generally distinguishable by their shape, size and/or weight from passenger cars. The smaller trucks, and some utilities and vans, tend to be less obviously distinguishable by size and weight. In the case of units such as the Volkswagen Kombivan the forward control driving position has been taken as justification for including this in the category of 'light truck' rather than 'car-type van, utility etc.'.

7.3 There were 59 accidents involving trucks. This is one seventh

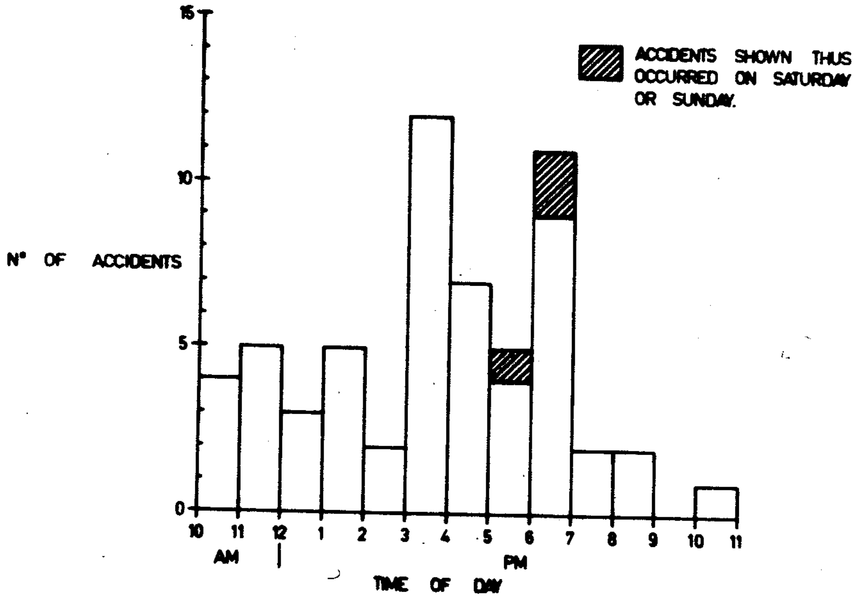


Fig. 7.1
Distribution of truck accidents by time of day.

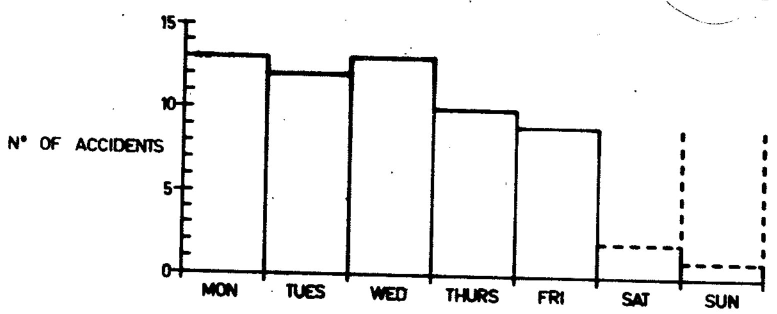


Fig. 7.2
Number of truck accidents by day of week (totals for Saturday and Sunday are not to be directly compared with weekday totals because of variation in working periods).

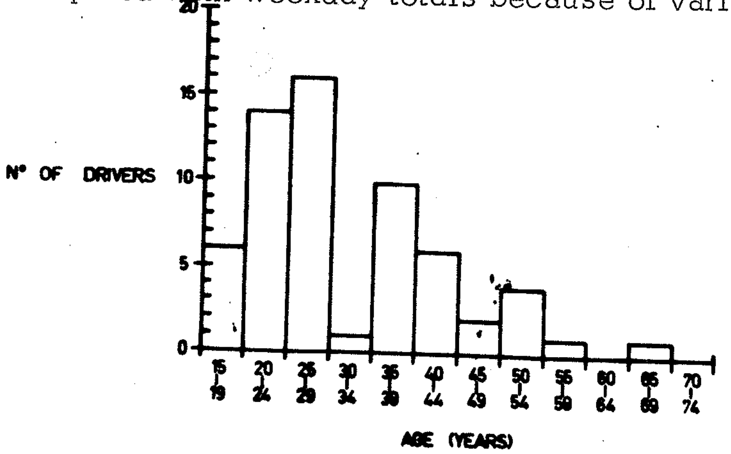


Fig. 7.3
Age distribution of truck drivers.

(14.4 per cent) of all the accidents we attended. The 59 accidents were divided into the following types.

Collisions with cars	34
Multiple vehicle collisions (more than two vehicles involved)	8
Collision between two trucks	1
Collision with pedestrian	7
Occupant falling from the tray of a truck	1
Collision with pedal cycle	4
Collision with motorcycle	4
Total:	59

There were 62 trucks with 85 occupants involved in the 59 collisions.

Time Distribution of Truck Accidents

7.4 A histogram (Fig. 7.1) shows the distribution of all truck accidents by time of day. There are two peaks, one between 3 and 4 p.m. and the other between 6 and 7 p.m. This is different from the other time distributions that have been studied, where there is only one peak, generally between 4 p.m. and 6 p.m. The height of these peaks may be influenced by the sampling bias towards the off-peak periods, i.e. there is a greater proportion of the accidents which occurred between 3 p.m. and 4 p.m. in the sample than of accidents between 6p.m. and 7 p.m.

Day of week

7.5 The distribution by day of week is shown in Fig. 7.2. The incidence is constant from Monday to Wednesday, then falls on Thursday and Friday. Saturday and Sunday cannot be included due to the inadequacies of the sampling technique.

Age of Truck Occupants

7.6 The age distribution of the 61 truck drivers in the 62 trucks involved is shown in a histogram (Fig. 7.3) and that for all occupants in Table 7.1. Their ages range between 17 and 66 years. There are two peaks: 20 to 29 years, and 35 to 39 years. There were 24 passengers, whose ages were distributed as shown in Table 7.1.

TABLE 7.1

	Age of Truck Occupants		
Age in Years	Drivers	Passengers	Total
5 - 9	0	1	1
10 - 14	0	2	2
15 - 19	6	5	11
20 - 24	14	2	16
25 - 29	16	6	22
30 - 34	1	1	2
35 - 39	10	2	12
40 - 44	6	2	8
45 - 49	2	1	3
50 - 54	4	2	6
55 - 59	1	0	1
60 - 64	0	0	0
65 - 69	1	0	1
Total	61	24	85

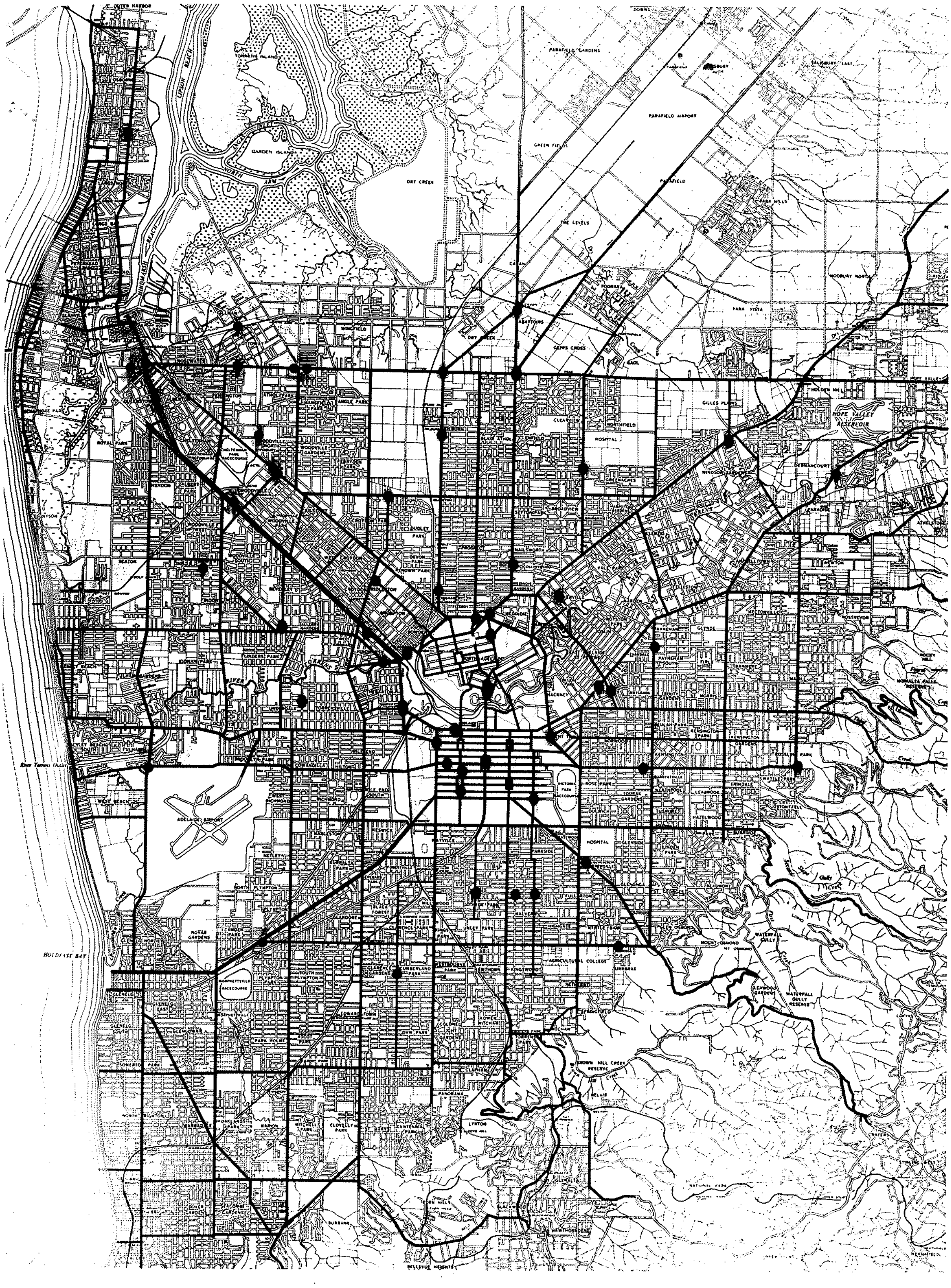


Fig. 7.4

Location of all accidents involving 'trucks' (TARU survey)

Location of these Accidents

7.7 Only about one sixth of these truck accidents were in the central city area, as shown by the spot map (Fig. 7.4). Most cases are located on the busier roads of the metropolitan area.

Types of Truck Accident

7.8 Cases involving trucks and pedestrians, pedal cyclists and motorcyclists have been considered earlier in this thesis. For completeness, these cases are also included in this Chapter, the emphasis here being on the role played by the truck in each accident.

Collisions with Pedestrians

7.9 These seven accidents have been discussed in Chapter 4 of this thesis. With the exception of one case, each of these pedestrians did not look in the direction from which the truck was coming. The exception was a man who deliberately ran onto the road into the path of a truck. The speeds of these trucks were all within the 35 m.p.h. speed limit, and all but one were proceeding straight ahead at the time of the accident.

Collisions with Pedal Cyclists

7 10 The one accident that involved a tricycle is included in this group of four accidents. The truck, a semi-trailer, was leaving a private parking lot and turning left onto the roadway. A small boy riding a 'Pilgrim Hi-speed' tricycle along the footpath rode into the rear wheels of the trailer. Apparently this small boy forgot that semi-trailers have

three sets of wheels. Fortunately he was not badly hurt.

7.11 One of the three pedalcycle accidents happened when a small girl made a 'U' turn in front of a heavy utility. The driver of the utility braked hard and his vehicle had very nearly stopped when it struck the cyclist. This is a typical pedal cyclist accident, in which the cyclist changes direction without giving sufficient warning, or any warning at all, to other traffic.

7.12 Another case resulted from a truck driver turning right, across the path of an approaching cyclist. This driver was annoyed with the cyclist because, as he said, 'If he had slowed down he would not have hit me'.

7.13 The final case was a more complex one as far as an understanding of right-of-way is concerned. It involved a cyclist riding along a cycle track on the median strip of a dual highway and a truck, travelling in the same direction, which turned right on a crossover road across the median. The cyclist rode into the side of the truck. It is not unreasonable to expect the cyclist to yield to the truck in this instance, but confusion can arise when comparing this case with those such as a truck turning left and forcing a cyclist into the kerb. If the cycle track had been on the footpath on the left side of the road there would be no doubt that the cyclist had right of way. The issue is not so clear in the present case.

Collisions with Motorcyclists

7.14 Of the four collisions between motor cyclists and trucks, two occurred at the same intersection. This intersection, known as Gepps Cross and referred to elsewhere in this thesis, is a five-way junction controlled by traffic lights. In both of these collisions the motor cyclist struck the side of the truck. The trays of many trucks are close to the level of the head of a motorcyclist as he is seated on his machine; consequently it is not surprising that in one of these cases the rider hit his head on the edge of the tray of the truck. He was wearing a crash helmet which may have reduced the severity of the injuries to his head.

7.15 It would be desirable, with regard to such collisions, for trucks to be fitted with barriers below the tray at the rear and the sides. Such barriers, if designed to take the main force of any collision with another vehicle, would reduce the injury potential of this type of accident. A careful study comparing the cost of these modifications to an estimate of the value of possible benefits should be the first step in any further consideration of this suggestion. (See also paragraph 7.29 and Fig. 7.10.)

Occupant falling from the tray of a Truck

7.16 In this case a 28 year old male fell from the tray of a moving tow truck. The truck was towing a car which had been swaying from side to side. The assistant was riding on the back of the truck to check on the

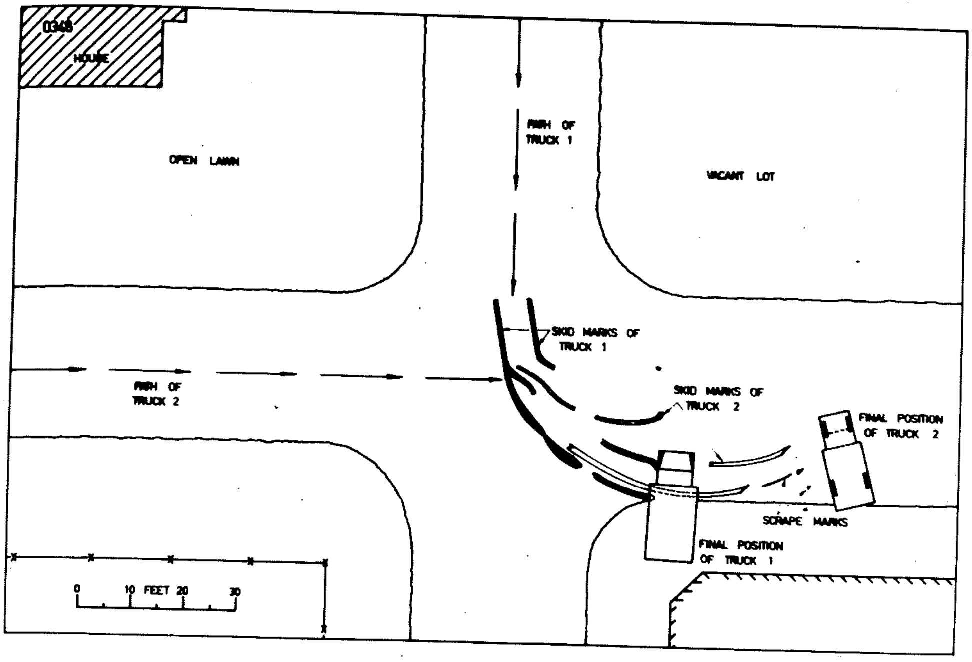


Fig 7.5
Case 0348.

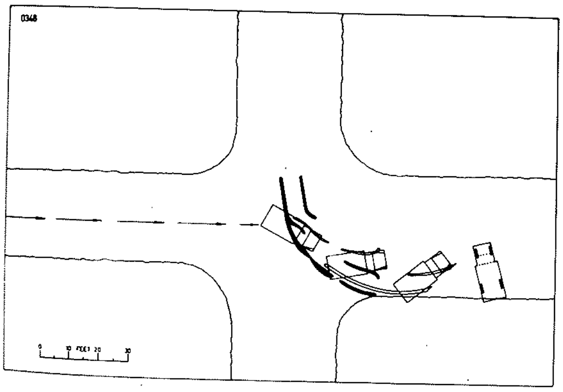


Fig. 7.6
Post-impact path of Truck 2
(see Fig. 7.5)

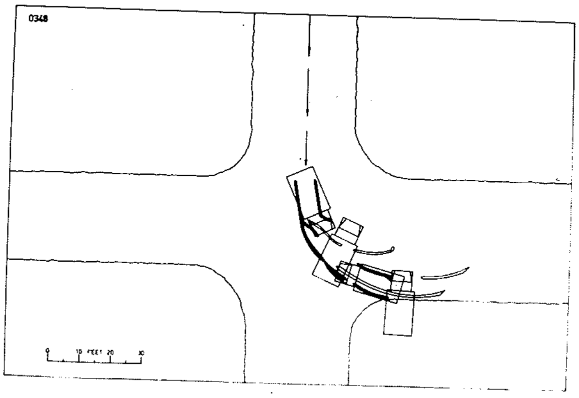


Fig. 7.7
Post-impact path of Truck 1
(see Fig. 7.5)

movements of the towed vehicle. He lost his hold and fell to the roadway, sustaining concussion from the impact with the road surface. Accidents of this nature are very similar to some types of industrial accidents and similar prevention programmes may be beneficial.

Collision between two Trucks

7.17 This accident (case 0348) involved a heavy truck and a heavy utility (Fig. 7.5). The utility was struck on the front of its left side by the front of the truck. The utility was travelling considerably faster than the truck at impact and spun 60° anti-clockwise, before rolling one half turn to its right onto its roof (Figs. 7.6; 7.9). The driver was ejected. The two passengers remained inside the cabin. The heavy truck was spun 180° anti-clockwise by the impact, coming to rest facing in the direction from which it had come (Figs. 7.7; 7.8). The driver of this vehicle was ejected when the truck stopped suddenly after sliding sideways. Both of the ejections were through doors which, although not hit in the initial collision, had come open. The precautions which are necessary to prevent the doors of passenger cars opening under collision conditions are obviously also applicable to heavier vehicles.

Multiple Vehicle Collisions

7.18 These eight accidents involved a total of 25 vehicles including 11 trucks. Table 7.2 shows the type of vehicle initiating the collision and also the type of the initial collision.

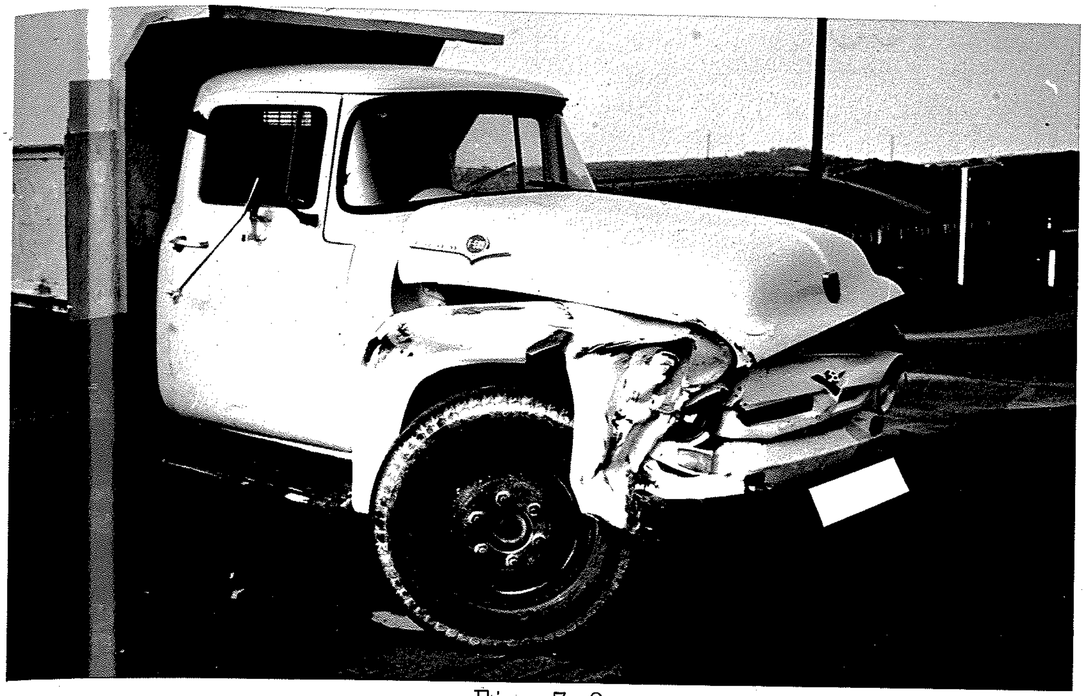


Fig. 7.8
Truck 1 (Fig. 7.5). The driver was ejected through the door shown.

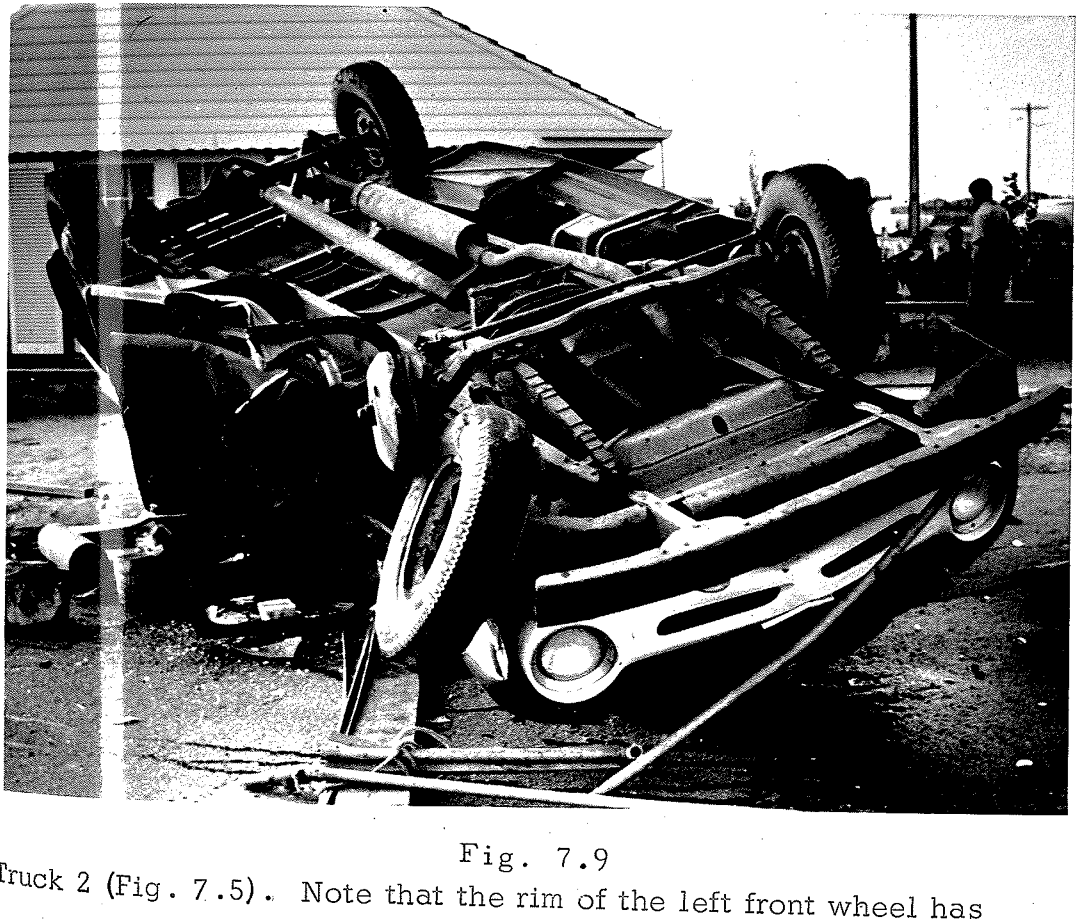


Fig. 7.9
Truck 2 (Fig. 7.5). Note that the rim of the left front wheel has separated from the centre of the wheel.

TABLE 7.2

Multiple Vehicle Collisions

Accident No.	First Two Vehicles	Type of Initial Collision	Other Units involved
0186	car light truck	rear end	bus car
0417	light truck car	rear end	light truck
0395	horse and cart heavy truck	rear end	car
0208	heavy truck car	truck reversing across roadway	car
0195	car car	'U' turn collision with overtaking vehicle	truck car car
0233	heavy truck car	intersection	car
0240	car car	intersection	heavy truck
0372	heavy truck railcar	level crossing	car

7.19 What features, if any, caused these initial collisions to result in subsequent collisions with other vehicles? Accident 0186 and 0417 are the familiar type of chain collisions. In accident 0395 it was, of course, the truck that ran into the back of the horse and cart. The truck then skidded to the left and hit a parked car.

7.20 Accident 0208 is similar to a chain collision in that the third vehicle involved ran into the back of the car that had hit the reversing truck. This type of initial collision can only be attributed to carelessness on the part of the truck driver. While recognizing that many drivers do not have assistants to guide them when reversing, it should be possible to find a person to assist in this task. To attempt to reverse unaided onto a busy road cannot be safe driving.

7.21 Accident 0195 was the most involved collision in our series. A car driver attempted a'U' turn in the middle of a busy 4-lane road. A second car, travelling at an excessive speed in the circumstances, and certainly faster than the legal speed limit, was sideswiped by the turning car. This second car then cannoned off a car approaching from the opposite direction and finally collided head on with a heavy truck. The third car veered to the left after the collision and hit a parked car.

7.22 The two intersection type accidents 0233 and 0240 became multiple collisions when one of the vehicles was deflected into a vehicle approaching the intersection. In case 0233 a heavy truck failed to stop at a stop sign.

7.23 The level crossing accident was at a crossing with no obstruction to vision, although it was dusk at the time. There was a stop sign alongside the roadway on either side of the crossing, but no warning device. The truck driver had stopped at the crossing to buy a newspaper from a paper boy. The driver heard the sound of a horn and thought that it was an impatient driver behind him. He looked both ways along the railway line and, not seeing a train, moved off. He was part way across the line when he realized that a railcar was approaching on his left. He tried to accelerate but was struck by the railcar. The truck was spun round and hit a car which was stationary on the roadway some distance back from the crossing. It is probable that the truck driver mistook the sound of the horn on the railcar for that of a vehicle behind him. It would also have been likely, as it was dusk, for the driver to have mistaken the headlight of the railcar for a light from some other source. As with the other level crossing accident in our series, it may be that too much is being expected of motorists by the railway authorities in the prevention of this type of accident.

Intersections and Truck Accidents

7.24 Almost 80 per cent of all collisions between a car and a truck happened at an intersection. Before continuing with the discussion of this type of collision we list the locations of the various types of truck accidents in relation to intersections (Table 7.3). An 'intersection type' accident is one in which the intersection played a significant role in the causation of the accident.

TABLE 7.3

Type of Truck Accident	At an intersection	Within 20 yds. of an intersection		Not at an intersection	Intersection Type Accident
		Before	After		
Single vehicle	-	-	-	1	-
Collision with pedestrian	1	1	2	3	1
Collision with pedal cycle	3	-	-	1	2
Collision with motor cycle	3	1	-	-	4
Collision with truck	1	-	-	-	1
Collision with car	27	-	1	6	27
Multiple collision	3	1	-	4	2
Total	38	3	3	15	37
Per cent of total	65%	5%	5%	25%	63%

Collisions with Cars.

7.25 Most of these accidents happened at intersections. In fact 27 of the 34 cases were actually at intersections, and in all but one of these cases the intersection had a significant bearing on the accident. There was one additional case which was located within 20 yards downstream from an intersection. In this case the intersection also played a significant part in the causation of the accident. The remaining six accidents were not near intersections.

7.26 The overall figures for this survey suggest that an intersection played a signficant role in approximately 60 per cent of the accidents we attended. In this particular group of accidents it can be seen that the intersection has even greater significance, as approximately 80 per cent of these car-truck collisions are of the intersection type.

7.27 These cases are now considered in two groups: those in which a truck did not yield to a car at an intersection (8 cases) and those in which a car failed to yield to a truck (11 cases). It should be obvious that the suspicion here was that there might be a tendency for the driver of the heavy vehicle to entertain the idea that 'might is right', and so be reluctant to yield to a smaller vehicle.

7.28 Of the former group six trucks were travelling at such a speed that the drivers were unable to avoid the collision. In these cases the present rule of the road, viz. yield to the vehicle on the right, could not be expected to be effective. At many suburban intersections the maximum safe speed at which one can enter an intersection can be less than 10 m.p.h. It is true that speeding is a cause of accidents, but this is a very relative term, and it is quite possible to drive at an excessive speed and yet never exceed 35 m.p.h. There are some comments that we can make on two of these six accidents. In one case a car driver, having stopped at a stop sign, moved off across the path of a heavy vehicle. While the rule of the road gives this driver the right to proceed once he has stopped at the stop sign, this does not automatically mean that it is safe to do so. In the other case the accident was one of four that we attended at the one intersection, that of Rundle Road and Gooden Avenue. This intersection gives the impression of having excellent visibility, but unfortunately during weekdays parked cars on the included angle of the intersection seriously restrict visibility. The effect of this is to reduce the safe speed across this intersection from 33 m.p.h. to 20 m.p.h. (see safe speed calculations for cases 0318 and 0359, Chapter 15). It is probable that many of the accidents occurring at this intersection could be avoided by banning parking on the north-western boundary. (This intersection has since been modified by the installation of traffic islands and Stop signs on Gooden Avenue.)

Divided Highway.

7.29 Of the remaining two of these eight cases one resulted from both drivers allowing an insufficient margin of safety at the 'T' intersection of a divided highway and a two-way road (Port Road and Grand Junction Road). Two trucks travelling along this road planned to cross the highway and then turn right and travel along it. The first truck stopped on the crossover of the median strip to allow traffic to pass along the highway from its left. The second truck, which was following closely behind, was then forced to stop, straddling the fast lane on the other side of the divided highway. A car driver, seeing the trucks cross in front of him, decided that they would clear his path without him having to diminish speed. When the second truck suddenly stopped in front of

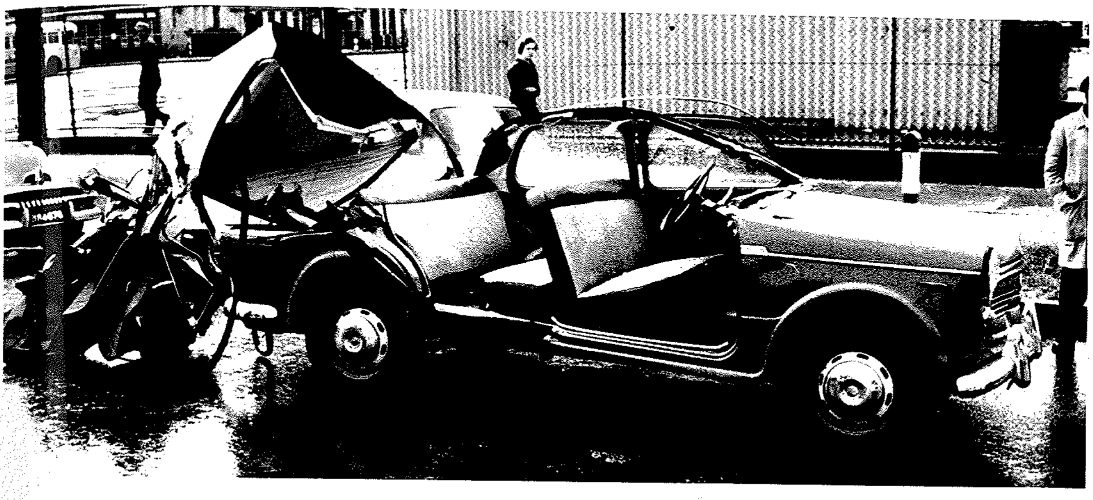


Fig. 7.10
This Fiat 1100 Sedan had its roof torn off when it ran under the overhanging tray of a truck.

Fig. 7.11
This 1954 Standard '8' ran into the overhanging load of a semitrailer which was reversing on to the roadway at night. The driver was concussed.

him he had to brake suddenly to attempt to avoid a collision. He was unsuccessful (Fig. 7.10). The point of impact on the car was on the right side of the roof, which hit the overhanging tray of the truck (see also paragraph 7.15).

7.30 The remaining case was at a similar location on a divided highway where two roads enter the highway on either side (Anzac Highway and Cross Road). A car was crossing from one of these roads over the highway to the other road. The driver of a truck travelling along the highway saw the car approaching from his right but continued on, expecting it to stop, and was unable to avoid hitting the car when it continued across in front of him. At this particular location there is room for doubt as to whether Cross Road does in fact continue straight across the highway. If it does, the car driver has right of way. If there is considered to be a discontinuity here, the truck driver has right of way. Our present road rules do not seem to be adequate under these circumstances.

7.31 Of the other group of accidents, namely cars not yielding to trucks at intersections, there are 11 cases of which six are relevant to our present subject. Each of these six cases involved either one or both of these vehicles travelling too fast for the conditions at the particular intersection, and remarks on safe speeds in the above section apply equally to these cases.

Stop Signs

7.32 Of the remaining five accidents in this category three involved a vehicle driving past a stop sign without stopping. In two of these cases a car drove past a stop sign and collided with a truck which was approaching on its right. The third case involved a large van which drove through a stop sign and struck a car travelling along the busier road on its left. If the truck had stopped at the stop sign it would then have been free to proceed, with right of way over traffic on its left. Traffic on its left, however, is still obliged to yield to the truck even if it does not stop at the stop sign. This accident is also listed in the group of multiple vehicle collisions.

7.33 These drivers, who did not stop, either had no regard for their own safety or they did not see the stop sign. There is little action that can be taken which is likely to produce very much change in the former attitude, but the latter response may be improved by ensuring that stop signs are readily visible under all conditions. This could mean duplicating the sign on the right hand side of the roadway and illuminating the face of the sign at night, as is the practice with some road signs in Britain.

Channelized intersections.

7.34 Two of these 11 accidents, and one other, happened at channelized intersections. These are listed as a separate category because the placement of these islands did seem to have some bearing on the causation of these accidents.

7.35 Two cases both happened at an intersection where two roads join a divided highway (Port Road and George Street). Islands had been located to lead traffic off the divided highway into one of the side roads, Their placement was such that traffic entering the highway from the other side road had very little warning that a car travelling along the highway was about to turn across their path. Both these accidents occurred in the interim period between the installation of these islands and the installation of traffic lights. A road layout designed for a light-controlled intersection may prove to be unsatisfactory without such control. When there must be an interim period, as in this case, either warning signs or possibly stop signs may be necessary to minimize the risk of accidents of this type.

7.36 The other location apparently has not been designed for use with any additional form of traffic control (Adam and Manton Streets). Most of the traffic from Manton Street turns left into Adam Street. There are some vehicles which continue straight ahead, on the far side of a small traffic island, and pass across Adam Street. This means that a driver approaching the intersection along Adam Street must decide whether a vehicle on his right is turning left or coming across in front of him. Possibly a stop sign for such vehicles from Manton Street would give drivers in Adam Street a little more time for evasive action, although the safe speed here is about 37 m.p.h. with the existing arrangement.

7.37 The remaining accident in this group of five accidents resulted from a car driver mistaking a green 'turn left' arrow for the green signal for straight ahead. When the green arrow came on, and a car alongside on the left moved off to turn the corner, the driver of the case car also moved off but continued across the intersection and was struck from the left by a light truck which was crossing the intersection with the green light.

7.38 From these two main groups of accidents it can be seen that cars and trucks yield to each other with equal frequency and there does not seem to be, from these figures at least, any basis for an assertion that truck drivers are less likely to yield right of way than car drivers.

Truck turning right.

7.39 There is one further group of accidents that can be considered and this is the case in which a truck turns right across the path of a car. There were five such cases, two of which occurred when a truck travelling in a slow lane of a dual highway started to turn right from the slow lane and collided with a car travelling in the same direction but along the fast lane of the highway. Two other cases resulted from a truck turning right despite the fact that there was a car approaching from the opposite direction. One of these cases (0226) was not at an intersection. The

Fig. 7.12
The truck was turning across the path of the car. (It had been backed off the car when this photograph was taken.)

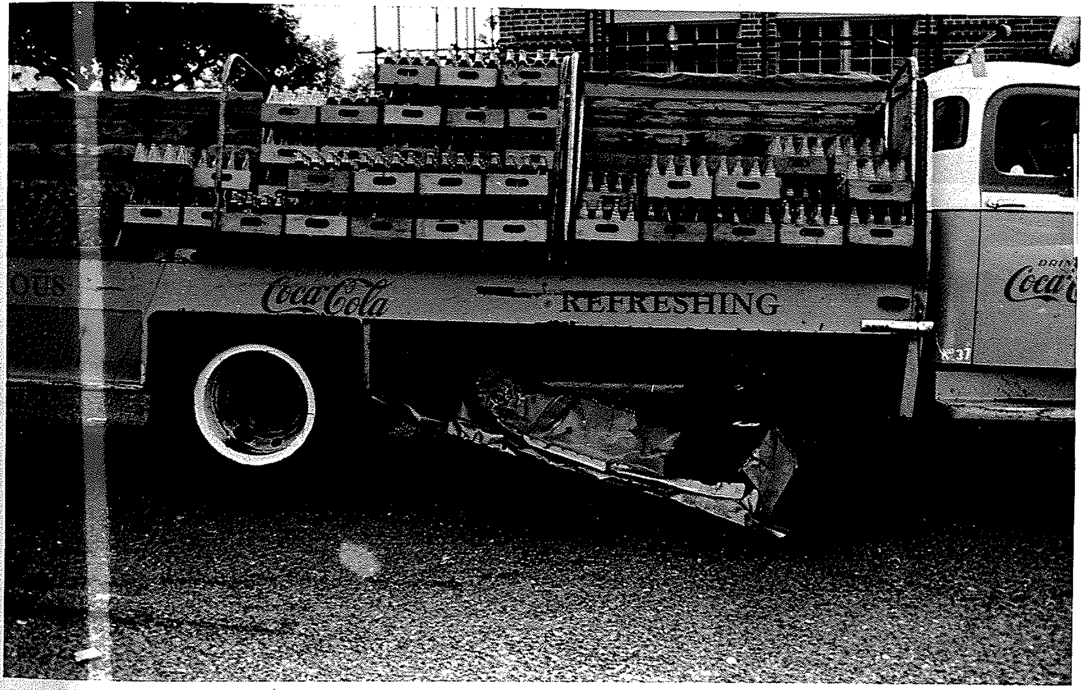


Fig. 7.13
The fuel tank on this truck was ruptured when struck by a car.

truck was turning to enter a private driveway (Fig. 7.12). The remaining case involved a heavy vehicle of considerable length turning right from the leg of a 'T' junction into a busier road. This truck was struck by a car which approached from his right. The average speed of cars along this particular stretch of road is high, around 40 to 45 m.p.h. It is possible that the truck driver did not make sufficient allowance for the high traffic speed at this location.

7.40 22 of the 27 intersection-type truck vs. car accidents have now been discussed. The remaining five accidents include one which has been described under the heading 'channelized intersections'. Two other cases involved a truck turning right. One of these accidents was essentially a rear end collision, for the truck was stationary, waiting to turn to the right, when it was struck from the rear by a car. This accident happened at night. The other accident involved a truck turning right and a car approaching from his right. The driver of the truck appeared to be most belligerent and possibly under the influence of alcohol. (We did not get close enough to smell his breath!) Another of these five accidents involved a car turning right across the path of a truck, virtually the reverse case of the previous accident.

7.41 The remaining accident in this group involved a truck entering a 'T' junction from the blind leg. The driver of the truck saw a small car approaching from his left at high speed and pulled over to the right hand side of the road to allow the car to pass. By this time, however, the driver of the small car had lost control of his vehicle and in the ensuing collision the car was in fact travelling sideways when it sideswiped the side of the truck with only minimal damage to both vehicles. There was a similar collision, although not of an intersection type, in which a car rolled on a gradual bend and, while rolling, sideswiped a truck travelling in the opposite direction.

Accidents not at an Intersection.

7.42 One of the accidents involving a car and a truck that did not happen at an intersection has already been mentioned. This was case 0226 in which the truck turned right across the path of a car in an attempt to enter a private property.

7.43 Of the remaining five cases that did not happen at an intersection one is similar to one of the multiple collisions. This involved a heavy vehicle backing out of a marshalling yard on to a busy road. This particular case happened at night. The vehicle was a semi-trailer with a long over-hanging load on the trailer. Insufficient care was exercised when reversing on to the road, and a small sedan ran into the overhanging load, which was projecting across the roadway (Fig. 7.11).

Collisions with Parked Trucks

7.44 There are two cases in this group of six accidents which involved a car running into the back of a stationary truck at night. In one of these cases a light truck-type utility was parked close to the side of the road and yet was struck by a small saloon car. Street lighting at this point was virtually non-existent and the driver of the car, although showing no obvious signs of having been drinking was found to have a blood alcohol level of over 0.08 per cent. As is mentioned in the discussion of single vehicle car accidents (Chapter 8), the influence of alcohol appears to be very marked in cases which involve a collision with a parked vehicle.

7.45 The other case of this nature involved a car which drove into the back of a bus while it was stationary at a stop but still on the traffic lane. It would appear to be important for the drivers of these buses to ensure that their vehicles encroach no further than is absolutely necessary on the carriageway, particularly at night. It would also be safer for such buses to be equipped with very distinctive rear lights.

7.46 Of the two remaining cases, one involved a car driver attempting a 'U' turn at a place where visibility is restricted by a curve in the road. The driver of the car claims that he looked behind him and saw the road was clear and then proceeded to do a 'U' turn. He was struck by a light truck which suddenly appeared round the bend. The obvious comment here is that the car driver should not have attempted a 'U'-turn in this particular location, even though there is no sign forbidding him to do so.

7.47 The remaining accident was a sideswipe between a car and a truck travelling in the opposite direction. In actual fact the two vehicles themselves did not make contact but the driver had his arm hanging over the windowsill of the car and received a very severely injured right arm. It would seem that this obvious exposure to injury should be sufficient to encourage people to keep their arms inside the car.

Crashworthiness of Trucks.

7.48 Injuries to truck occupants are commonly less severe than those to car occupants. The 'crashworthiness' of trucks has therefore not been subjected to the same degree of critical appraisal as has been the case with the passenger car. Furthermore, such work that has been done has concentrated more on the safety of persons whose vehicles collide with a truck. The notes above on crash barriers beneath the tray are in this category.

7.49 One feature, related to the safety of both truck occupants and the occupants of a colliding vehicle, is shown in Figure 7.13. This truck collided with a Holden Station Sedan at an intersection. The car hit just behind the cab on the right hand side, tearing away a side panel and rupturing the fuel tank. In this case the spilt fuel did not ignite, but the hazard is obvious. Relocation of the fuel tank may be practicable in some cases. When the tank must be mounted in a vulnerable location such as this, it would be most desirable for it to be fitted with an inner, leak resistant, fuel cell to minimise spillage in a case such as that illustrated in Figure 7.13.

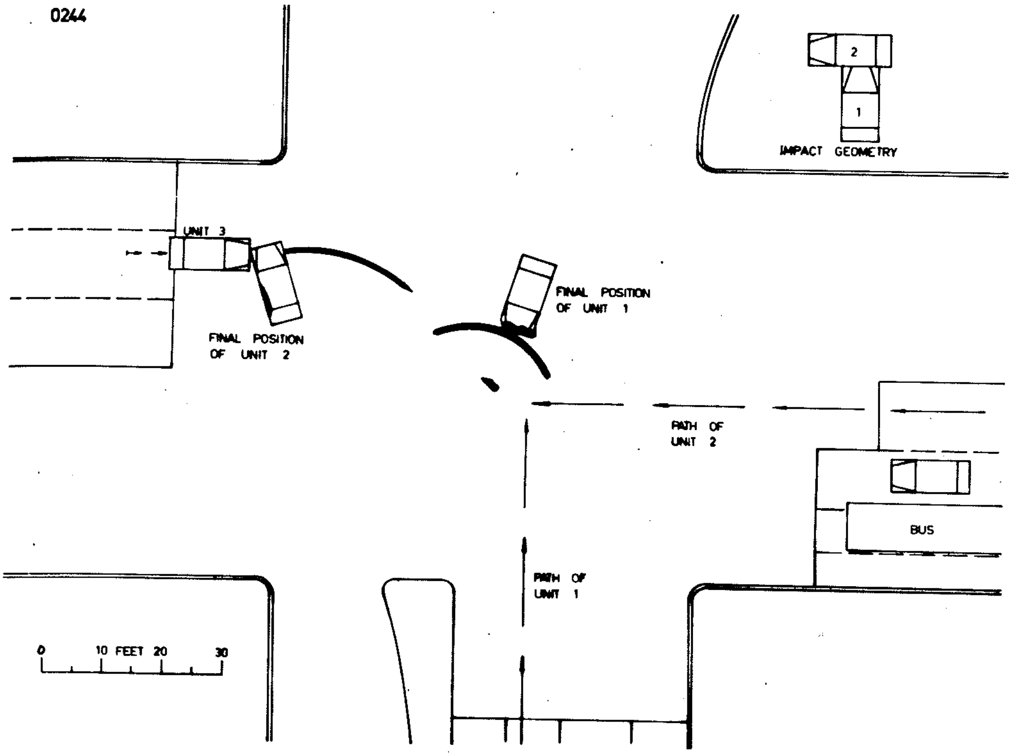


Fig. 8.1
Case 0244.

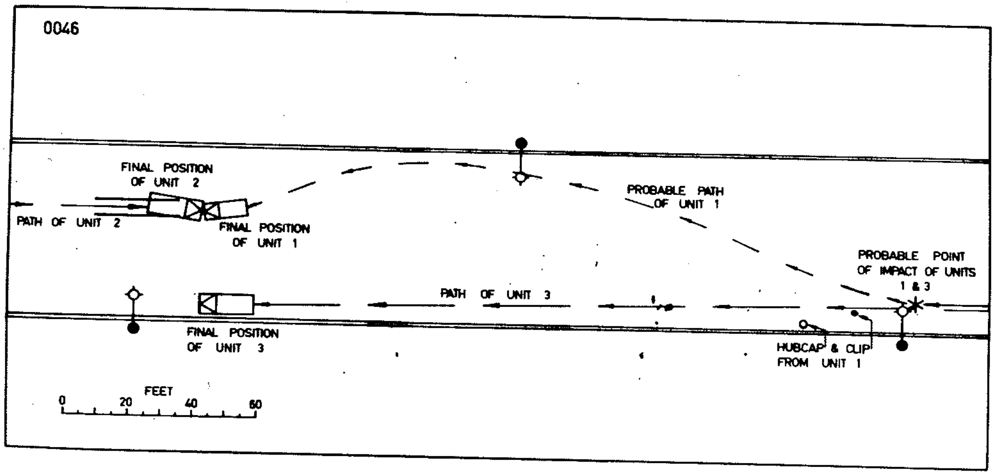


Fig. 8.2
Case 0046.

CAR ACCIDENTS.

CHAPTER 8

8.1 Cars form the greatest proportion of the motor vehicle population: 80 per cent (Census of Motor Vehicles, 1962). Consequently collisions between two cars are the commonest type of car accident. In most of these collisions between two cars there is only one impact, both coming to rest without striking anything else. In some cases a car is involved in a subsequent collision, either with another motor vehicle or with a fixed object of some description.

8.2 The magnitude of these collisions varies greatly, making exact classification difficult e.g. accident 0244 (Fig. 8.1).

> 0244 The front of a Peugeot (Fig. 8.3) struck the left side of a Ford Zephyr (Fig. 8.4) at a traffic light controlled intersection. The Zephyr was spun anti-clockwise through 270° and came to rest against the front of a Simca which had just moved off with the green light. The first collision resulted in injury to the driver of the Peugeot and to a rear seat passenger of the Zephyr. The collision with the Simca caused almost no damage to the cars, and no injury to the occupants.

8.3 Compare accident 0244 with the next example, accident 0046 (Fig 8.2).

> 0046 A Volkswagen saloon, while overtaking a Humber Super Snipe saloon, lightly struck the right rear corner of the Humber with the left front wheel. The Volkswagen then veered across to the opposite side of the road where it struck a Ford Mainline utility head-on (Fig. 8.5). The damage to the Volkswagen was more severe than the damage to the Ford (Fig. 8.6). The driver of

Fig. 8.3
1958 Peugeot 403, after colliding with the Ford Zephyr shown in Figure 8.4

Fig. 8.4
1959 Ford Zephyr, struck by the Peugeot shown in Figure 8.3. Note that the rear door has come open.

of the Volkswagen suffered concussion, a fracture dislocation of the neck leading to complete paralysis, broken ribs and a fractured right thigh. On impact the steering column was forced back into the passenger compartment (Fig. 10.1). The driver struck the wheel and column with his chest and the area above the windscreen with his head. The passenger compartment of the Ford was relatively undamaged (Fig. 10.6). The driver suffered a fracture of the right knee cap when his knee hit a knob on the instrument panel. The left front seat passenger struck the windscreen and the top of the instrument panel with her face, fracturing her front teeth. (Fig. 10.11).

8.4 The initial collision between the cars is more important in the first case, and of only minor importance in the second case where the second collision is more important. Where the effects of the car-to-car collision on personal injury have been specifically studied, such cases as these have been included in the same category as accidents in which only two vehicles were involved.

8.5 The following tabulation summarizes the types of car accidents covered in this survey. These categories are not necessarily exclusive and so the totals should be regarded as only an indication of the frequency of these various types of car accidents.

Type of Car Accident	No. of cases	
Collision between two cars, no subsequent collision		108
Initial collision between two cars, subsequent collision with -		
one or more motor vehicles	15	
utility pole	8	

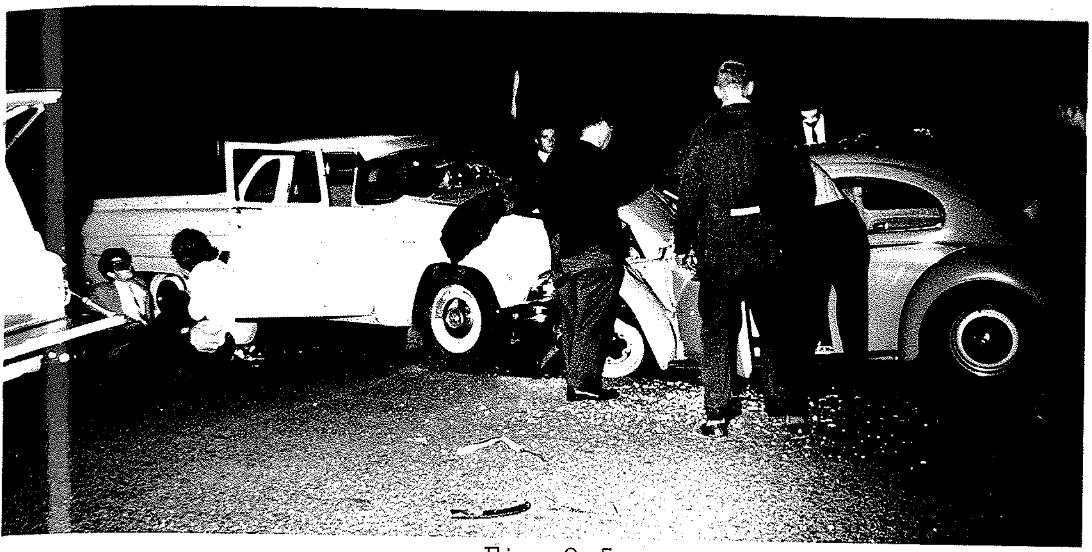


Fig. 8.5

Case 0046: collision between a 1955 Ford Mainline Utility and a 1962 Volkswagen. The driver and passenger of the utility are on the road beside their vehicle. The driver of the Volkswagen is still inside his car.

Fig. 8.6

Case 0046: arrows indicate the damage due to the initial collision between the Volkswagen and a Humber.

Initial collision between two cars subsequent collision with - (Contd.)		
tree	1	
building	4	
kerb	3	
ditch	1	32
Single car accidents -		
collision with utility pole	8	
rollover only	8	
rollover followed by a collision	4	
collision with tree	6	
assorted fixed objects	3	
unloosed trailer	2	31
Collisions with parked vehicles		13

Time Distribution

8.6 The distribution in time of 210 accidents involving cars is shown in Fig. 8.7 and 8.8. These accidents include all car-to-car collisions, all single car accidents, and most of the collisions between cars and trucks. The distribution of accidents by time of day shows a peak around 6 p.m. which gradually falls off to 11 p.m. The distribution of accidents for each day of the week is interesting because, notwithstanding the fact that Saturday was only sampled half the number of times as Monday through Friday, there are almost as many accidents recorded. The height of the Saturday column should therefore be doubled, to approximate the proper relation of Saturday to the rest of the week. These accidents were almost evenly split between night (100) and day (110). In three quarters (155) of the 210 accidents an intersection played a significant part in the production of the accident. Only 27 occurred on wet

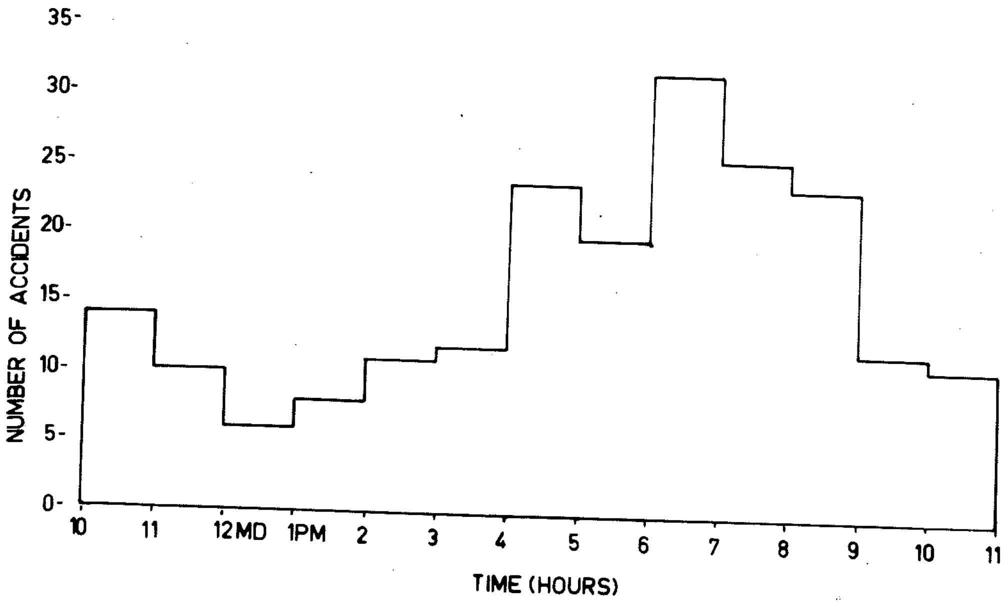


Fig. 8.7
Time distribution of accidents involving cars.

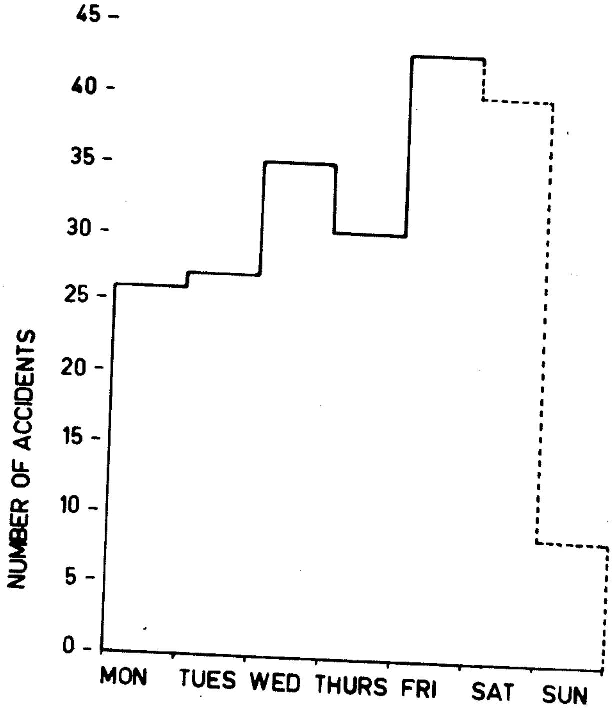


Fig. 8.8
Accidents involving cars for each day of the week.

roads.

Age, Sex and Seated Position.

8.7 Fig. 8.9 shows the age distribution of all drivers, front seat passengers and rear seat passengers. The most common age group of drivers involved is 20 to 24 years. Half of the drivers are less than 35 years old. There is a secondary peak at 35 to 39 years, after which the numbers gradually decrease with increasing age.

8.8 The numbers of drivers who had consumed alcohol are shown in Table 8.1., together with the percentages that these numbers form of total drivers in these age groups. About one tenth of all drivers had obviously consumed alcohol, the greatest proportion being in the age range 40 to 49 years. This distribution of persons showing evidence of alcohol is rather similar to that of pedestrians.

TABLE 8.1.

Drivers who had consumed Alcohol Age (Years)	No. of drivers with alcohol	Per cent of all drivers in each age group
15-19	6	8.7
20-24	13	12.0
25-29	6	11.8
30-34	5	8.6
35-39	11	14.9
40-44	9	20.9
45-49	8	20.0
50-54	2	6.7
55-59	2	10.0
60-64	2	14.3
65-69	1	6.6

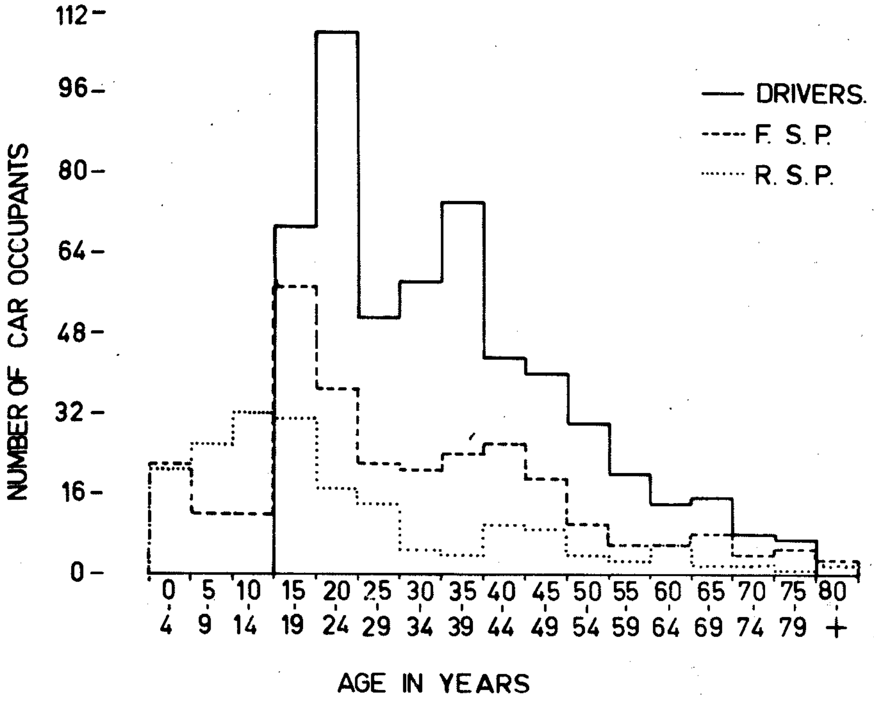


Fig. 8.9
Ages of car occupants.

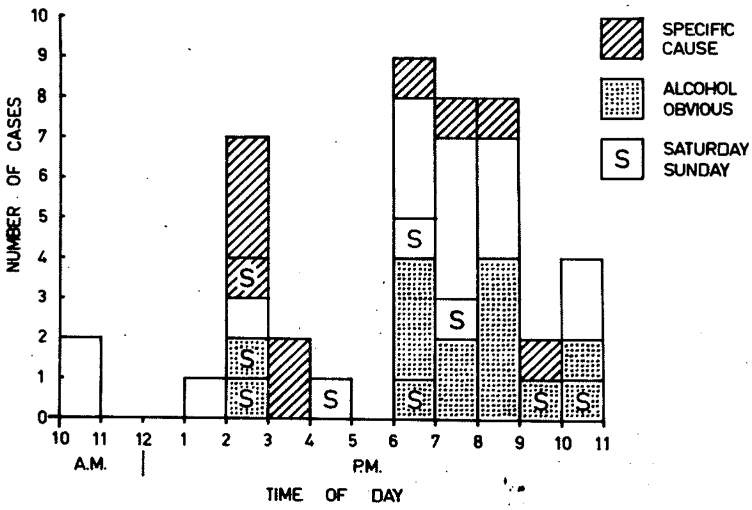


Fig. 8.10
Single car accidents by time of day.

8.9 The largest number of front seat passengers are in the 15 to 19 year age group. 63 per cent of rear seat passengers are less than 20 years old, with a peak at 10 to 14 years.

8.10 The sex and age distribution of the occupants in these seated positions is shown in Table A 8.1 in the Appendix for the 1,020 persons for whom this information was known. Only one sixth of these car drivers are women. The most frequently involved age group for men is 20 to 24 years; for women it is 35 to 39 years. Among front seat passengers women (57 per cent) slightly outnumber men. But after age 35 years there are many more women than men. Rear seat passengers are almost equally divided between male and female, and are mostly young children.

Driving Experience.

8.11 The driving experience of the 265 drivers from whom this information was obtained, is set out below:

Less than 6 months	9
7 to 12 months	7
13 months to 5 years	66
6 to 10 years	63
11 to 20 years	59
21 to 40 years	53
More than 40 years	7

The rate of accident occurrence decreases rapidly with increasing

Fig. 8.11
This trailer broke loose and crashed into a parked car.

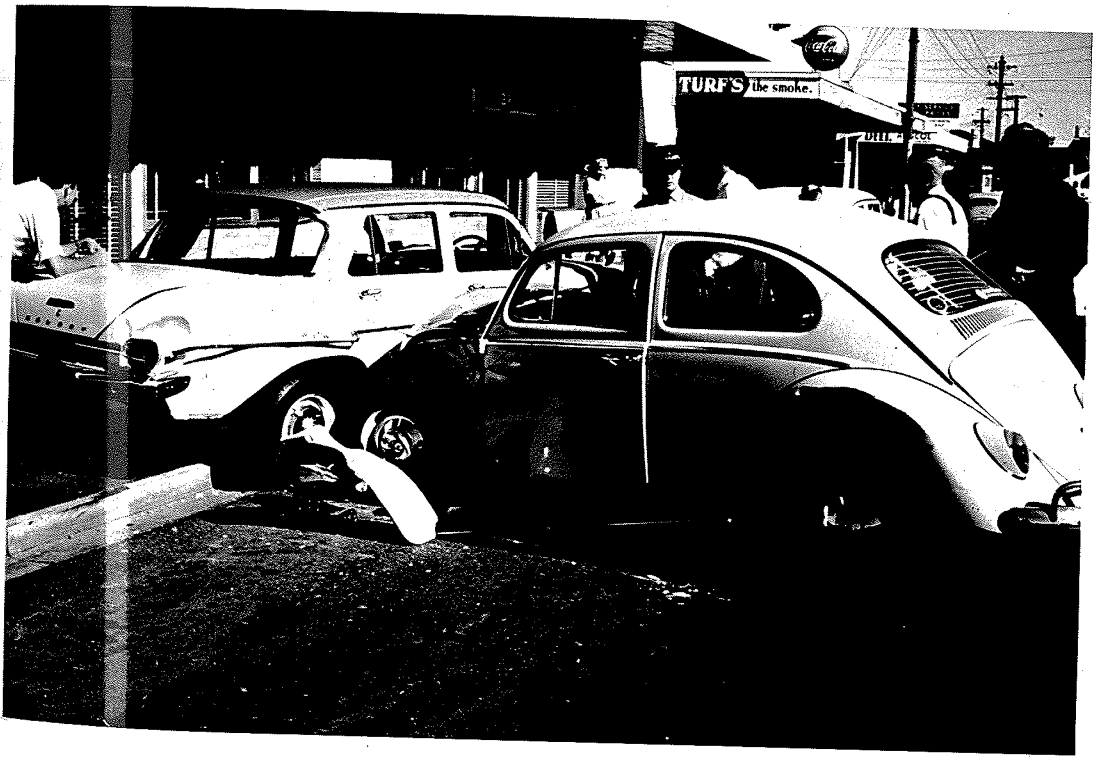


Fig. 8.12
A small child in this 1962 Volkswagen pushed the back of the driver's seat forwards. The driver lost control and the car sideswiped a parked car before hitting the Holden shown here. This Holden was pushed into yet another parked car.

experience after the first 10 years. 55% of the accidents happened to drivers who had been driving less than 11 years.

Single Vehicle Accidents.

8.12 Forty-four of the 408 accidents in this survey were essentially single car accidents. Included in this group are 13 cases of cars running into parked vehicles, and two cases of trailers coming loose and hitting cars. The various types of accidents in this group are listed in paragraph 8.5. Some of these accidents had obvious and specific causes. In two cases the driver collapsed at the wheel andeach of the cars swerved off the roadway and hit a tree. Two other cases appeared to have been deliberate attempts to crash a car; in each case the motive may have been to win the sympathy or attention of another party. One driver lost control of a Volkswagen 1200 when a small child pushed the back of the driver's seat forwards (Fig. 8.12). Another driver mistook first gear for reverse and, instead of backing out of an off-street parking area, bounced forwards over a low concrete kerb, crossed a roadway and crashed into the side of a parked car. Two drivers claimed that they were distracted, one by a hat falling to the floor, the other bya moth flying into his eye. They both drove into the rear of parked cars. Finally there were the two accidents mentioned earlier which were caused by trailers breaking loose from their towing vehicle and colliding with other cars.

8.13 The failure of the safety chains on the towing attachments of each of these trailers points to the need for specifications for both the strength of such chains and the method of attaching them to both the trailer and the vehicle. It may also be desirable to make it an offence to tow a trailer which is not fitted with chains which meet such a specification. The condition of such chain is important. Thus Fig. 8.13 shows the chain from a trailer (Fig. 8.11) in one of the accidents listed above. Notice that one link has been replaced with thin wire, and that the other links are almost worn through.

8.14 Apart from these specific causes the effect of alcohol is perhaps the most noteworthy feature of these single vehicle accidents (Fig. 8.10). Over one third - 16 in 44 - of these drivers had obviously consumed alcohol not long before their accident. The number of drivers actually affected by alcohol could have been higher than this. Towards the end of our survey we had the use of a simple device which indicates blood alcohol levels based on a breath sample. In one case the driver showed none of the customary effects of alcohol, no smell or obvious effects at all apart from rather slow movements. The breath test showed that this driver had consumed more than enough alcohol to cause a significant deterioration in driving ability. It is in accidents of this type, involving one driver only, that the role of alcohol as a causative factor would be expected to be most marked.

8.15 Fig. 8.10 shows the distribution of these accidents by time of day. Those cases in which alcohol was obvious are also shown. While it is tempting to point to the sudden rise in accidents after 6 p.m., the time at which the hotels close, it is important to note that the proportion of cases involving alcohol remains very nearly constant until 11 p.m. Those cases which occurred on a Saturday or a Sunday have been marked with an 'S'. These include the two cases in which the drivers had been drinking in the daytime.

8.16 The single car accident appears to be chiefly a night-time phenomenon. There were 27 cases at night and only 17 in the daytime. Seven of the 17 daytime accidents were rollovers, without a prior collision. There were five rollovers at night. Now it is reasonable to assume that whether one rolls a car over or not is unlikely to be closely related to lighting conditions. But the likelihood of collisions with poles, trees and parked cars may well be greater at night. These figures certainly suggest that this is so. There were nine such collisions in the daytime and 21 at night. These consisted of 13 collisions with parked vehicles, eight with utility poles, six with trees, one with a roundabout, one with a rock garden on a median strip, and one with a series of fixed objects.

8.17 All but one of the collisions with parked vehicles were at night. The driver of the striking car in the one daytime accident recalled having

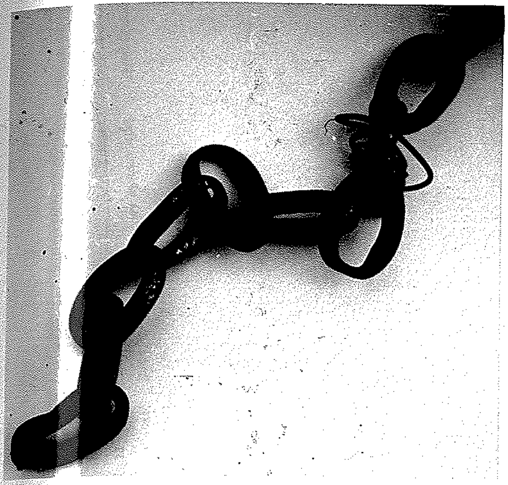


Fig. 8.13
Safety chain, from the trailer shown in Figure 8.11.

Fig. 8.14
Roundabout struck by the car shown in Figure 8.15. Arrow shows point and direction of impact.

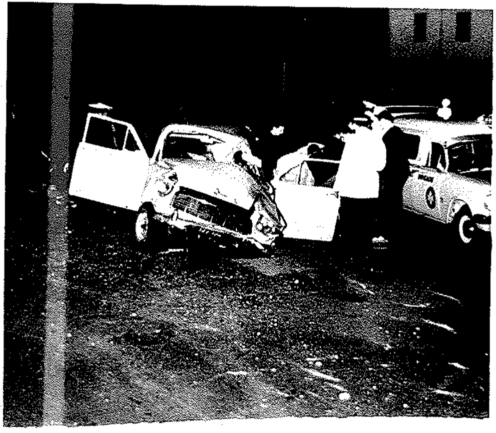


Fig. 8.15
1957 FE Holden after colliding with the roundabout shown in Figure 8.14.

glanced at his speedometer and then having looked up to see the parked car just before the impact. There was one night accident in which a faulty street light made it more difficult for the driver to see the parked car. In three other cases the street lighting was virtually nil. There was one case in which the street was well lit and the driver sober. Unfortunately the events leading up to this collision are not known because the driver was concussed and unable to remember. It may have been a similar case to the two detailed in paragraph 8.12 in which the drivers were distracted. Once again, the effect of alcohol appears to be very great. Five of these eight drivers had been drinking. One of them was hardly able to stand upright by himself.

8.18 The collision with a roundabout was a mysterious case. There was no indication of any attempt having been made to avoid a collision, such as skid marks due to braking, etc. The car struck the 18 inch high edge of the roundabout and rolled end over end. Once again the driver was concussed and unable to give any coherent explanation for the collision. A sloping rather than a vertical edge (Fig. 8.14) to the roundabout would certainly have reduced the damage to the vehicle and possibly the injuries to the driver. The existing vertical edging did not prevent the car from crashing onto the roadway on the far side of the roundabout, which is over 12 yards in diameter (Fig. 8.15).

Fig. 8.16
The driver of the Morris 850 braked and swerved to the left to avoid hitting a dog. The car mounted the footpath and collided with this tree.

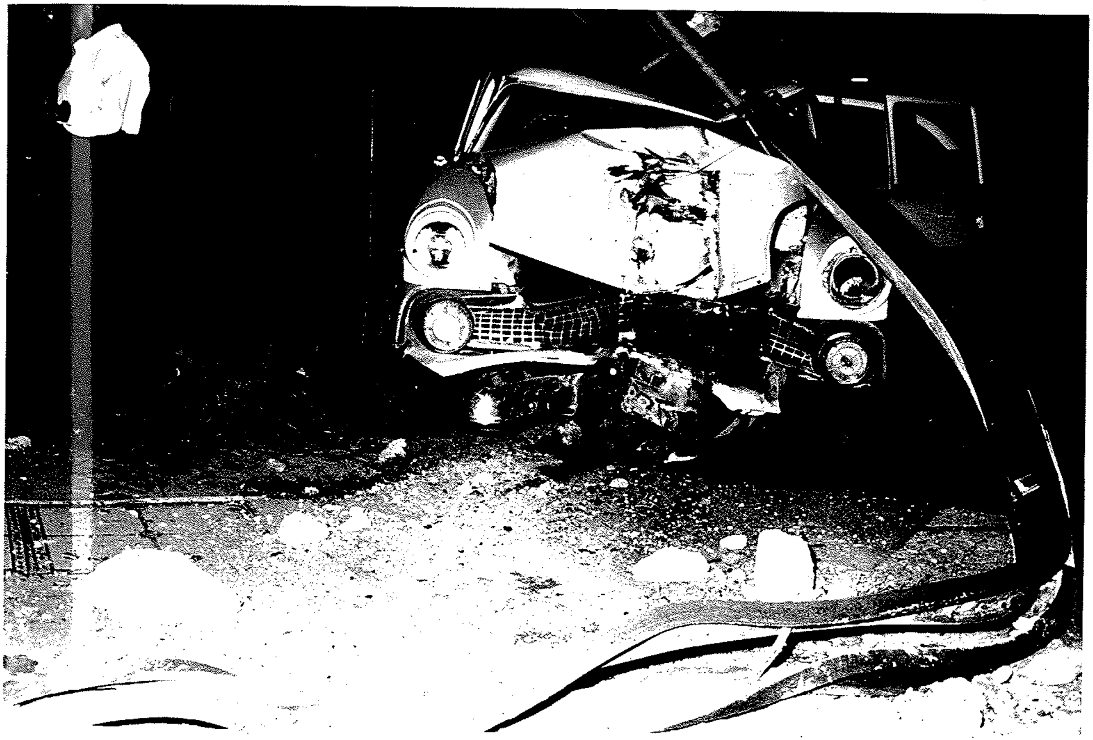


Fig. 8.17
1955 Ford Customline, after colliding with a steel and concrete utility pole. The base of the pole is in the bottom left corner. The car approached from the left.

8.19 The driver whose car ran into a rock garden on a centre plantation of a divided highway had braked hard well before the impact in a successful attempt to avoid a pedestrian.

8.20 The collisions with trees call for little comment. Obviously if a car runs off the road it is likely that it may hit either a tree (Fig. 8.16) or a utility pole. If we were to choose further to denude our streets of trees, and to place all our power lines underground, the risk of this type of collision would be reduced, at the expense of damage to fences, etc. and possibly to pedestrians. A collision with a pole can result in severe damage to the vehicle and serious injuries to the occupants (Fig. 8.17). Utility poles can be modified to minimize the damage to a car which hits one (Ref. 36). One accident in this series, 0430, was partly due to an irregularity in the road alignment resulting in a line of utility poles being in the path of approaching traffic (Fig. 8.18). More effective street lighting and/or clearly visible markings on the poles may reduce the risk of collisions such as this one.

0430 An M.G. Magnette saloon struck a utility pole with the front left corner (Fig. 8.19). Both occupants were affected by alcohol. The driver, a male aged 19 years, sustained concussion, lacerations to the bridge of his nose from the windscreen, an abrasion over his sternum from the steering wheel, and a deep laceration over his right knee and bruising of his left knee (instrument panel). The left front seat passenger a male aged 26 years, sustained concussion and a deep laceration involving his left eyebrow and left forehead

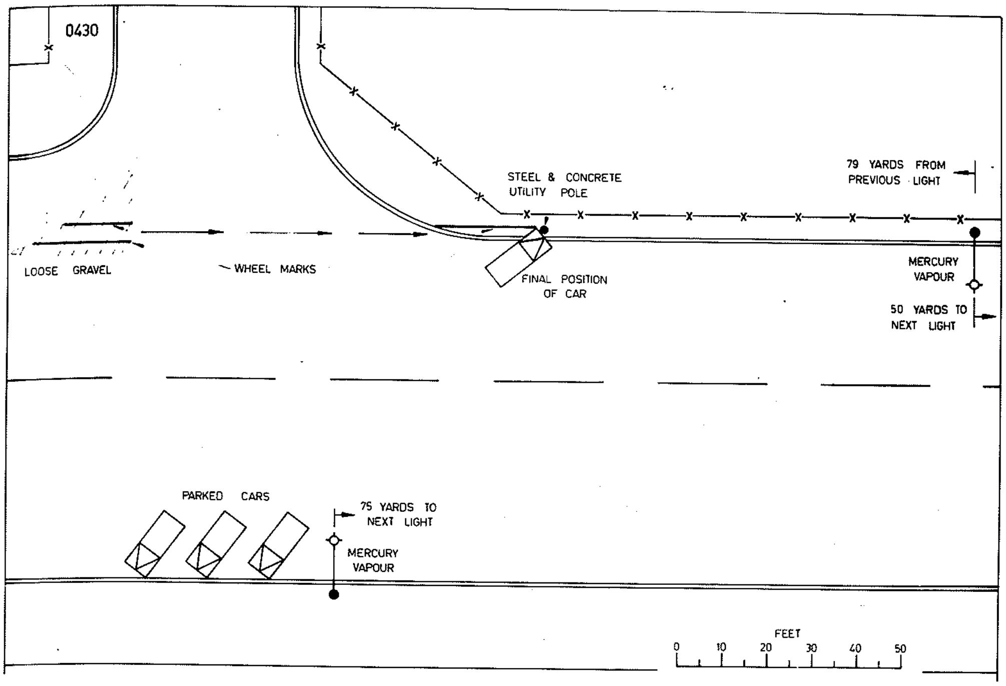


Fig. 8.18
Case 0430.

Fig. 8.19
1954 M.G. Magnette, after colliding with a utility pole (see Fig. 8.18).

(from the windscreen). He also had a laceration to the left corner of his mouth, a bruise across his chest and left shoulder, and abrasions to both knees (instrument panel).

Single Car Rollovers.

8.21 Twelve cars rolled over without having been involved in an earlier collision. There are several factors which are worthy of special mention in these twelve accidents.

8.22 Speeds were much higher than the average speeds for all cars in this survey. The average travelling speed for this group was 35 to 40 m.p.h. The average speed on rollover was slightly less, about 35 m.p.h. (the corresponding figures for all cars in the survey are 27 m.p.h. and 21 m.p.h.).

8.23 Nine of these 12 drivers were under 25 years of age. The other three drivers were aged 33, 48 and 79 years. The younger drivers had an average of three years' driving experience, varying from as little as four months up to nine years.

8.24 The effect of age and inexperience is very marked in this type of accident. While recognizing that the number of cases here are very few, the young (under 25) driver is involved in three quarters of these accidents. Compare this with the age grouping of all car drivers who were involved in accidents covered by this survey, in which one third were under 25. This result is not unexpected; youth and inexperience can produce a

Fig. 8.20
A passenger in the back of this 1951 Austin A40 Utility was killed when it overturned and struck a tree.

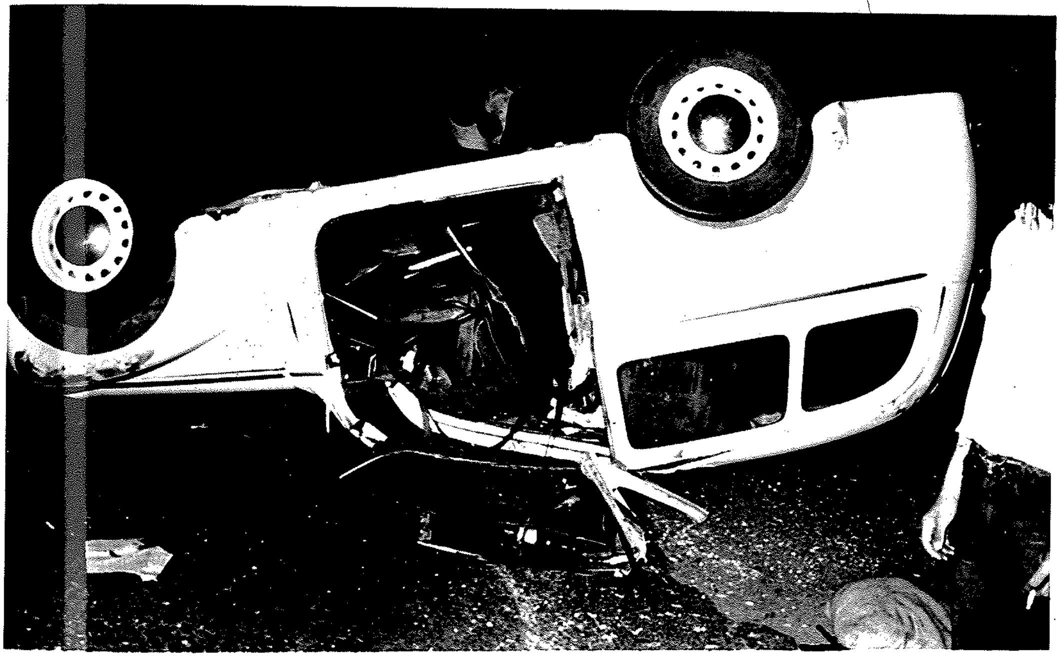


Fig. 8.21
This 1950 Skoda rolled over after swerving from one side to the other on a straight road.

potentially dangerous combination of poor driving skill and underdeveloped awareness of road hazards.

8.25 The role of alcohol is also particularly marked because it has similar effects, in that it reduces the levels of skill and awareness in a driver, often with tragic consequences. Four of these twelve drivers had obviously been drinking not long before the accident occurred.

8.26 Nine drivers were alone in their cars. One car had one passenger, another had three and the remaining car had four passengers.

8.27 The vehicles are notable on two counts. First, half of these cars were manufactured before 1955. This may simply be a reflection of theage of the driver, i.e. young drivers may drive older and therefore cheaper cars. The other point, and one which is directly related to vehicle design, is that five of these 12 cars had independent rear suspension of the swing-axle type. These cars were two Volkswagen 1200 sedans, two Skoda sedans (Fig. 8.21), and one Renault Dauphine. The drivers of these cars had mostly been driving for more than five years. One driver in fact claimed 45 years' driving experience.

8.28 The condition of the tyres on these cars was generally good. However, because all these accidents occurred on dry roads, the condition of the tyre tread would not have been very significant. Tyre pressures were measured in six of these cases. Two cars were found to

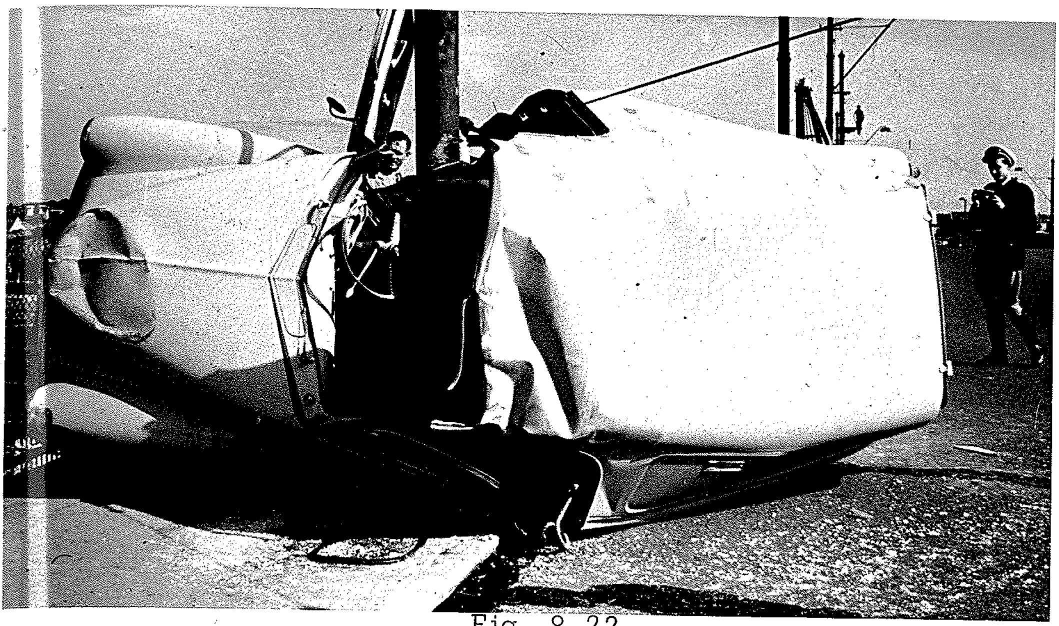


Fig. 8.22
This 1955 FJ Holden Panel Van rolled over and struck a steel utility pole. The front corner posts and the steering wheel were cut to extricate the driver from the damaged car.

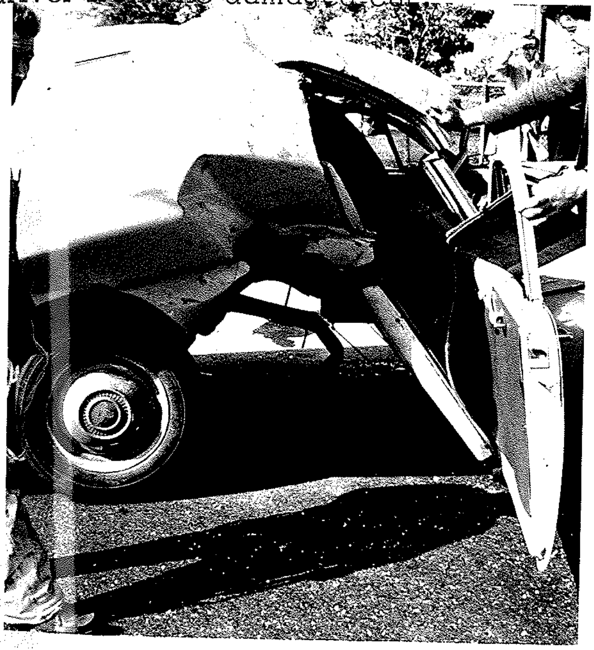


Fig. 8.23
The Holden Panel Van shown in Figure 22.

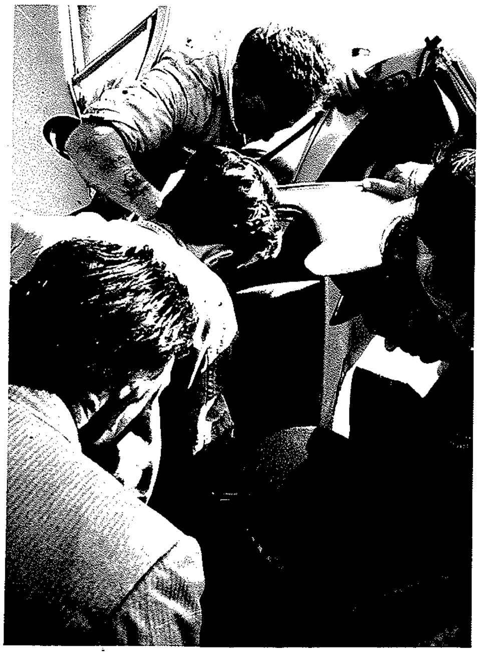


Fig. 8.24
Police, ambulance and tow truck operators working to release the driver from the damaged car.

have low pressures which would have reduced the stability of vehicles, to a marked degree in one case(0314).

0314 A 1955 FJ Holden panel van approached a bridge on a gradual left curve at a speed which may have been in the range 40 to 50 m.p.h. A slight bump in the road surface caused the vehicle to slew to the left. The driver was unable to bring the car back to the straight ahead position and it rolled over to the right. It continued to roll until it hit a steel utility pole with the underbody of the car (Fig. 8.22). The deformation of the car at this point was 24 in. (Fig. 8.23). The driver, an 18 year old girl, was trapped by the legs between the under-surface of the instrument panel and the bottom of the seat (Fig. 8.24). She was not released from the car until the front corner posts had been sawn through, the steering wheel cut away, and the daw and instrument panel forced apart using portable hydraulic jacks. She suffered concussion, a minor fracture of one vertebra of the neck, and bruises and abrasions to both thighs.

The right rear tyre had a pressure of 10 p.s.i. The left rear was 20, the right front 24 and the left front 25 p.s.i. The low pressure in the right rear tyre may have been one of the main factors which resulted in this vehicle's rolling over. This was a commercial vehicle and it seems that this was one accident in which neglected maintenance cost a firm a vehicle and also injured an employee.

8.29 Apart from one car which ran off a track and rolled down a steep hillside, all these cars rolled over on dry bitumen roads. Rolling over when attempting to take a bend accounted for five accidents. Four cars rolled over when turning too quickly at intersections, two of them when swerving to avoid a second vehicle approaching from the right. The remaining two cases occurred almost inexplicably when the case car was

Fig. 8.25
Collision between a Jaguar and an FB Holden.

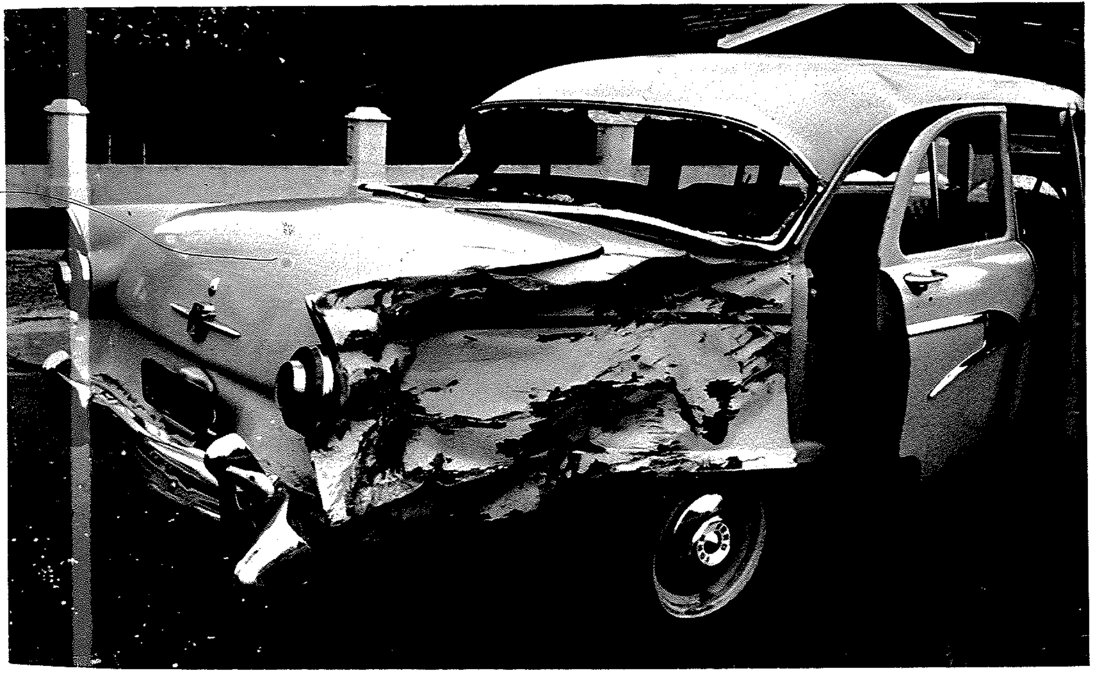


Fig. 8.26
The doors of this Ford Customline came open during the accident shown in Figure 8.28.

overtaking another vehicle on a straight road.

Car to Car Collisions.

8.30 The commonest configuration in car to car collisions was the front of one car striking the side of another (Fig. 8.25). The fact that Adelaide's street plan is based on a 90° grid with large numbers of right-angled intersections accounts for the prevalence of the front to side configuration. This also has the important consequence that car occupants, because of this configuration, are injured by the sides of the interior of the car as often as by the front.

8.31 In these collisions between cars it was found that 79 per cent of the 151 drivers for whom the information was available did not see the other vehicle until it was too late to avoid a collision, as Table 8.2 shows.

TABLE 8.2

Distances at which the Driver saw the other car.

Driver of	Saw the car		Not at all	Not known	Total
	In the distance	Close			
Unit 1	15	60	4	25	104
Unit 2	17	44	11	32	104
	32	104	15	57	208

8.32 Accident 0386 (Fig. 8.27) is an example of a collision between two cars. It is significant that the driver of the Holden looked only in one

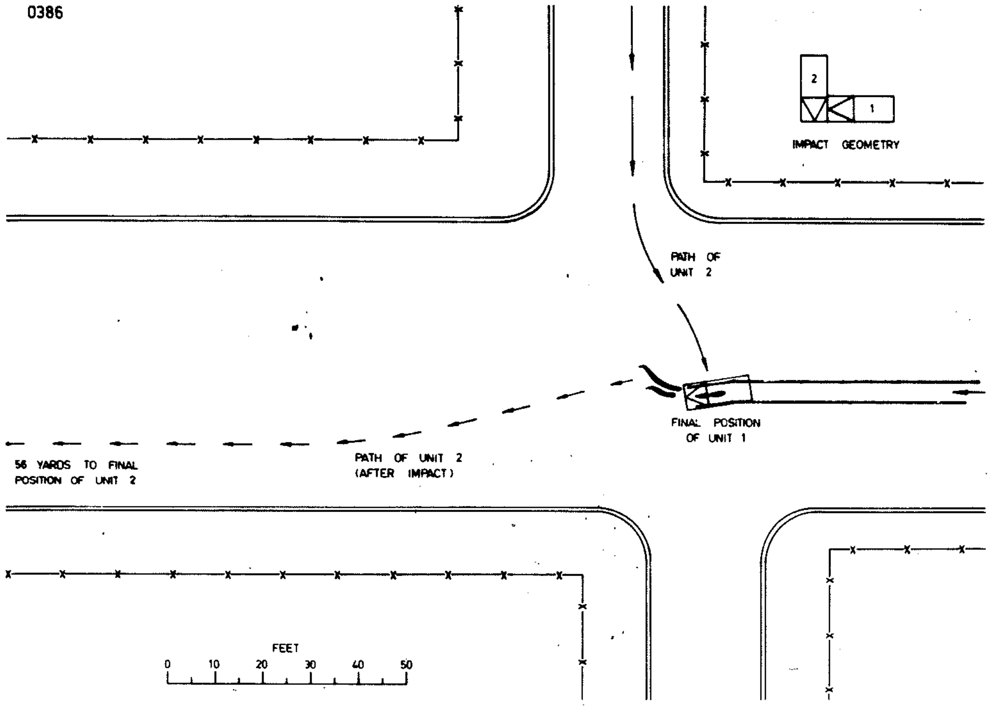


Fig. 8.27
Case 0386.

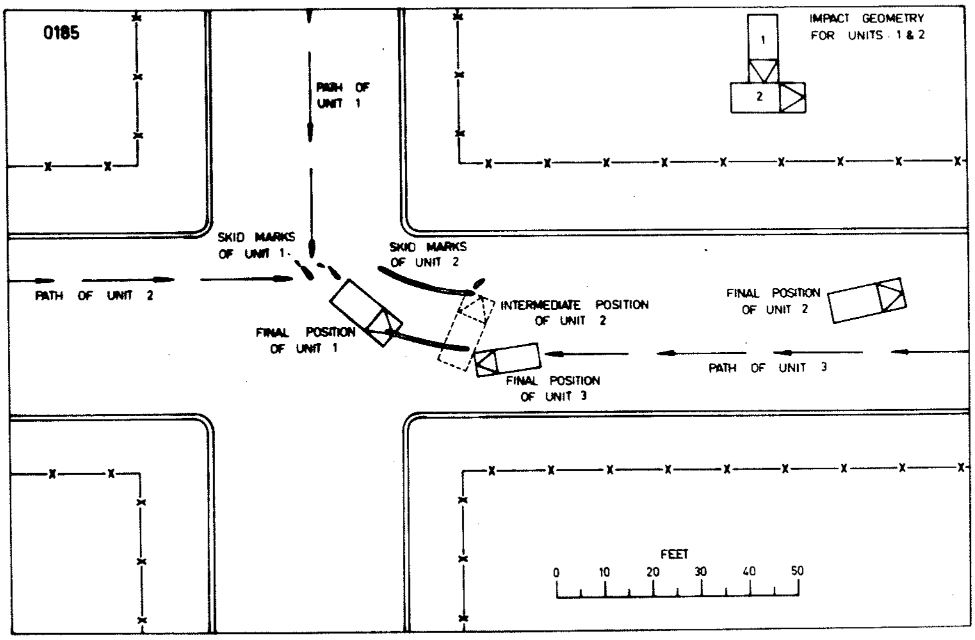


Fig. 8.28
Case 0185 (see also Fig. 8.26).

direction (right) before entering the intersection.

0386 A Ford Falcon sedan was travelling on a very wide main road, when a Holden EH station sedan came out of a side street without stopping. The driver of the Holden had looked to his right as he entered the intersection, but looked to his left only immediately before the impact. The front of the Ford struck the right front wheel of the Falcon. The Holden was spun clockwise through 90° by the impact, and rolled off down the road with its brakes inoperative. The Falcon skidded 18 yards before the impact. The driver of the Falcon sustained an abrasion to his upper lip and a small laceration to his tongue. The driver of the Holden suffered bruises to his left forehead and left elbow.

8.33 The complex nature of a collision between two cars, followed by a subsequent collision, is further illustrated by accident 0185 (Fig. 8.28).

0185 At a right-angled intersection with a good sight distance a Ford Customline was struck on the centre of its left side by the front of a Standard Vanguard II. The Customline spun 90° anti-clockwise, and struck an Austin A40 which was approaching the intersection from the opposite direction. The original impact caused the right side doors of the Customline to come open and then the impact of the right rear corner with the Austin stopped the Customline's rotary motion, causing the two occupants to be ejected, one through the front door and one through the rear door (Fig. 8.26). The Customline then spun 90° clockwise, coming to rest facing its original direction. The driver of the Vanguard could not remember the impact or events immediately preceding the collision. He had a small abrasion on his right forehead. The driver of the Customline was concussed and had abrasions to his right shoulder, right buttocks, right hand and right knee, and his right forehead. He could not remember anything except the very start of the trip. The passenger of the Ford was seated in the centre of the rear seat. He sustained abrasions and small lacerations to the right side of his face, a fracture of his right shoulder blade and fractures of his right eighth, ninth, tenth and eleventh ribs. He also fractured the fourth and fifth metacarpal bones in his right hand. In both men the injuries were all on the right side of the body, which is consistent with the fact that they were ejected from the right side doors of the car and landed on the road. The driver of the Austin sustained a small abrasion to the bridge of her nose, bruising of her chest caused by the steering wheel, and bruises and abrasions to both knees caused by the instrument panel.

The impact on the side of the Customline caused it to spin sideways and also sprung open the doors on the opposite side. This sequence then set the stage for the ejection of the occupants which took place when the car stopped spinning, as it struck the other car.

8.34 This accident illustrates three characteristics of the intersection collision: (a) the front of one car strikes the side of another car; (b) the impact on the side may spring open doors, particularly those which do not have safety door locks, and also (c) the impact may spin the car into the path of a third car. The subsequent collision may ensure the ejection of the occupants.

8.35 Over one third (148 of 408) of the accidents covered by this survey were primarily collisions between two cars. In some of these accidents one of the cars was involved in a subsequent collision with another vehicle or with a fixed object. But the initial impact in all these cases was with another car.

8.36 To facilitate the description of these collisions between two cars a simple numerical code has been devised. The 'case car' – the car

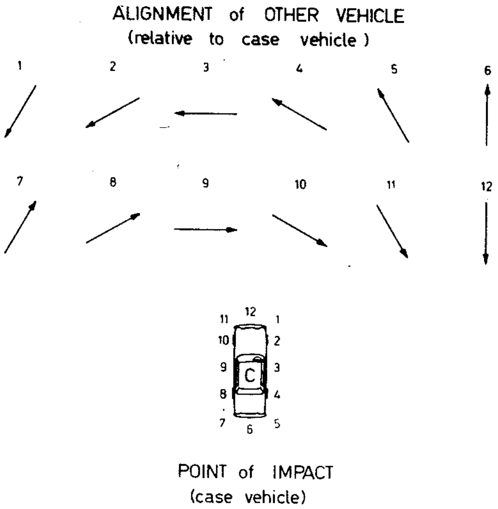


Fig. 8.29
Diagram of numerical code used to describe two-car collisions

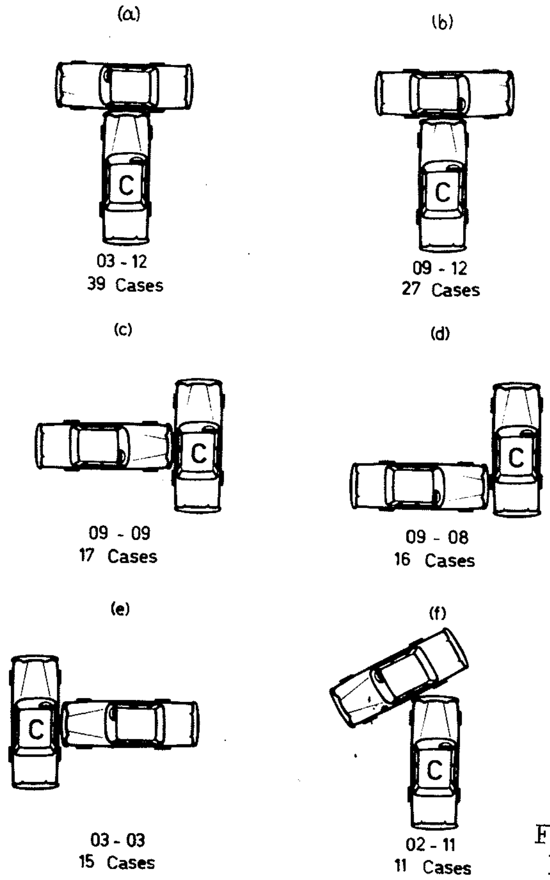


Fig. 8.30
Most frequent types of impact.

to which the numbers refer - has been marked with a 'C' in Figure 8.29. The alignment of the other car to the case car is described by allocating it to one of 12 positions which are set at 30 deg. intervals to the longitudinal axis of the case car, as is also shown in Fig. 8.29. The point of impact on the case car is described according to the following classification:

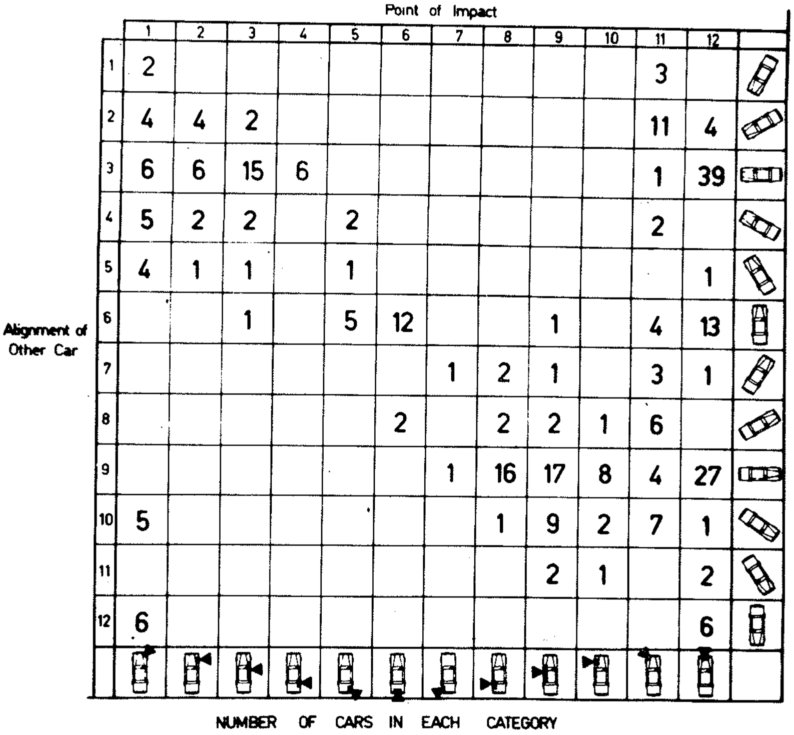
Right front corner	1
Right front wheel	2
Right side between wheels	3
Right rear wheel	4
Right rear corner	5
Centre rear	6
Left rear corner	7
Left rear wheel	8
Left side between wheels	9
Left front wheel	10
Left front corner	11
Centre front	12

Any impact with a second car can now be described by two sets of figures, the former set indicating the alignment of the other vehicle, the latter set indicating the point of impact on the case vehicle. Some examples are given in Fig. 8.30. Please note that the first set of numbers refer to the alignment of the other car, and the second set of numbers to the point of impact with the case car.

8.37 There are two warnings that should be made regarding the use of this convention. While these two numbers do describe the alignment of the cars to each other and the point of impact on the case car, they do not necessarily give the point of impact on the other car. For example Fig. 8.30 (a) could be drawn from the point of impact anywhere along the left side of the other car. The impact geometry would still be 03-12 for the case car. To describe the impact geometry completely in this case we would also have to give the point of impact on the other car, viz. point 09.

8.38 The second point which may be overlooked is that these numbers, and the diagrams, give only the impact geometry. They do not necessarily give the direction of the impact. With two cars the true direction of impact is along the line of their velocity relative to each other. Should the case car be stationary, the direction of impact is the same as the direction in which the other car is moving. Should the other car be stationary, the direction of impact is along the path of the case car. More commonly both cars are moving. If in Fig. 8.30 (a) the case car is travelling at 20 m.p.h. and the other car at 34 m.p.h. then the direction of impact on the case car would be 02, and on the other car, 10.

8.39 This convention, which allows for 12 possible angles between the cars and 12 possible points of impact on the case car, gives us 144



	1	2	3	4	5	6	7	8	9	10	11	12
1	2										3	
2	4	4	2								11	4
3	6	6	15	6							1	39
4	5	2	2		2						2	
5	4	1	1		1							1
6			1		5	12			1		4	13
7							1	2	1		3	1
8						2		2	2	1	6	
9							1	16	17	8	4	27
10	5							1	9	2	7	1
11									2	1		2
12	6											6

Fig. 8.31
Impact geometry for two-car collisions.

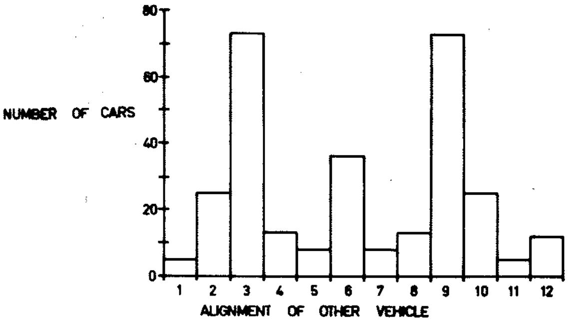


Fig. 8.32
Alignments of other vehicles in two-car collisions.

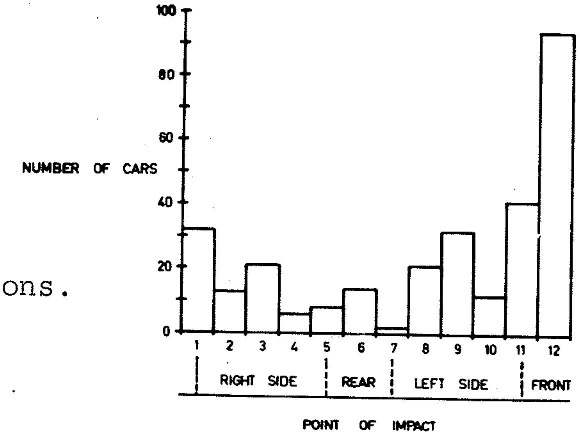


Fig. 8.33
Points of impact in two-car collisions.

different combinations. Some of these are unlikely, such as two cars reversing into each other (12-06). In fact only 56 of these 144 categories are represented by the 296 cars in these 148 accidents (Fig. 8.31), and in only 20 of these 56 categories are there 5 or more cases. These 20 squares contain 225 of the 296 individual cases. This is a rather roundabout way of saying that some types of impact occur more often than others.

8.40 The totals for each row and column of Fig. 8.31 are shown in the histograms of Fig. 8.32 and 8.33 The most frequent point of impact is on the centre of the front of the case car (point 12). The left rear corner of the case car receives the fewest impacts (point 7). The other vehicle is most likely to be aligned at right angles to the case car - alignments 3 and 9 of Fig. 8.32. There are comparatively few cases in which the other car is pointing in the opposite direction to the case car (alignment 12).

8.41 The six most frequent types of impact are shown in Fig. 8.30. The two most likely types of collision for a car are for it to strike, head on, the side of another car. The diagrams illustrating these two impacts, Fig. 8.30 (a) and (b), show the case car striking the passenger compartment of the second car. While the actual point of impact can be anywhere along the side of the struck car, in fact almost all the impacts are in the region of the passenger compartment of the struck car. There

Fig. 8.34
Impact on the side of the passenger compartment of a 1954 Vauxhall Wyvern.

Fig. 8.35
The damage to the rear of this Simca was caused by the initial collision with another car. The frontal damage resulted from a subsequent collision with the side of a hotel.

are no such impacts on the right rear corner, point 5, and only one on the left rear, point 7. The next most common types of impact are those in which another car strikes the side of the case car. Please note that only individual cars, not accidents, are being considered at the moment. It is obvious that Fig. 8.30 (c), (d) and (e) are particular types of the accidents shown in Fig. 8.30 (a), and (b). The impacts on the case car are very different however. In (a) and (b) it is a frontal impact. In (c) (d) and (e) it is a side impact at a particular point along the side of the car. Impact type (f) arises mainly from the other car turning across the path of the case car. As with cases (a) and (b) it is essentially a frontal impact for the case car.

8.42 Each of these six most frequent impact types are almost all intersection accidents. This is understandable in any metropolitan area, and particularly in Adelaide which consists almost entirely of a 'grid' of streets intersecting at right angles. Whatever the reason, the fact remains that many of these impacts are on the side of the case car, including the sides of the passenger compartment. This has particular significance for both vehicle designers and for traffic engineers.

8.43 The sides and top of the passenger compartment are probably the most vulnerable parts of the structure of a car, as far as deformation of the passenger compartment is concerned (Fig. 8.34). The ends of the compartment are protected by the front and rear sections of the car, which will in many cases crumple on impact, leaving the passenger compartment relatively undamanged. A similar protective section at the sides is not possible with the conventional layout of the passenger car. The alternative is for the sides of the compartment to be made strong enough to withstand collision forces. If the door locks and hinges are designed to retain the doors in place as structural members in the event of a direct impact then this may be possible without very great changes in existing layouts.

8.44 The sides of the interior of the passenger compartment, which are generally the door, could easily be made safer on many cars. It is not uncommon for the 'special' models of some cars to be fitted with arm rests on the doors, and the 'standard' models to lack such conveniences. Unfortunately the people who choose the 'special' expose themselves to the risk of serious internal injuries if they are thrown against the arm rest on the door, as happens when a car is hit from the side.

8.45 At many locations it is possible for the traffic engineer to control the angles at which vehicles approach each other. One way in which this is done is by the installation of suitably designed traffic islands. It is of course generally recognized that a rear end collision is likely to have less serious consequences than a head on collision under similar circumstances. But what of impacts on the sides of cars? We have noted that the side of the passenger compartment is a particularly vulnerable part of the structure of a car. Could it be that side-on impacts tend to be as severe as those in which the cars hit head-on?

8.46 Both the severity of injury to the occupants and the degree of damage to the car have been related to the impact geometry. For this first analysis those cars which were involved in subsequent collisions of a severity comparable to or greater than the initial collision have been excluded. There is an argument in favour of including these cases because the risk of a subsequent collision may be related to the point and direction of the initial impact. Cars which rolled over after the initial impact have not been excluded for this reason. Later investigations have shown that there is almost equal justification for retaining all cases involving a subsequent collision.

Subsequent Collisions and Initial Point of Impact.

8.47 The following two examples are cases in which two cars collided with each other and one subsequently hit another object.

> 0096 A 1961 Simca sedan had almost completed a right turn at a light-controlled five way intersection when it was struck on the left rear corner by a Vauxhall Velox sedan. The resulting damage from this impact was moderate to both cars. The Simca, however, was spun clockwise and crashed into the side of an hotel (Fig. 8.35). This subsequent impact resulted in severe damage to the car. The occupants sustained lacerations and abrasions.

The next case illustrates the considerable deformation resulting from a subsequent collision with a utility pole. Figure 8.23 is a similar example of a collision with a utility pole.

> 0223 A 1954 Hillman Minx sedan was struck on the right hand side by an FC Holden utility at an intersection. The Hillman was spun clockwise and began to roll over to the left, striking a utility pole as it did so. The resulting damage to the passenger compartment was very severe (Fig. 8.39). The driver was slightly concussed, and also suffered multiple abrasions.

8.48 To test for any relationship between the initial impact points on the case car and the risk of the case car being involved in a subsequent collision the points of impact have been grouped into front, rear and side. The results are as shown:

Point of impact	Subsequent collision	
	Yes	No
Front	6	125
Side	27	117
Rear	10	11

$$\text{Chi square} = 30\ {*}{*}{*} \quad (p_{0.001} = 17)$$

This means that the risk of being involved in a subsequent collision is almost negligible in frontal impacts, about one chance in five for side impacts, and an even chance for impacts on the rear of the car. The value of Chi square shows that this distribution is almost certainly not due to chance.

Subsequent Rollover and Initial Point of Impact.

8.49 The accident described below is typical of the 36 cases of rollover following a two car collision.

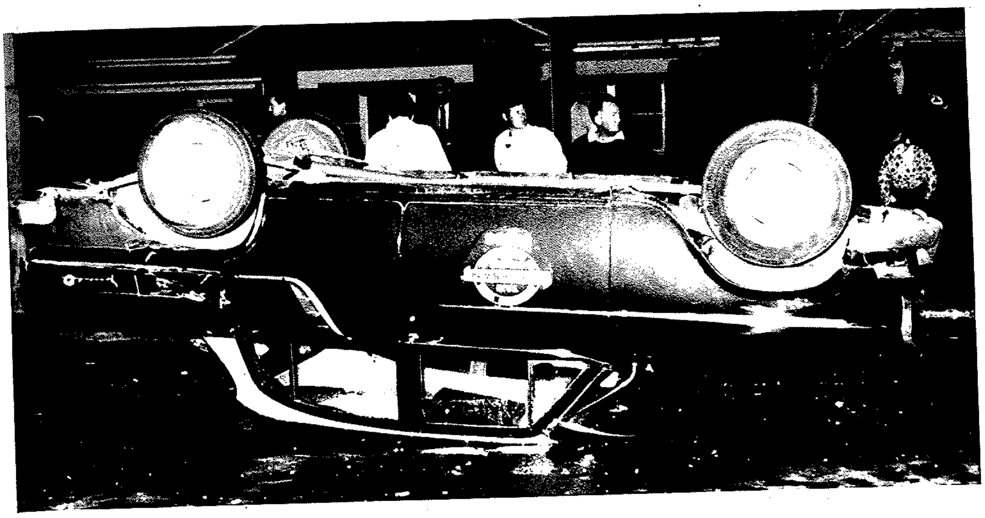


Fig. 8.36
This FC Holden taxi rolled over after being struck on the left side, behind the rear wheel, by the Holden shown in Figure 8.37.

Fig. 8.37
Note the relatively small amount of damage to this car. The struck car (see Fig. 8.36) was spun anti-clockwise by the impact and rolled over.

0412 An FC Holden taxi (Fig. 8.36) was struck on the left rear corner by an EK Holden sedan (Fig. 8.37). Although the damage resulting to both cars from this impact was not great, the taxi was spun anticlockwise and rolled over (Fig. 8.38). It then struck a utility pole and spun round again to face in its original direction, but upside down. The driver and one rear seat passenger of the taxi suffered bruises. The other rear seat passenger was concussed. The two occupants of the other car were not injured.

8.50 Grouping impacts into front, rear and side gives the following results:

Point of impact	Subsequent rollover Yes	 No
Front	3	128
Side	33	111
Rear	0	21

Combining front and rear into one category and comparing this with side impacts we get a Chi square value of 28.429***. Once again this shows that the above distribution is not due to chance. Impacts on the side of the car are much more likely to cause it to roll over than front or rear-end impacts.

8.51 In neither of these two tests has allowance been made for the alignment of the other vehicle, except when the impact was on one of the corners of the case car. However, 20 of the 36 subsequent rollover cases were in three impact categories, viz. 03-03, 09-08 and 09-09.

<u>Impact Geometry and Vehicle Damage</u>

8.52 After excluding the cases mentioned above the average vehicle

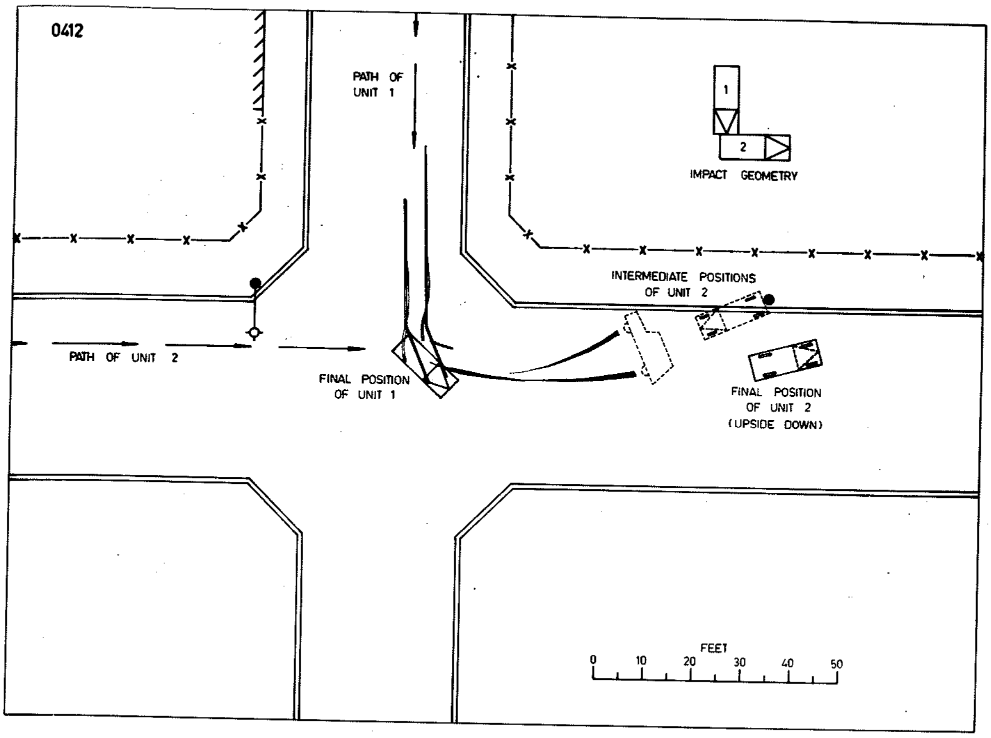


Fig. 8.38
Case 0412 (see also Figs. 8.36 and 8.37).

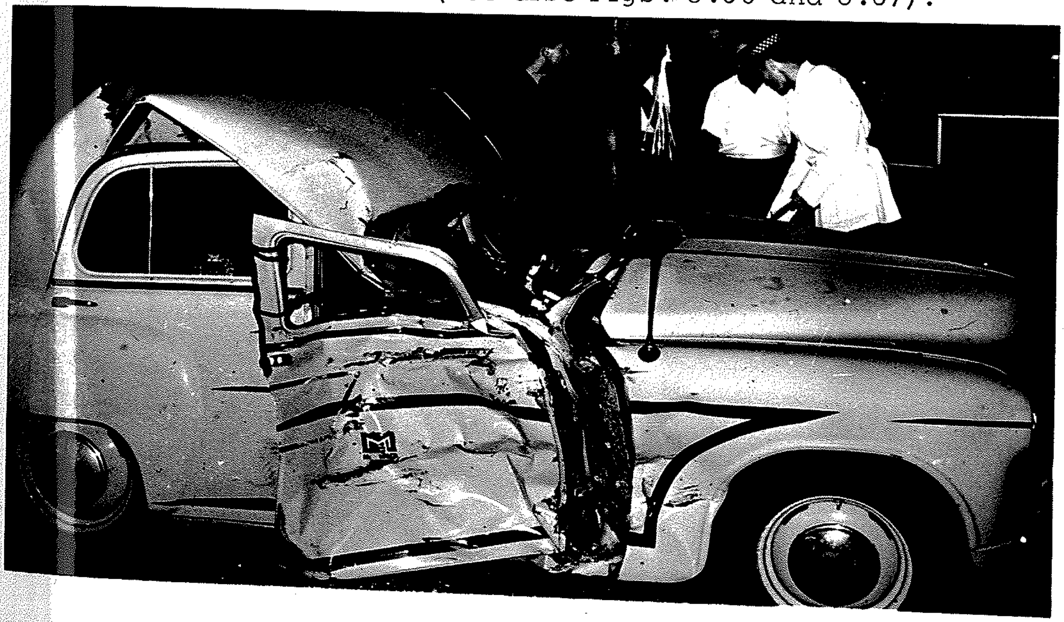
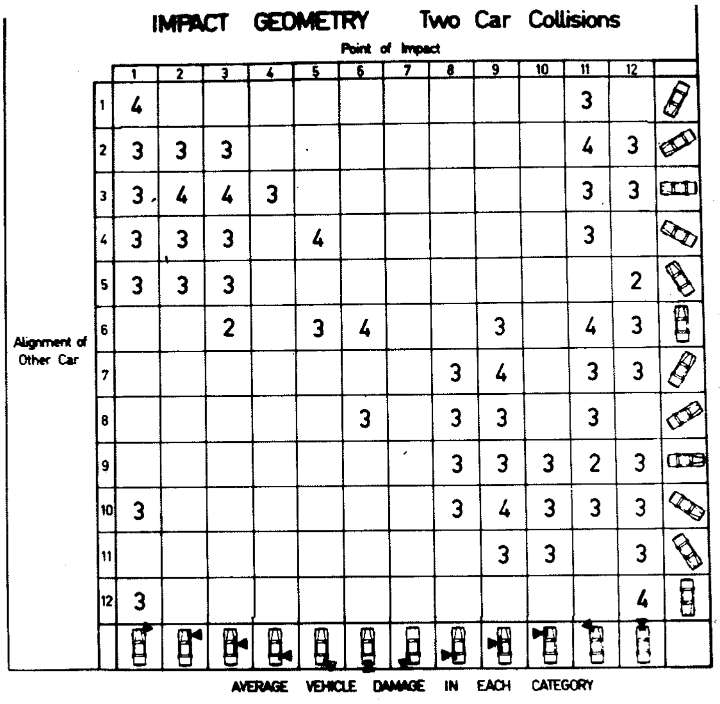


Fig. 8.39
This Hillman Minx rolled over after being struck by another car on the door shown. It hit a utility pole while rolling over.

damage was calculated for each impact category. This was done by averaging the damage to each of the front, centre and rear sections and then calculating the average overall damage from these three sections damage averages. Fig. 8.40 shows the variation of this average of overall vehicle damage with the geometry of the impact. The coding used is:

minor damage	2
moderate damage	3
severe damage	4

8.53 There is no category in which the average damage is extremely severe, nor is there any marked variation in the degree of vehicle damage between impact categories. An analysis of variance shows that there is in fact more variation in the degree of vehicle damage within impact categories than between categories. These variations within categories, i.e. differences in the degree of vehicle damage for the same type of impact, can obviously arise from differences in impact speeds and weights of vehicles. Furthermore the significance of each of these average damage ratings depends on the number of cases in each category. A guide to the number of cases is given in Fig. 8.31. This is only a guide because those cases which were excluded from the vehicle damage calculation have not been removed from this table. This has had a marked effect on the totals in only a few categories, such as square



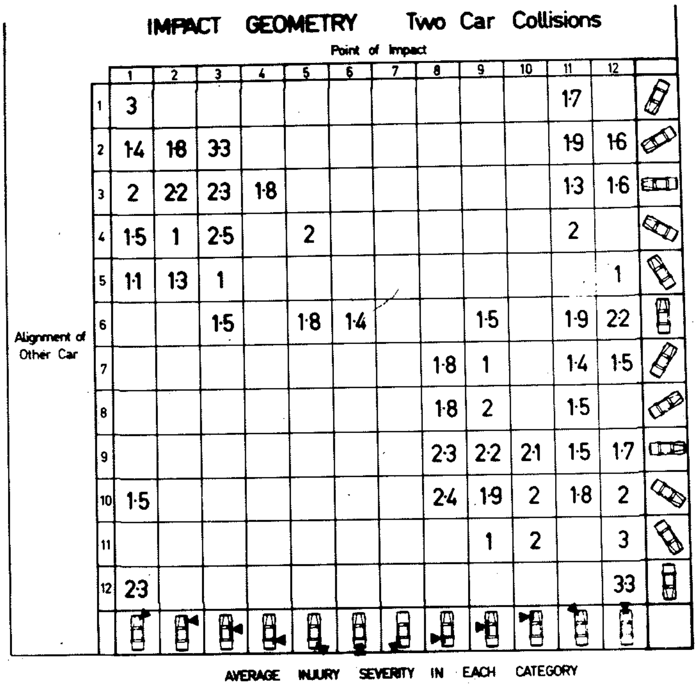
IMPACT GEOMETRY Two Car Collisions

Point of Impact

Alignment of Other Car	1	2	3	4	5	6	7	8	9	10	11	12
1	4										3	
2	3	3	3								4	3
3	3	4	4	3							3	3
4	3	3	3		4						3	
5	3	3	3									2
6			2		3	4			3		4	3
7								3	4		3	3
8						3		3	3		3	
9								3	3	3	2	3
10	3							3	4	3	3	3
11									3	3		3
12	3											4

AVERAGE VEHICLE DAMAGE IN EACH CATEGORY

Fig. 8.40
Impact geometry and degree of vehicle damage for two-car collisions.



IMPACT GEOMETRY Two Car Collisions

Point of Impact

Alignment of Other Car	1	2	3	4	5	6	7	8	9	10	11	12
1	3										1·7	
2	1·4	1·8	3·3								1·9	1·6
3	2	2·2	2·3	1·8							1·3	1·6
4	1·5	1	2·5		2						2	
5	1·1	1·3	1									1
6			1·5		1·8	1·4			1·5		1·9	2·2
7								1·8	1		1·4	1·5
8								1·8	2		1·5	
9								2·3	2·2	2·1	1·5	1·7
10	1·5							2·4	1·9	2	1·8	2
11									1	2		3
12	2·3											3·3

AVERAGE INJURY SEVERITY IN EACH CATEGORY

Fig. 8.41
Impact geometry and degree of injury severity for two-car collisions.

03-03 where the number of cases has been reduced from 15 to 10 and square 06-05, from 5 to 2. With the result obtained from this analysis, namely that there is some variation in the degree of vehicle damage which is related to the impact geometry, but not to a significant degree in the cases presented, the injury severity was then related to the impact geometry.

Impact Geometry and Injury Severity

8.54 The procedure here was very similar. Once again some cases were excluded. For example a parked car with no one in it is unlikely to tell us much about the risk of injury to car occupants. These exclusions were spread more evenly through the categories than was the case in the vehicle damage analysis. The most marked changes were in category 06-05 which had three cases removed and 12-01, two cases. In an attempt to find a relationship that could be shown to be significant, injury ratings were taken to two figures, as shown in Fig. 8.41. The coding used in Fig. 8.41 is:

no injury	1
minor injury	2
moderate injury	3
severe injury	4

The squares showing a rating of 1.3 or less all have only one or two cases and are therefore of doubtful significance. This also applies to some other squares (see Fig. 8.31). An analysis of variance shows that there is a significantly greater variation in injury severity within categories than between categories.

8.55 In addition to the above-mentioned uncontrolled variables of impact speeds and vehicle weights there are further complicating factors as far as the severity of injury is concerned, such as age, sex and seated position for each occupant. An attempt has been made to minimize the effect of the number of occupants in a car by taking an average injury severity for each car and calculating the category average on this basis. This means that these calculations have been based on an average injury rating for each car, not the rating for each individual. Otherwise a fully laden car would exert a disproportionate influence on the category average over a car having only one occupant.

8.56 The next step was to reduce the number of impact categories to four, viz. frontal, right side, rear, left side. This meant, of course, increasing the number of cases in each category and also increasing the variation in the type of impact within each category. These two effects seem to have largely balanced each other. The variation of injury severity within each group is less pronounced but is still larger than the variation between groups. In the case of the vehicle damage analysis, reducing the number of impact categories to four had virtually no effect on the variations both within and between categories.

8.57 It therefore appears that the effects of the uncontrolled variables must be reduced before useful results can be obtained. This will require particular care to ensure that the final analysis is performed on a body of data which is not so closely controlled as to be no longer representative of the wide range of collisions between cars in traffic today.

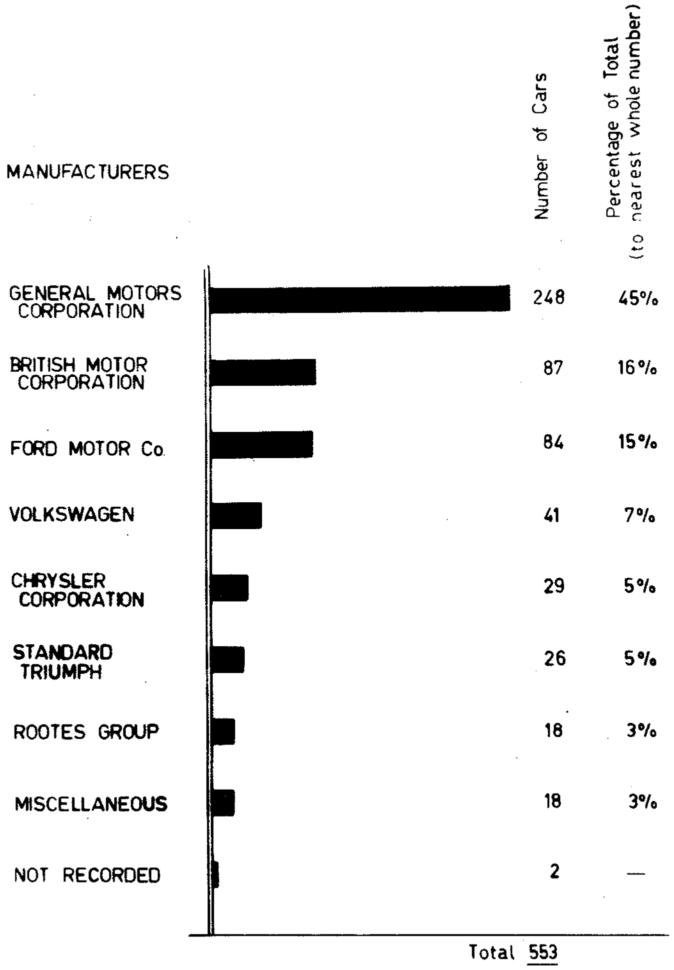


Fig. 9.1
Manufacturers of passenger cars.

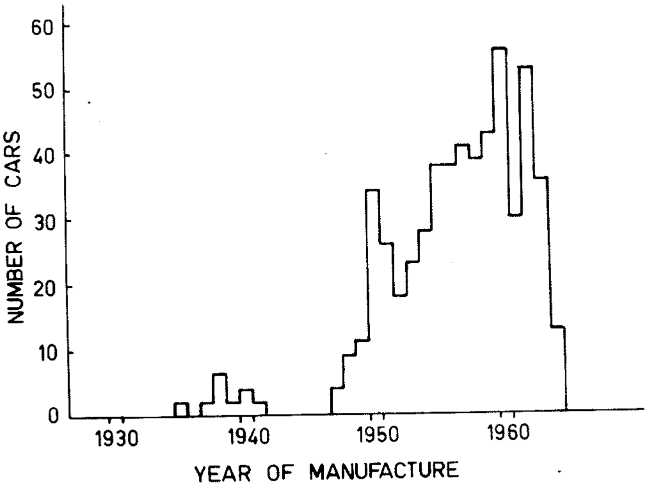


Fig. 9.2
Year of manufacture of passenger cars.

THE CAR

CHAPTER 9

Makes and Models of Cars

9.1 Reference to the Vehicle Data code in the Appendix will show the makes and models of cars which appeared in this survey. These have been regrouped according to the manufacturer of each car, and the information is presented in Fig. 9.1. It can be seen that cars produced by General Motors Corporation account for nearly one half of all cars in the accidents in this survey. This is obviously a very much higher proportion than that of any other manufacturer. British Motor Corporation and the Ford Motor Company, with 16 per cent and 17 per cent respectively of the total, are the next largest groups.

9.2 Throughout this thesis the very close relationship that exists between vehicle design and injury, to both car occupants and other road users, has been emphasised. Particular features that do cause injuries are mentioned. If these features were to be changed, how would the possible reduction in the frequency of the related type of injury be estimated, for the whole population of road users?

9.3 It is tempting to say that the effect would be proportional to the number of such models that have been changed compared to the total number of cars. But the measure that we are really seeking is the number of such models that are likely to be involved in accidents, for it is only in an accident that people are injured.

9.4 In Table 9.1 the number of Holden cars (including station sedans, panel vans and utilities) in this survey is related to the number in the Adelaide metropolitan area in 1962. (Holden cars account for 84% of all General Motors cars in this survey.) This is also done for all Ford and Volkswagen car-type vehicles. The Volkswagen 1200 is the only model from this manufacturer in this survey. There are, of course, many models which have been grouped together under 'Ford'. The figures listed for the metropolitan area are based on the Commonwealth Bureau of Census and Statistics Census of Motor Vehicles (1962). The Chi square test shows that the distribution shown in Table 9.1 is most unlikely to be due to chance.

TABLE 9.1

Cars in Survey related to Number in Adelaide Metropolitan Area, 1962.

Make of Car	Number of cars T.A.R.U. survey	Adelaide metropolitan area
Holden	213	53,718
Ford	77	24,588
Volkswagen	41	6,582

Chi square = 15*** ($p_{0.001}$ = 13)

9.5 The meaning of Table 9.1 is easier to grasp if it is presented in the form of percentages. These percentages are based on the total number of cars in the survey and in the metropolitan area, not merely on the total numbers of the three makes listed here (see Table 9.2). Holdens appear in the accidents covered by the survey slightly less frequently than they appear in the whole population of vehicles in Adelaide. Fords do not appear as frequently as their percentage of the total number of cars suggests that they should. Volkswagens however seem to be involved in more accidents than their numbers suggest they should be.

TABLE 9.2

Cars in Survey related to Percentage of Car Population

Make of Car	Percentage of all cars T.A.R.U. survey	Adelaide metropolitan area
Holden	38.5%	39.6%
Ford	13.9%	18.1%
Volkswagen	7.4%	4.9%

9.6 It can be seen from these percentages that because the Holden is such a popular car its 'crashworthiness' is the factor which largely determines the nature of the injuries received by road users in one third of all the cars that are involved in accidents. Even slight improvements in the design of the Holden, such as the new door locks fitted to the HD model, will eventually affect about one third of all car occupants who are involved in an accident. ('Eventually' because, of all the Holdens on our roads, only a small number are the later models with the new door lock. As time passes however, the HD and subsequent models will become a larger proportion of the total number of Holdens in use in Adelaide. This assumes (for the purpose of this discussion), that the Holden's percentage of the market remains substantially unchanged.)

9.7 A change in the design of the Volkswagen, such as improved door locks or steering column would be potentially much more effective than the proportion of Volkswagens on our roads would indicate. This is because these design changes would only be important when the car is involved in an accident. Before being assailed by both the manufacturer and a horde of satisfied Volkswagen owners, it should be emphasised that the concern here is to show that, for whatever reason or reasons, some makes and models are more likely to be involved in an accident than others. This may not necessarily be a reflection on the roadworthiness of that particular model of car. It may be that one particular type of driver, e.g. a young driver, favours that model, and the consequent accident involvement is more a reflection of the type of driver than of the characteristics of the car.

9.8 Whatever the reasons may be, the frequency with which a particular model of car is involved in accidents is the measure on which we must base any attempt to predict the potential reduction in death and injury which might follow a change to the design of that model. Similarly those models which form the bulk of the cars which are involved in accidents on our roads are those which we should look at with the most critical eye, for even very slight improvements in the 'crashworthiness' of these cars would mean a significant reduction in the frequency of injuries to road users.

Year of Manufacture.

9.9 The years of manufacture of the cars involved in these accidents are shown in Fig. 9.2 Cars more than 20 years old account for only a very small proportion of the total. The peak is in the years 1960 to 1962, then falls to 1963 and 1964. These were the two years in which the survey was conducted, and there were obviously no 1964 models on the roads in mid-1963.

9.10 The marked fall in the number of cars for the year 1961 is not because cars made that year were much safer than those made in the adjacent years. 1961 was a time of temporary economic recession in Australia and this may have affected the number of new cars registered that year. The annual increase in the total number of cars registered in South Australia did not change markedly from the increase in 1960 but there may have been many more older cars retained in use in 1961 than in 1960.

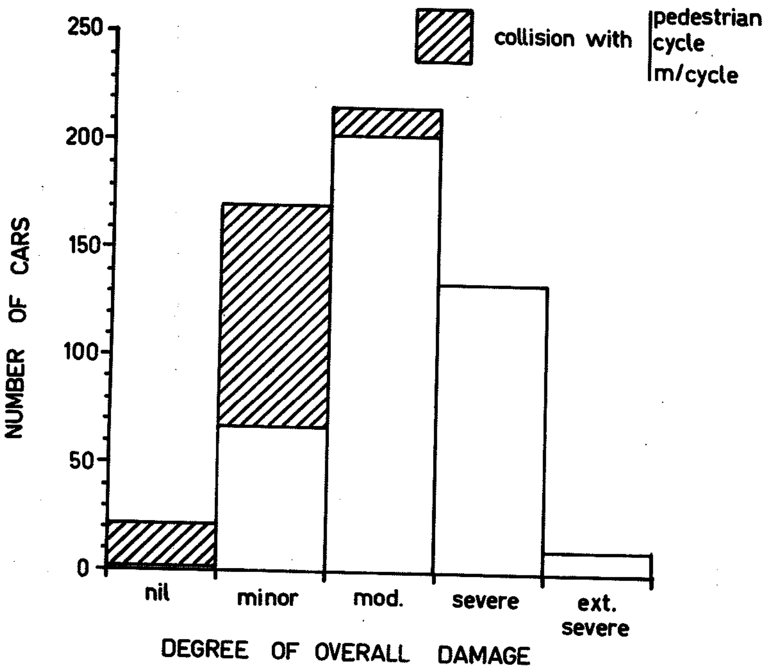


Fig. 9.3
Degree of overall damage for all cars in the TARU survey.

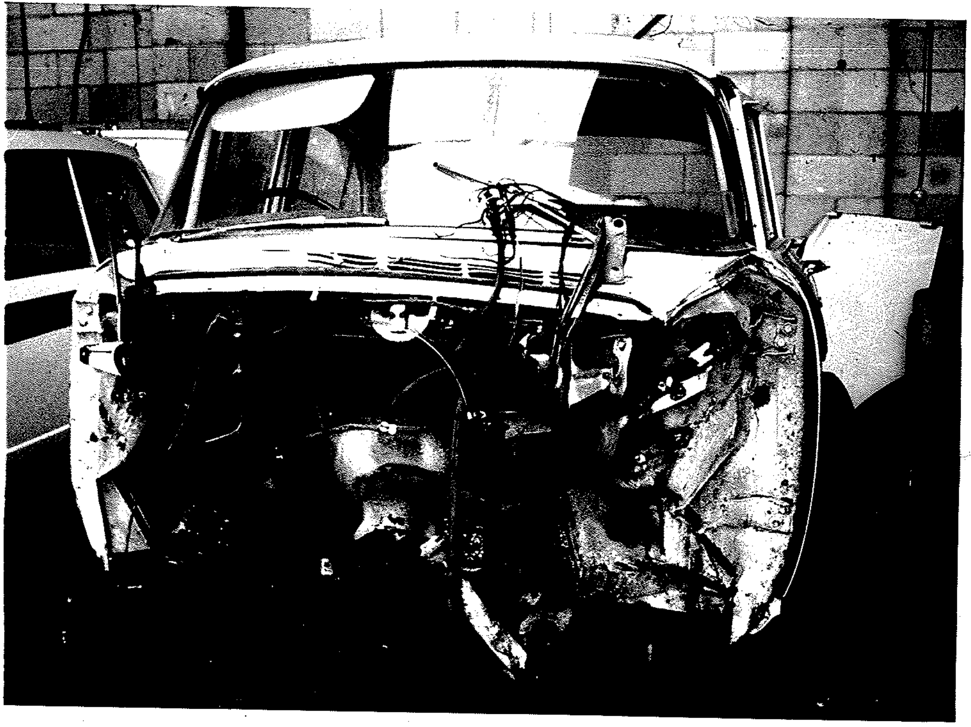


Fig. 9.4
The damaged FB Holden, shown in Figure 8.25, stripped for repairs.

Degree of Damage

9.11 The degrees of damage to all the cars in this survey are shown in Fig. 9.3. The overall pattern is naturally markedly changed when cases involving collisions with pedestrians, cyclists and motorcyclists are removed.

9.12 The method adopted to calculate an overall damage rating is outlined in Chapter 3. The moment that any numerical order is assigned to a rating such as this an assumption is made regarding the relative importance of each rating. This is an obvious but very important point which the following examples may clarify.

9.13 Fig. 9.5 shows the average section damage ratings against speed on impact for all cars. The damage scale used in this Figure is 0:1:3:7:10, as set down in Chapter 3. The lines of best fit are shown for each section.

9.14 Taking the same data, and the same scale for speed on impact, the damage scale is now modified to minimise as far as possible the variance within each speed category. Figures 9.6, 9.7 and 9.8 show the results. In Fig. 9.6 the scale reverts, rather ironically, to 0:1:2:3:4. This was the equal intercept scale that was discarded because Minor damage to three sections of a car had the same overall damage value as Severe damage to one section. The scales for the compartment and the rear section are 0:3:5:6:7 and 0:1:3:7:15.

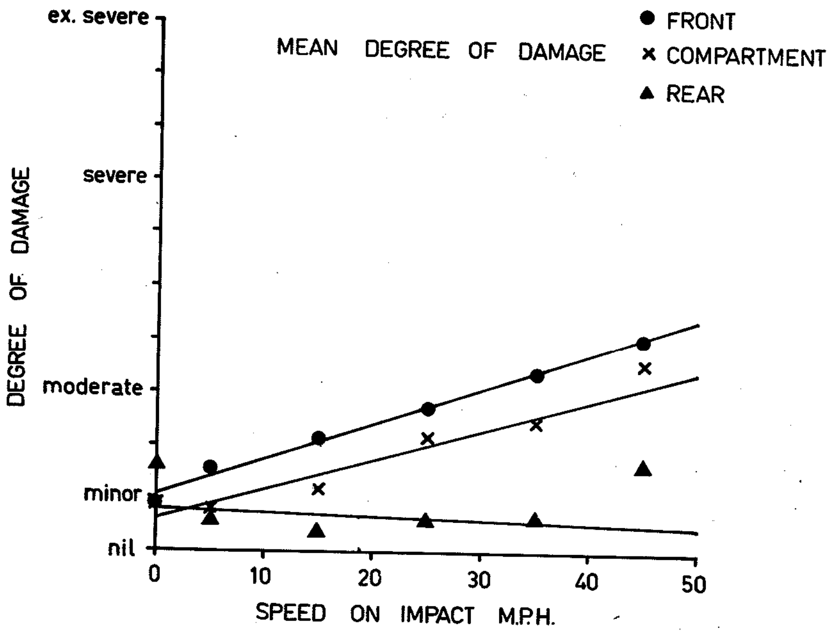


Fig. 9.5
Section damage by speed on impact, all cars.

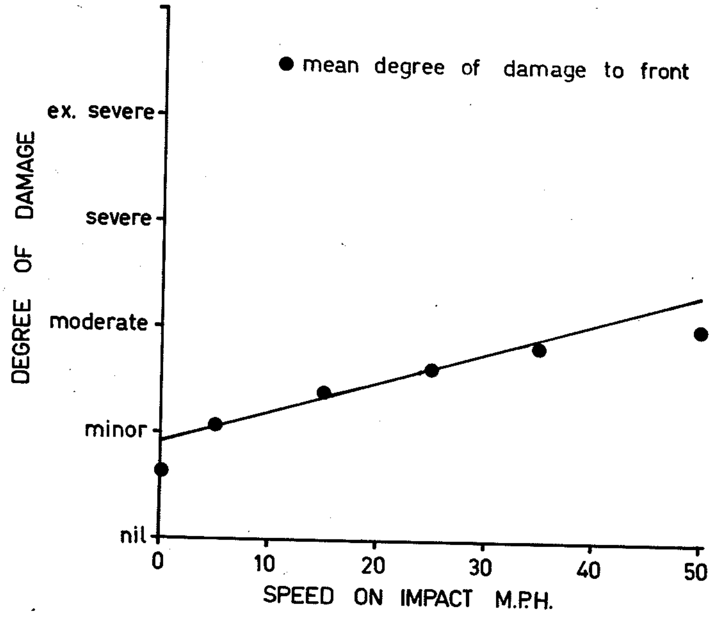


Fig. 9.6
Damage to front by speed on impact, all cars.

9.15 These Figures have been included to illustrate this particular point rather than to display the relationship between section damage and speed on impact. Because all cars, for which this speed is known, are listed the nature of the collisions varies greatly, ranging from pedestrian accidents to collisions with trucks. Also 'speed at impact' is not as closely related to the degree of damage as would be 'relative impact speed'. Furthermore the assumption that the speed scale is linear is not necessarily a justifiable one. In fact the scale should probably be based on the square of the speed. However it is interesting to note that the slower one drives the more severe the damage to the rear of the car is likely to be if involved in a collision. The parked car, which is usually hit from the rear, has some bearing on this result.

Cost of Repair.

9.16 In the second year of this survey I tried to find out the actual cost of repair for each vehicle (see Fig. 9.3). I generally did this by recording both the registration number of the particular vehicle and the name of the towing service which removed it from the scene. This proved to be a far from foolproof method, for very often such vehicles would seem to 'disappear without trace'. Had I also noted the name of the owner of the car I might have been more successful, for the owner's name seemed to be the only record that was kept by some towing services. I tried to resist the temptation to assess the cost of repair on the spot, even in cases when there was not much chance of serious error.

9.17 Table A9.1 in the Appendix lists the cost of repair to 86 passenger cars. Half of these were severely damaged, and only two received minor damage. This is not representative of the whole picture of the degree of damage to cars in this series, and there is naturally little point in attempting to draw any conclusions about the average cost of repair on the basis of these 86 cases which are not representative of the whole. The bias towards the cases of severe damage arose because it proved to be very much easier to trace a car which had to be towed away from the scene of the accident than one which could be driven away. Furthermore, if a car receives only a small dent it is likely that it may never be repaired.

9.18 Attempts have previously been made to relate the cost of repair to impact velocity (Ref. 37) and also to relate it to the damage index devised by Moreland (Ref. 9). The cost of repair has also been taken as an indication of the degree of damage sustained by a vehicle (Ref. 38).

9.19 An inspection of Table A9.1 reveals the wide range of repair cost of the same degree of damage. For example, the cost of repair for moderate damage, varied between limits of £15 and £450. This is mainly due to similar variations in the market value of the vehicles concerned.

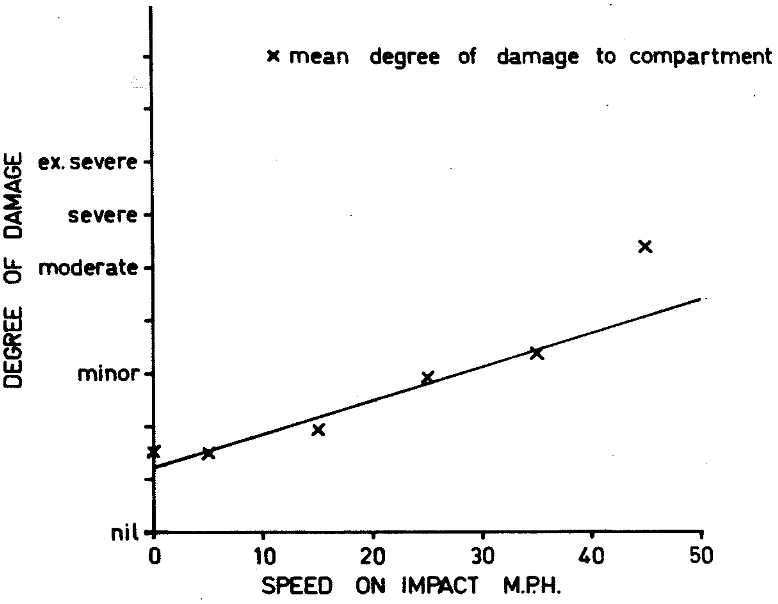


Fig. 9.7
Damage to passenger compartment by speed on impact, all cars.

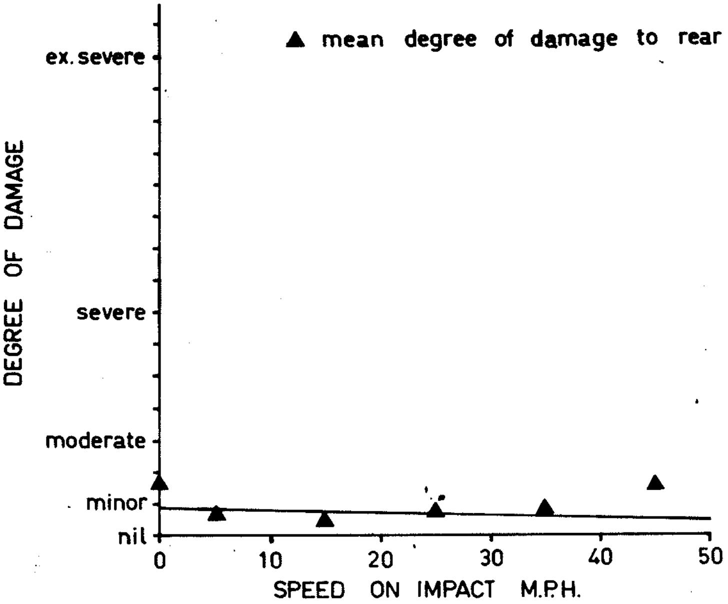


Fig. 9.8
Damage to rear by speed on impact, all cars.

However, considerable differences in repair costs can exist even between cases involving similar cars with apparently similar degrees of damage (Ref. 37). This can be due to a greater amount of damage to the motor or transmission in one of the cars. Smaller differences arise from the quality of the repair work. Some insurance companies seem to insist on replacing damaged body panels with second hand panels from wrecked cars. These are naturally less expensive than new panels.

9.20 I have tried to minimize the effect of such variations by dividing the cost of repair (A) by the current market value of the vehicle (B). A booklet published by a motoring journal has been used as a guide in estimating the market values of these cars (Ref. 39). Some allowance has been made for the general condition of each vehicle. The market values for the two cases cited above were £30 and £2,400 respectively. These give 'cost of repair over market value' figures of 0.50 and 0.19. The average value for moderate damage is 0.24, based on 35 cases. The values for all degrees of vehicle damage are listed in Table 9.3.

TABLE 9.3

Values for Different Degrees of Vehicle Damage

Degree of Overall Damage	A/B	Range of A/B	No. of Cases
Minor	0.05	0.03-0.08	2
Moderate	0.24	0.09-1.00	35
Severe	0.62	0.28-1.00	44
Extremely severe	1.00	all 1.00	5

(Cars only: from Table 9.2A)
A = Cost of repair. B = Market value.

It will be appreciated that an upper limit of A/B = 1.00 is to be expected even with moderate damage. With only two exceptions among these 86 cars, a value of 1.00 represents a 'write off', i.e. the car was not repaired because the cost of repair would have exceeded the market value of the car.

9.21 The average values of A/B shown above are in the ratios 1:5:12:20 from minor through to extremely severe. When these ratios are compared with the median values of each range of the overall damage scale (Chapter 3) it can be seen that there is a remarkably close correlation (Table 9.4).

TABLE 9.4

Indices of Repair versus median values of Overall Damage Index

Overall Damge Index Scale	 Median values	(Cost of Repair/Market Value) x 20
Minor	1.5	1.0
Moderate	5.0	4.8
Severe	11.0	12.4
Extremely severe	22.5	20.0

9.22 This shows that these two ways of rating the degree of damage to a car can give very similar results. It should be emphasised that these are two distinctly different methods. The fact that they agree so closely may perhaps be taken as some encouragement for the continued use of the present ratios between the median values of the damage ratings, viz. 1.5:5.0:11.0:22.5. for minor through to extremely severe damage on the overall damage scale. These ratios originally arose from an attempt to avoid anomalous results when basing the overall damage assessment on the three section damage ratings. For example, if the ratios were simply 1:2:3:4 for minor through to extremely severe, then moderate damage to two sections of the car would be given the same value as extremely severe damage to the passenger compartment. With the chosen ratings for section damage, viz. 1:3:7:10, the former case has an overall damage value of 6 which is in the moderate overall damage range, and the latter case 10, which is in the severe overall damage range. Discrepancies can still arise with this system, but they do so less frequently than with the 1:2:3:4 ratios between classes of damage.

Time taken to complete Repairs.

9.23 In some cases I have been able to present the length of time taken to repair the vehicle. This appears to be subject to extraneous circumstances far more than does the cost of repair. For example, the dust scarcely settles around a taxi before repairs commence, whereas a vehicle used for private purposes may be untouched for a week or more. Repair times are listed for 41 cars in Table A9.1. Naturally the length of time taken is related to the amount of damage. Average times are listed in Table 9.5.

TABLE 9.5

Average Times for Repairs.

Degree of Overall Damage	Average Repair Time	No. of Cases
Minor	2 days	1
Moderate	2+ weeks	23
Severe	3.1/2 weeks	16
Extremely severe	2+ months	1

Roadworthiness.

9.24 Accurate estimation of the roadworthiness of a vehicle that has been involved in an accident is complicated by the often extensive collision damage. I lacked the authority and time to make a sufficiently detailed examination of the roadworthiness of each of the vehicles covered by our survey. Therefore I wish to make it quite clear that I did not attempt a comprehensive inspection of these vehicles for roadworthiness.

9.25 However there were only two cases, both single vehicle accidents, in which deficiencies in the roadworthiness of the vehicles were obviously of more than minor importance in the causation of the accident (these two cases represent 0.5 per cent of all accidents in the survey). There were other cases, such as one in which car fitted with a tinted glass windscreen crashed into the rear of a stationary car which was about to turn right. This accident happened at night and it is possible that the driver of the striking car may have been able to have avoided the collision had his sight distance not been reduced by the tinted screen. However, the fact that deficiencies in roadworthiness were not more obvious reflects both the extremely complex nature of the metropolitan traffic accident, which can rarely be attributed to one specific cause, and the minor part that the roadworthiness of vehicles seems to play in such accident causation.

9.26 A programme of compulsory vehicle inspection should be sufficiently comprehensive at least to ensure that unroadworthy vehicles do not become more significant as a cause of accidents. But the considerable cost of such a programme must be related to the possible benefits. There are so many ways in which action can be taken to try to reduce the frequency of traffic accidents that some order of priority must be established if the maximum return is to be obtained from such efforts.

DAMAGE TO THE INTERIOR OF THE CAR.

CHAPTER 10

10.1 It should be obvious that injuries to car occupants are almost invariably caused by contact with some part of the interior of the car. There are exceptions, of course, particularly the case of an occupant who is ejected from the car and who generally receives additional, often serious, injuries from striking the road. In the metropolitan traffic accident the great majority of car occupants remain inside the vehicle in an accident. We tried in each case to relate each injury to the part of the interior of the car which caused it. We also noted the damage to the interior of the car, and tried to determine whether this was a direct consequence of damage to the vehicle body or whether it was mainly due to the occupants being thrown around inside the car.

10.2 The incidence and probable cause of damage to four components, the steering wheel, the instrument panel, the header area and rear vision mirror, and the front seat, are presented here.

10.3 Of the 553 cars in this survey there were 20 which were parked and had no occupants. A further 143 cars were excluded because they struck pedestrians, pedal cycles, or motor-cycles. In these accidents little or no damage is caused to the interior of the passenger compartment. This left a total of 390 cars.

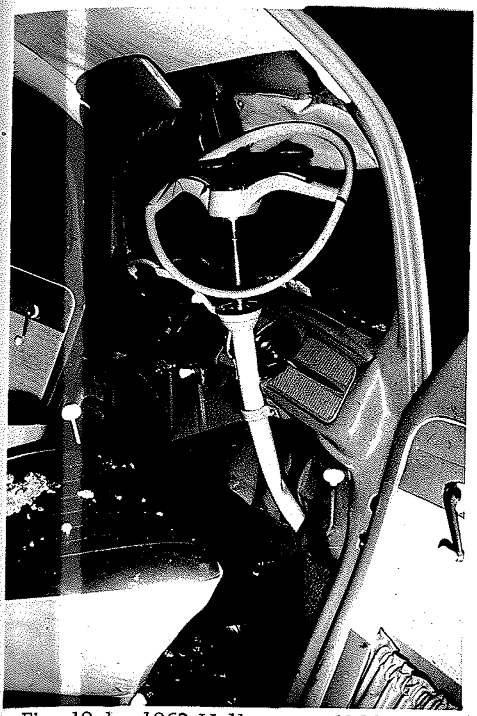


Fig. 10.1 - 1962 Volkswagen 1200 steering column forced back in a head-on collision with another car. Note also the dent in the header strip made by the driver's head and the shoe trapped by the pedals.

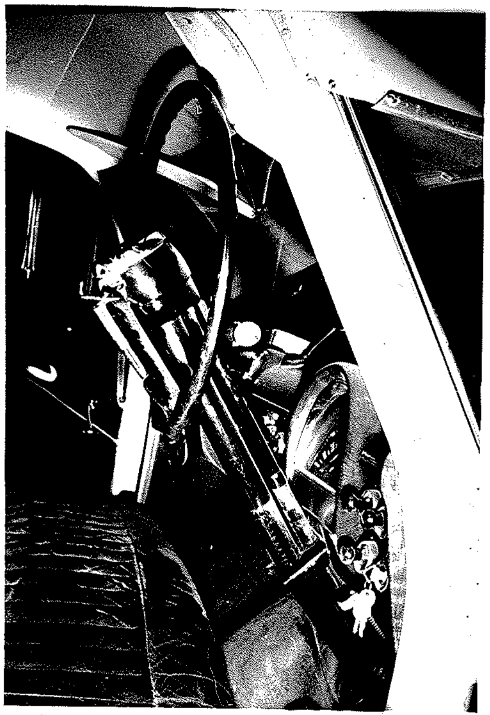


Fig. 10.2 - 1953 Ford Customline two-spoke steering wheel damaged by the driver being thrown against it. The collision, with a tree, has forced the steering column back four inches.

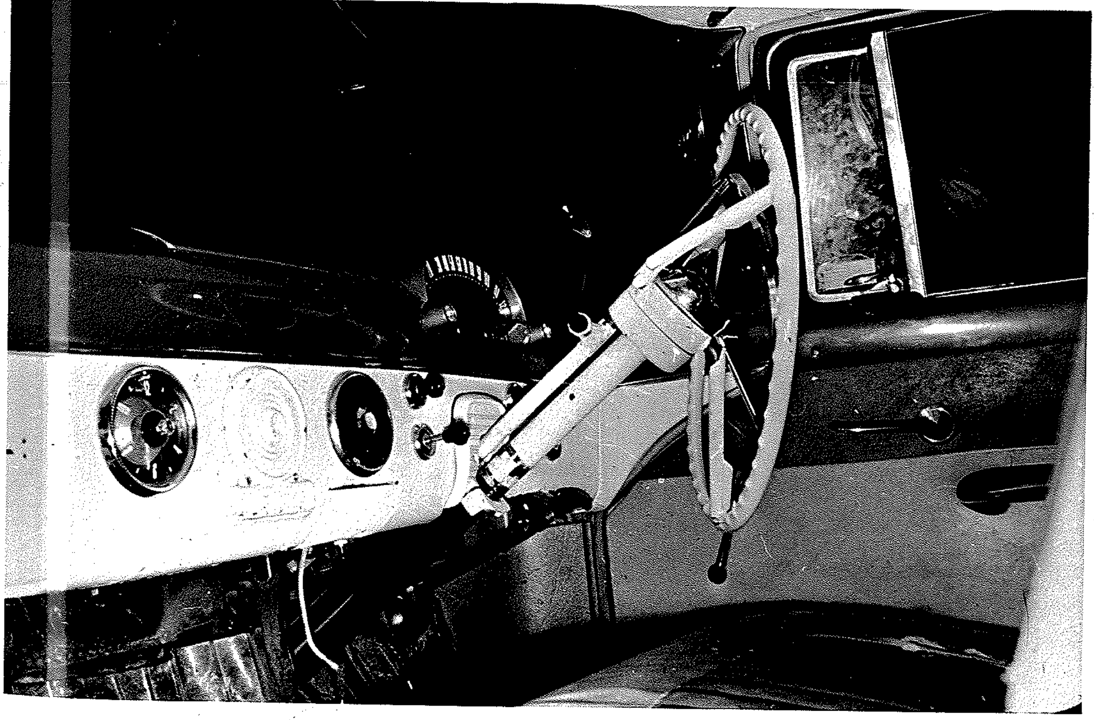


Fig. 10.3

Three-spoke 'dished' wheel of a 1957 Ford Customline, damaged by the driver being thrown against it in a head-on collision with another car.

Steering Wheel.

10.4 One hundred and twelve of the 390 cars we are considering (28.7 per cent) had the steering wheel damaged by an occupant, usually - but not always - the driver, being thrown against it. In 62 cases the wheel was only slightly bent or cracked, but in 50 cases it was severely damaged. The spokes of the wheel sometimes failed, allowing the occupant to strike the far more solid hub of the wheel (Figs. 10.1 and 10.2). This impact with the hub can be reduced in severity or even avoided altogether by recessing the hub of the wheel. Such a design is often termed a 'dished' wheel. A case in which a wheel of this type has deflected the driver away from the hub is shown in Fig. 10.3. This particular wheel - the car is a 1957 model Ford Customline - has three spokes. This seems to be more effective than having a wheel having only two spokes. e.g. Figs. 10.1 and 10.2, whether such a wheel is dished or not. It is surprising therefore that the latest models of Ford cars are fitted with a two-spoke wheel.

10.5 A comparison is now made between the damage to the steering wheels of two makes of cars, Holdens and Volkswagens (Table 10.1). These two makes are chosen because they appeared frequently in the accidents covered by our survey and also because the design and arrangement of the interiors of these two makes of cars are different. The Holden has been considered in three model groups, first the early models up to and including the FJ series, then the FE, FC, FB and EK models and finally the EJ and EH models.

TABLE 10.1

Comparison of Damage to Steering Wheels

Make & Model of Car	Damage to Steering Wheel (by Occupant Contact)		Total cars involved	Percent damaged
	Minor	Severe		
Holden (FX, FJ)	3	4	39	35.2%
Holden (FE to EK)	17	15	91	18.0%
Holden (EJ, EH)	4	1	21	23.8%
Volkswagen 1200	11	2	31	42.0%
	35	22		

This table suggests that the steering wheel of a Volkswagen is more likely to be damaged by the occupant being thrown against it than is the case for any model of the Holden. The damage to the wheel is unlikely to be severe however. This may be because the wheel is close to the instrument panel and the occupant will be restrained by hitting the panel and the windscreen area as well as the steering wheel.

10.6 Note that it is not necessarily a good thing that the wheel should be only slightly damaged. If the driver is thrown against a wheel which bends easily he is less likely to be injured than he is if the wheel is very strong and rigid, unless he strikes the hub of the steering wheel.

10.7 In two of the 35 cases in Table 10.1 in which the steering wheel received minor damage, two drivers sustained small abrasions to their lips from striking the upper rim of the steering wheel. In the other 33 cases no definite relationship could be established between the damage to the steering wheel and an injury, if any.

10.8 In the 22 cases of severe damage to the steering wheel there were 12 cases where no occupant injury could be related to the damage to the wheel. There were six cases of bruises to the chest, one laceration of a lip and two cases of fractured ribs. One case of severe facial lacerations and fractures occurred when the occupant struck the steering wheel hub. One of two cases of fractured ribs was in a Volkswagen; the other was in an FE model Holden. Therefore in this series of 57 cases the most severe injuries occurred when the occupant struck the hub of the steering wheel. All other contacts with the steering wheel produced little or no injury.

10.9 The illustrations to this section (Figs. 10.1 and 10.2) show that the steering column is sometimes pushed further back into the passenger compartment. (Note the mark on the column, shown in Fig. 10.2, adjacent to the mounting clamp on the instrument panel.) This is usually a consequence of an impact on the front of the car. There are some models which are very poorly designed in this regard. Of the cars in these 408 accidents the one in which the steering column proved to be the most dangerous was the Volkswagen. This does not necessarily mean that the steering columns of some other models of cars are not also dangerous.

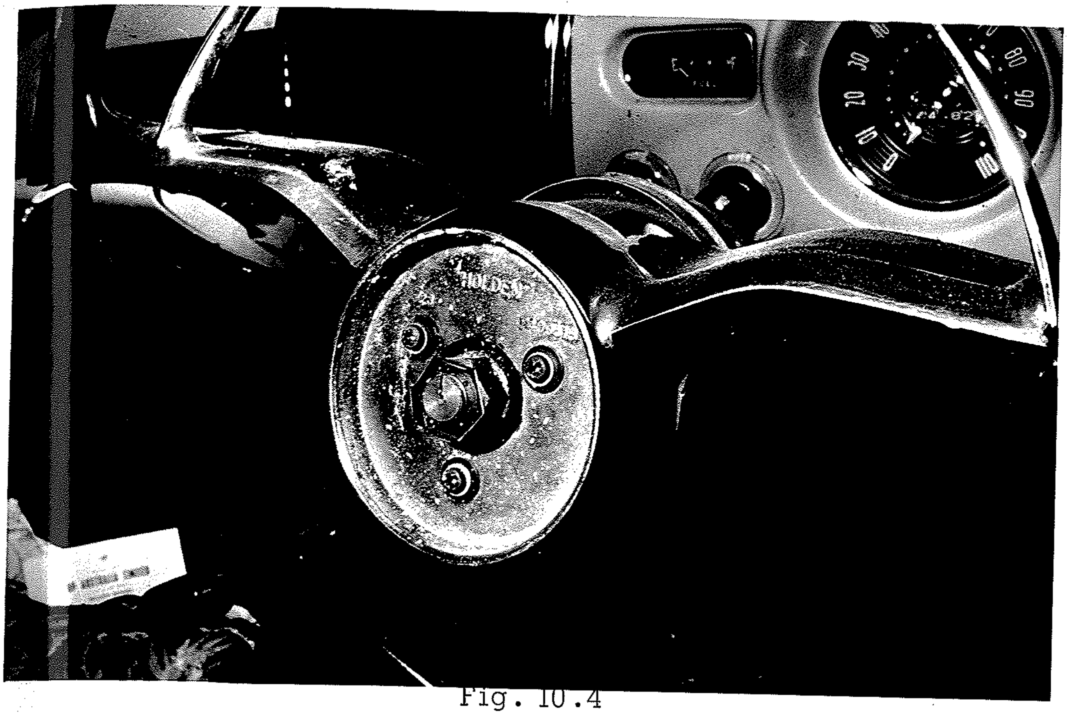


Fig. 10.4
Holden steering wheel hub. Note flanges broken off the tab washer. It is not known whether the plastic cover was in place before the accident.

Fig. 10.5
Severe facial lacerations from being thrown against the steering wheel hub shown in Figure 10.4.

The Volkswagen is specified because of the following case. The driver of the car shown in Fig. 10.1 is now a quadraplegic as a result of the injuries he sustained in this accident. If the steering column of his car had not been forced back nearly 10 in., this driver might not have received such serious injuries. It is unfortunate that this model could have been produced for so many years without the manufacturers realizing the injury potential of this steering column.

10.10 Much of the trim, eg. horn button or horn ring, on or around the steering wheel can aggravate injuries. Figure 10.5 shows the extremely disfiguring injuries which can result from contact with a steering wheel hub (Fig. 10.4). There were also some cases in which the horn ring had broken and the jagged end lacerated the driver's arm.

Instrument Panel.

10.11 One hundred and thirty-six or 35 per cent of these 390 cars had the instrument panels damaged by the occupants being thrown against them. The panels of 100 cars received minor damage (bent knobs, etc.) and 36 were severely damaged (large dents). The bent control knob shown in Fig. 10.6 is an example of minor damage. It fractured the driver's knee cap. Fig. 10.8 shows a case of severe damage to an instrument panel, and Fig. 10.7 the resulting injury to the driver's knee.

10.12 The same three model groups of Holdens and Volkswagen 1200

Fig. 10.6
Interior of 1955 Ford Mainline which collided with the Volkswagen shown in Figure 10.1. Note that the steering column has been forced back only half an inch. Arrow indicates control knob which fractured the driver's knee-cap.

Fig. 10.7
Injuries caused by striking the instrument panel shown in Figure 10.8.

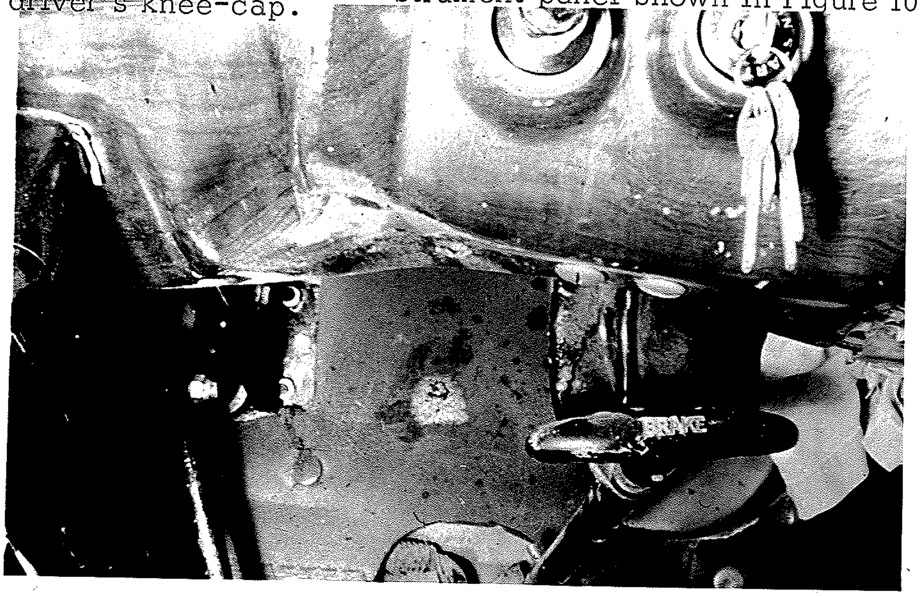


Fig. 10.8
Dent in instrument panel of Ford Customline made by driver's knee. Note flesh mark on bulkhead.

are now compared for the reasons stated earlier in this Chapter.

TABLE 10.2

Comparison of Damage to Instrument Panels.

Model of Car	Damage to the Instrument Panel (by Occupant Contact)			
	Minor	Severe	Total number of cars	Percent damaged to any degree
Holden FX, FJ	11	6	39	46.2%
Holden FE to EK	21	6	91	29.7%
Holden EJ, EH	6	0	21	23.9%
Volkswagen 1200	6	5	31	35.5%

10.13 In the 44 cases of minor damage the injuries sustained were

(a) 16 cases of superficial injuries to knees, shins and thighs,

(b) 1 case where both knee caps were fractured on the lower edge of the instrument panel (Figs. 10.9 and 10.10),

(c) 1 case where both lower legs were fractured on a home-made parcel shelf below the instrument panel.

In the 17 cases of severe damage there were

(a) 2 cases where no injury could be related to the damage.

(b) 13 cases of superficial injuries.

(c) 2 fractures of the midshaft of the femur.

(d) 1 case of dislocation of the hip.

One of the cases of fracture of the femur and the dislocated hip occurred in the same car.

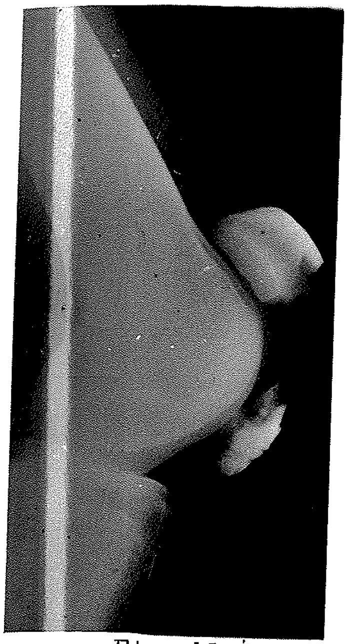


Fig. 10.9
Fractured knee-cap, resulting from striking the instrument panel shown in Figure 10.10.

Figure 10.10
Arrow indicates dent made by driver's knee in Holden instrument panel.

Fig. 10.11
Passenger's knees struck the front of the instrument panel. Arrow indicates teeth marks in upper surface of metal panel.

10.14 From this it appears that the majority of injuries caused by the instrument panel are minor, in accidents in the metropolitan area. These minor injuries could be minimized, and the more serious ones reduced in severity, if the instrument panel were designed to present a smooth projection-free surface to the occupants, and to deform readily when struck. The dent in the top of the panel shown in Fig. 10.11 was made by the passenger's face. Several of her front teeth were fractured.

10.15 A first step in the redesign of the instrument panel has been to add 'crash padding' in some cars. This has been shown to reduce the frequency of minor injuries caused by striking that particular part of the panel (Ref. 40). In some models it has not been located where the occupants most frequently hit the panel (Figs. 10.9 and 10.10). In other cases the padding consists only of a thin layer of sponge rubber set over what feels to be a rigid metal section. Sponge rubber in this form may feel soft to the touch, but it can absorb only a negligible amount of the force of the impact of a person who is hurled against the panel. The most promising approach would seem to be to design the entire instrument panel area to crumple on impact, thereby minimizing the deceleration forces and the degree of injury sustained by the occupants.

Rear Vision Mirror and Header Area.

10.16 In 50 cases, or in 12.8 per cent of these 390 cars, an occupant hit the rear vision mirror. In 9 cases there was no resultant damage to the mirror. In the other 41 cases the damage to the mirror varied from a bent standard to shattered glass and/or a fractured standard which left a jagged end exposed.

10.17 The same four groups of cars are compared again here. Unfortunately, as far as this analysis is concerned, there are not many cases.

TABLE 10.3

Comparison of Damage to Rear Vision Mirrors.

Model of Car	Damage to the Rear Vision Mirror (by Occupant Contact) Cases of damage	Total number of cars	Percent damaged
Holden FX, FJ	3	39	7.7%
Holden FE to EK	3	91	3.3%
Holden EJ, EH	3	21	14.3%
Volkswagen 1200	7	31	22.5%

10.18 The last two groups may have a higher rate of occupants hitting the rear vision mirror because the mirrors are closer to the occupants than they are in the models in the first two groups. However, a car having a driver and a passenger may be twice as likely to have an occupant hit the rear vision mirror as a car which has only one occupant, the driver. The average number of occupants in the front seats of all these 180 cars was close to 1.5 of the three groups of Holdens but was almost 1.8 for the Volkswagen. This variation alone is not sufficient to explain the higher rate of occupant contact with the rear vision mirror in the Volkswagen.

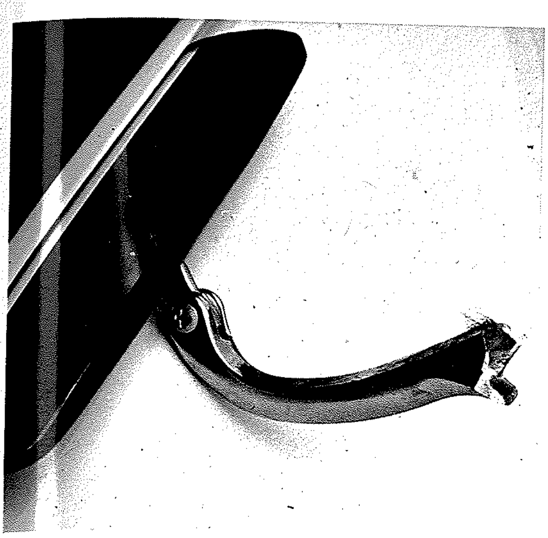


Fig. 10.12
E.J. Holden rear vision mirror standard. Note hairs and skin on jagged end.

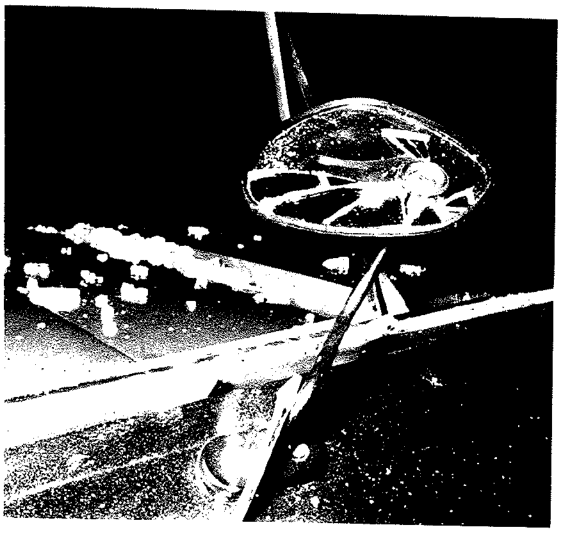


Fig. 10.13
Rear vision mirror of a 1963 Renault R4, broken when struck by an occupant.

Fig. 10.14
Holden sunvisor pivot mounting. Note skin and hair.

Fig. 10.15
Laceration in driver's forehead, produced by the sunvisor pivot shown in Figure 10.14.

10.19 The injuries in these 16 cases were mostly concussions and lacerations. The lacerations from the mirror itself were not very severe but they were located around the forehead and eyes. Facial lacerations of any type may leave a permanent scar and possibly impair muscular control. This alone is sufficient to cause concern, without the additional hazard to a person's eyesight.

10.20 In one EJ model Holden the rear vision mirror standard fractured, exposing a jagged end (Fig. 10.12), which lacerated the driver's forehead. Attempts have been made to obviate this by mounting the mirror on a more flexible arm, but this does not prevent the mirror from breaking, e.g. Fig. 10.13. Mercedes Benz have designed the rear vision mirror to be readily knocked away from the mounting on the header area, complete with the mounting arm. Even this is only a partially effective solution. The effect on an occupant who hit this mirror at an (occupant) impact speed of, say, 20 m.p.h. would be no less than if this mirror and mounting arm assembly were thrown at the occupant's face at the same speed. The inertia of any assembly which is designed to be knocked away is very important.

10.21 The requirements for a safe rear vision mirror are therefore

(a) glass which will not, when broken, expose sharp edges or small, sharp fragments;

(b) low inertia, both in regard to the mass of the mirror assembly and to the force required to knock it aside.

10.22 It is realized that these may be conflicting requirements, and that (b) in particular is limited by the need for vibration-free and sufficiently large mirrors. One means of achieving a reasonable field of view from a small mirror is to use a magnifying mirror, as in the case with some Rover cars. This is not a satisfactory approach, for a magnifying mirror gives the illusion of much greater distance than is actually the case. This means that a following car will be much closer than is apparent when viewed in a rear vision mirror of this type. The ultimate solution is probably to develop external rear vision mirrors to the stage where it is not necessary to have one inside the passenger compartment.

10.23 The header area, that part of the interior of the car above the windscreen, is frequently hit by the occupants of a car involved in a frontal collision. Figure 10.14 shows the pivot mounting for a Holden sun-visor. The tell-tale strands of hair were left by the driver (Fig. 10.15). Because the occupant's head strikes this area, the resulting injuries can be dangerous to life. The basic design of the header area should therefore allow for a controlled rate of deformation on impact which will keep decelerations below the dangerous-to-life injury threshold.

Front Seat.

10.24 Damage to the front seats of cars arose from two main causes.

The less frequent cause was direct collision damage: 25 cases in the 390 cars, or 6.4 per cent. Seats were more often damaged by inertia forces of the seat itself and/or the occupants. There were 66 such cases, or 16.9 per cent of all these 390 cars.

10.25 The following comparison is between the three model groups of Holdens and the Volkswagen and also two basic types of seat, the full width bench seat (Holden) and the separate 'bucket' seats (Volkswagen). The only type of damage to the seat that is being considered here is that due to inertia forces and/or occupant contact.

TABLE 10.4

Comparison of Damage to Front Seats

Model of Car	Damage to Front Seat (Due to Inertia of Seat or Occupant Contact)		
	Cases of damage	Total number of cars	Per cent damaged
Holden FX, FJ	4	39	10.3%
Holden FE to EK	8	91	8.8%
Holden EJ, EH	2	21	9.5%
Volkswagen 1200	10	31	32.2%

The Volkswagen is a lighter car than any model of the Holden, and therefore more likely to be subjected to higher decelerations in a collision with another car. But this difference alone cannot account for the poorer performance of the seat mountings of the Volkswagen.

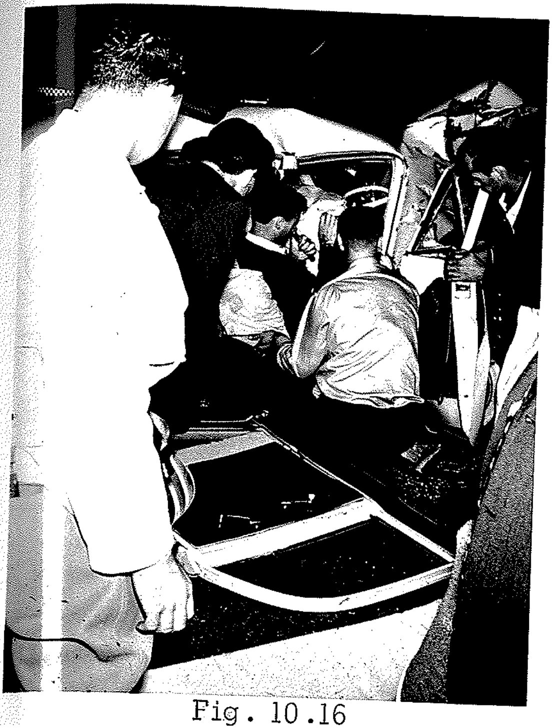


Fig. 10.16
Driver trapped in an FX Holden by the front seat, which moved forward in the collision.

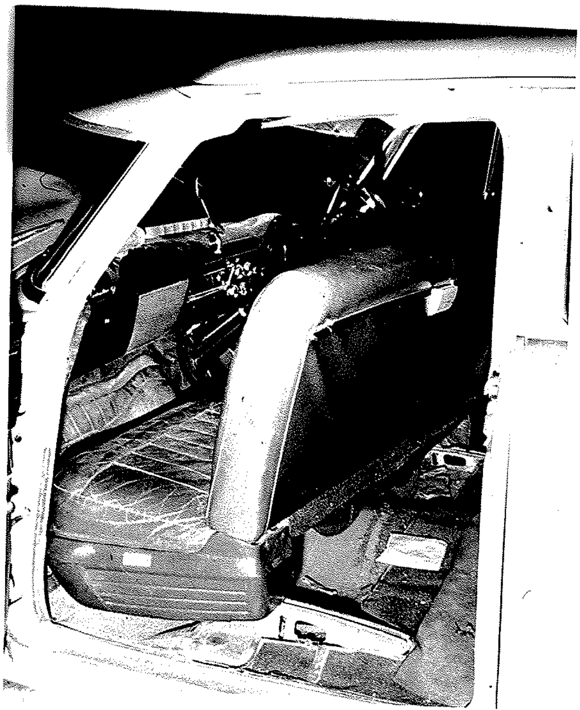


Fig. 10.17
Front seat completely off adjustment runners, 1953 Ford Customline.

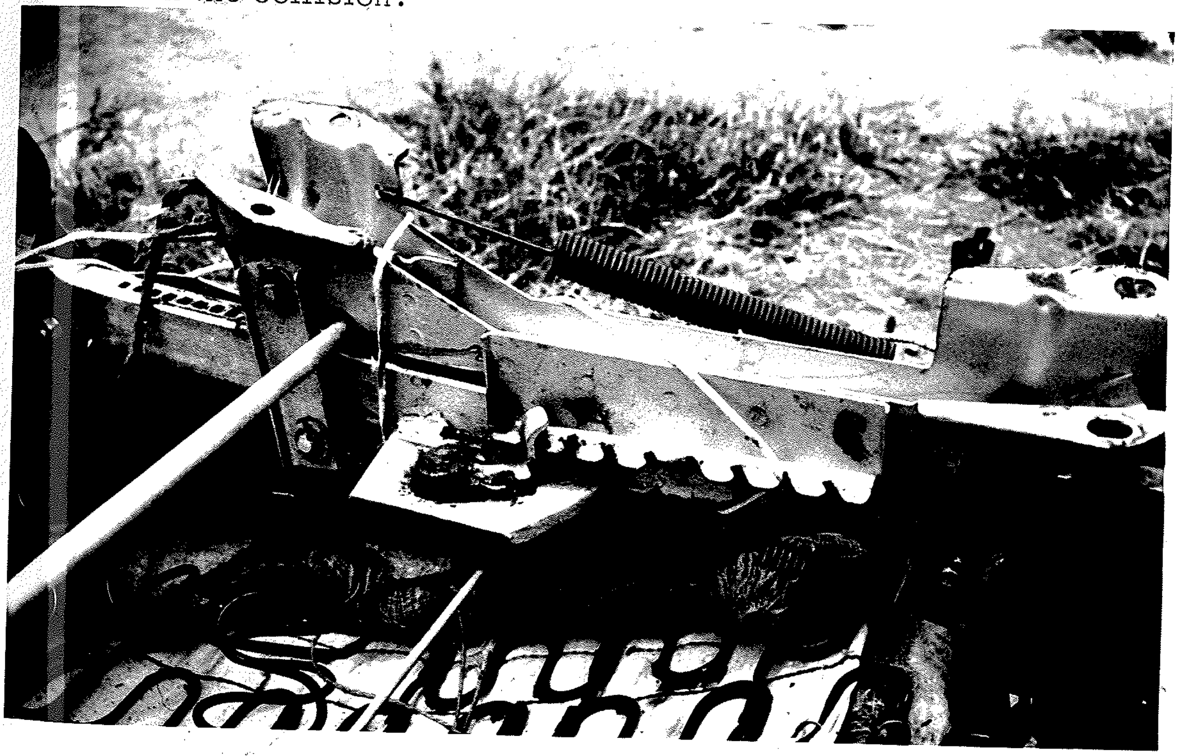


Fig. 10.18
Seat adjustment locking mechanism (passenger's side) of the 1952 FX Holden shown in Figure 10.16.

10.26 Failure of the seat mountings, whether it is failure of the adjustment catch or complete failure of the mountings, means that the front seat occupants are forced by the front seat up against the instrument panel and steering wheel in a frontal impact. This additional force alone is bad enough, but in some cases, particularly with the 'bench' seat, the seat may become jammed, wedging the occupants up against the instrument panel. Fig. 10.16 shows ambulance men, police and tow truck drivers working to release a driver who has been trapped in this way. The seat had come forwards and the damaged adjustment (Fig. 10.18) prevented it from being pushed back. The driver, who had a severe compound fracture of the right femur, was released after the seat had been unbolted from the floor of the car. The whole procedure took nearly three quarters of an hour. In some cases the complete seat will come off the adjustment runners (Fig. 10.17). While this is less likely to trap the occupants it obviously will increase the force of the impact with the instrument panel or steering wheel.

10.27 Rear end impacts also place a considerable load on the seat mountings. Fig. 10.19 shows a case in which the mountings failed and the occupants were thrown against the back of the back seat and struck their heads on the rear window surround. The window was broken and the surround dented. The occupants were both concussed.

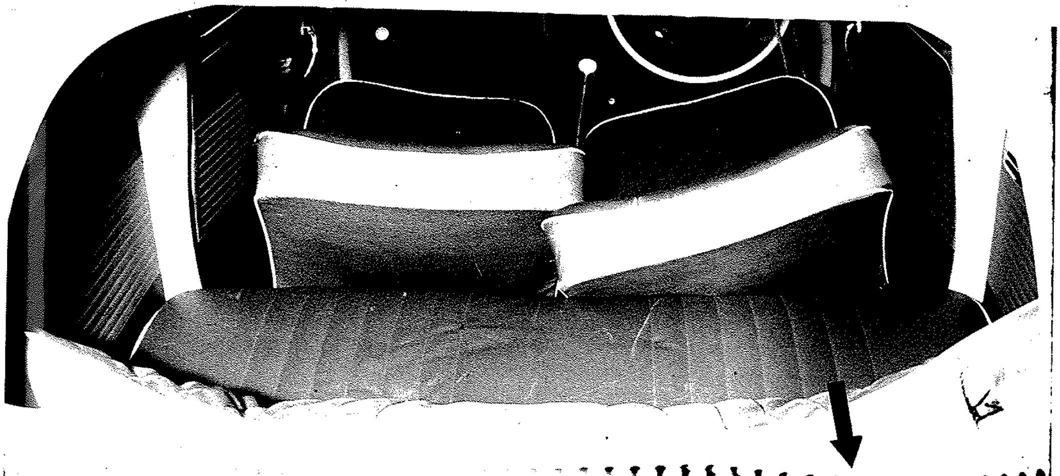


Fig. 10.19 - The front seat mountings of this 1960 Volkswagen failed when it was hit from the rear by another car. Note the damage to the back of the rear seat, and the dent (indicated by arrow) below the rear-window, which was made by the driver's head.

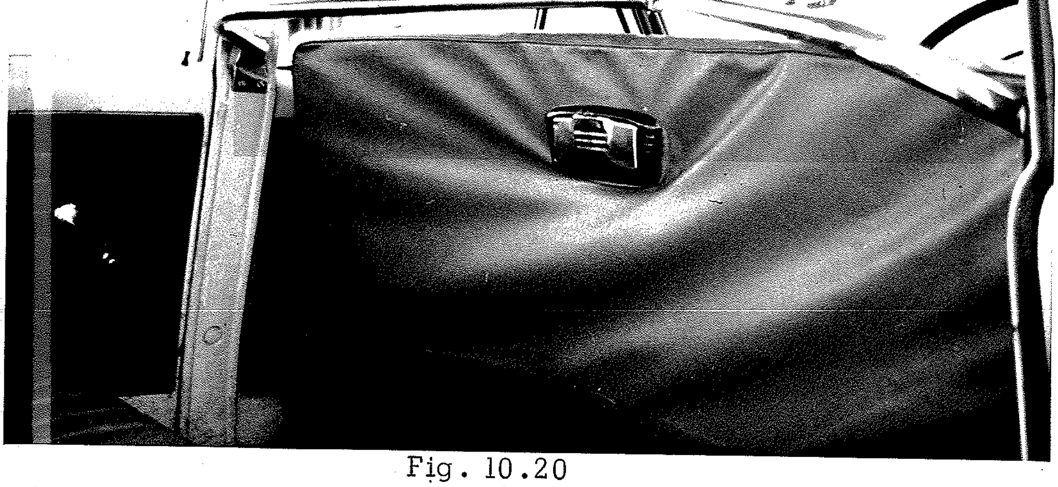


Fig. 10.20
Handrail of a 1959 FC Holden taxi, struck by a rear seat passenger.

Fig. 10.21
'In 1910 the safety or packaging of the rear seat passengers was not considered very important compared with the exposure to severe weather. Heavy brass robe rails were attached to the seat back." (Figure 12 from Ref.41.)

10.28 Passengers in the back seat will obviously hit the back of the front seat in frontal impacts. This is one way in which injuries can be directly attributed to the design of the seat and associated fittings. For some years it has been possible to buy Holdens that are fitted with a hand rail across the back of the front seat. This is, of course, directly in front of the rear seat passengers, who are thrown against it (Fig. 10.20). Perhaps consideration for the safety of car occupants has not advanced as far as the following caption to an illustration (Fig. 10.21) from Reference 41 would have us believe. "In 1910 the safety or packaging of the rear seat passengers was not considered very important compared with the exposure to severe weather. Heavy brass robe rails were attached to the seat back."

AUTOMOBILE GLAZING

CHAPTER 11

11.1 The first use of glass in automobiles was as a screen to protect the driver from wind and rain. Later, as the all enveloping saloon body became popular, side windows and rear windows were added. The prime concern was to ensure that the windscreen provided adequate visibility, and this required high optical qualities in the glass. Before long, however, the injury-producing potential of this glass became obvious for, of course, the glass could be broken in a collision or by the occupants of the vehicle being thrown against it. Normal annealed glass broke into large fragments, the edges of which had a razor sharpness. This led to the first attempts to produce a safety glass. Safety glass as now defined by British Standard 857 (Ref. 42) is "a glass which, after fracture, gives fragments which are less liable to cause severe cuts than those of ordinary glass". The American Standards Association has drawn up a similar standard for safety glazing materials (Ref. 43).

11.2 It was not until the year 1930 that safety glass was legally required in the windscreens of motor cars in the United Kingdom. Four years later, in 1934, some States of the U.S.A. introduced legislation requiring that motor vehicles be equipped with safety glass. These regulations are unique in that they were the first and, until recently, the only laws which had as their purpose the minimising of the effects of accidents. (Ref. 2).

11.3 The two chief types of safety glass used in automobiles today are laminated and toughened, or tempered, glass. These two types of safety glass have different properties and in the words of the American Standard Z.26 "one safety glazing material may be superior for protection against one type of hazard while another may be superior against another type. Since accident conditions are not standardised, no one type of safety glazing material can be shown to possess the maximum degree of safety under all conditions, against all conceivable hazards".

11.4 Laminated glass consists of two sheets of annealed glass with a relatively thin transparent plastic inter-layer between them. It has the characteristics of a single sheet of annealed glass except that in the event of fracture the inter-layer holds the pieces together and prevents sharp edges from being exposed. Should the screen be penetrated by the striking object then sharp jagged edges are exposed and there is the attendant risk of injury to a person striking them. The main concern in the development of laminated glass has been to minimise its injury potential rather than to improve its optical qualities.

11.5 Toughened glass windscreens are made from a single sheet of plate glass which has been heat treated in manufacture to stress the surfaces of the glass. The glass retains a high resistance to bending because of this prestressing, hence the term "toughened glass". Because this toughening is normally accomplished by heat treatment the American term for this type of safety glass is "tempered glass". The internal stresses in the glass are normally in equilibrium, but in the event of the glass being broken the entire screen fractures immediately into small particles. The edges of these particles are not sharp, and until recently the toughened glass screen was not thought to be a significant cause of injury. Further development of the toughened glass windscreen has therefore had as its prime aim improving visibility through the broken screen.

11.6 The characteristics of these two types of safety glass are further discussed in Reference 30. The literature on the subject will be briefly reviewed here under the two main headings of visibility and injury production. It will be noted that only toughened glass is considered under the former heading. Laminated glass generally permits adequate visibility, even when cracked.

11.7 The American Standard for windshield glass is so worded as to preclude the use of toughened glass. The relevant test in this standard is a dart penetration test. A dart when striking a laminated screen will, up to a certain impact speed, be arrested by the plastic inter-layer between the two sheets of glass. Such a dart when striking a toughened glass screen will cause the screen to shatter and allow the dart to pass through. Because visibility from a car is only critical through the windscreen, there has been little or no work done in America to control the fracture pattern of toughened glass to ensure adequate visibility.

Visibility.

11.8 The early attempts to produce a toughened glass windscreen concentrated more on protection from injury than on ensuring adequate visibility through a fractured screen. Consequently the British Standard 857 (Ref. 42) for 1949 specified that there should be at least 40 glass particles per square inch on a fractured toughened glass windscreen. Work done at the Road Research Laboratory in Britain showed that such a screen, which is said to have a 40 particle count, so restricted visibility that it was not safe to go at more than a walking pace after the screen had been fractured. A screen which broke into larger fragments, in the order of 20 to one square inch, permitted reasonably safe travel at speeds up to 20 m.p.h. Due allowance was made here for the additional restriction in visibility after fracture due to the normal inclination of the windscreen of a vehicle. (Ref. 44.) These tests were performed under realistic conditions in which the windscreen glass was shattered while the car, in which the observer was seated, was moving. The observers found it much easier to see through a shattered glass windscreen at night than in the daytime, and it appears that the intensity of the incident light is a critical factor.

11.9 Attempts were then made to resolve this conflict between adequate visibility and protection from injury after fracture. Lister (Ref. 45) describes some of the work of the Road Research Laboratory which led up to recent changes in the British Standard 857 to allow for modified zones in toughened glass windscreens. By varying the degree of toughening across the screen it is possible to have a relatively low particle count in the area directly in front of the driver, thereby ensuring adequate visibility in the event of fracture of the screen. This work is also discussed in Ref. 30.

11.10 The sudden shattering of a toughened glass windscreen is accompanied by a loud bang, almost after the nature of a small explosion. Quite apart from the serious reduction in visibility it has been suggested that this unexpected event may cause the driver to lose control of his vehicle. The Road Research Laboratory investigated accidents on the London/Birmingham Motorway and, finding that none of these accidents was caused by the shattering of a windscreen, concluded that this phenomenon was not a serious cause of accidents. Far more convincing information on this matter has been provided by Ameling, of the Main Roads Department, Western Australia (Ref. 46). His study of claims handled by an Insurance Company and also Police Accident Records for the State of Western Australia showed that one subsequent accident resulted from an average of 450 cases in which windscreens were broken by flying objects. In the metropolitan area of Perth one accident in 10,000 was due to this cause. In the country areas the ratio was one in 750.

Injuries from broken glass.

11.11 Schwimmer and Wolf (Ref. 13) analysed A.C.I.R. accident data and found that 11.3% of all car occupants were injured by the windscreen. (Their study considered only 1956 and later model cars in America.) While this percentage may appear to be high it must be recognised that there are many components which can cause injury. This study in fact showed that the windscreen was the third most common cause of injury to car occupants. As it was an American study the windscreens were all of laminated glass.

11.12 The British Standard 857 (Ref. 42) in its latest revision, 1964, makes only one direct mention of the injury potential of broken safety glass. "To reduce the injury potential of particles retained in the glazing channel after fracture of a windscreen, a margin of highly stressed glass at least 2.1/2" wide is required all round the glass, and the glass between that margin and the zone itself is permitted to have fracture characteristics not coarser than that of the zone." The British Standard tests for laminated glass do control the total weight of the fragments, both collectively and individually, which may separate from a laminated glass specimen. This concern is obviously related to the injury potential of the glass but this is not explicitly stated.

11.13 The lacerative potential of broken glass is obvious, but it appears that the more serious injuries that have been received from striking windows and windscreens of cars are those of a concussive nature. The risk of concussion is closely related to the force required to break the sheet of glass. Shand (Ref. 47, p.215) lists the strength of three types of glass. Laminated glass, as found in motor vehicles, requires a lower force to cause failure than does ordinary plate glass. Toughened glass is much stronger than ordinary plate glass, therefore the risk of concussion could be expected to be greater with toughened glass than with laminated glass.

11.14 The increasing use of toughened glass in the side windows of American cars, along with developments in laminated glass, has stimulated work aimed at minimising concussion injuries. One of the initial problems was to establish human tolerance levels for this type of injury. Work at Wayne State University by Patrick has produced a human tolerance curve of deceleration against time (Ref. 48). This has enabled the interpretation of the results of experiments in which cadavers were projected into automobile windscreens and side windows (Ref. 49). Crash testing in the laboratory using human dummies has been carried out by some vehicle manufacturers (Ref. 50 and 51).

11.15 The relative advantages and disadvantages of both tempered and laminated side window glass have been compared by Severy in the series of controlled automobile collisions performed at the University of California, Los Angeles, (Ref. 37). This work has recently been extended to a series of collisions in which the main investigation was into the nature of safety glass breakage by the occupants of the vehicles (Ref. 52). The results of these controlled collisions between occupant and windscreen both in the laboratory and in vehicles involved in actual collisions can be compared with data obtained at the scene of accidents.

11.16 Rutley and Cook of the Road Research Laboratory in Britain have made a survey of the incidence of head injuries to the occupants of cars and commercial vehicles (Ref. 53). They found that toughened glass windscreens, which are more prevalent in Britain, caused fewer and less severe injuries than laminated windscreens. This work is also reported in Refs. 30 and 45. A study of 500 accidents in Germany by Friedhoff produced a similar result. Laminated windscreens were found to be four and a half times as likely to produce injury as toughened glass windscreens (Ref. 21).

11.17 In 1958 Tourin, Garrett and Moore produced a preliminary report on automobile side window glass (Ref. 54). They found that the risk of the glass cracking or shattering was greater for laminated than for tempered glass. Also, in every exposure examined, there appeared to be a higher risk of injury for laminated than for tempered glass.

11.18 Campbell and Hopens followed this preliminary report with a study plan of glazing as an injury factor in accidents (Ref. 55). They found neck injuries to be the most severe injury associated with windshields. These neck injuries were primarily lacerations resulting from complete penetration of the windscreen. Their comparison of tempered and laminated glass was of necessity confined to side windows. They were unable to find a significant difference between the injury potential of tempered and laminated glass. In fact, and in marked contrast to work in Europe, they were concerned to emphasize the similarities between the two types of glass in this regard.

11.19 Their paper is notable in that, in addition to considering injury caused directly by contact with glass, it considers ejection through glass areas and also cases in which it might have been necessary for the occupants to escape through a glass area in the event of being trapped in a wrecked vehicle. It is of interest to note that in the 30,000 cars in the Cornell sample there was not one case in which injuries to the occupants were aggravated by their being unable to escape through glass areas when the doors were jammed shut.

11.20 The study by Campbell and Hopens was sponsored by the American Standards Association, and this is one indication of the heightened interest in the design of safety glass for automobiles. Factors in the development and evaluation of safer glazing are discussed in Ref-

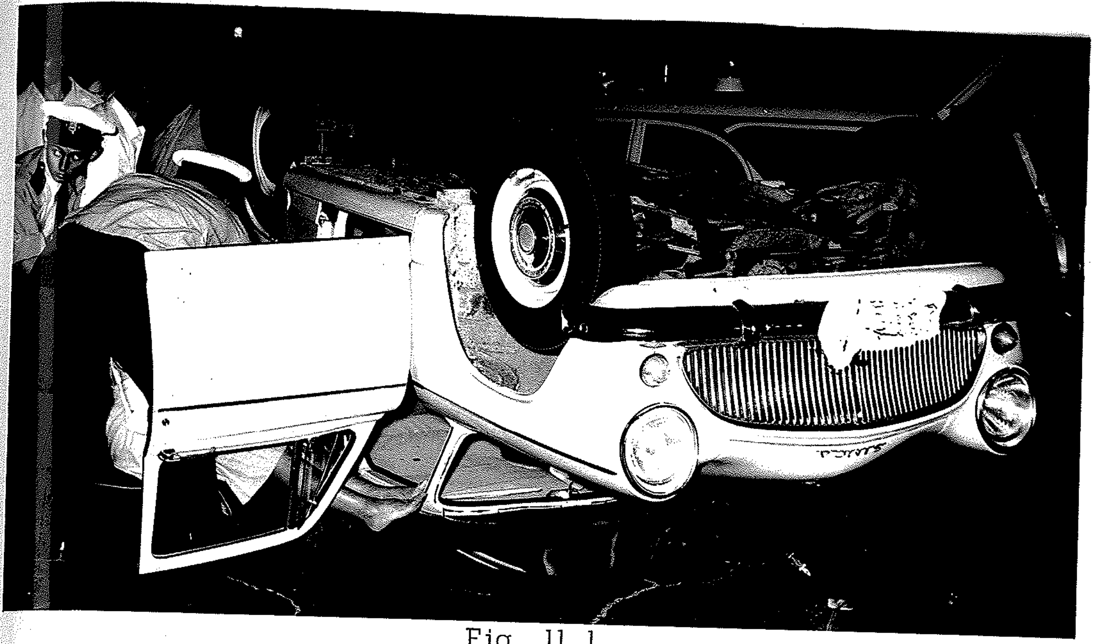


Fig. 11.1
Windscreen ejected unbroken from Simca Station Sedan on rollover.

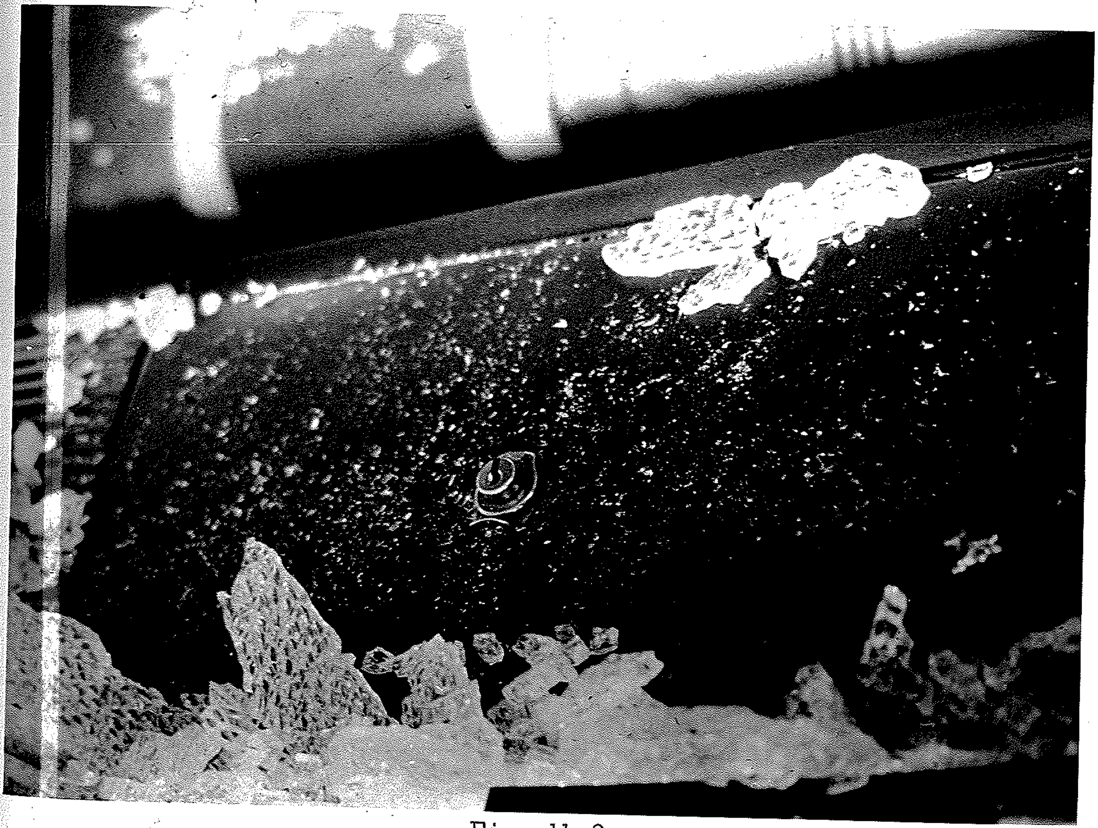


Fig. 11.2
Fine fragments of toughened glass from shattered 1962 Holden windscreen.

erence 56 by Rieser and Michaels. They conclude that "in general, the most desirable safety glass laminate appears to be one in which the rigid members fracture into a multitude of cracks with a relatively low force, thus allowing the flexible plastic inter-layer or inter-layer components to arrest the motion of the impacting object". The search for greater flexibility, and hence lower decelerations on impact together with greater penetration resistance, in laminated glass is discussed in Ref. 57. Mention is also made here of thinner tempered glass which can be produced by new quenching methods and also by chemical tempering, in which the surface is stressed by an ion-exchange process. The Society of Automotive Engineers has been developing further test procedures to ensure quality control of the newer designs of laminated windshields (Ref. 58).

Results from TARU Survey: Glass.

11.21 The information on glass reported in this survey can be classified under three basic headings, the type of glass used, the frequency and nature of failure, and the consequences of failure, especially in relation to injury to persons involved in the accident.

11.22 Greater attention was paid to windscreen glass than to side or rear window glass. Tables 11.1, 11.2 and 11.3 list the information recorded on the type of windscreen glass, the form of the windscreen, and any damage to the windscreen. Only the type of damage, if any, was recorded for window glass (Table 11.5).

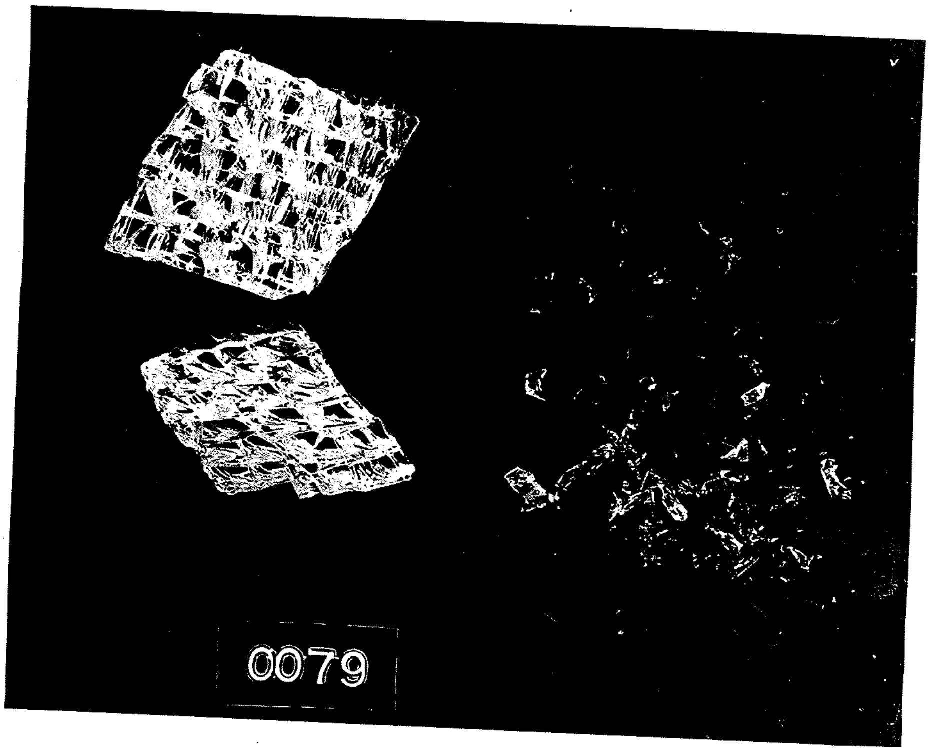


Fig. 11.3
Fragments of toughened glass from a 1961 Volkswagen windscreen (actual size).

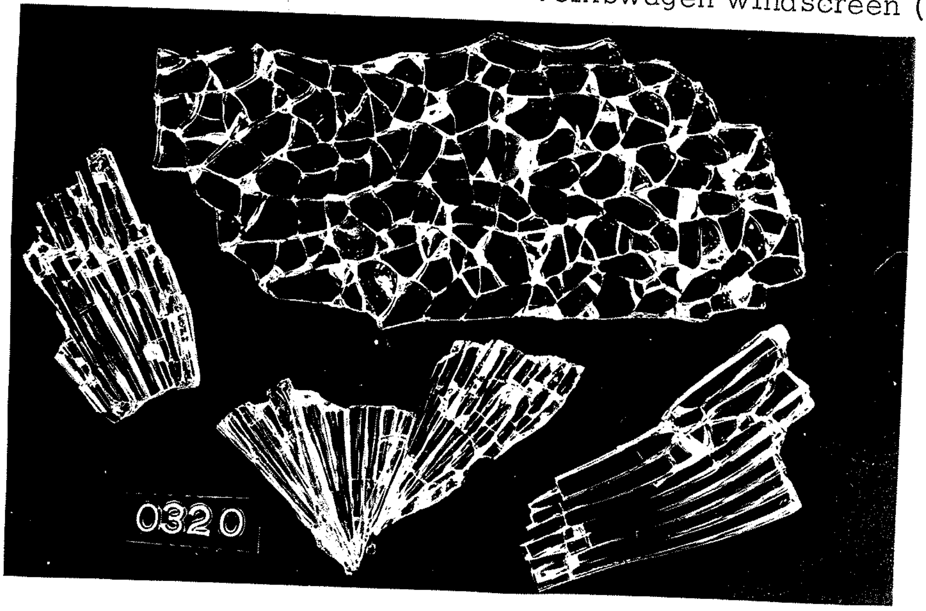


Fig. 11.4
Fracture lines radiate out from point of impact. (Passenger's head hit the windscreen.)

Windscreen Glass

11.23 One of the major problems in recording the information listed in Table 11.1 was to distinguish between tempered and laminated glass. This was a simple matter when the glass was cracked or broken, as the accompanying illustrations show. If the glass was undamaged, very often it was extremely difficult to distinguish between the two types. Trademarks on the glass were frequently a reliable indication of the type of glass. There are, however, over 200 different trademarks in use on safety glass. While only comparatively few of these are likely to be seen in Australia there were many cases in which the trademark provided little information about the type of glass (Ref. 59). It was found possible, with the more common trademarks, to determine the age of the glass. This was a useful check on the estimate of the age of the vehicle.

11.24 In most cases samples were taken of broken windscreens and side windows. Sections of glass were obtained from 59 windscreens, two of which were of laminated glass. Fifteen samples were obtained of damaged side and rear windows. These were all of toughened glass.

11.25 The information listed was recorded at each accident involving a car or a truck. Here the term 'truck' is used, as elsewhere in this report, to include vehicles ranging from light jeep type vehicles to heavy trucks and buses. Passenger cars form 90% of the 623 vehicles listed in Tables 11.1 to 11.5.

11.26 The column numbers listed in the following Tables refer to the Vehicle Data Code which is presented in the Appendix to this thesis.

TABLE 11.1

Column 56:	Type of Windscreen Glass	No. of cases	Percentage of Recorded cases
1.	Tempered	544	95
2.	Laminated	23	4
3.	Plate	3	0.6
4.	Tempered (Tinted)	2	0.4
5.	Laminated (Tinted)	-	
6.	Plate (Tinted)	-	
7.	Not elsewhere classified	-	
8.	Not applicable	-	
9.	Not recorded	51	
		623	

11.27 It can be seen from Table 11.1 that almost all these vehicles had toughened glass screens. The figure of 95% shown here is higher than a corresponding figure of 85% quoted in Ref. 53 for the United Kingdom. The figure from Ref. 53 is based on one count of parked vehicles in the town of Slough. This may or may not therefore be representative of the country as a whole. Virtually all cars in the U.S.A. have laminated glass windscreens for the reasons mentioned earlier.

11.28 Rows 4 to 6 of Table 11.1 record cases in which the windscreen was tinted. This information was correlated with the type of accident in which the vehicle was involved. Only two vehicles were recorded as having tinted windscreens. In one of these two cases the car was the striking vehicle in a rear end collision at night. The car it hit was stationary on the traffic lane waiting to turn right. Had the striking driver's visibility not been significantly impaired by the tinted windscreen he might have been able to avoid the collision. A tinted windscreen inevitably increases the hazards associated with driving at night, or in conditions of poor visibility.

11.29 The form of the windscreen was recorded as follows:

TABLE 11.2

Column 57:	Form of Windscreen Glass	No. of Cases	Percentage of Recorded cases
1.	Curved, one piece	368	59.4
2.	Flat, one piece	102	16.5
3.	Curved, two piece	3	0.5
4.	Flat, two piece	128	20.6
7.	Not elsewhere classified	1	
9.	Not recorded	21	
		623	

Most of the windscreens were the familiar curved one piece screen (59.4%). The next most frequent type is the flat two piece screen (20.6% of the recorded total). The earlier model Holdens were the most common make having this type of screen in this survey. The only other type having significant numbers is the flat one piece screen, such as is fitted to the Volkswagen 1200.

11.30 The frequency of damage to the windscreen is listed in the next Table.

TABLE 11.3

Column 58	Damage to Windscreen	No. of Cases	Percentage of Recorded cases
1.	No damage	505	82.4
2.	Tempered glass broken, probable occupant contact	55	9.0
3.	Tempered glass cracked or broken, no occupant contact	13	2.1
4.	Laminated glass cracked or broken, probable occupant contact	6	1.0
5.	Laminated glass cracked or broken, no occupant contact	3	0.5
6.	Not elsewhere classified; but occupant contact probable	18	2.9
7.	Not elsewhere classified; no occupant contact	13	2.1
8.	Not applicable	2	
9.	Not recorded	8	
		623	100.0%

All cases of damage to windscreens listed in Table 11.3 were the result of damage sustained in an accident. There was not one accident in the 408 in this survey which happened after a windscreen shattered.

This may be compared with Ameling's estimate of one accident in 10,000 being consequent on a shattered windscreen in the Perth metropolitan area (Ref. 46).

11.31 Table 11.3 shows that about one vehicle in six had its windscreen broken. Note that in addition to the range vehicles represented in this table, ranging from passenger cars to heavy trucks, there is also a very wide range of accident types. These accidents include collisions with pedestrians, cyclists and motor cyclists as well as with other four-wheeled vehicles. In addition there are some single vehicle accidents. Adding together the totals for Rows 2 and 3 and Rows 4 and 5 gives the total number of tempered and laminated glass windscreens that were broken. Comparing these totals with the total number of tempered and laminated screens as given in Table 11.1 shows that a higher proportion of laminated screens were broken. These figures are also presented in Table 11.4.

TABLE 11.4

	Type of Windscreen Glass		
Damage to Glass	Laminated	Toughened	Total
Glass cracked or broken	9	68	77
No damage	14	478	492
Total	23	546	569

Chi square = 13.4*** $(p_{0.001} = 10.8)$

The value obtained for Chi square (13.4) suggests that this result was not due to chance. This difference may, in part, be due to significant differences in the accident types sustained by the two groups. But it has already been noted (Ref. 47) that laminated glass is weaker than toughened glass of the same overall thickness. This would mean that laminated glass would be more readily broken in an accident than toughened glass, as the figures in Table 11.4 suggest.

11.32 Rows 6 and 7 of Table 11.3 were included to cover those cases in which a windscreen was partially or completely dislodged from its mounting. Figure 11.1 shows a case in which a toughened glass windscreen was completely ejected onto the road without shattering. Row 6 of Table 11.3 also includes cases in which an occupant hit the windscreen without breaking it. It is now realised that Row 6 in fact includes two possible categories, one in which the screen was damaged, the other in which the screen was not damaged. Therefore, it is not possible from Table 11.3 to list exactly all cases in which the windscreen was damaged. It is, however, possible to list all cases in which the glass itself was damaged.

11.33 In these 623 vehicles there were 79 cases in which a person hit the windscreen. Occupant contact is not here restricted to the occupants of the case vehicle. It may also include cases in which pedestrians, cyclists, or motor cyclists were thrown against the windscreen. Occupant contact occurred in 12.9% of all the recorded cases. There were 77 cases in which a windscreen glass was cracked or broken.

In 61 (78%) of these cases a person hit or was hit by the broken glass.

11.34 The classification "occupant contact" does not presuppose that the screen was intact when hit by the occupant. Contact in this sense may merely mean "hit by flying fragments". Figure 11.2 shows fragments on the dashboard of a 1962 EJ Holden sedan. The large number of very small fragments, shown also in Figure 11.3 may cause serious injury to the eye. Work by Patrick (Reference 48) suggests that these small fragments are unlikely to cause soft tissue injuries. (Figure 11.3 shows fragments and particles from a 1961 VW windscreen. The particle count is in the order of 80 per square inch. Other glass in this vehicle was marked ARMOURPLATE. As noted above this does not necessarily mean that the screen was of the same brand, although in this case it is likely that it was.)

11.35 One of the early attempts to improve visibility through a shattered toughened glass windscreen was to retain a portion of annealed glass in front of the driver. One such attempt is commonly referred to as the "magic circle" windscreen. When shattered, such a screen can release large fragments from the annealed "magic circle". Case 0217 (Fig. 11.5) is an example of this. Four pieces from within the magic circle are shown together with a large composite fragment from the edge of the magic circle. This glass is from a 1958 Simca (Fig. 11.7). It was broken by the head of the front seat passenger, a 20 year old male.

Fig. 11.5
Large fragments from 'magic circle' windscreen (full size).

Fig. 11.6
Annealed glass fragment, 1937 Pontiac side window (full size).

Fig. 11.7
1958 Simca windscreen, struck by passenger's head. (See also Fig. 11.5 for fragments from this screen.)

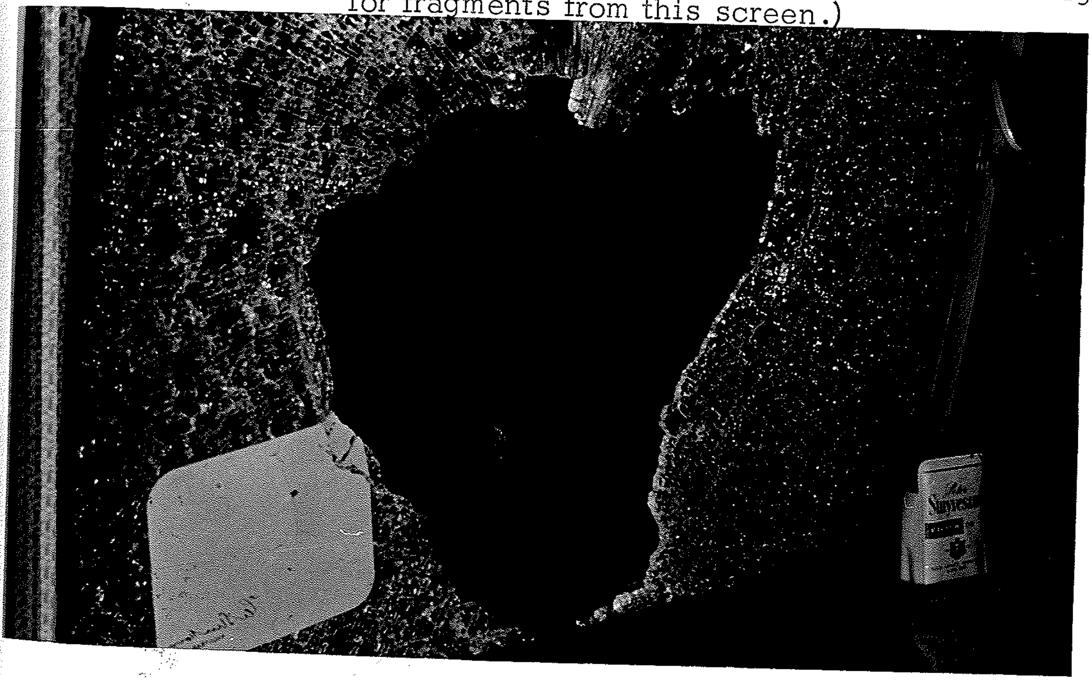


Fig. 11.8
1956 FJ Holden windscreen, broken by the passenger's head.

He sustained a deep laceration above the left eye and was unconscious for five minutes after the impact. Other window glass in this car was marked GLACE SECURIT.

11.36 The fragments of annealed glass which are released from the "magic circle" windscreen are not as large as those released from a screen composed entirely of annealed glass. A fragment of annealed glass from a side window of a 1937 Pontiac Sedan is also shown in Figure 11.6. Although the fragments from the "magic circle" are smaller, they do have the sharp edges which are common to fractured annealed glass (Ref. 30). (Annealed glass is referred to as plate glass in Table 11.1.)

11.37 A fracture of one side of a two piece flat screen is shown in Figure 11.8. The vehicle is a 1956 FJ Holden Utility. The other piece of the screen was marked ARMOURPLATE. The passenger's side of the screen was broken by the head of the 22 year old female passenger. The point of impact can be determined from inspection of the "streamlines" inthe fracture pattern of the glass. Case 0320, Figure 11.4, shows the fan-shaped fragments which radiate from the point of impact. Further away from the point of impact the customary fracture pattern is resumed, as is shown by the large fragments. The samples shown in Figures 11.3 and 11.4 were both taken from Volkswagen windscreens; in Case 0079 the screen was broken by frame deformation. In Case 0320 the screen was

Fig. 11.9
Jagged edge of broken glass retained in rubber mounting strip (Ford Customline).

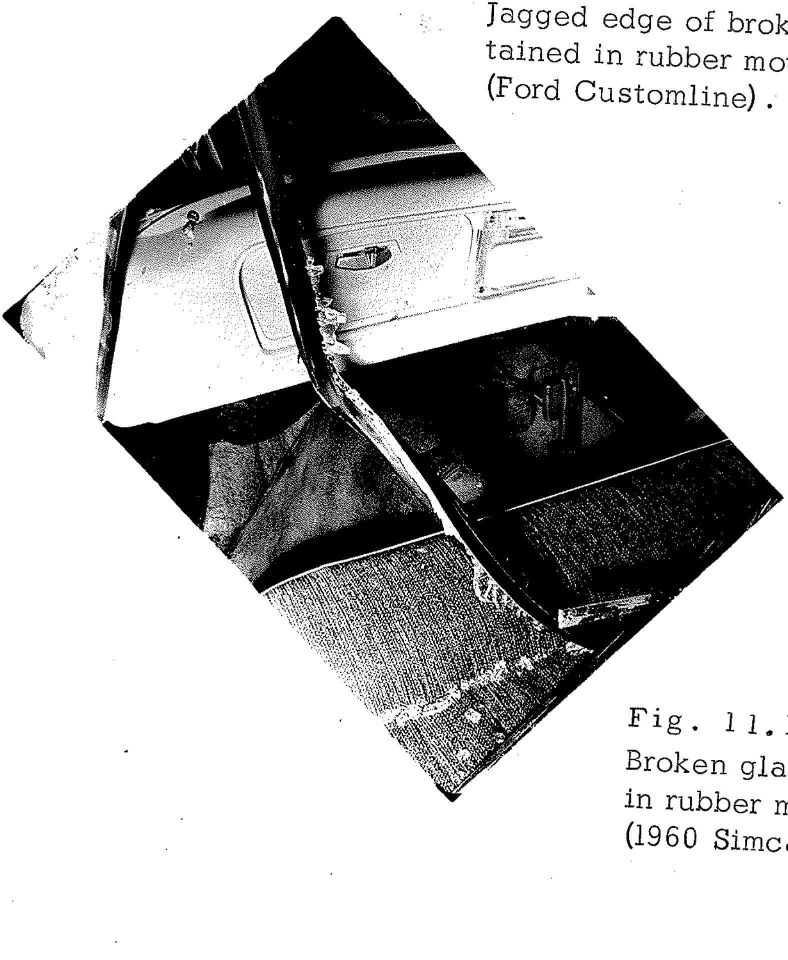


Fig. 11.10
Broken glass retained in rubber mounting strip (1960 Simca).

broken by the impact of the head of the front seat passenger. Following the streamlines in the screen shown in Figure 11.8, the point of impact is located about one-third of the way down from the top of the screen. The shape of the hole in the screen suggests that the passenger's head, after fracturing the glass, moved downwards breaking out the glass fragments to the base of the screen. The passenger was not concussed, but sustained a one and a half inch long laceration across her chin, a loosened tooth, and a lacerated tongue.

11.38 This case leads on to a consideration of the most obvious injury potential of toughened glass. British Standard 857, 1964, (Ref. 42) mentions the lacerative potential of the jagged edge of the fractured glass which is retained in the frame of the screen. Figure 11.9 shows such a case in which the front seat passenger struck his forehead on the jagged edge of broken glass. There are three points to be made here. First the jagged edge is in a place, on the upper surface of the dashboard, where an occupant of the car is likely to be thrown against it. Secondly the head and face are the parts of the body most likely to come into contact with this jagged edge. Thirdly, the head comes straight down onto this jagged edge in such a manner that the glass fragments are unlikely to be pushed out of the way. The injuries sustained are not necessarily dangerous to life, but they may result in considerable disfigurement.

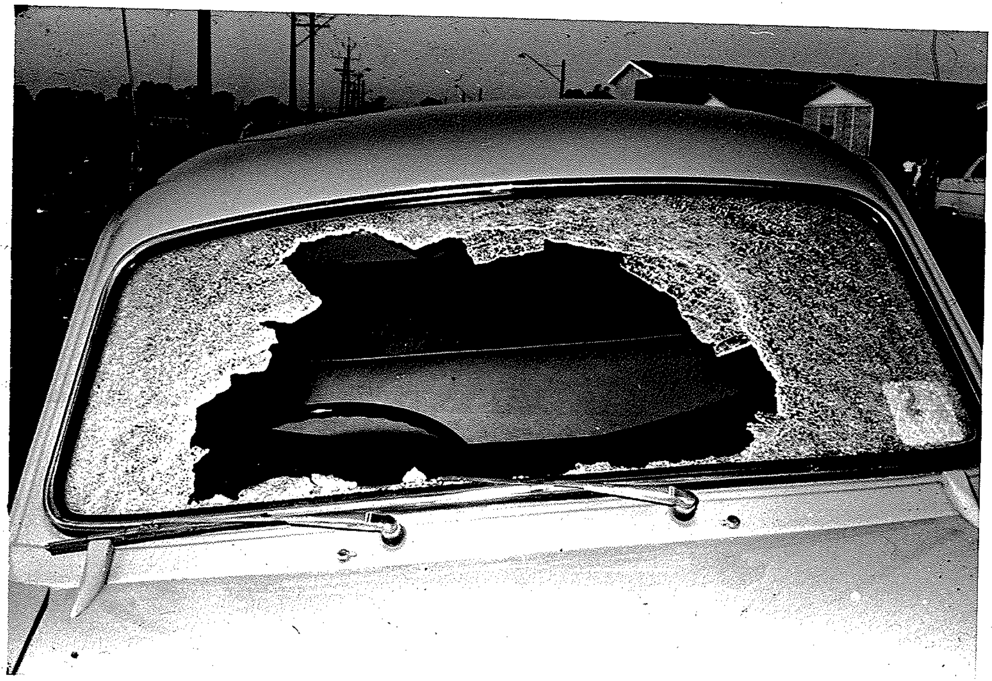


Fig. 11.11
Windscreen of 1962 Morris Elite, broken by cyclist being hurled against it.

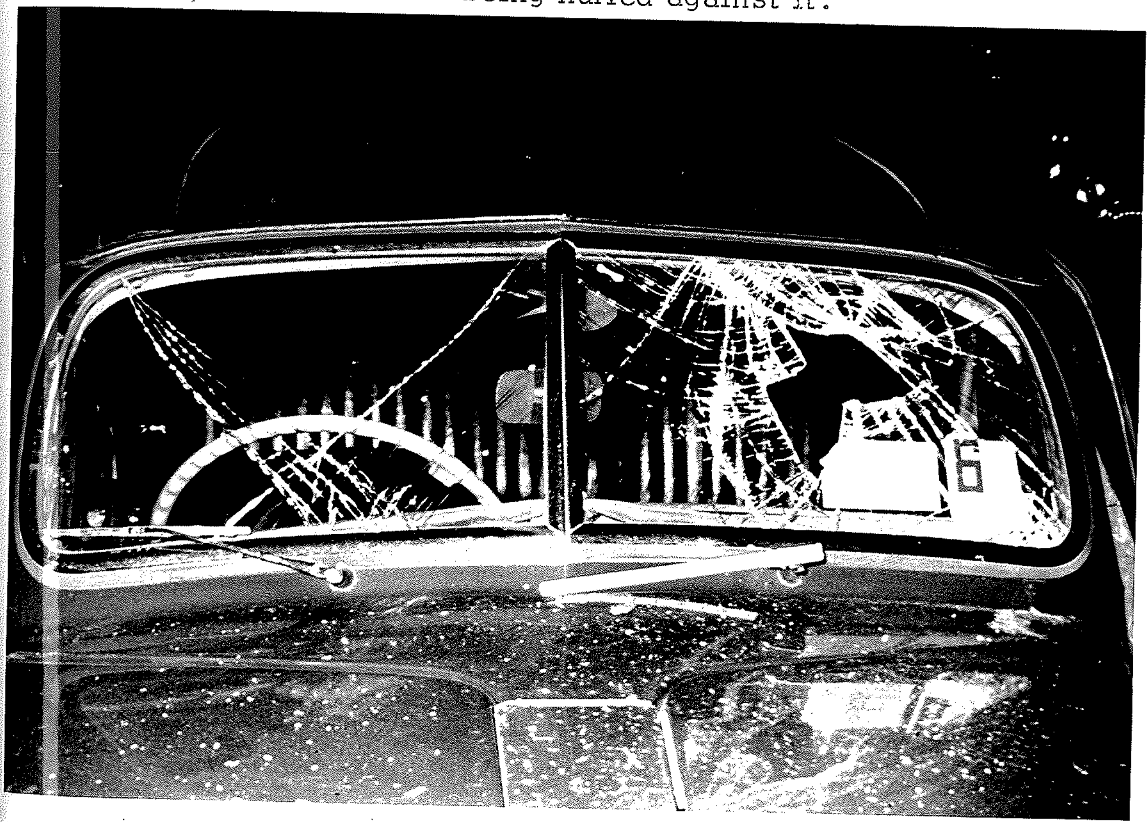
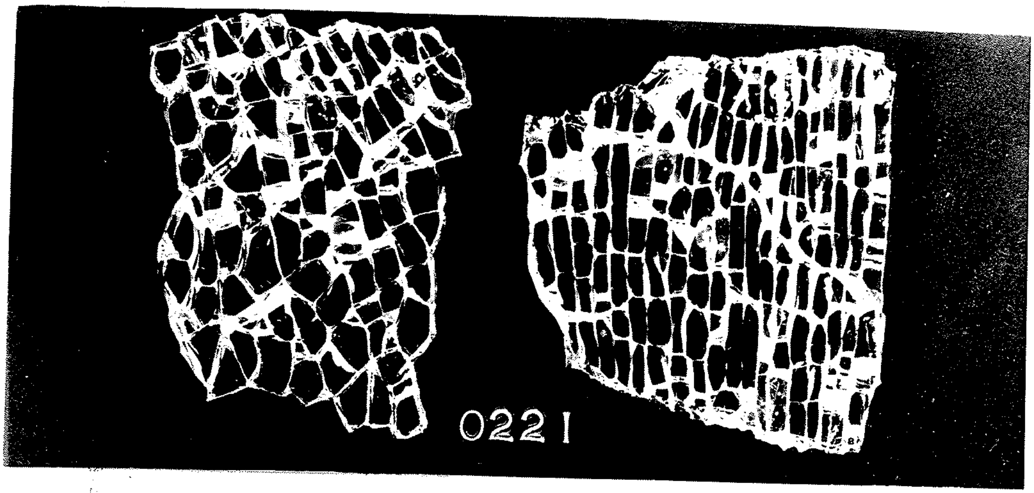
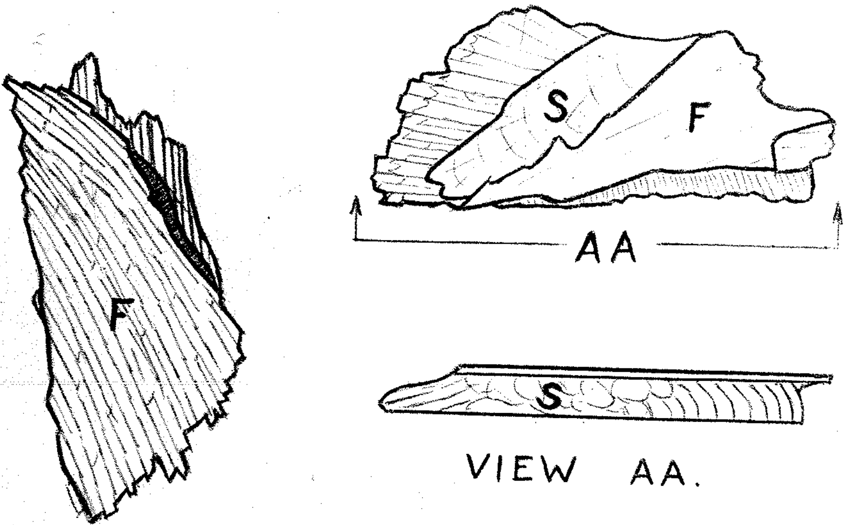


Fig. 11.12
1952 Riley. 'Grid' fracture on driver's side, 'web' fracture of laminated glass on passenger's side.





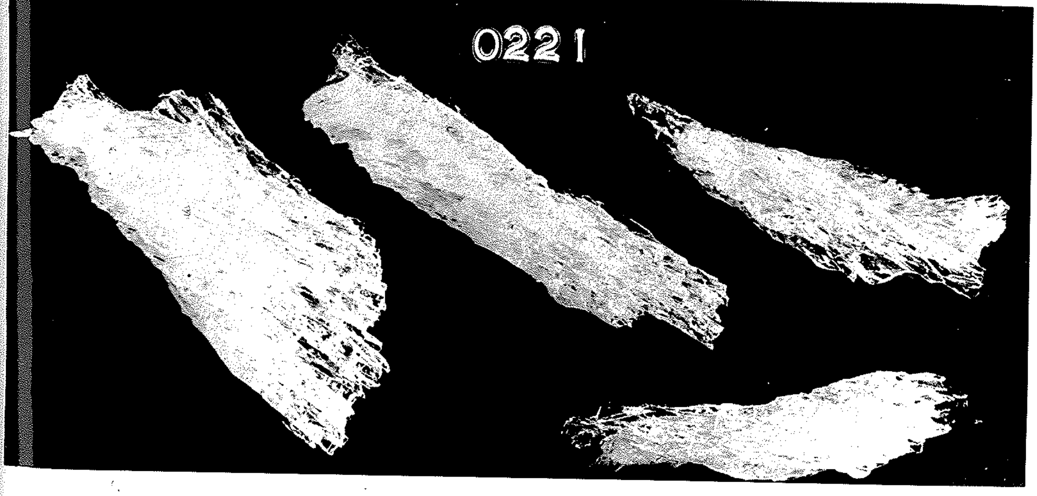


Fig. 11.13
Fragments from the windscreen shown in Figure 11.11 (full size).

11.39 It is therefore desirable that either the screen should be completely ejected (Fig. 11.1) when struck by an occupant, or that the frame of the screen should not retain broken fragments. Figure 11.10 shows the rubber moulding strip from the windscreen of a 1960 Simca Sedan. The windscreen was broken by deformation of the frame. The rubber mounting strip for the windscreen has come away from the frame of the screen. It still carries with it jagged glass fragments. This is undesirable, but it is to be preferred to having the jagged edge of glass rigidly attached to the top of the dashboard.

11.40 Some windscreens were broken by pedestrians or cyclists being thrown against them, for example Case 221 shown in Figure 11.11. (The car is a 1962 Morris Elite Sedan. The window glass is marked ARMOURPLATE.) The area of impact in a case such as this is frequently larger than those in which a passenger hits the screen. This is because the passenger usually strikes the screen with his head. The cyclist very often slides across the bonnet of the car and strikes the screen with his body. The broken glass is then pushed into the car, as shown in Figure 11.2.

11.41 Samples taken from the screen of the vehicle shown in Figure 11.11 show a regular fracture pattern in some fragments (those at the top of Figure 11.13, which have particle counts varying between 56 and 42 per sq. inch). Other fragments from this same screen display most irregular

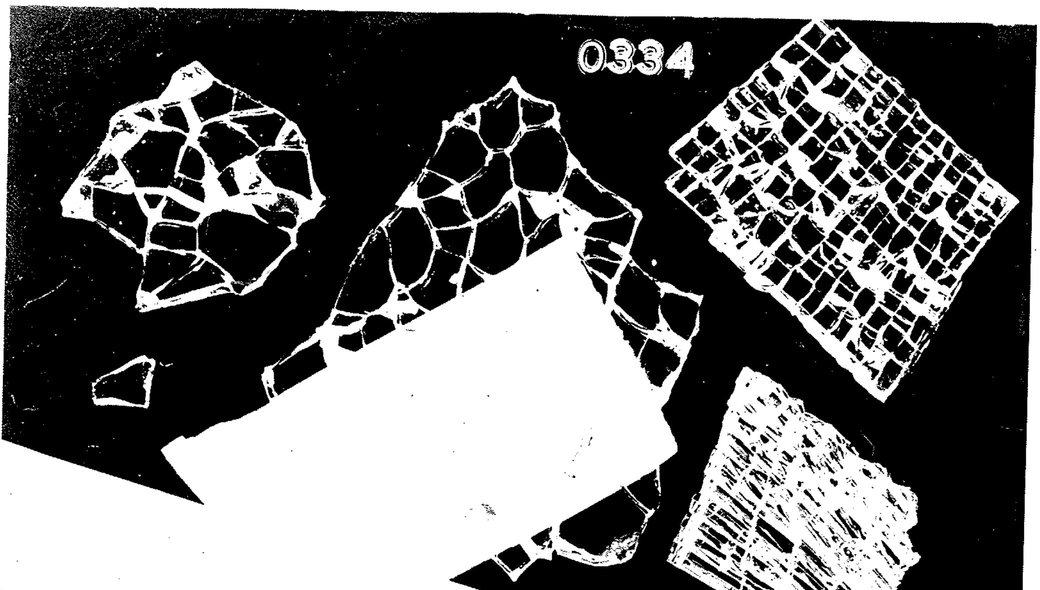


Fig. 11.14
Variation in particle count across a windscreen (full size).

Fig. 11.15
Fragment of laminated glass (full size) from the screen shown in Figure 11.12.

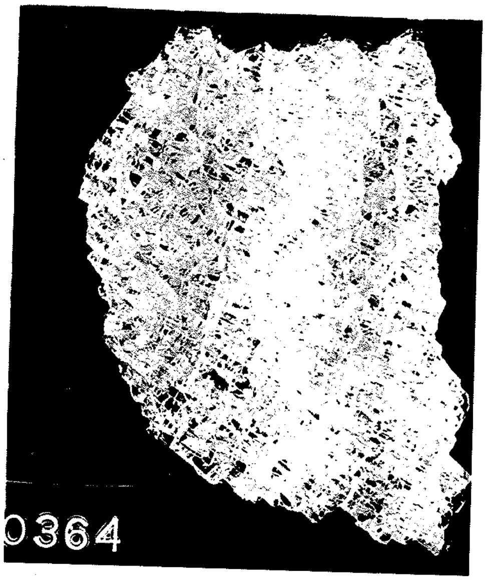


Fig. 11.16
Highly stressed toughened glass, yields high particle count on fracture (full size).

fracture patterns (those shown at the bottom of Figure 10). These irregular fragments were taken from the lower edge of the fractured screen. It is difficult to show the detailed fracture lines in a photograph. Therefore a sketch of the piece on the left hand side is shown in the centre of Figure 11.13. The underside of the fragment and a side view are also shown. The surfaces marked F are the flat faces of the screen. S indicates areas where the glass has spalled away. The highly stressed parts of this piece of glass are of course the two faces. The side view shows that one of these surfaces, the upper surface in this view, is more highly stressed than the other. Note also that the fracture lines in the two stressed surfaces are not parallel. The angle between them varies between 20° and 35°. In the samples taken from 59 toughened glass screens, this type of fracture was only seen twice. In each case the sample was obtained from a curved screen which had been hit by a cyclist.

11.42 Particle size can vary greatly across a fractured toughened screen. Figure 11.14 shows fragments from the toughened glass screen of a Renault Dauphine Sedan which rolled over. The screen was broken by deformation of the frame. The large fragment in the centre is from the lower right hand corner of the screen. The white area is a paper sticker on the glass. This piece has a particle count of 17 per sq. inch. The fragment in the upper right hand corner of Figure 11.14 has a particle count of about 80 per sq. inch.

11.43 Variations in the degree of toughening can also affect the particle size. This is discussed at length in Reference 30, and the requirements of the British Standard (Ref. 42) have been noted above. Figure 11.16 shows a fragment of a fractured toughened glass windscreen from a 1949 Sunbeam Talbot. The screen was broken by the deformation of the frame. At the time that this screen was manufactured the British Standard required a minimum particle count of 40. There was no upper limit on the particle count. Hence some windscreens were toughened to such a degree that when fractured they were virtually opaque.

11.44 The glass fragment from Case 75, shown in Figure 11.15, is from a laminated glass windscreen. The fractured screen is shown in Figure 11.12. The vehicle is a 2.1/2 Litre Riley Saloon, manufactured in 1952. Each side of the two piece windscreen displays a different type of laminated glass fracture. The piece on the driver's side is "grid" cracked. The piece on the passenger's side is "web" cracked. These two types of failure are further illustrated in Reference 55. The grid type of failure is caused by distortion of the frame of the glass. The web type of failure is caused by an object striking the glass. In the case shown the driver, on realizing a collision was imminent, put her left arm across in front of the front seat passenger. On impact the passenger was thrown forwards pushing the driver's forearm through the laminated windscreen, resulting in extremely severe lacerations. The fragment

Fig. 11.17
Penetrated laminated glass windscreen.

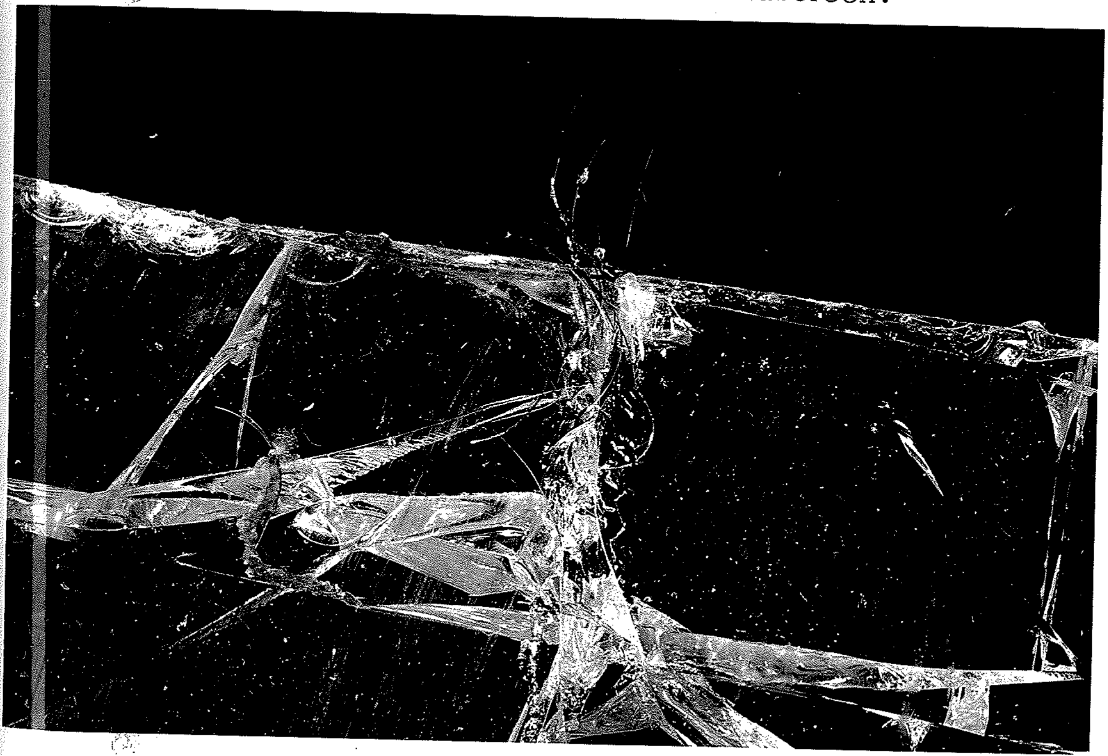


Fig. 11.18
Enlarged view of edge shown in Figure 11.19.

shown in Figure 11.15 was pushed out by the driver's forearm. The exposed edges of this fragment have a razor sharpness.

11.45 Figure 11.17 shows the windscreen of a 1954 MG Magnette. Both driver and passenger were thrown against the windscreen in a collision. The passenger, who was not deflected by the steering wheel, penetrated the inter-layer of the laminated glass screen. The left hand side of the penetrated portion is shown, full size, in Figure 11.19. An enlarged view of the edge of this portion (Fig. 11.18) clearly shows the inter-layer between the two sheets of glass The grease smears on the glass run from the top right hand corner diagonally down to the left. This indicates that the passenger's head after going forwards and breaking the glass then moved downwards sliding across the broken glass. Strands of hair and pieces of skin and flesh are caught in the exposed sharp edges of this piece of glass. The passenger sustained a severely lacerated forehead involving arterial bleeding. He was also unconscious for nearly four hours after the collision.

11.46 These two examples of fractured laminated glass windscreens emphasise the importance of reducing the risk of penetrating the broken glass. Hence new developments aim at increasing the penetration resistance of the plastic interlayer (Ref. 56).

Window Glass.

11.47 Many of the comments made above in relation to windscreen

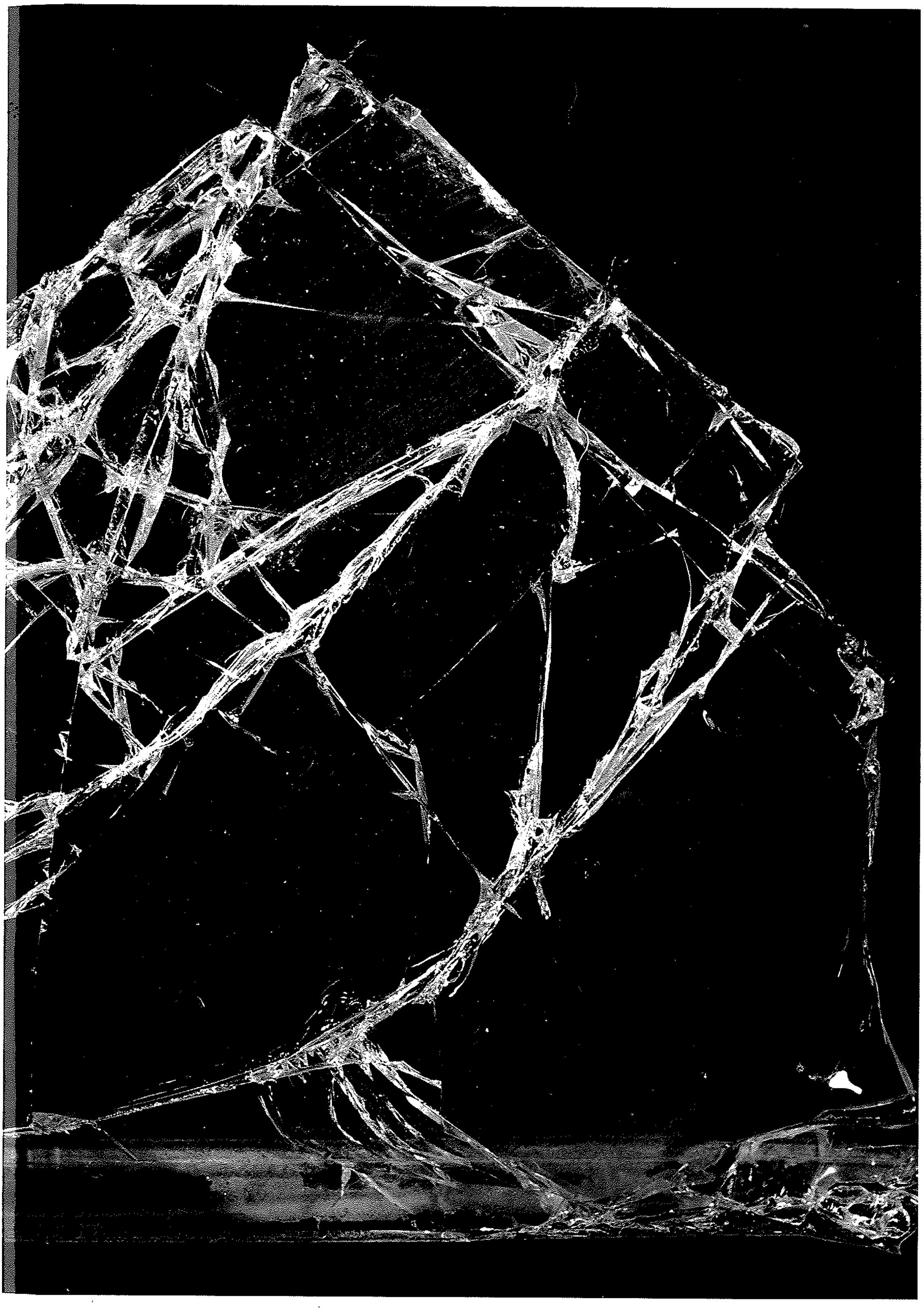


Fig. 11.19
Full size fragment from the left hand side of the screen shown in Figure 11.17.

glass are also applicable to window glass. Perhaps the chief difference is that visibility is not as critical through window glass. Therefore in the case of toughened glass side windows there need not be a maximum particle count limit.

11.48 Figure 11.20 shows a fragment of side window glass from a 1950 Vauxhall Wyvern Sedan (Case 0328). The glass was struck by a cyclist when the car turned across in front of him. The particle count is about 200 particles per square inch.

11.49 Compare this with Case 0429, also shown in Figure 11.20. In this case the glass fragment is from the driver's side window of a 1964 EH Holden Sedan. The glass was broken by the driver being thrown against it. Severy (Ref. 52) notes that very often in such circumstances the glass is in fact broken by deformation of the sill of the door before the occupant's head strikes it. In this particular case the driver was unconscious for about half an hour after the accident. There was no evidence that his head struck anything but the glass. It therefore appears unlikely that in this case the glass was broken before his head hit it.

11.50 As noted earlier in this section, concussion is the most serious injury associated with automobile glass. The strength of the glass should therefore be no higher than is necessary to avoid failure under normal operating loads.

11.51 The risk of laceration from toughened glass side windows is, as

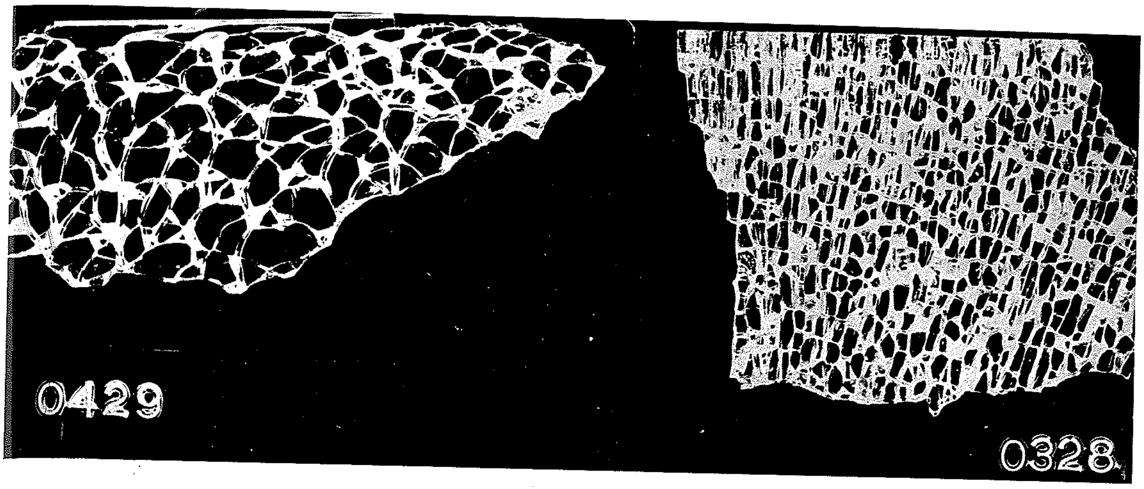


Fig. 11.20
Differences in toughening and hence in particle counts on fracture. Side window glass, full size.

Fig. 11.21
Jagged glass edge retained in EK Holden quarter-light.

Fig. 11.22
1952 Ford Con sul Sedan, window shattered by motor-cyclist during a collision. Rider received severe lacerations from jagged edge of broken glass.

with windscreens, confined to jagged fragments which can be retained in the frame. This is most likely to occur with fixed or pivoted windows having a fixed frame. An example of this is shown in Figure 11.21. The window is a quarter-light of an EK Holden Sedan. The driver did not come into contact with this glass edge.

11.52 Figure 11.22 shows the left front window of a 1952 Ford Consul Sedan. This car turned right across the path of an approaching motor scooter. The rider of the scooter was thrown against the side of the car and broke the window glass with his body. He then slid along the side of the car and across the jagged edge of broken glass which was trapped in the window runner. The rider sustained severe multiple lacerations across the base of his neck and over his left collarbone.

11.53 The frequency of damage to window glass is listed in Table 11.5. It can be seen from this Table that 14.7% of the 603 vehicles for which this information was applicable or was recorded had at least one window damaged. This figure is less than half of that recorded by Tourin, Garrett and Moore (Ref. 54). In a study of their series of highway accidents they found that 35.1% of these vehicles had one or more side windows damaged. A possible explanation of the different damage ratios is that the American cases were collected in rural accidents, whereas the present study is concerned with metropolitan accidents. The metropolitan accident will generally occur at a lower speed than a rural accident. However, the higher frequency of side impacts, resulting from intersection collisions, in metropolitan accidents would tend to offset such a difference in accident severity.

TABLE 11.5

Column 59:	Damage to Window Glass (other than windscreen)	Number of cases	Percentage of Recorded cases
1.	No damage	514	85.3
2.	Damaged, probable occupant contact	52	8.6
3.	Damaged, probable occupant contact	37	6.1
4.	No damage, probable occupant contact	-	-
8.	Not applicable	6	-
9.	Not recorded	14	-
		623	100.0

11.50 The type of glass in the side windows of cars in this survey was not recorded. There was however only one case in which laminated side window glass was broken. There were two cases of annealed side window glass being broken. One of these is shown in Figure 11.23, a left rear side window of a 1937 Pontiac Sedan. The window was struck by the forehead of a 13 year old girl. She sustained a long deep laceration of the left side of her forehead. A fragment from this window is also shown in Figure 11.6.

Fig. 11.23
Side window of 1937 Pontiac (see also Fig. 11.6)

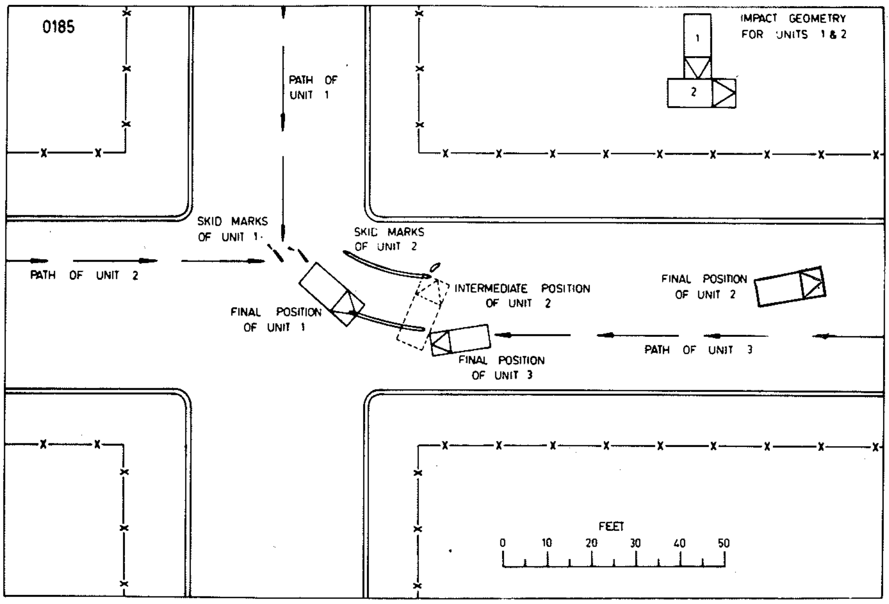


Fig. 12.1
Case 0185.

EJECTION, SEAT BELTS AND DOOR LATCHES.

CHAPTER 12

12.1 For a car occupant, 'ejection significantly increases the risk of moderate through fatal injuries'. This was the conclusion from the now well-known paper by Moore and Tourin on automobile doors opening under crash conditions (Ref. 60). This early (1954) work on Automotive Crash Injury Research of Cornell University also showed that ejection very nearly always occurred through a door which had come open. A later (1958) paper by Tourin stated that '25% of all fatalities can be eliminated if ejection is completely prevented' (Ref. 61). There would be a similar reduction in the severity of injuries to survivors of car accidents. The frequency of ejection in the accidents in this study is discussed in this Chapter, along with two methods of reducing this frequency, viz. seat belts and safer door latches.

12.2 Thirty-five of the 1,029 car occupants involved in these accidents were ejected. This is an ejection rate of 3.4%. Table 12.1 lists the severity of the injuries received by both the ejected and non-ejected groups.

TABLE 12.1

Car occupant was:	Injury Severity: Nil and minor	Injury Severity: Moderate and greater	Total
Ejected	18	16	34
Not ejected	832	155	987
Total	850	171	1,021

Chi square = 23.2*** $(p_{0.001} = 10.8)$

12.3 The data in the above Table are heavily biased towards the Nil and Minor injury group. Many of these occupants were in cars which hit pedestrians or cyclists, and the risk of ejection was therefore slight. Those ejected were injured more often than those who were not ejected, and this effect becomes more marked when the more severe degrees of injury are compared. Those ejected received moderate to fatal injuries five times as often as those not ejected. The value obtained for Chi square means that this result is most unlikely to be due to chance.

12.4 Ejection appears to be associated more with the spinning vehicle than with the one that rolls over. Spinning is generally a consequence of an impact on the side of the car, as in accident number 0185 (Fig. 12.1). The impact on the side of the car set it spinning and also sprang the doors open on the opposite side, thereby setting the stage for the ejection of the occupants.

Seat Belts.

12.5 Fifty-eight (5.6%) of 1,029 car occupants had seat belts available for their use, and 24 (2.3%) were wearing a belt. The types of seat belt fitted were as follows:

Lap	13
Lap and sash	42
Diagonal	2
Not recorded	1
Total	58

Fig. 12.2
Collision between Morris 850 and stationary Morris Convertible - seat belt not worn.

Fig. 12.3
Collision between Morris 850 and stationary Morris Convertible - seat belt worn.

43% of those who had a seat belt available for their use were wearing it. There is an argument in favour of voluntary installation of seat belts on the basis that people are more likely to use the belts if they themselves have had them installed in their car. But a study in the State of Wisconsin U.S.A. has shown that, because legislation ensures that many more cars have belts in them, twice as many people will be wearing belts than would be the case without legislation (Ref. 62).

12.6 There were several cases in this survey in which the wearing of a seat belt undoubtedly reduced the severity of injury, or even protected the wearer from injury altogether. In two of these cases the accidents were almost identical (0170 and 0301). Each involved a Morris Mini Minor crashing into the back of a stationary Morris convertible. In the first case the driver, not wearing a seat belt, broke the windscreen with his head, sustaining concussion and lacerations of the face. In the other case the car sustained damage very similar to that of the first car (Figs.12.2 and 12.3) but the driver was wearing a diagonal seat belt and suffered only momentary breathlessness and bruising of the chest. These two collisions were virtually identical, the only difference being in the wearing of the seat belt and consequent prevention of injury in the second case.

12.7 In one other case a small car collided head-on with a truck (Fig. 7.12). Both occupants were wearing lap and diagonal seat belts,

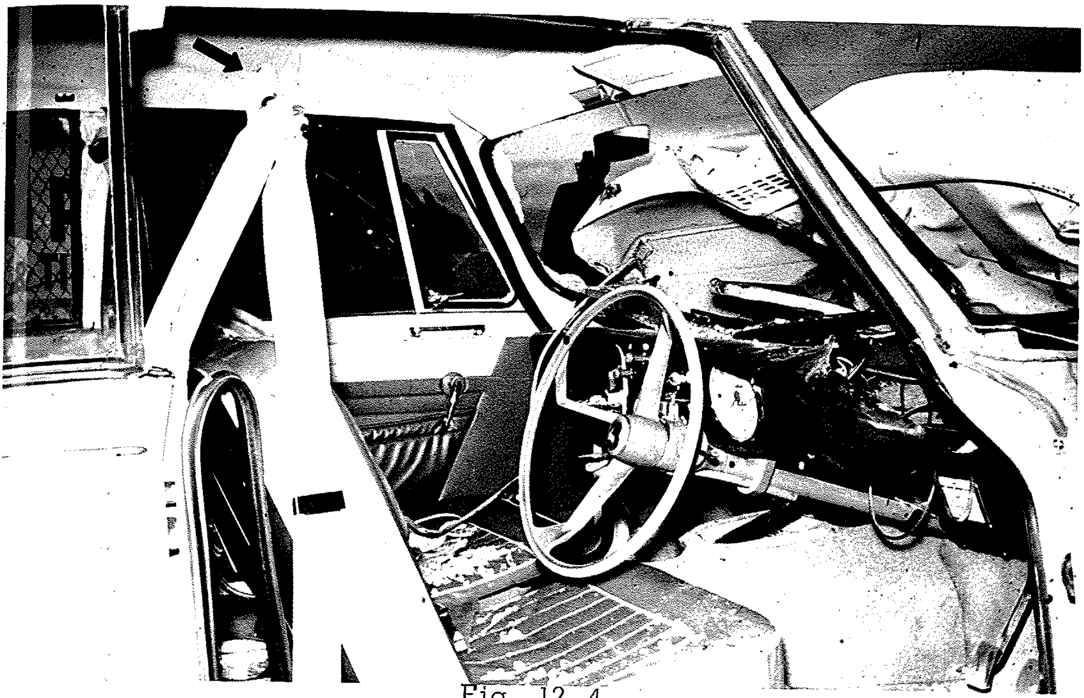


Fig. 12.4
Failure of seat belt mounting on a 1960 Triumph Herald (arrow). Distortion of the mounting on the passenger's side is also indicated. This vehicle is also shown in Figure 7.12.

Fig. 12.5
1960 Vauxhall Victor, struck on the right side by another car at an intersection. Both doors on the right side were sprung open.

and despite the fact that the upper mounting points failed, both occupants suffered only small abrasions to the face and concussion. A close-up of the failed mounting is shown in Fig. 12.4. It can be seen that the load on the belt has caused the welds at the top of the centrepost to fail, allowing the post, mounting point and belt to come forward. Obviously mounting points should be incorporated in the basic body frames of all cars. This is particularly important in the case of the mounting point for the sash belt, as the above example illustrates.

Door Latches.

12.8 The latch on a car door has the obvious function of keeping the door closed. In normal service it does its job well, and we no longer have to worry about doors flying open as the car takes a bend. Unfortunately doors often do come open when cars are involved in accidents (Fig. 12.5). In this survey 8.6 per cent of all car doors came open. This includes all accidents involving cars. In many of these, e.g. pedestrian accidents, there is no additional loading on the door latch and doors rarely come open.

12.9 The above-mentioned work on door latches and ejection by ACIR (Ref. 60), along with crash testing by vehicle manufacturers and the University of California at Los Angeles, prompted modifications to the door latches of cars manufactured in the U.S.A. from late 1955 onwards. Reference 63 is entitled 'An evaluation of door lock effectiveness:

Fig. 12.6 - This 1954 FJ Holden was struck on the right side by another car. The front seat transmitted the force of the impact across the car to the centrepost, which was pushed out as shown, the spot welds being partly torn away (arrow). The rear door had been removed previously.

Fig. 12.7
Striker plate of a 1956 FJ Holden.

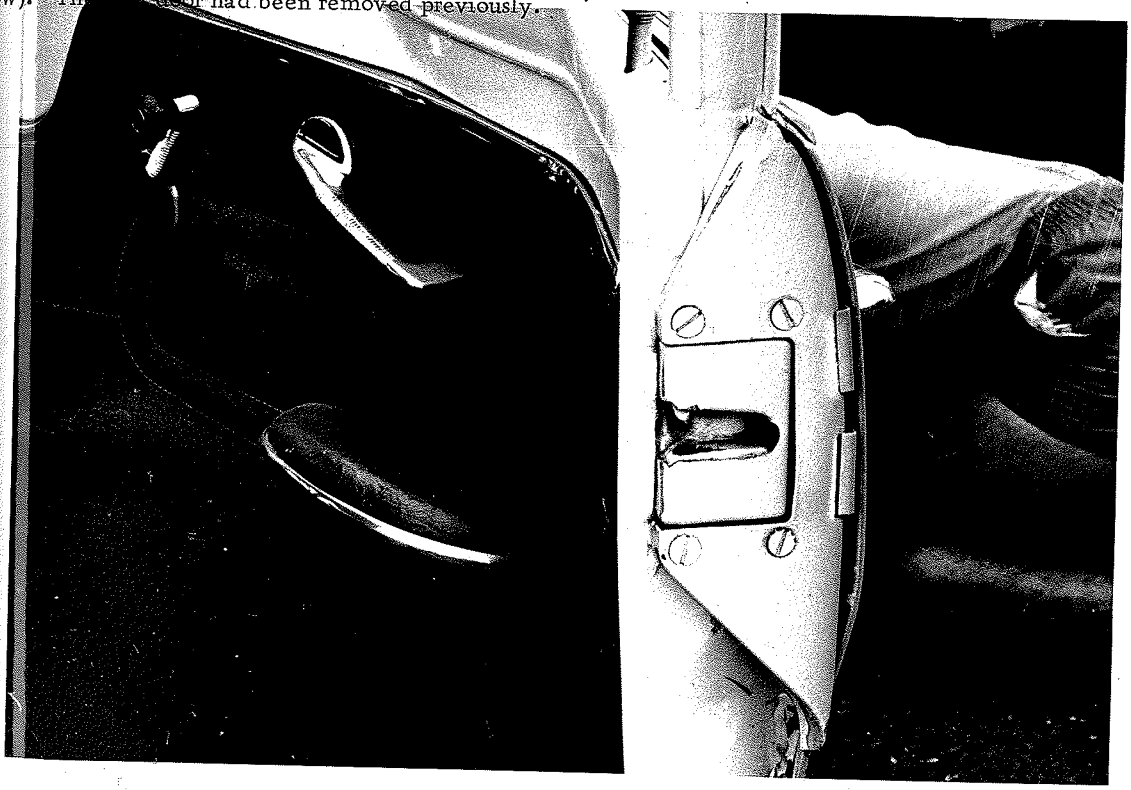


Fig. 12.8
Door latch of a 1956 FJ Holden.

Figure 12.9 - 1964 EH Holden which hit a high kerb with the right front corner when skidding sideways. Note shattered glass and buckled door panel, both caused by the driver being thrown against the door.

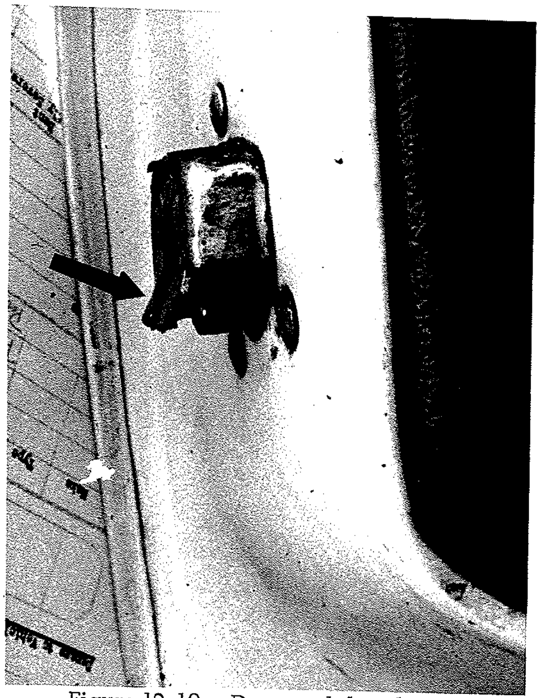


Figure 12.10 - Damaged door latch on a 1957 FE Holden. Arrow indicates bent flange. This latch superseded the one shown in Figure 12.8.

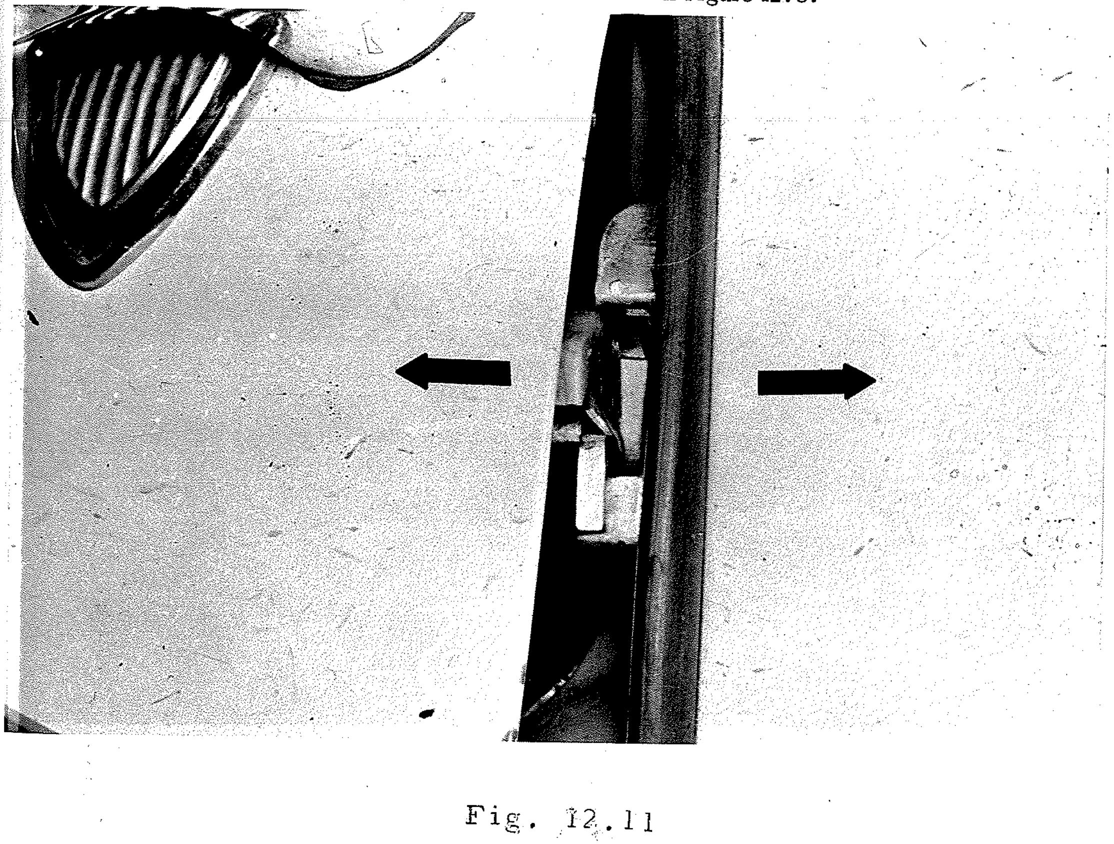


Fig. 12.11

1960 FB Holden door latch. The flange is bent, as in Figure 12.10, but the latch is still engaged with the striker plate and the door has not opened. The forces on the lock, due to the distortion of the body frame of the car, are in the directions shown by the arrows.

pre-1956 vs. post 1955 automobiles'. This paper showed that the new locks were saving about 800 lives. (Wherever door 'lock' is referred to here the meaning is the same as door 'latch'.) With these new latches the frequency of occupant ejection was reduced by nearly 40 per cent. If all cars in use had been fitted with these improved door locks a saving of 1,800 lives annually might have resulted. These figures refer, of course, to the U.S.A. alone. Subsequent comparisons have been made between the performance of 1962 to 1963 automobile door latches and earlier designs (Ref. 64).

12.10 This new generation of door locks had one basic aim, to hold the door closed no matter what loads might be imposed. The ways in which high loadings can be placed on door locks are many (Ref. 65). Fig. 12.6 shows how the front seat can break loose and transmit the collision forces from a side-on impact to the far side of the car. The centre post has been forced out, and the door opened. Even the driver being hurled sideways against the door can result in considerable damage to the door frame and failure of the lock. In the case shown in Fig. 12.9 the driver also shattered the side window with his head. He was fortunate that there was no arm rest fitted to the door, for rigid arm rests can cause serious internal injuries in cases such as this.

12.11 More frequently, however, the door lock is loaded by distortion of the body frame of the car or by direct impact on the door itself. Figs. 12.7 and 12.8 show the driver's door latch and striker of an FJ model

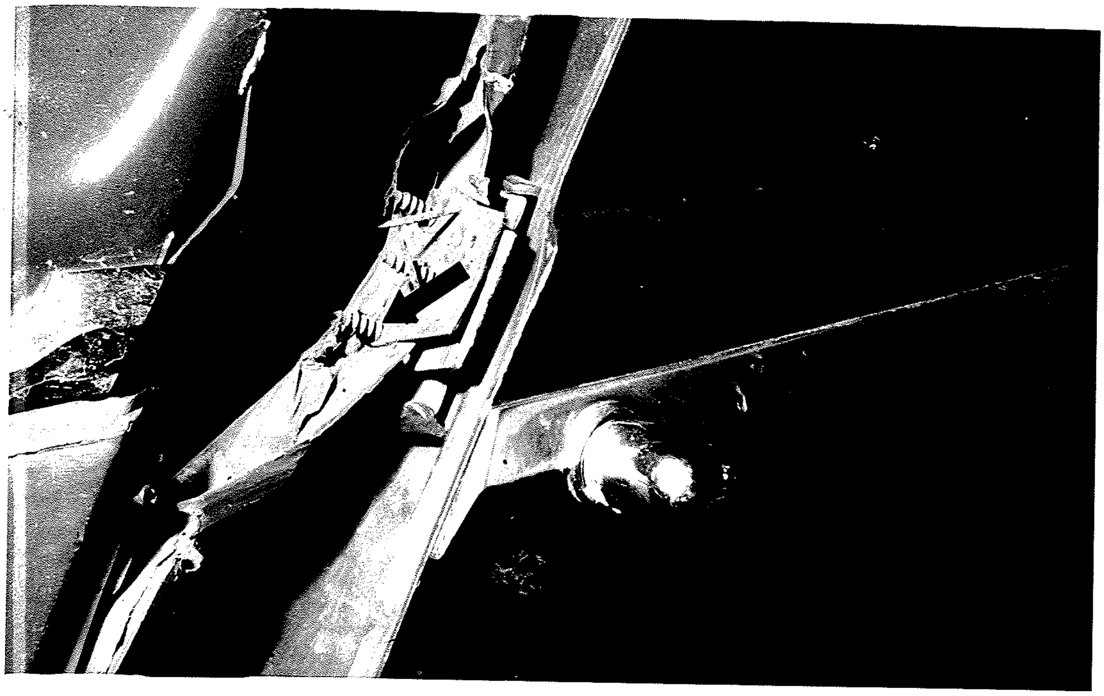


Fig. 12.12
Door lock failure on a 1952 Riley Saloon. Arrow indicates one of three wood-screws used to mount the striker plate to the body of the car.

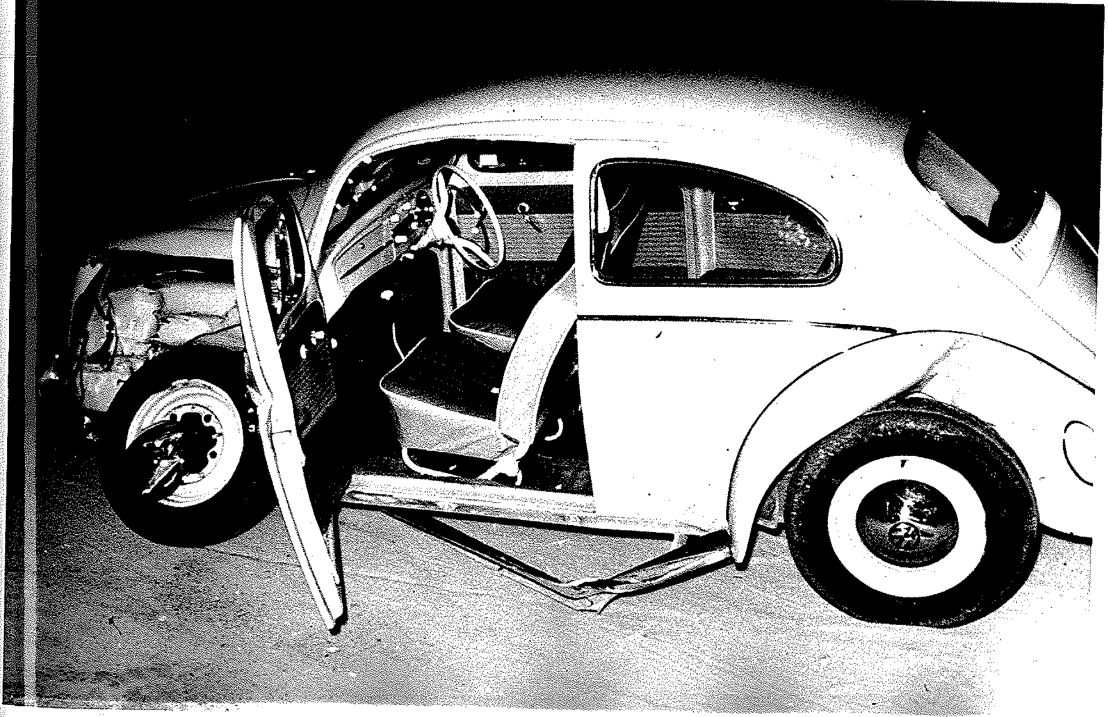


Fig. 12.13
The door of this 1960 Volkswagen came open during a collision with another car at an intersection.

Holden which was struck on the right front corner by another car at an intersection. The door has been damaged and the latch has been dragged forwards across the striker until the two seperated and the door came open. This was one of the types of failure that the 'new generation' of door locks were designed to overcome.

12.12 Many manufacturers had previously provided some form of longitudinal restraint to reduce the chance of the two halves of the lock separating from each other. The initiative for such measures had generally come from embarrassing experiences such as a door springing open when the car hit a bump in the road. Consequently these devices were sadly inadequate when subjected to the much higher forces resulting from collisions or rollover. In some cases the mounting for the lock was even weaker than the lock itself (Fig. 12.12).

12.13 The early attempts to design a lock to withstand collision forces met with varying degrees of success (Ref. 63). A common failing is shown in Fig. 12.10. Here a flange has been incorporated into the latch to prevent it from being pulled away from the striker. The flange was not strong enough and has bent, allowing the door to come open. A similar lock is shown in Fig. 12.11. Although badly distorted it is still engaged and has kept the door closed.

12.14 When recording the performance of door locks on the cars involved in accidents covered by this survey the type of lock was also noted.

The results are shown in the following Table.

TABLE 12.2

<u>Car Doors (after the accident)</u>

	Front Right Door		Front Left Door		Rear Right Door		Rear Left Door		
	A*	B**	A	B	A	B	A	B	Total
Door remained closed:									
Operates normally	169	181	166	172	163	142	159	149	1301
does not operate normally	15	35	17	32	6	20	8	8	141
jammed shut	13	25	14	37	8	23	9	18	147
Door came open:									
operates normally	1	-	-	2	-	-	1	-	4
cannot shut, no damage to door	6	21	7	17	-	6	3	6	66
cannot shut, door damaged	8	15	10	24	6	4	3	15	85
Not elsewhere classified	-	2	-	-	1	2	-	-	5
Not applicable	-	-	-	-	31	91	31	92	245
Not recorded	7	15	5	10	4	6	5	6	58
Total	219	294	219	294	219	294	219	294	2052

*A: door lock incorporates some form of longitudinal restraint.

**B: door lock does not incorporate any form of longitudinal restraint.

12.15 The performance of door locks incorporating some form of longitudinal restraint is compared with those that do not in Table 12.3, using the same notation as in Table 12.2.

TABLE 12.3

Performance of Door Locks.

	Type of Door Lock (all cars)		
	A	B	Total
Door came open	45	110	155
All other cases	769	884	1653
Total	814	994	1808

Chi square = 17.5*** ($p_{0.001}$ = 10.8)

Expressed in percentages of the total number of doors, 5.5 per cent of those having type A locks came open, compared with 11.1 per cent of those having type B locks. In other words, those door locks having some form of longitudinal restraint failed only half as frequently as those which lacked such a device. This result is almost certainly not due to chance.

12.16 There is one other somewhat surprising consequence of the improved type of door latch. Not only does it halve the risk of a door coming open but it also halves the risk of it being jammed shut in such a way that it cannot be opened. Parallel improvements in the stiffness of body shells may also have influenced this result in some cases. Table 12.4 lists the figures for doors which were jammed shut.

TABLE 12.4

Incidence of Doors Jamming Shut

	Type of Door Lock (all cars)		
	A	B	Total
Door jammed shut	44	103	147
All other cases	770	891	1661
Total	814	994	1808

Chi square = 14.7*** ($p_{0.001}$ = 10.8).

12.17 While the above results are statistically very significant, there is a great variation in the types of door locks, particularly in group A (those having some form of longitudinal restraint). Included in this group are locks such as that shown in Fig. 12.12. In an attempt to define more clearly the differences in the behaviour of these two basic types of a door lock we now consider two periods in the design of locks that have been used on the Holden car. Both locks have been shown, the earlier model in Figs. 12.6, 12.7, 12.8 and the later model in Figs. 12.10, 12.11. This later type of lock was also fitted to the door shown in Fig. 12.9. The complete results are listed in the next Table.

TABLE 12.5

Holden Doors

	Front Right Door A*	Front Right Door B**	Front Left Door A	Front Left Door B	Rear Right Door A	Rear Right Door B	Rear Left Door A	Rear Left Door B	Total
Door remained closed:									
operates normally	126	26	122	29	125	26	120	28	602
does not operate normally	12	8	13	8	2	3	5	1	52
jammed shut	9	5	10	5	8	5	8	1	51
Door came open:									
operates normally	1	-	-	-	-	-	-	-	1
cannot shut, no damage to door	5	4	6	3	-	-	2	3	23
cannot shut, door damaged	5	3	8	3	3	-	3	1	26
Not elsewhere classified	-	-	-	-	-	-	-	-	0
Not applicable	-	-	-	-	20	13	20	14	67
Not recorded	3	2	2	-	3	1	3	-	14
Total	161	48	161	48	161	48	161	48	836

*A: FE to EH models, all having type 'A' door locks.

**B: FX and FJ models, all having type 'B' door locks.

The additional case in the last column of the 'not applicable' category is illustrated in Fig. 12.6. The left rear door had been removed before the accident.

12.18 Condensing Table 12.5 in the same way as before (see Table 12.6), we find that 4.8 per cent of the doors in group A came open and 8.9 per cent of those in group B. This confirms the conclusion drawn from Table 12.3: the new type of lock was an improvement. Once again, simultaneous improvements in the rigidity of the vehicle body from one model to the next may also have lessened the loads placed on the door locks.

This result is in close agreement with a similar analysis based on General Motors cars in the U.S.A. (Ref. 63).

TABLE 12.6

Performance of Holden Door Locks

	Type of Door Lock A	Type of Door Lock B	Total
Door came open	31	17	48
All other cases	560	145	705
Total	591	162	753

Chi square = 5.9* $(p_{0.05} = 3.8)$.

12.19 There is no significant difference in the types of accidents (e.g. single impact, rollover) or the types of collisions (e.g. pedestrian, moving vehicle) between the vehicles in groups A and B. There is therefore unlikely to be any consequent bias affecting the results presented in paragraph 12.18. The value of Chi square for the data in Table 12.6 shows that the distribution is unlikely to be due to chance.

12.20 One other model which appeared often enough (41 cars) in this survey to make this type of investigation feasible was the Volkswagen 1200 sedan. This car has only two doors, the locks having no form of longitudinal restraint. 11 per cent of all Volkswagen doors came open in these accidents, e.g. Fig. 12.13. This is a little worse than the early model Holdens for which the figure was 8.9 per cent.

12.21 Finally, the extreme importance of this feature of the detail design of the passenger car must be emphasised. An effective door lock is a safety feature which is built into the car and is operating all the time. Its effectiveness is not dependent on the commonsense of the occupants of the car, as is the protection afforded by safety belts (Ref. 70). If the door locks of all new cars can be improved to the point at which it is no longer the lock but the hinges or even the door which fails, many lives will be saved and much needless suffering avoided. This stage has been reached on some cars (Ref. 64). But many manufacturers seem unconcerned about the safety of their customers in this regard.

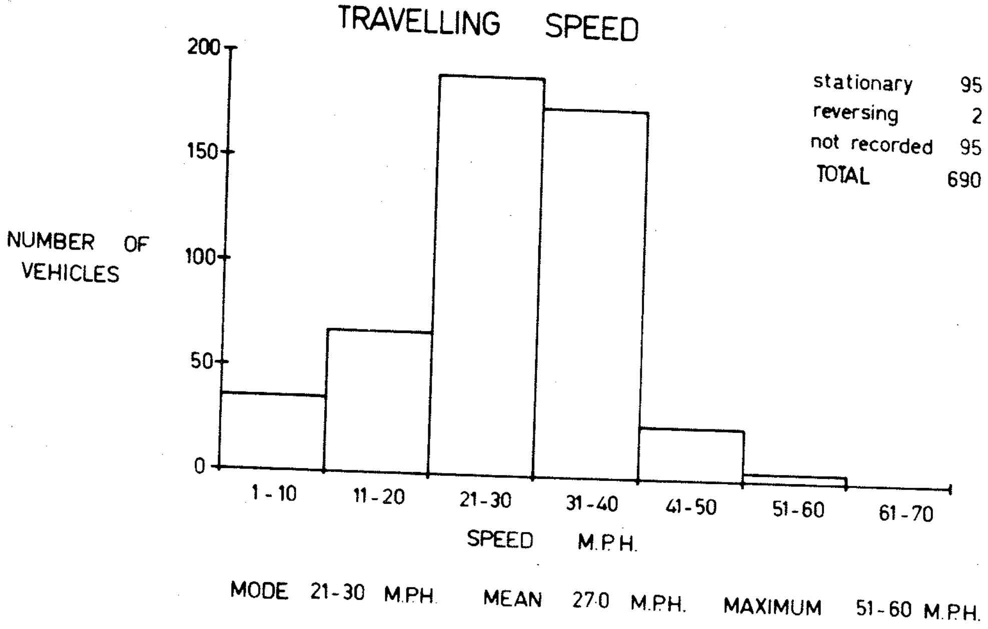


Fig. 13.1
Travelling speeds: all motor vehicles.

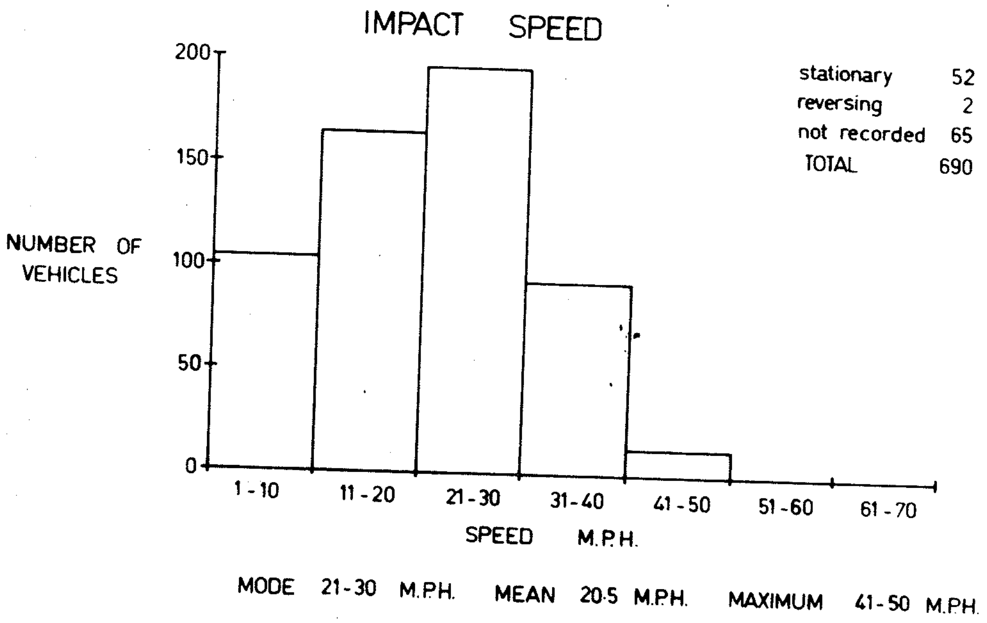


Fig. 13.2
Impact speeds: all motor vehicles.

SPEED ESTIMATION AND SKIDDING

CHAPTER 13

13.1 Both the travelling and impact speeds were estimated for all the vehicles in this sample. The 'travelling speed' is the speed of the vehicle before evasive action, if any, was taken by the driver. 'Impact speed' is the speed of the vehicle on impact. In cases in which there was no impact, e.g. rollover, the speed of the vehicle at rollover or in the case of a motorcyclist, on falling from the machine, has been taken. The travelling speed is usually greater than the impact speed because braking is the most common evasive action. The exceptions include vehicles which moved off from a standstill immediately before colliding with another car. The travelling speed of such vehicles is recorded as zero.

13.2 The ranges of travelling and impact speeds of all motor vehicles in this survey are shown in Figs. 13.1 and 13.2. The mean values are quite low: 27.0 m.p.h. and 20.5 m.p.h. The mean speeds for the 17 accidents which resulted in fatalities are higher: 35 m.p.h. and 31 m.p.h. If these mean values and the ranges of speeds are accurate, the effect of 'speeding' in the popular sense of the word is not very marked. This would mean that most accidents happen to people who are travelling well within the 35 m.p.h. speed limit. But how accurate are these recorded speeds?

13.3 The estimation of the speed of a vehicle after the event is beset with countless difficulties. Drivers' statements are unreliable, and those of witnesses often little better. This is not necessarily because of a wish to deceive or to avoid charges of speeding. Many drivers simply do not know how fast they are travelling without actually looking at the speedometer, and in an emergency there are more important things to be done. Probably the most frequent replies to the question 'how fast were you going?' were 'about 25' or 'not very fast'. There are other clues which are of considerable assistance, and perhaps the most useful of these are skid marks due to braking. The final estimates of speeds were usually much higher than those of the drivers who had been involved in the accident. Despite this the mean values are still low when compared to the speeds of traffic streams on many metropolitan roads. This is a reflection of the fact that slow speeds can still be dangerous speeds in a metropolitan area. This is particularly true at intersections (Chapter 15).

13.4 Considerable use was made of skid testing to estimate speeds whenever a vehicle had skidded when braking. I made the assumption that the coefficient of friction between a skidding tyre and a uniform road surface is independent of both the weight and speed of the vehicle. This enabled the speed lost in the test skid to be related to the speed lost by the vehicle which skidded in the accident. This will, of course,

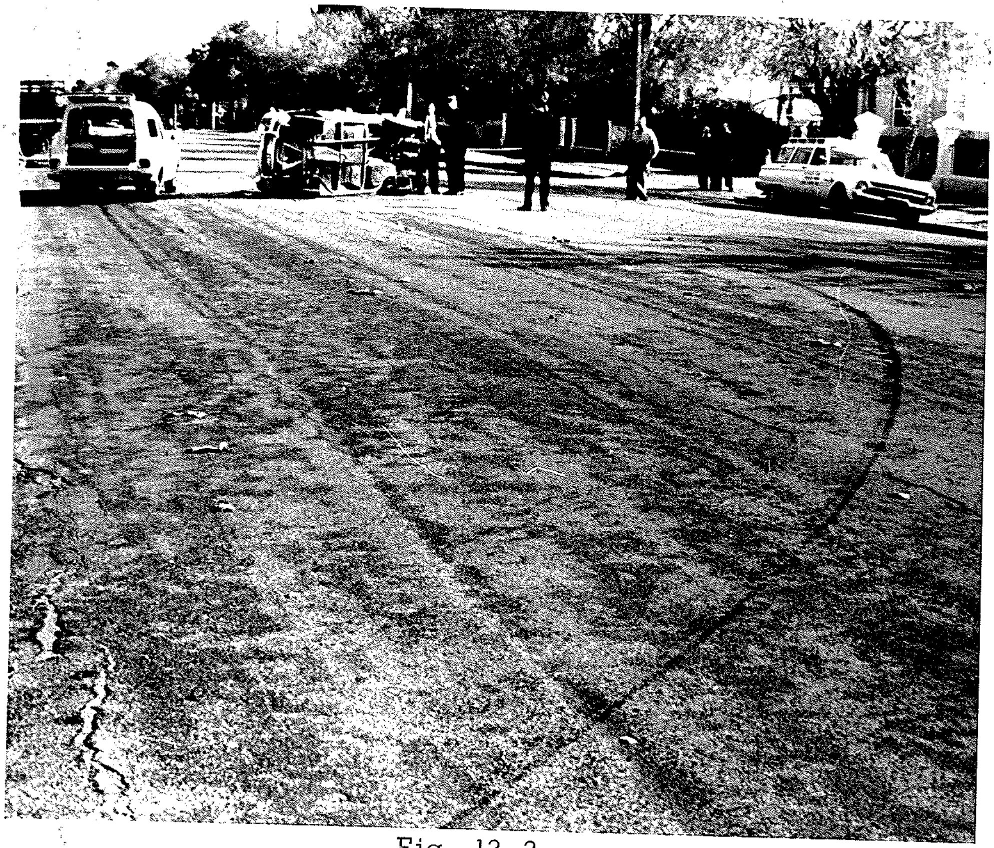


Fig. 13.3
The driver of this 1962 Renault Dauphine swerved to the left to avoid a vehicle on his right at an intersection. His car skidded and rolled over.

Fig. 13.4
The arrows indicate the ends of the skid marks made by the 1959 Ford Zephyr as it slid sideways before rolling and after being struck on the left side by another car. The braking skid marks of the other car can be clearly seen.

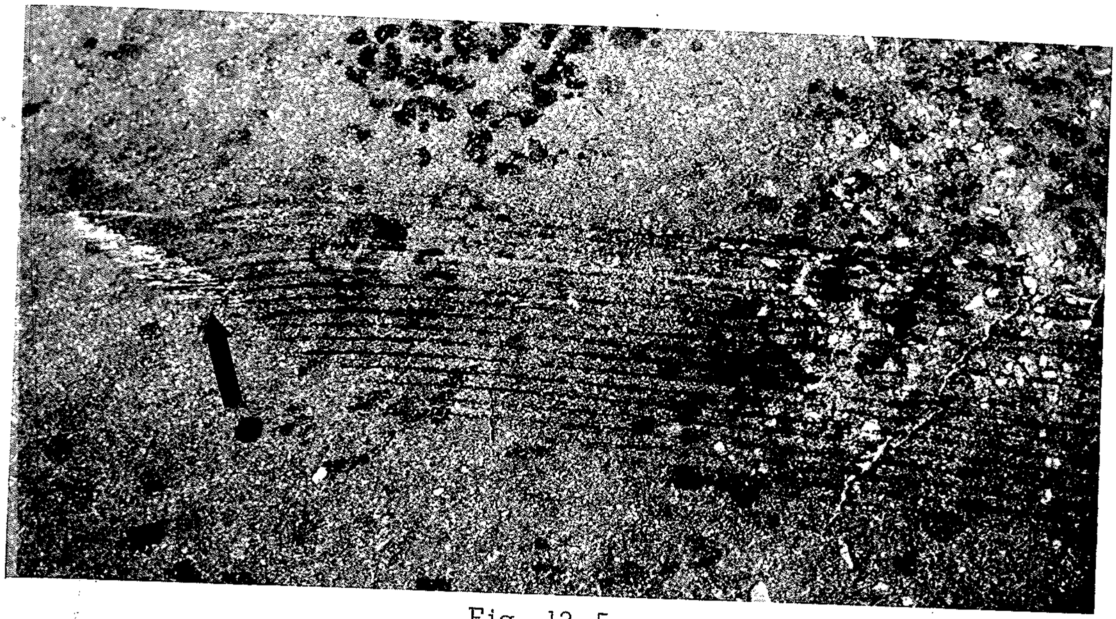


Fig. 13.5
The end of the skid mark shown by the right hand arrow in Figure 13.4. The direction of travel here was from right to left. The arrow indicates a gouge mark made by the wheel rim.

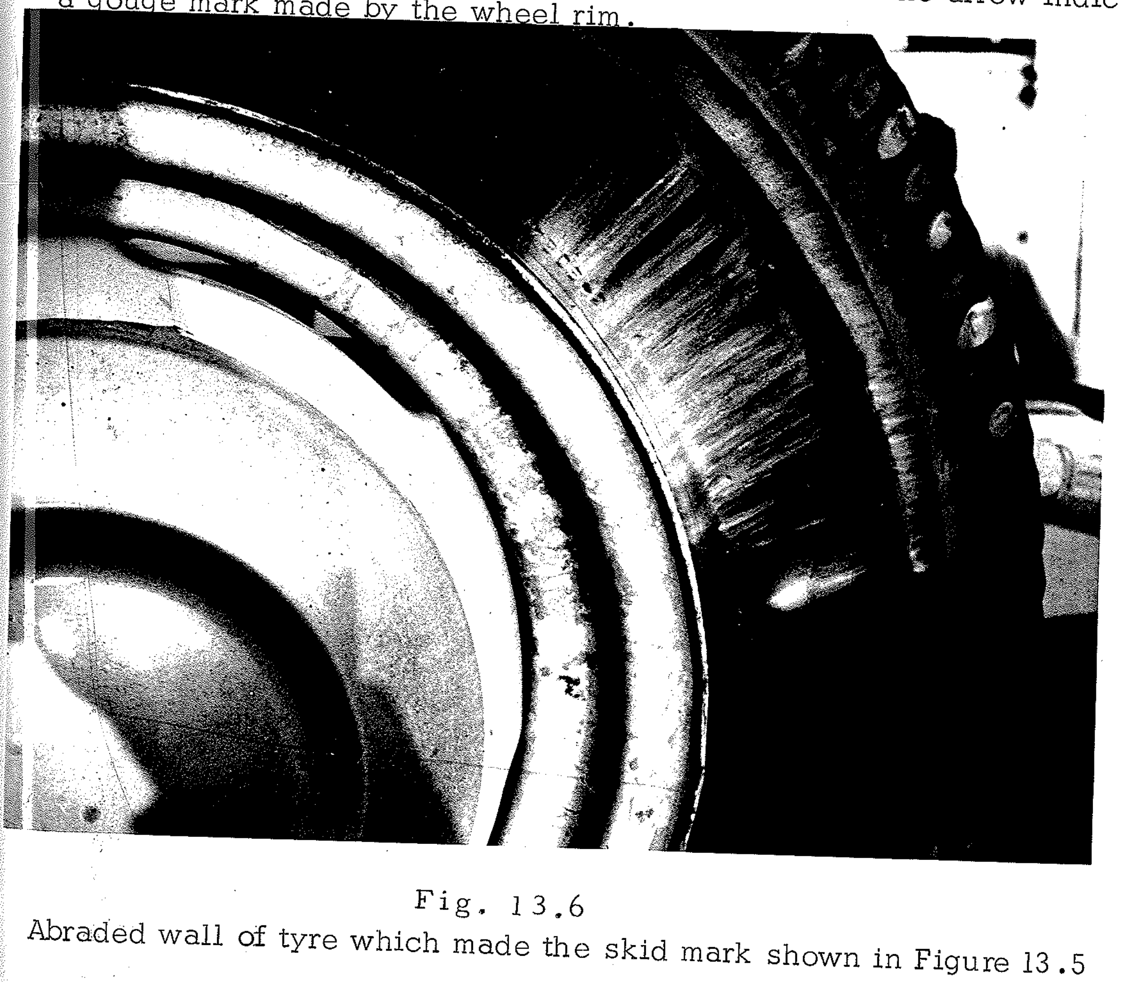


Fig. 13.6
Abraded wall of tyre which made the skid mark shown in Figure 13.5

give a complete picture only in accidents in which any collision is of a minor nature as far as the skidding vehicle is concerned, e.g. a collision between a car and a pedestrian. In some pedestrian accidents it was possible to calculate the speed of the vehicle when the wheels started to skid and its speed when it hit the pedestrian the point of impact being located by scuff marks made by the pedestrian's shoes, as long as the vehicle did skid to a stop. In a collision between two vehicles the difference between travelling and impact speeds alone could be estimated with any accuracy.

Skidding and Accidents.

13.5 Considerable emphasis is often placed on the relationship between skidding and accidents (Ref. 66). Skidding can result from cornering too rapidly (Fig. 13.3) and is also a feature of the post-impact motions of a car involved in a collision (Figs.13.4, 13.5, 13.6). There is, of course, always a small amount of sliding taking place between the tyres and the road, chiefly when cornering. This section concentrates on skidding due to braking (Fig. 13.7).

13.6 When the road wheels of a moving car stop turning, the vehicle is sliding or skidding over the road surface. This has two important consequences. First, all steering control is lost. Second, the effective braking force is reduced because the force of friction between a rolling wheel and the road surface is greater than that for a sliding wheel. In

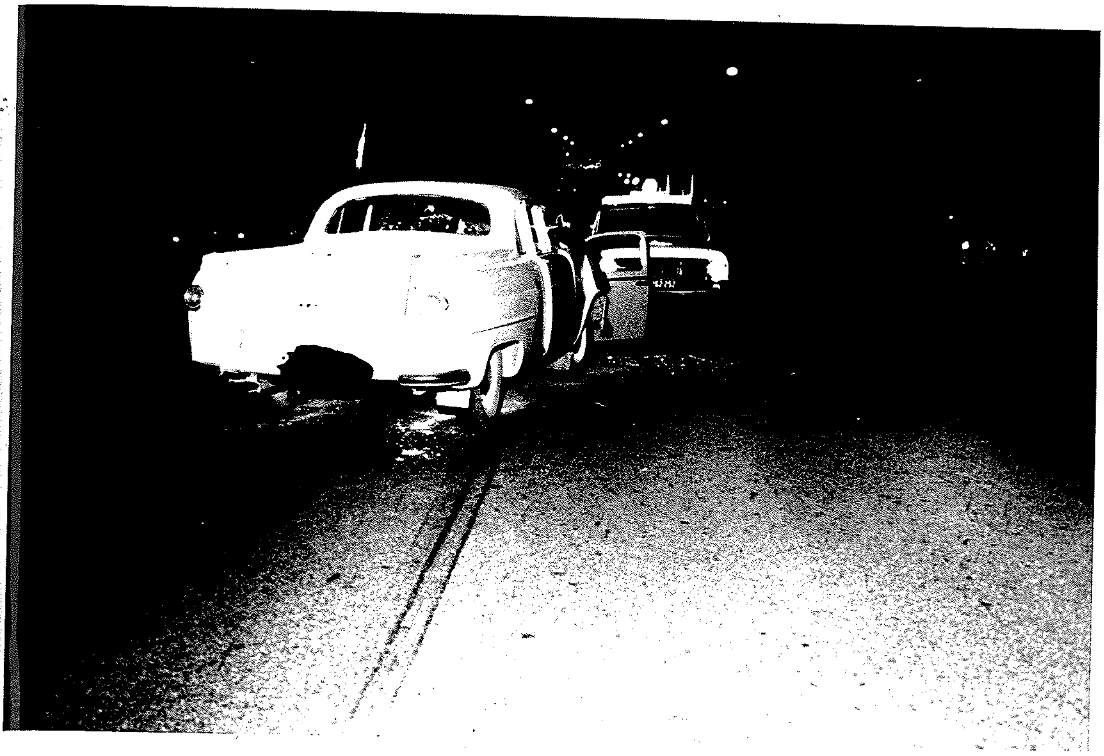


Fig. 13.7
Skid marks due to braking. This accident is also shown in Figure 8.2.

Fig. 13.8
The braking skid marks referred to in the text are those on the right. The car on the left was pushed sideways by the impact.

other words, a skidding vehicle will take longer to stop from a given speed, and will not respond to the steering controls as long as all wheels are not rotating.

13.7 In an emergency, when it is necessary to stop in as short a distance as possible, it is therefore desirable not to lock the wheels, to achieve maximum braking and retain effective steering control. There are devices which will permit a driver to brake as hard as he can and yet not lock the wheels (Ref. 67). These have not yet found ready acceptance by the automobile industry. There may be some drivers who, in an emergency, can stop a car in the most efficient manner, i.e. braking as hard as possible without locking the wheels. I suspect that such people are few and that virtually all drivers will brake so hard that their vehicle is likely to skid in an emergency stop. The braking skid marks shown in Fig. 13.8 were made by an experienced racing driver.

13.8 The frequency of skidding due to braking and the type and condition of the road surface was recorded. Of the 623 motor vehicles for which this information was recorded, 180 skidded when braking. This does not mean that all of the remaining 443 vehicles were not also braking. Some of them doubtless were, but they did not skid. Initially I was not able to determine whether or not a vehicle had skidded when the road was wet, for then skid marks are not visible. In most cases, however, if skidding has taken place faint skid marks will appear when the road dries out.

Road Surface.

13.9 Whether or not the wheels lock depends, of course, on the skid resistance of the road surface. It is very easy indeed to skid on a surface covered with melting ice. It is much more difficult, fortunately, to do so on a dry concrete or sealed surface. All of the 180 vehicles which skidded were on bitumen roads. This is to be expected because, with only one or two exceptions, this was the only type of road surface encountered in this survey. The term 'bitumen surface' is at the best a rather vague one. It encompasses surfaces which vary in nature from the machine-laid 'hot mix' to the poorly maintained macadam-based surface found in many suburban sidestreets.

13.10 Consider for the present only a clean dry bitumen road. There can be a great variation in the skid resistance of this type of road surface. I was able to confirm this at many accident locations by performing skid tests with our own vehicle. These tests were usually a series of two or three locked wheel skids from a steady 30 m.p.h. to a standstill. I repeated the test at each location until at least two values were obtained for stopping distance which were within 10 per cent of each other. Obviously a test of this nature can only be performed safely in very light traffic and where there are few pedestrians. This often meant that I had to return to the accident scene at an 'off-peak' period.

13.11 Under locked wheel skidding conditions the coefficient of friction

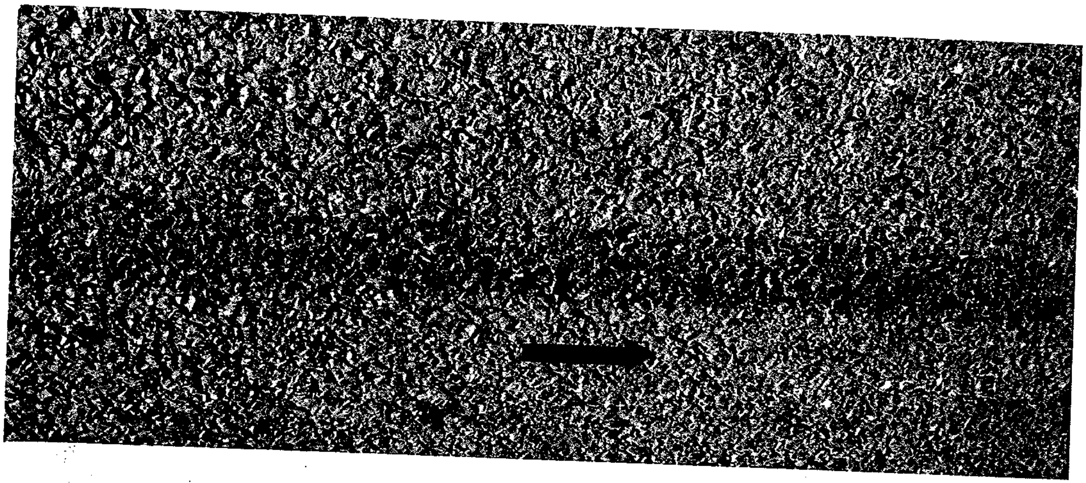


Fig. 13.9
Braking skid marks.

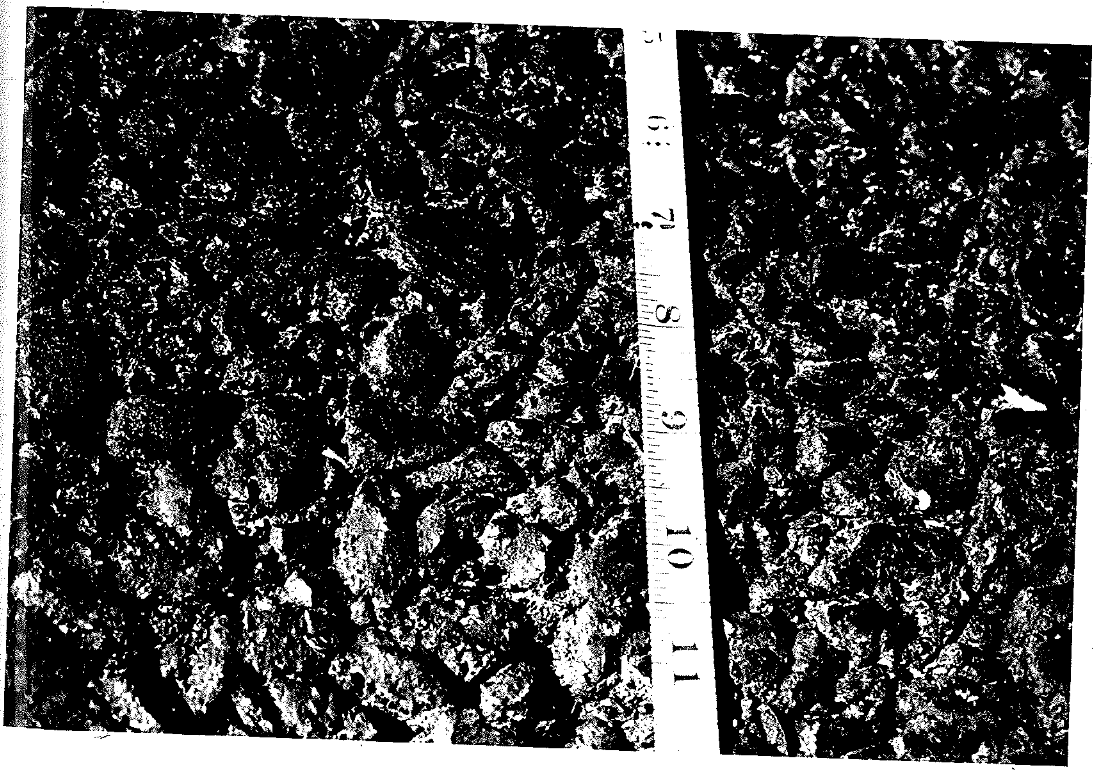


Fig. 13.10
Close-up view of surface shown in Figure 13.9.

between the tyre and the road surface is virtually the only factor determining stopping distance. These tests gave stopping distances, from 30 m.p.h., varying from 11 to 22 yards on dry, clean bitumen. Road test reports frequently quote shorter stopping distances for braking from 30 m.p.h. On the same surface as that on which an 11 yard skid length was obtained a shorter stopping distance could only be achieved if the wheels did not lock. Under the circumstances of a road test the driver knows in advance that he must stop, and may well be able to do so without locking the wheels. Once again, I doubt whether this would be the case in an emergency stop in traffic or at an intersection.

13.12 A stopping distance of 22 yards from 30 m.p.h. on a dry, clean bitumen surface is most surprising. The particular surface is shown in Figs. 13.9 and 13.10 and the poor skid resistance is apparently due to the large aggregate being coated with bitumen, which is melted by the heat generated by the tyre sliding over it. The resulting skid mark is a molten tar mark and not an abraded rubber mark. The vehicle is in fact sliding on molten tar. This surface is a basecourse for the final layer of hot mix. As there often seems to be a delay of some months before the final layer is applied signs should be displayed warning motorists of the slippery surface.

13.13 Mention should be made in this section of the skid resistance of white road markings. The white paint that is commonly used for road markings has a skid resistance that is much less than that of a bitumen road surface. While it is most unlikely that the area of paint will be such that a vehicle will skid to a standstill on the painted surface alone it is possible for even one wheel to skid on a painted marking and for this skid to continue onto the bitumen surface. In other words the painted area can initiate a skid in much the same way as a patch of oil on the road. Reference 30 includes a discussion of the skid resistance of various road-marking materials.

13.14 Even a dry road surface will have its skid resistance reduced if it is covered with a layer of loose material. This was not very common; only 16 vehicles out of more than 600 were on such a surface, but 10 of these 16 vehicles skidded on the loose material. Some of these cases could have been avoided altogether if regular road maintenance had included the removal of loose material, e.g. by a street sweeping machine. The significance of skidding on loose material is accentuated when we look at the frequency of skidding on wet roads.

Weather Conditions.

13.15 The average annual rainfall in Adelaide is 21 in. This tends to come in short sharp falls of rain. The roads are therefore not wet as frequently as would be the case in an area of similar annual rainfall where light showers are more common. Much of the work that has been done in other countries on skid resistance has concentrated on wet pavements (Ref. 68 and 69).

13.16 Exactly one eighth of the accidents in this survey occurred on wet roads. The ratio is very nearly the same when calculated on a vehicle basis. There were 75 motor vehicles travelling on wet roads at the time of their accident, but only ten of these were recorded as having skidded. In 16 cases I could not tell whether skidding had occurred. Taking only the recorded cases of skidding on wet roads we find that in fact there are just as many cases of skidding on loose material. This highlights the importance of keeping sealed roads free from loose gravel, etc.

13.17 Temperature effects in Adelaide do not appear to be critical. The possibility of ice forming on the road surface is very remote. The softening of road tars in mid-summer may be more of a problem. There was no case of this but we did not investigate any accidents during the hottest months. The exceptionally long stopping distance of 22 yards from 30 m.p.h. was recorded when the road surface temperature was 80°F.

Tyres.

13.18 Considerable emphasis is placed on the relationship between the condition of a vehicle's tyres and the risk of skidding, and hence being involved in an accident. Many insurance assessors will query damage claims if the tyres of the particular vehicle are not in 'good' condition. Tables 13.1 and 13.2 relate the condition of the tread of the tyres of motor vehicles in this survey to the incidence of skidding due to braking (excluding those cars in which I was unable to tell whether skidding had occurred or not). In this assessment I have taken a 'good' tyre to be one with a well defined tread pattern, the depth of tread being at least 1/10th of an inch. If even one tyre on the vehicle could not be classified as 'good' I have placed that vehicle in the 'worn' tyre category.

TABLE 13.1

Skidding due to Braking

	Road Surface		
	Wet	Dry	Totals
Vehicles with good tyres	7	87	94
Vehicles with worn tyres	3	64	67
Condition of tyres not recorded			19
			180

TABLE 13.2

No Skidding due to Braking

	Road Surface		
	Wet	Dry	Totals
Vehicles with good tyres	25	161	186
Vehicles with worn tyres	23	167	190
Condition of tyres not recorded			130
			479

13.19 Looking at each of the three columns of figures in Tables 13.1 and 13.2 we see that more vehicles with good tyres (94) skidded than did those with worn tyres (67). This was so, even for skidding on wet roads.

although here the numbers are small (7:3). It is tempting to deduce from this that it is better to have worn tyres if one wishes to minimize the risk of skidding. This, of course, is not so, but further consideration of these figures will suggest to us that tyres in poor condition play a much smaller role in metropolitan accidents than is commonly supposed.

13.20 The first point to be made is that the number of vehicles that were in fact braking is not known. If this were known, and also the numbers having good tyres and the numbers having poor tyres, then these figures could be compared with those in Table 13.1. This would enable us to form some estimate of how much difference the condition of a vehicle's tyres makes to whether or not it skids when braking. The second point is that even if we could do this we are still assuming that other conditions are constant. This is not so. As we have seen, the skid resistance of even dry clean bitumen surfaces can vary by as much as 100 per cent.

13.21 The recent development of high hysteresis rubber which improves the non-skid performance of a tyre is unlikely to have biased these figures at all. Such tyres were only just coming on to the market in Adelaide during the last year of the survey.

13.22 The risk of a tyre hydroplaning is related to the design and condition of the tread. The phenomenon is chiefly associated with high speeds on very wet roads and is unlikely to be a significant factor in

Fig. 13.11
Collision between a bus and a car. The arrows indicate the positions of the front wheels on impact.

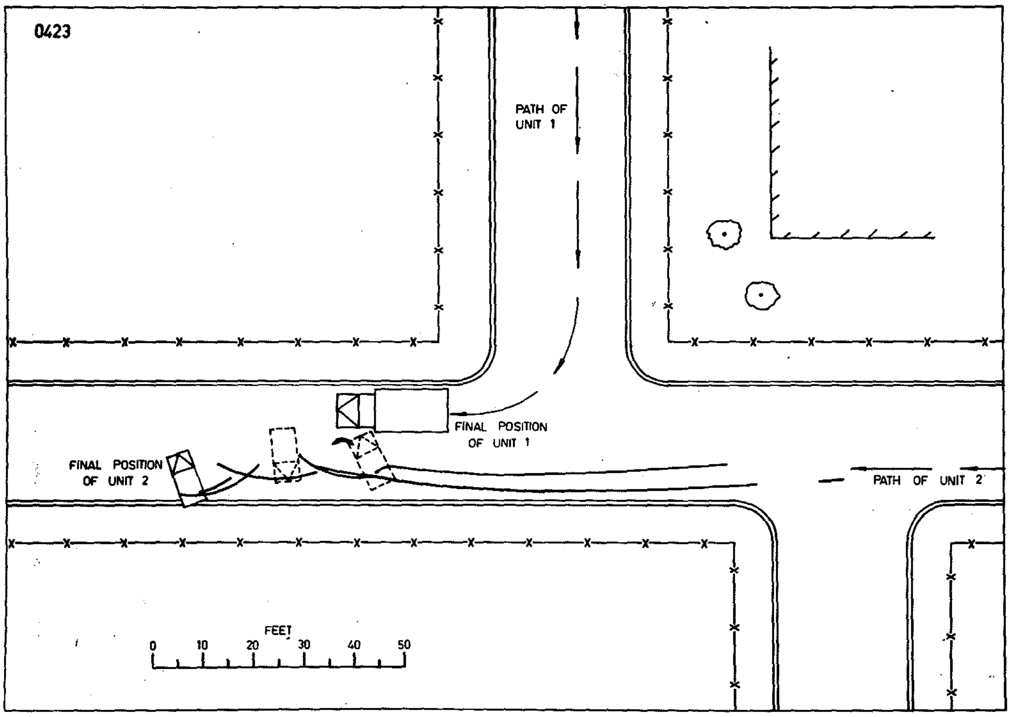


Fig. 13.12
Case 0423.

metropolitan accidents.

13.23 Bearing in mind these very important qualifications we can now look at Table 13.2. This table shows that of those vehicles which did not skid there are almost equal numbers of vehicles with good tyres as with worn tyres. This indicates that there is unlikely to be a bias in Table 13.1 arising from there being more vehicles with good tyres. Why then have more vehicles with good tyres skidded than have those with worn tyres? Possible reasons to explain this curious result have been mentioned. But these other factors would have to be shown to be very significant indeed before one could justly claim that worn tyres play a major role in the causation of metropolitan traffic accidents.

Information from Skid Marks.

13.24 Skid marks on the road convey much more information than merely an indication that a vehicle has skidded. Figure 13.8 shows that one car has been knocked sideways on impact. The position of the wheels on impact is often very clearly defined (Fig. 13.11). As was noted above, all steering control is lost when a vehicle skids. If all four wheels lock a car will continue straight ahead. The only deviation, if any, will be due to the car sliding down the camber of the road or to irregularities in the road surface. The sharp deviation in the skid marks running down from the top of Figure 13.11 is due to the impact of a bus from the left of the picture. Note that the deviation in the skid marks made by the bus is slight when compared to that of the other set of skid marks, which were made by a car.

13.25 Under certain conditions it is possible to relate the momenta of the vehicles on impact by measuring the angle through which the skid marks have been deflected. There are, however, many variables, such as the point of impact on the struck car, which can influence the magnitude of this deflection.

13.26 The post-impact path of a car may also be clearly shown by its skid marks. In Figure 13.11 the car, which was struck on the right side, has been pushed sideways while still retaining some forward motion. The resulting path is as shown. Note that the back wheels, which were tracking behind the front wheels, before the impact, have followed paths that are parallel to but separate from the front wheels after impact. If the track and wheelbase of the car are known it is possible to determine the position of the car at any point along its skid marks. This can be of great assistance when trying to find out what was happening to a car at the moment when, for example, an occupant was ejected. This method has shown that ejection of a car occupant, through a door of the car, often occurs as the car slides sideways after a collision.

13.27 If skidding does not take place on all four wheels the vehicle may tend to yaw away from the initial direction of travel. This is the case when only the rear wheels skid. The following case is an illustration of this.

0430 A 21 year old male driving a Morris Mini Minor along a suburban street saw a truck enter the street some distance ahead. The car driver braked hard, locking the rear wheels. In an excellent demonstration that the coefficient of sliding friction is less than that of rolling friction the car yawed to the right and was actually travelling sideways as it sideswiped the truck (see Fig. 13.12).

The impact encouraged the rotation of the car which spun through a full turn before coming to rest. The driver sustained a lacerated forehead and a bruised arm. His initial speed would have been in the range of 50 to 60 m.p.h. (This accident has also been noted in paragraph 7.41.)

ACCIDENTS AT INTERSECTIONS

CHAPTER 14

14.1 Table 14.1 lists the location of the car accidents that did not involve any other type of vehicle or a pedestrian. Once again it should be noted that the layout of the streets in the Adelaide metropolitan area is such that there are very many intersections which are joined by wide, straight roads.

TABLE 14.1

Location of Car Accidents not involving Pedestrians or other Types of Vehicle

Location of Accident	Number of Accidents	Percentage
At an intersection	129	70.5
Within 20 yards before an intersection	4	2.2
Within 20 yards after an intersection	10	5.5
Not at an intersection	40	21.8
Total	183	100.0
Total intersection-type accidents	131	71.6

14.2 The accidents at intersections are particularly interesting when we look at the numbers happening at stop signs and traffic lights. Taken together (there are 17 car accidents at stop signs and 25 at traffic lights), these two groups of accidents account for 42 out of the 129 accidents at intersections.

Fig. 14.1
Stop signs: this semi-trailer was unable to slow down sufficiently to avoid hitting the car which had moved off from the stop sign(arrow) on the far side.

Fig. 14.2
Note the cross-road warning sign hidden by the utility pole. The car in the distance had just been pushed back onto its wheels after being rolled over in a collision.

Stop Signs.

14.3 The stop sign (Fig. 14.1) naturally requires a driver to stop, but having stopped, this vehicle then has right of way over traffic approaching from the left. Twentyfive of 129 accidents at intersections in this series were at intersections where there were stop signs. Three of these 25 cases are of no particular interest as far as behaviour at stop signs is concerned. These were cases where a vehicle was stationary at a stop sign when hit by another car which had been involved in a previous collision.

14.4 Nine vehicles that had stopped as required at a stop sign collided with a vehicle on the intersecting road. This vehicle was approaching from the right in five cases, and from the left in the other four cases. There are two points to mention here. One is the role of a third vehicle which creates a 'blind spot' for the driver moving off from the stop sign. Either these drivers did not realize that a vehicle might be hidden behind the third car or they decided, foolishly, to take a chance that the road was clear. The other point is that some drivers do not seem to appreciate that, if they move off suddenly from a stop sign, approaching traffic may not be able to stop in time to avoid a collision.

14.5 In 11 of these 25 accidents a vehicle did not stop at the stop sign. There were a further two cases in which this probably happened. At some locations a single stop sign on the left side of the roadway may

Fig. 14.3
Warning sign left in position after changes to the road layout.

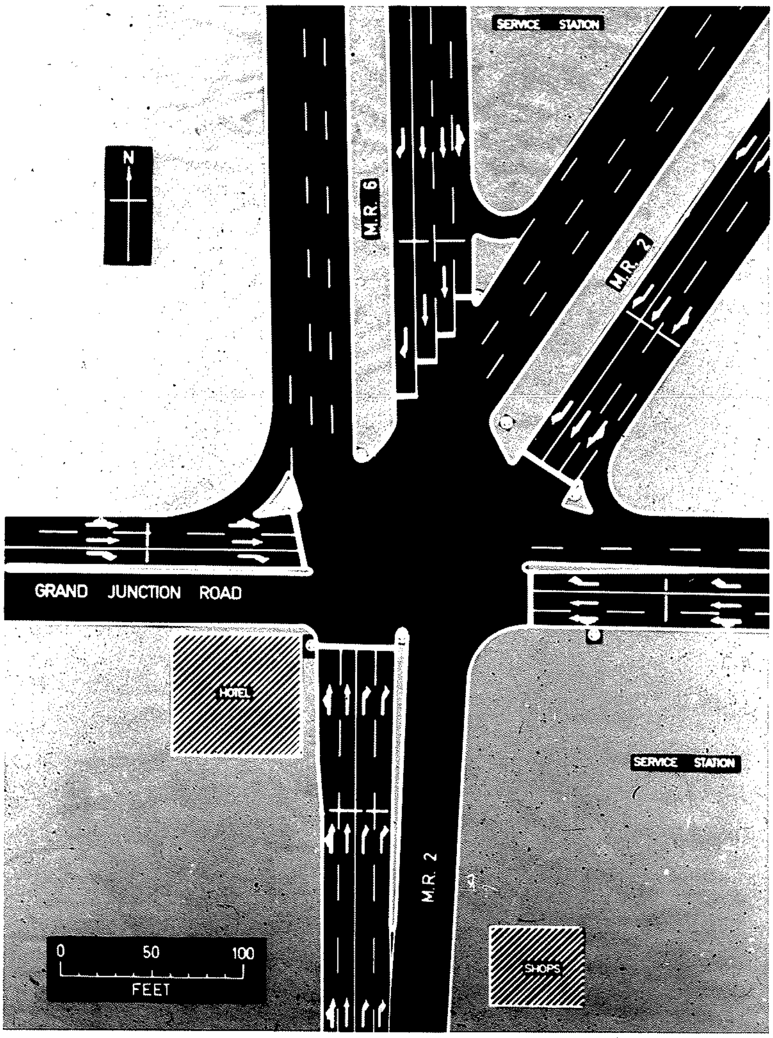


Fig. 14.4
Gepps Cross intersection.

not be adequate. An overtaking vehicle may not be able to see the sign because it is obscured by the overtaken vehicle. At intersections where the roadway has been widened, e.g. for a bus stop, the sign may well be to one side of driver's line of sight. In such circumstances an additional sign on the right hand side of the road, or on a median, may reduce the risk of error.

Warning Signs.

14.6 Of the warning signs that are used in this area the most common is probably the cross roads warning sign. Cross road warning signs are presumably erected at a busy intersection because the risk of a collision there is greater than is the case at a less frequented intersection. How heavy must the traffic be, or how many accidents must take place, before an intersection warrants warning signs? Do intersections that lack such signs demand less care on the part of the motorist?

14.7 Maintenance of signs is important, and this includes such details as cutting back foliage to ensure that the sign is not hidden from the motorist. A far more original attempt to fool the motorist is shown in Fig. 14.2, in which a utility pole has been placed directly in front of a cross road warning sign (the car at the intersection had just been rolled back onto its wheels after a collision).

14.8 Redundant signs are also obviously undesirable, e.g. Fig. 14.3. If drivers become accustomed to ignoring a sign such as this they may tend not to pay attention to more important signs.

Traffic Lights.

14.9 Thirtyseven of these 408 accidents were at traffic lights. These accidents consisted of two main groups. In one group both vehicles were proceeding straight across the intersection. In the other group of accidents one vehicle was turning right. The few remaining cases were collisions with pedestrians and one of the type of accident which is discussed in relation to the Gepps Cross intersection (para. 14.13 et seq.).

14.10 There were 16 collisions in which both vehicles were proceeding straight across the intersection. The most common feature in these 16 accidents was a collision between two vehicles during or at the end of the amber phase of the lights. An all-red phase seems to be the only way to minimize this type of collision.

14.11 Three of the accidents in this group were at Gepps Cross and are discussed in detail elsewhere in this section. There were two cases in which a driver mistook a green 'turn left' arrow for the green light for 'straight ahead'. Casual observation suggests that most drivers realize their mistake and stop before proceeding further across the intersection, but these cases show that there are exceptions. There may be improvements that could be made to the arrangement of traffic lights in such situations to minimize the risk of wrong interpretation. Finally, there was one accident which may have been partly caused by the late afternoon sun shining straight into the traffic lights, making it very difficult to decide which of the three lights was illuminated. If such extraneous light could be absorbed rather than reflected by the traffic light this chance of error would be eliminated.

14.12 The second main group of accidents at traffic lights involved a vehicle turning right across the path of another vehicle approaching the intersection from the opposite direction. This is the classic type of motor-cycle accident in this series, and five of these 15 accidents involved a motor-cycle which was hit by a turning vehicle. In one case, which has been described in the section on motor-cycle accidents, the driver's statement suggested that the lights may have been on split-phase operation, i.e. a car turning right had the red light come on while the motor-scooter still had a green light. This can easily cause confusion, which may result in a severe collision.

Accidents at a Signalized Intersection

14.13 Curiously enough the intersection attended most frequently in the course of this survey is controlled by traffic lights. This is Gepps Cross, which is situated near the northern boundary of the Adelaide metropolitan area (Fig. 14.4).

14.14 The history of this intersection is interesting. The present layout was set down and traffic lights began operating on July 17, 1959. That source of all knowledge, the barman of the hotel at this corner, claimed that there were many more accidents at the intersection after the lights had been installed. Unfortunately accident records are not available for the period before 1961, so we cannot check on the accuracy of this information. The records for 1961 to 1964 are shown in Table 14.2. The last column on the right refers to one particular type of collision now to be described. The phasing of the lights allows traffic to proceed north from M.R.2 into M.R.6 and M.R.2. It also allows traffic from M.R.2 to proceed south along M.R.2 or to bear right along Grand Junction Road. This means that there is a right of way situation between two streams of traffic, both of which have a green light. The alignment of their paths is such that there is frequently a third car, travelling north on M.R.2 and bearing right to continue along M.R.2, which obscures the other two cars from each other.

TABLE 14.2

		Genoa Cross	
Year	Total Accidents Reported	Personal Injury Accidents	Collisions
1961	83	17	16
1962	69	7	21
1963	118	22	34
1964	143	25	39

14.15 The particular type of collision that results can produce serious injuries and severe vehicle damage. Over the 4 years listed above, this feature of the phasing of the lights accounted for one quarter - 110 - of

Fig. 14.5
The Volkswagen 1200 Sedan from accident 0320.

Fig. 14.6
Gepps Cross: view looking west along Grand Junction Road. Arrows indicate wrecked motor-scooter and immobilized truck (accident 0239).

all the accidents at this intersection. The severity of these accidents was such that they form half of all the personal injury accidents and account for half of the total value of property damage over this 4-year period. In 1964 the property damage from all 143 accidents was estimated to have been £15,000.

14.16 Six of the accidents in this survey were at an intersection. Each one of these accidents can be directly attributed to deficiencies in the phasing of the traffic lights. Three cases were of the type described above, e.g. case 0320.

> 0320 A Volkswagen 1200 sedan was stationary, facing south, at the traffic lights on M.R.2. When the lights changed to green this car moved off and began to bear right to continue on along Grand Junction Road. An FE Holden sedan entered the intersection from the south at about 30 m.p.h. after the lights had turned green. This car was proceeding straight ahead, to enter M.R.6. Neither driver saw the other car until just before the left front corner of the Holden struck the left side and rear wheel of the Volkswagen, which was moving at about 20 m.p.h. The Volkswagen was spun twice by the impact and the front seat passenger, a 48 year old woman, was ejected. She was concussed and also received many abrasions and injured the small vertebrae at the base of her spine. The passenger in the left rear seat, a 19 year old girl, received concussion, abrasions and bruises. The driver's face was lacerated on the left side. The 20 year old man driving the Holden was not injured. The damage to the left side of the Volkswagen is shown in Figure 14.5. This accident happened on a fine, clear night.

14.17 The remaining three cases arose from the amber period allowing vehicles insufficient time to clear the intersection. Consider vehicles travelling west along Grand Junction Road (Fig. 14.6). The distance from the stop line to the far side of the intersection, plus the length of a car, is 135 feet. The amber period is three seconds. There is no all-red phase. To cover 135 feet in 3 seconds demands a minimum speed of 32 m.p.h. But a driver must be able, on seeing the green change to amber, either to stop before the intersection or cross over within the amber period. In this case if a driver is travelling fast enough to cross the intersection he is travelling too fast to stop, should the amber phase begin when he is still some distance back from the stop line. With this phasing of the lights the condition is always present in which it is impossible for a driver to cross the intersection without risking a collision with a vehicle moving off from the southern leg of M.R.2; e.g. Case 0239.

0239 A truck carrying a load of peaches, total weight 8 tons, was travelling west along Grand Junction Road at about 20 m.p.h. After entering the intersection the lights changed to amber and then to red. A motorscooter moved off from the southern leg of M.R.2 (see Fig. 14.6). Although it was midday the rider could not see this truck because there was another truck alongside him on his right on M.R.2. The scooter hit under the left side of the tray of the truck and was run over by the rear wheels. The rider, a 32 year old man, received a fractured rib and multiple abrasions. His pillion passenger, a 30 year old woman, received abrasions and a deep laceration to the right knee. They were both wearing safety helmets. The driver of the truck was not injured. The truck was immobilized in what was rather a "David and Goliath" sequence. As the left rear wheels passed over the scooter the rear spring broke, allowing the wheels to act as a roller between the bottom of the tray and the road.

> This dragged the rear axle back far enough for the tail shaft to pull out of the splines at the gearbox. The free end of the shaft then snagged on the road surface.

14.18 A similar situation exists for vehicles travelling south from M.R. 6 into M.R. 2. Here the distance from the stop line in the left hand lane to the south side of east bound traffic on Grand Junction Road is 165 feet.

SAFE SPEEDS AT INTERSECTIONS

CHAPTER 15

15.1 In one week two accidents were attended on the same through street. Each of these accidents was a collision between two cars at an intersection. While attempting to measure the positions of the skid marks which had been made by these cars I frequently had to jump aside to get out of the way of other cars that were speeding across these intersections. This made me wonder how many drivers could hope to avoid a collision, should a second vehicle suddenly appear along the intersecting road.

15.2 At the end of the survey I returned to 34 intersections at which accidents of this type had happened, and which were covered by the survey. The approach and crossing speeds were recorded for 451 vehicles. A radar speed meter was used to measure these speeds. This meter was borrowed from the S.A. Highways and Local Government Department. As far as possible each intersection was visited at the time of day and day of week that corresponded with the timing of the accident that was attended there. Hence more than one set of readings were made at some intersections. The meter was available for one week only, and this restricted the time spent at each location. The sample size was consequently severely restricted at some intersections; at two places no vehicles crossed in one hour. The relevant sight distances had been measured at the time of the accident, and the stopping distances from a given speed were also known (from skid testing). This enabled the calculation of the critical approach speed for each intersection.

15.3 The critical speed that I was seeking is that speed at which a driver can either continue on or slow down and avoid a collision with a vehicle approaching on his right. The method used to calculate this speed is described later in this Chapter.

15.4 The calculated critical speeds were then compared with the measured speeds for each intersection. The comparison showed that 81% of these 451 vehicles were exceeding the critical speed. In other words only about one fifth of these drivers could have obeyed the yield to the vehicle on the right rule in all cases.

15.5 This conclusion has caused some comment, and it has been suggested that the calculated speeds are unrealistically low. They range between 11 m.p.h. and 37 m.p.h. The observed approach speeds varied from 50 m.p.h. - all the locations were in a 35 m.p.h. limit area - to those of vehicles which came to a stop before continuing across the intersection.

15.6 The same recorded data has therefore been compared with critical approach speeds calculated by a method set down by the American Association of State Highway Officials (AASHO), (Ref. 71). These

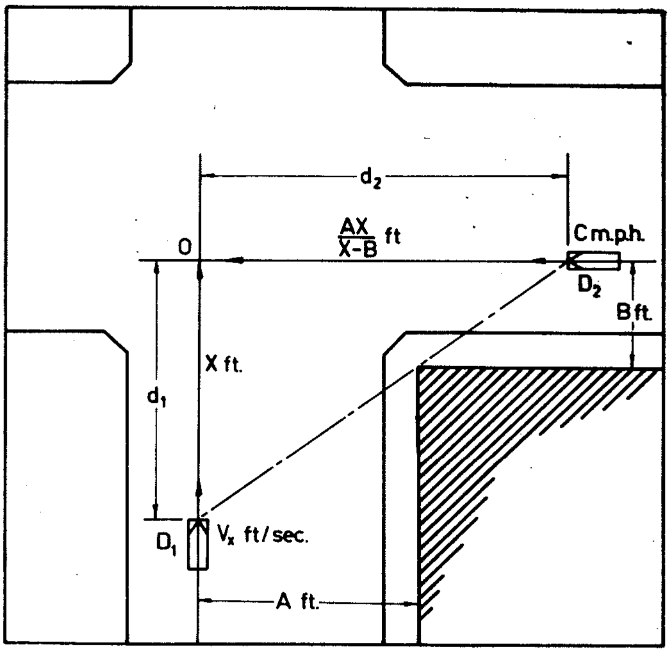


Fig. 15.1
General case of an intersection with limited sight distance.

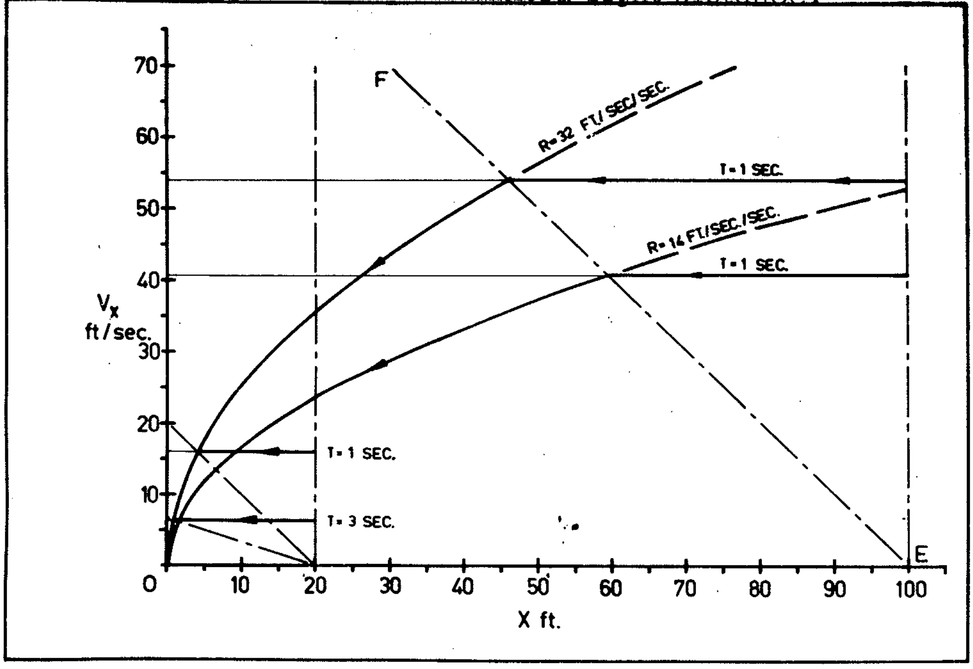


Fig. 15.2
The effect of R and T on Vx.

critical speeds are less than one third the value of the corresponding speeds obtained by the first method (which will be referred to as the TARU method in the following discussion). At no intersection was there even one vehicle travelling at or below the AASHO critical speed.

15.7 But how accurately do these comparisons assess the safety of approach speeds at intersections in Adelaide? There are assumptions used in both the TARU and the AASHO methods of calculating critical speeds. Are these reasonable assumptions? Is the recorded data both accurate and representative? Before considering these questions each method will be described so that the role of the assumed values and the degree of accuracy required in the recorded speeds can be more clearly understood.

Calculation of Critical Speeds.

TARU method:

15.8 Figure 15.1 is a general example of a four way intersection having the two roads at right angles to each other. The intersection has an obstruction to vision, such as a wall or a hedge, on the relevant corner. The case car is D_1. As it approaches the intersection the driver can see further and further along the street on his right. If he is careful, and a little fortunate also, he will be looking to his right and will see the second car, D_2, at the instant that it appears from behind the obstruction to vision. The driver of D_1 has now to make up his mind what to do. Should he slow down and let D_2 pass across in front of him?

15.9 This is what is required by law in South Australia, viz. yield to the vehicle on the right. If D_2 is a long way back from the intersection D_1 may decide that he can get across first without risking a collision. These are the two alternatives. There is of course a third alternative, and that is to collide with D_2.

15.10 Consider first the collision case. Referring again to Figure 15.1 D_1 is travelling at V_X ft/sec. when a distance X feet back from the path of D_2. The layout of the intersection stipulates that D_2 can be no further back from the path of D_1 than $\frac{AX}{X-B}$ feet if D_1 is to be able to see him. If D_2 is set at $\frac{AX}{X-B}$ feet back from the path of D_1 and assumed to be travelling at a steady speed of C m.p.h., it is possible to find V_X, the speed of D_1, which will ensure that D_1 and D_2 will collide. This is done by allowing each vehicle the same time to reach the conflict point.

D_1 will take $\frac{X}{V}$ seconds

D_2 will take $\frac{AX}{(X-B)} \cdot \frac{1}{C} \cdot \frac{15}{22}$ seconds

(note that V_X is in feet per second and C in m.p.h.)

therefore $V_X = X \cdot \frac{(X-B)}{(AX)} \cdot C \cdot \frac{22}{15}$ ft./sec................(15.1).

This means that at any distance X feet back from the path of D_2 it is possible to stipulate a steady speed V_x which will ensure that D_1 and D_2 collide.

15.11 Consider now the case in which D_1 decides to slow down or stop and let D_2 pass. Here V_X is defined as the maximum speed from which D_1

can stop within X feet. This means that at any point distant X feet back from the conflict point O, D_1 is travelling slowly enough to be able to stop his vehicle without encroaching on the path of D_2.

15.12 There are two additional factors involved here. The first is the braking performance of vehicle D_1. Skidding, even on clean, dry surfaces, was the common consequence of emergency stops at intersections in the accidents covered by this survey. It is therefore assumed that D_1 will, in an emergency, skid to a standstill. This assumption enables a value to be assigned to its retardation (R feet/sec/sec.).

15.13 In the examples which follow the values of R were determined by skid testing at each location. They range between the limits of decelerations of 1g and 0.7g, these values being equivalent to locked wheel skid lengths of 11 and 16 yards respectively from 30 m.p.h. The values are valid for dry roads only - all the speeds were recorded when the roads were dry.

15.14 These variations in R have been assumed to depend only on the physical characteristics of the road surface at each particular location. Differences in types and conditions of tyres and weights of vehicles are unlikely to have a significant effect on R on dry bitumen roads as in these examples. Similarly any variation in the coefficient of sliding friction with speed is unlikely to be significant in the speed range

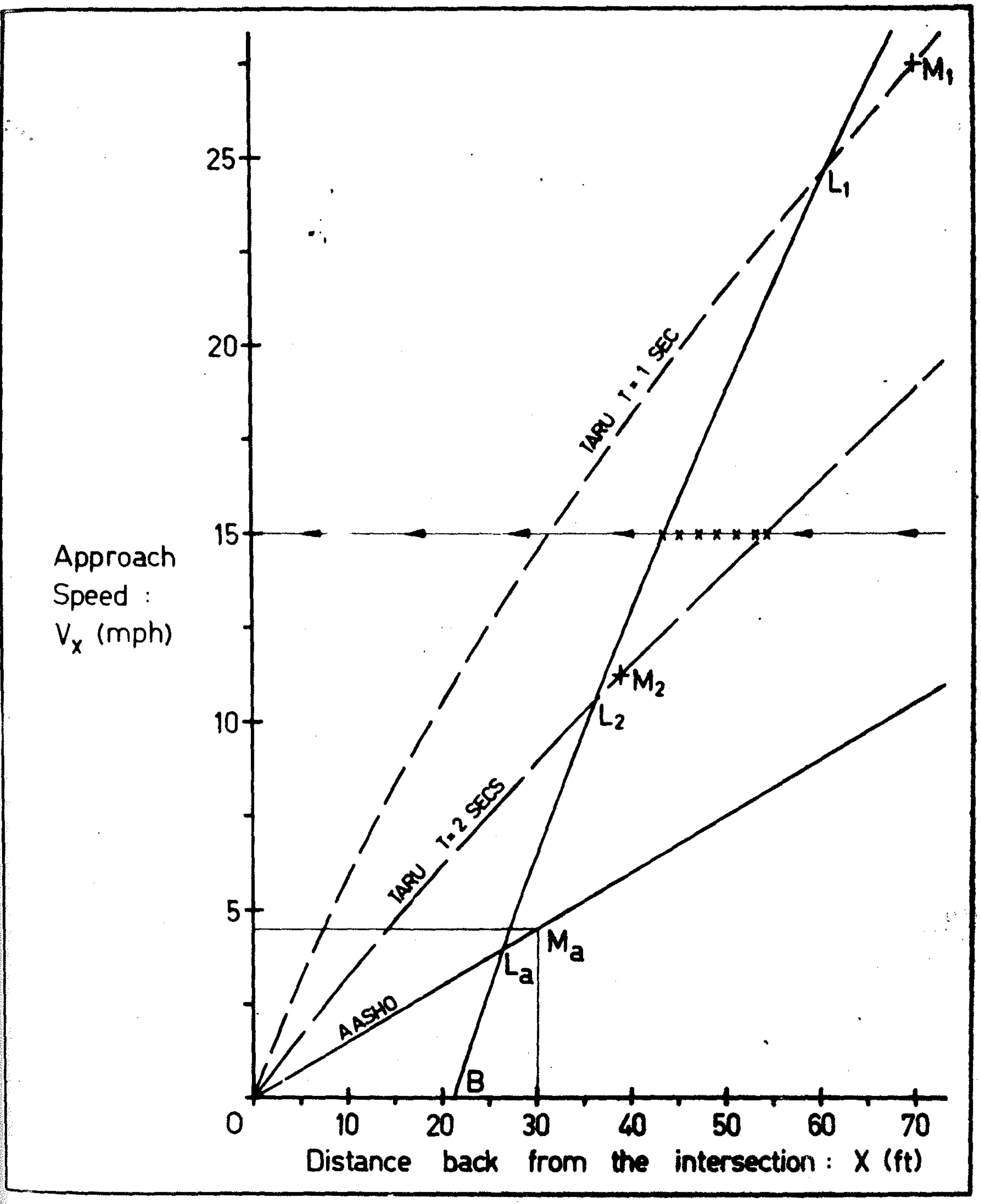


Fig. 15.3
TARU and AASHO safe speeds (graphical solution).

considered here, all the critical speeds being less than 40 m.p.h.

15.15 The second factor is the time taken by driver of D_1 to see the other vehicle and decide to stop or to continue on. If he decides to stop this time is measured up to the instant that he applies the brakes. This whole interval we have taken as his reaction time, T. Initially this was assumed to be one second. The AASHO method allows between two and three seconds, and so T has also been taken as two seconds to facilitate the comparison of the results of the two methods.

15.16 It is true that under favourable circumstances, e.g. on a "Miles" trainer, a person may recognise a hazard and apply the brake within 0.4 seconds. In traffic when the driver must also look ahead and to his left he may not be looking to his right when D_2 first appears from behind the obstruction to vision. In fact casual observation of driver behaviour at intersections suggests that many drivers do not attempt to look to their right.

15.17 Using the above notation the following is the expression for the maximum speed from which D_1 can stop in X feet.

$$V_X^2 = 2R \, . \, (X - V_X \, . \, T) \text{ ft/sec.}$$

which reduces to

$$V_X = -RT + \sqrt{R^2T^2 + 2RX} \text{ ft/sec.} \ldots\ldots\ldots\ldots\ldots\ldots (15.2)$$

This expression is plotted, for two values of T, in Figure 15.3 (Curves O L_1 M_1 and O L_2 M_2). Figure 15.3 relates to accident 061.

15.18 Note that no clearance has been allowed for between D_1 and the path of D_2. This would need to be only 3 or 4 feet and would have only a small effect on the value of V_X in most cases since X is much greater than3 feet.

15.19 When considering the remaining alternative in which D_1 passes across in front of D_2, it is reasonable to allow some clearance, S (feet). A constant value of 15 feet has been taken for S. This is measured back from the driver of D_1. We now have D_2 distant $\frac{AX}{X-B}$ feet back from the path of D_1 and travelling towards the conflict point at C m.p.h. We arrive at an equation similar to 15.1 above.

$$V_X = (X + S) \; . \; \frac{(X - B)}{(AX)} \div \frac{22C}{15} \quad \text{ft/sec..............(15.3)}$$

This expression is also shown in Figure 15.3 (Curve BL_1).

15.20 The curves plotted from these two equations express differing demands on the driver. The stopping distance curves define maximum speeds which must not be exceeded if vehicle D_1 is to be able to be stopped before reaching the conflict point O. But the curve BL_1 from equation (15.2) specifies a minimum speed which must be maintained if D_1 is to continue on at this speed and pass across in front of D_2 which is approaching at C m.p.h. These two requirements can not both be satisfied, (for all values of X), above the point at which the retardation curve crosses curve BL_1.

15.21 An effective reaction time of T = 2 secs. means that point L_2 defines the maximum steady approach speed (10.1/2 m.p.h) which is safe at all points on the approach to the intersection. A line on Figure 15.3 corresponds to a steady approach speed of 15 m.p.h. Note how this line crosses the stopping distance curve for T = 2 at X = 54 feet and then crosses curve BL_1 at X = 43 feet. Should D_2 first come into view when D_1 is located anywhere between these two values of X, then a subsequent collision at point O is unavoidable. (Note again the assumption that D_2 does not attempt to slow down but continues on at a steady speed of C m.p.h. This is consistent with the sequence of events in many of the accidents on which this study is based.) In this example the part of the approach path, for which D_1 is at risk, is covered in a very short time ($\frac{1}{2}$ sec.). At a steady 20 m.p.h. this distance is doubled and the time that D_1 is at risk increases to $\frac{3}{4}$ sec.

15.22 The importance of the length of the effective reaction time of the driver of D_1 can readily be seen from Figure 15.3. Reducing T from 2 seconds to 1 second increases the critical speed from 10.1/2 m.p.h. to nearly 25 m.p.h. These actual values refer only to the particular example shown in Figure 15.3, i.e. accident 061. However the effective reaction time of the driver of D_1 is always inversely proportional to a function of the critical speed for any intersection of this type.

15.23 I have ignored the effect of D_1 accelerating in an attempt to avoid a collision. The values of X that have been obtained, taken together with the corresponding values of V_X, allow a time of about two seconds in which D_1 can accelerate. This will commonly make a difference of less than 5 feet in the distance D_1 travels. Even with a car having a high performance this increase will be unlikely to be more than 15 feet. There is also the sobering thought that driver D_2 may try to accelerate past D_1. I have assumed a steady speed of approach for D_2.

15.24 A graphical solution of the critical speed has been chosen here to illustrate the method in a clearer way than is possible by a mathematical solution. In the examples which follow these critical speeds have been calculated on an IBM 1620 computer. This approach, and the programme which is used, are presented in the Appendix to this paper.

AASHO Method:

15.25 It is assumed that readers wishing to familiarise themselves with the details of this method will consult page 315 of Reference 72. While no attempt will be made here to duplicate the detailed description contained therein, the following general outline will show that the AASHO approach is basically different from the TARU method in three respects. This comparison therefore considers only the AASHO condition which enables vehicles to stop. This is more demanding than their alternative condition which enables vehicles to change speed to avoid a collision.

15.26 The first of these three basic differences is that the AASHO method does not allow for vehicle D_1, using the above notation, to continue on across the intersection in front of D_2 if it is safe to do so. Without this provision it is not possible to define a critical speed using the TARU method.

15.27 The second basic difference is that the AASHO method assumes that the drivers of both D_1 and D_2 see each other in time for the vehicles to stop, if necessary, before reaching the intersection. The speed of D_2 is assumed to be the design speed of that road, and reference to Table 15.1 which relates stopping distance to speed will locate D_2 a fixed distance, say d_2 feet, back from O. It is this condition, that D_2 be able to stop, that the AASHO use to define the sight triangle for any given intersection such as the one shown in Figure 15.1. Note that the TARU method does not assume that D_2 will slow down.

15.28 The AASHO, having defined a sight triangle, thereby locate vehicle D_1. (By similar triangle proportion $d_1 = \frac{Bd_2}{d_2-A}$). The same table of stopping distance is then used to determine the maximum speed from which D_1 is able to stop before reaching point O, i.e. in the distance d_1 feet. This speed is the critical speed for vehicle D_1.

15.29 The third basic difference is in the estimation of stopping distances. This is chiefly responsible for the very large differences between the critical speeds calculated by the two methods. The TARU approach takes a constant value for the effective reaction time and combines this with a locked-wheel stopping distance which is determined at each location. By contrast the AASHO use a constant overall stopping distance, regardless of possible variations in retardation from one location to the next.

15.30 In the following calculations it is necessary to extrapolate values from Table 15.1 because all of the AASHO critical speeds are less than 30 m.p.h. As there is a linear relationship between design speed and safe stopping distance from 30 to 50 m.p.h. and 50 to 70 m.p.h. then the range 0 to 30 m.p.h. has also been assumed to be linear. (Line O $L_a M_a$; Figure 15.3.)

TABLE 15.1

Design Speed and AASHO Stopping Distance

Design speed, m.p.h.	30	40	50	60	70
AASHO safe stopping distance, feet	200	275	350	475	600

The fact that the AASHO do not cover this range in their table is an indication that their method is intended to be applied to the highway, and not to the suburban street.

15.31 The case shown in Figure 15.3 has the distance d_1 = 30 feet. This gives the point M_a on the extrapolation of the AASHO retardation line, and so the corresponding value of 4.1/2 m.p.h. for the critical speed for the vehicle D_1. It is possible to use the AASHO stopping distances in conjunction with curve BL_1 of the TARU method to define a critical speed. This is given, as before, by the intersection point of the two curves, point L_a in this case. Similarly it is possible to use the TARU stopping distances in the AASHO method. This gives points M_1 and M_2, corresponding to effective reaction times of one and two seconds respectively.

15.32 The most valid comparison between the two methods takes a common effective stopping distance curve. Therefore the TARU critical speeds, points marked with an L, are compared with AASHO critical speeds on the same curves, points marked with an M. Figure 15.3 shows that point M is higher than point L for each of the three curves. That is, the AASHO critical speed is not, by the TARU definition, safe for all values of X. The actual distance that the vehicle D_1 would be at risk is very small however. In the three conditions shown on Figure 15.3 it is less than five feet.

Results of Calculations.

15.33 These two methods for calculating critical approach speeds have been applied to each of the thirty four intersections where speed measurements were made. Table 15.2 lists the measured and assumed data along with three values of X and V; two from the TARU method with T = 1 and 2 seconds and one from the AASHO method. These values are distinguished by the headings X', V'; X", V"; and X, V respectively.

15.34 Although only 34 intersections were studied, the results of calculations on 37 accidents are included in Table 15.2. Obviously more than one accident occurred at some of these intersections. Accident 359 was at the same location as 318, but in the latter case parked cars restricted the sight distance. Accident 236 was also at this intersection, and once again parked cars restricted visibility, but a different value has been assumed for C.

15.35 Accident 35 is identical to accident 77 as far as the information presented in Table 15.2 is concerned. They have both been included because in each case the critical speeds are compared with speeds recorded at the time of day and day of week which corresponded to the timing of the accident (Table 15.3).

15.36 Tables 15.2 and 15.3 show that the original TARU calculation of critical speeds, based on T = 1 second, is by no means pessimistic. That 81% of these 451 vehicles should have been travelling too fast was surprising. But the 94% and 100% given by the T = 2 seconds assumption and the AASHO method respectively more than confirm the first result. Therefore the original query about possible false assumptions in the TARU method must also be extended to the AASHO method.

The Effect of Changes in R and T

15.37 The assumptions relating to effective stopping distance have been discussed earlier in this Chapter. It is obvious that the AASHO

TABLE 15.2

Critical Speeds.

Acc. No.	A (ft)	B (ft)	C (mph)	R (ft/s/s)	X (ft)	X' (ft)	X'' (ft)	V (mph)	V' (mph)	V'' (mph)
29	25	24	35	22	27	31	28	4	14	8.3
31	76	18	40	27	25	49	29	4	21	8.8
35	70	24	40	27	32	57	38	5	24	11
61	70	21	35	27	30	60	36	4½	25	11
62	52	30	40	27	37	53	42	5½	22	12
73	33	20	35	23	23	28	24	3½	14	7.4
77	70	24	40	27	32	57	38	5	24	11
106	24	20	35	23	26	29	27	4	14	8.1
117	54	50	35	27	65	94	76	10	34	20
124	24	18	45	22	20	21	20	3	11	6.1
134	27	18	30	22	21	25	22	3	12	6.6
155*	53	12	35	27	15	23	16	2	12	5.1
156	26	21	35	25	24	27	24	3½	13	7.5
157	26	33	35	29	38	44	39	5½	20	12
158	30	90	35	23	103	118	110	15	37	26
162	32	18	40	22	22	24	21	3½	12	6.4
185	34	30	45	27	34	40	36	5	18	11
191	33	42	45	27	47	55	50	7	23	14
196	21	21	40	23	23	25	23	3½	12	7.1
204	40	36	40	23	42	53	46	6½	21	13
217	25	21	35	23	24	27	24	3½	13	7.4
223	27	21	50	32	23	26	23	3½	13	7.3
236*	27	36	40	27	40	46	42	6	20	12
240	50	42	50	27	49	62	49	7½	25	15
284	22	20	35	22	23	25	23	3½	12	6.9
292	30	45	35	23	52	61	55	8	24	15
295	34	30	40	23	34	41	36	5	18	11
297	33	24	40	22	27	32	29	4	15	8.5
315	46	18	35	22	22	31	24	3	14	7.2
318*	27	36	45	27	40	45	41	6	20	12
346	34	45	40	25	51	62	55	7½	24	15
348	66	48	45	27	61	88	71	9	32	19
359	81	18	45	27	86	92	89	13	33	23
382	24	18	35	23	20	23	21	3	11	6.3
386	39	18	35	29	22	28	23	3	14	7.1
401	35	37	35	29	43	55	47	6½	24	14
412	24	51	45	25	59	61	58	9	24	16

* - Parked vehicles limit sight distance.

TABLE 15.3

Recorded Speeds and Critical Speeds.

Acc. No.	No. of Speeds Recorded	No. above Critical Speed			% above Critical Speed		
		AASHO	TARU		AASHO	TARU	
			T=1	T=2		T=1	T=2
29	3	3	3	3	100	100	100
31	2	2	1	2	100	50	100
35	22	22	22	22	100	100	100
61	8	8	8	8	100	100	100
62	9	9	7	9	100	178	100
73	13	13	13	13	100	100	100
77	22	22	20	22	100	91	100
106	11	11	11	11	100	100	100
117	24	24	0	22	100	0	93
124	5	5	5	5	100	100	100
134	21	21	21	21	100	100	100
155	17	17	17	17	100	100	100
156	25	25	25	25	100	100	100
157	12	12	12	12	100	100	100
158	15	15	1	11	100	7	73
162	3	3	3	3	100	100	100
185	16	16	16	16	100	100	100
191	8	8	4	8	100	50	100
196	1	1	1	1	100	100	100
204	5	5	3	5	100	60	100
217	11	11	11	11	100	100	100
223	24	24	24	24	100	100	100
236	23	23	22	23	100	96	100
240	8	8	4	8	100	100	100
284	0	-	-	-	-	-	-
292	0	-	-	-	-	-	-
295	19	19	19	19	100	100	100
297	14	14	13	14	100	93	100
315	7	7	7	7	100	100	100
318	16	16	16	16	100	100	100
346	6	6	4	6	100	66	100
348	13	13	4	12	100	31	92
359	23	23	0	21	100	0	91
382	5	5	5	5	100	100	100
386	17	17	17	17	100	100	100
401	19	19	17	19	100	90	100
412	4	4	4	4	100	100	100
	451	451	363	424	100	81	94

practice of using a set table relating design speed to effective stopping distance is much easier to apply than the TARU approach, which takes the actual value of the skid resistance, or retardation, of the road surface at each location. Is this concern for an exact value for R justified? If it is not, then a single value can be chosen for all locations, thereby reducing the on site work involved.

15.38 The range of likely values for R has been taken to be between 14 and 32 feet/sec/sec. These values were the limits of the range found in the skid testing conducted during the TARU survey. It may be desirable to take an even lower value than 14, for this was obtained on a dry bitumen road (Ref. 72). These two values are plotted against V_X and X in Figure 15.2.

15.39 The retardation R appears only in equation (2).

$$V_X = -RT + \sqrt{R^2T^2 + 2RX} \qquad \text{..................(2)}$$

This equation shows that when attempting to relate variations in V_X with corresponding changes in R due allowance must be made for the effect of any variation in T and X. It can be shown that the shorter the effective reaction time the greater will be the effect of changes in R, particularly for large values of X. The line X = 100 is therefore taken as the starting point for this comparison and a short reaction time, T = 1 sec., is chosen. (Fig. 15.2).

15.40 Once again, as in Figure 15.3, we are assuming that the case vehicles are travelling towards the conflict point O at such a speed that they can stop before passing it, i.e. in a distance X feet. Two cases are considered, both starting from the line X = 100 and both travelling on for 1 second (T = 1) before braking commences. This far the two cases appear to be identical, but reference to Figure 15.2 will show that if they are to follow different retardation curves to the common end point O, then they must join these curves at different velocities. These velocities are defined by the points where line EF crosses the retardation curves. EF is drawn at an angle to the line X = 100 such that it is the locus of the end point of the distance (V_X . T) feet, measured from the line X = 100.

15.41 It should now be clear that the effect of reducing the value of R from 32 to 14 ft/sec/sec is to reduce the maximum value of V_X (for X = 100) from 54 ft/sec to 41 ft/sec, a reduction of 24%. The effect on the value of a critical speed would be greater because the base line is then inclined (BL_1 of Fig. 15.3) and not vertical (X = 100 of Fig. 15.2).

15.42 A variation of 25 to 30% in the calculated value of V_X is considerable and, taken by itself, would suggest that on-site testing of skid resistance is worthwhile. But there are other factors which influence V_X and probably the most marked of these is the effective reaction time, T.

15.43 The effect of different values of T can be shown in a similar way on Figure 15.2. They are most obvious for low values of X and high values of R. The line X = 20 is therefore chosen as a starting point and the retardation curve R = 32 ft/sec/sec as the final part of the path to O. Drawing a line parallel to EF from the point X = 20 on the X axis will, as before, define the end points of the T = 1 sec. parts of the paths. A similar line drawn from the same point, but at an angle in this case arc tan $\frac{1}{3}$ to the X axis, will define the end points of the T = 3 seconds parts of the paths. The paths corresponding to T = 1 and T = 3 for the chosen values of R and X are shown in Figure 15.2. The effect of increasing T from 1 second to 3 seconds is to reduce V_X from 16 to 6.4 feet per second, a reduction of 60%.

15.44 Over the range of values in use changes in T can therefore have more effect on the calculated critical speed than can changes in R. But it should be noted that T can vary proportionally more than R and so changes of similar degree will have a less marked effect than the above values suggest. The examples shown in Figure 15.2 are extreme cases and the effects of changes in both T and R are reduced for other values of X within the range X = 20 to X = 100. Even so, T will always have more influence on the critical speed than will R.

15.45 This concentrates attention on the actual value chosen for T. It is easy to argue that three seconds is too long a period. Most traffic lights operate with an amber period which is no longer than this. But one second may well be too short, for reasons mentioned above. Purely on this rather arbitrary basis it seems that 2 seconds may be a reasonable value for the effective reaction time for suburban intersections.

15.46 Only 6% of the recorded speeds are at or below the TARU critical speeds, using T = 2 secs (Table 15.3). This is not the complete excess as when compared with the AASHO critical speeds, but the situation is certainly most undesirable. Possible errors in the calculation of the critical speeds have been considered. Probably the only remaining chance of serious error is in the choice of a value for C, the speed of the vehicle on the right.

<u>Validity of the Assumed Value of C</u>.

15.47 The speed C is based on recorded speeds and this leads into a consideration of the validity of these speeds in this application.

15.48 All these speeds were measured with a radar speed meter, the same meter being used to measure the speeds (V) of the case vehicles at each intersection. Therefore any error in C would be partly compensated for by a corresponding error in V, as far as the comparisons made in Table 15.3 are concerned.

15.49 A more likely chance of error could arise from the assumed value of C being based on unrepresentative recorded speeds. This was a serious problem, for sample size was often severely restricted by the time allotted (para. 15.2). But wherever the speeds of 15 or more vehicles were recorded the assumed value of C is never more than 5 m.p.h. above the highest speed recorded.

TABLE 15.4

Recorded Speeds and Assumed Value of C.

Acc. No.	117	155	196	204	236	240	295	297	359
No. of vehicles	26	21	15	22	24	25	19	19	24
Highest speed recorded	33	30	40	38	36	45	35	40	40
Assumed speed	35	35	40	40	40	50	40	40	45

(401 speeds were recorded at 34 intersections.)

15.50 It can be argued that attempting to set a value of C on the basis of recorded speeds is unrealistic at some intersections. This is particularly so at locations where almost all drivers slow down because they realise the intersection has its dangers whereas the very occasional driver who does not know the area may proceed across without reducing speed.

15.51 Because some of the 37 accidents considered here did involve drivers who were unfamiliar with the intersections, the corresponding assumed values of C are not closely related to the recorded speeds. This is more a criticism of the unrepresentative sample of recorded speeds than of the assumed value of C.

15.52 Comparison of the critical speeds with the recorded approach speeds will only be meaningful as long as the approach speeds are recorded over a certain distance. If the approach speed is recorded too far back from the intersection the vehicle may subsequently slow down to below the critical speed at the critical distance X", (Table 15.3). In a small number of cases, fewer than 20, this may have happened in this study. In almost all the remaining 430 cases the actual crossing speeds, or speeds at 0 (which were also recorded), are equal to or greater than the corresponding approach speeds. Most of these drivers, if they slowed down at all on the approach, started to accelerate as soon as they judged the intersecting road to be free of traffic.

The Choice of Intersections for this Study

15.53 It can finally be argued that the intersections chosen for this investigation are not a representative sample. This is not easy either to prove or disprove. However they were chosen from a representative sample of injury - producing accidents. This suggests that they should be reasonably representative, at least insofar as accidents are concerned and hence the safety or otherwise of the approach speeds.

CONCLUSIONS.

CHAPTER 16

16.1 The aim of this thesis has been to report on an investigation of the engineering aspects of metropolitan road traffic accidents. The results of this investigation have been presented in the main body of this thesis, along with the discussion of certain points which have proved to be of particular interest. In this concluding Chapter these points of engineering concern are presented under four main headings, the Vehicle, the Road, the Traffic System, and the Road User.

THE VEHICLE

16.2 Generally in this report I have been concerned with those features of vehicle design and condition which determine the "crashworthiness" of the vehicle. This is a word which is being used to describe the performance of a vehicle as far as the protection of the occupants from injury in an accident is concerned. "Roadworthiness" is a far more common word, although it too has grown up with the motor car. It refers, of course, to the handling and reliability of a vehicle, which is dependent on both initial design and also on regular maintenance.

Roadworthiness.

BRAKES 16.3 The brakes of a motor vehicle should not lock the wheels. The frequency of locked wheel skidding on braking was high in this survey. The loss of directional stability and steering control is more important in the metropolitan traffic accident than the slightly increased stopping distance when the wheels are locked.

TYRES. 16.4 Adhesion between the tyre and the road is the ultimately critical factor in skid resistance. The locking of a road wheel usually resulted in either abrasion of the tread rubber and/or melting of the road tar. Further study of these two phenomena would therefore appear to be justified.

16.5 Much of the work that has been done on skid resistance has concentrated on skidding on wet roads. Skidding on loose material was equally as frequent as skidding on wet surfaces in the accidents in this survey. It may be too much to hope that a tread pattern can be evolved which would minimise the reduction in the skid resistance caused by a layer of loose material on a hard road surface, but the benefits would be significant in the Adelaide area.

16.6 The condition of the tread of the tyre could not be shown to have a great bearing on whether or not a vehicle skidded under braking. This was probably due to the fact that most of these cases of skidding were on clean dry roads

16.7 There was no case in which a tyre obviously had blown out and caused an accident There were many cases in which a tyre had been deflated by collision damage.

16.8 The extreme deformation of the tyres following a side impact collision was particularly remarkable. In several instances a tyre deformed sufficiently, when the car was skidding sideways, to allow the rim of the wheel to dig into the road surface. That this happened is not in itself surprising, but in many of these cases the vehicle did not roll over and the tyre was not deflated.

16.9 The influence of the tyres on the stability of the vehicle was not obvious in more than a few of these accidents. This is more a reflection on the nature of the accidents, in which vehicle stability was not often a critical factor, rather than on the characteristics of the tyres. The cases in which the stability of the vehicle was affected all involved incorrect tyre pressures. It does not appear to be reasonable for vehicle designers to assume that the driver will always check that the tyres of the car are at the correct pressures before commencing a journey. The stability of a vehicle should therefore be designed to be as independent as possible of the pressures in the tyres. In particular, attempts to reduce inherent oversteer by specifying higher tyre pressures in the rear tyres than in the front tyres must assume that all drivers check the pressures in the tyres of their car and that all service station attendants know of the particular specifications of such cars.

ENGINE MOUNTS. 16.10 Many engine mounts failed when the car either rolled over or was struck from the side. If the engine is not retained in its correct position in the frame there is the risk of further loss of control as throttle linkages are distorted. There is also the risk of fire from broken fuel lines and electrical wiring.

SUSPENSION DESIGN. 16.11 Vehicles with a swing-axle type of rear suspension accounted for nearly half of the cases of single car rollover, but formed less than one tenth of all the cars in this survey.

SEATS. 16.12 Front seats having backs that are designed to tilt forwards should incorporate a mechanism which locks the back of the seat in position when the doors of the car are closed.

LIGHTS. 16.13 The British practice of deflecting the headlamp beam down and to the left has some disadvantages in the metropolitan area. Many pedestrians are hit when they are standing in the centre of the road waiting for the traffic to pass. A headlamp beam which is deflected to the left will not illuminate the centre of the road. The continental practice of retaining a high intensity dipped beam with a horizontal cut-off appears to be far more suited to roads on which there are pedestrians than does the British practice.

REFLECTORS. 16.14 Collisions with parked vehicles at night were common in this survey. This suggests a need for improvements in reflectors on the rear of vehicles. The effect of road dirt on the efficiency of these reflectors should be investigated and if found to be significant then means should be devised to locate the reflectors in a position where they will be protected from such deposits. But the need for efficient reflectors is particularly important in the case of vehicles which have frequently to stop in the traffic lane, for example passenger buses.

WINDSCREEN. 16.15 The shape and location of the windscreen obviously should be such as to afford the maximum possible unobstructed field of view to the driver. With the present give way to the right rule of the road the right hand front corner post of the screen can be a major obstruction.

16.16 The glass of the windscreen should absorb a minimum amount of the incident light. Any treatment of the glass, such as tinting, which reduces the amount of light transmitted must inevitably make it more difficult for the driver to distinguish objects on the road at night.

16.17 A film of road dirt on the windscreen can greatly increase the disability glare from the sun or from approaching headlights. Windscreen washers must therefore be regarded as an equally important part of the equipment of a vehicle as windscreen wipers. In a similar way, screen demisters are necessary to avoid the considerable restriction of vision from condensation on the inside of the frequently extensive screens fitted to many passenger cars today.

MOTORCYCLE. 16.18 There are two points which should be emphasized in regard to the roadworthiness of motorcycles. The first is that, in the motorcycle accidents in this survey, the motor cyclist was not seen by the other vehicle in the accident. The problem therefore is to make the motorcycle more conspicuous. One readily available means of doing this would be for all motorcycles to travel with the headlight turned on in the daytime, this being when this problem is most acute, as has been shown in Chapter 6

16.19 Skidding due to braking is as great a problem with the motorcycle than it is with the car. The loss of directional stability is more likely to happen with damaging results to the motor cyclist than to the occupant of a car. The Road Research Laboratory of Great Britain is currently conducting trials of an anti-locking device for the brakes of a motorcycle (Ref. 73).

PEDAL CYCLE. 16.20 The pedal cycle accidents that happened at night in this sample frequently resulted from the car driver not seeing the cyclist in time. Because of the large difference in speed between motor vehicles and pedal cycles, there is an even greater need for a readily visible tail light on a pedal cycle than on a motor vehicle.

Crashworthiness.

STEERING WHEEL. 16.21 The most successful design of steering wheel in this survey, from the crash injury viewpoint, appears to have been the three-spoked dished wheel. Even with the dished wheel the hub of the wheel should be designed to spread the energy of an impact over as large an area as possible, and so to absorb some of the energy of the impact.

16.22 The trim around the steering wheel, for example the horn rim, if it cannot be removed altogether, should be made of a malleable material which will not fracture on impact. The designer of a steering wheel should bear in mind the fact that the wheel is very frequently hit by the driver or passenger of the car in the event of a collision. Furthermore the point of impact is the face and/or chest, and hence the impact can result in disfiguring and even fatal injuries.

STEERING COLUMN. 16.23 The location of the steering column is one of the most obvious features of the crashworthiness of any passenger car, at least in the design stage. The problem here is obviously not a technical one. In this report there is no more telling example of the disregard for the safety of vehicle occupants than the illustration in Chapter 10 of the steering column in a Volkswagen which has penetrated ten inches back into the passenger compartment.

16.24 Even if the column itself is not forced back into the passenger compartment in a collision, the driver will most probably be thrown against the steering wheel. Recent moves in the U.S.A. to incorporate an energy absorbing section in the steering column are therefore to be commended.

INSTRUMENT PANEL. 16.25 The crashworthiness of the instrument panel can be related to both the basic design of the panel and the detailed design of fittings such as control knobs. There is no car on the market today which can be said to have a crashworthy instrument panel. This is not because there have been no attempts to improve on previous designs, but rather because the ultimately satisfactory solution will probably be to remove this member as we know it today and replace it with a thick (about eight inches) wall of energy-absorbing material. To minimise facial injuries, this material should be soft enough to mould itself to the contours of the face on impact, and yet rigid enough to arrest the forward motion of the head before it strikes the basic supporting structure.

16.26 With reference to contemporary instrument panel design, criticism must be levelled at those sections of panels that are obviously designed for maximum strength. This, of course, also means that the deceleration forces on impact are high. Padding of existing dashboard sections is at least an attempt to minimise the built-in hazards. The suspicion that such padding is intended to relieve anxiety rather than minimise injuries is supported by those cars in which the padding is poorly located and also of a non-energy-absorbing material such as sponge rubber.

16.27 The under side of the panel, which is not visible from the normal seated position, is nevertheless frequently struck by the occupant's knees. It is therefore not a suitable place to locate fuse blocks or other similar items of equipment. The parcel shelf also is inevitably hit by the lower legs of the occupants if the car is involved in a frontal impact The designers of the Rover 2000 have developed what may be an acceptable compromise in the parcel bins constructed of a material which is designed to crush on impact.

16.28 In the Triumph Herald the impact strength of the instrument panel has been reduced by constructing it of a pressed fibre. This seems unlikely to be an acceptable solution because there is still a rigid structural member behind the fibre board.

16.29 Control knobs, if they must be on the instrument panel, should be located in a recessed area in the centre horizontal strip of the panel. The French Panhard has the controls located on a nacelle above the steering column and behind the steering wheel. This location would appear to be preferable to the more conventional position on the lower edge of the dashboard.

HEADER AREA. 16.30 This part of the interior of the car should be designed to absorb the energy of impact by the head of an occupant of the car. No other equipment, such as sun visors or rear vision mirror, should be located in the header area if it will in any way increase the injury potential of this area.

REAR VISION MIRROR. 16.31 The glass of the rear vision mirror should not expose sharp edges when broken. This can be achieved by attaching the glass to a rigid backing strip, and enclosing the free edges of the glass. These edges of the rear vision mirror backing plate should not present any exposed ridges.

16.32 The mounting of the rear vision mirror should incorporate at least two pivots to enable the mirror to be pushed aside without the standard breaking. A fractured standard can leave a jagged end which may produce very severe facial lacerations.

16.33 The inertia of the whole assembly should be kept to a minimum. Unfortunately this conflicts with the above-mentioned requirements for the mounting of the glass of the mirror. The Mercedes practice of having the mirror and standard readily detachable from the header area has much to commend it. However, there is still room for further improvement in this design by reducing the effective mass of the assembly.

GLASS. 16.34 The windscreen, whether it be made of toughened or laminated glass, should be ejected completely, rather than fracture, when struck by an occupant. The force required to eject the glass should be below the concussion threshold. Toughened glass, when shattered, should not be retained in the screen mounting strip. This remark also applies to side window glass, which should not leave jagged fragments in the mounting channels when the glass is broken.

SEATS. 16.35 Unless the strength of seat mountings and adjustments can be increased to withstand the considerable inertia forces which arise in automobile collisions, the seat itself should be incorporated in the basic structure of the car, and some form of position adjustment be provided on the control pedals and the steering wheel.

16.36 When separate front seats are fitted to a car care should be taken to ensure that when one seat is capable of being located ahead of the other the then exposed edge of the seat back is not likely to cause injury to the occupant of the other seat in the event of a side-on impact. Similarly central rests in bench seats should be readily knocked sideways in the event of a side-on impact.

16.37 The back of the front seat is frequently struck by the rear seat passengers. This part of the front seat should therefore be designed to crumple on impact. It should not be used as a convenient location for ash trays or hand rails.

DOORS. 16.38 The inside of the door is naturally a frequent point of impact in the side-on collision. The arm rest in the centre of a bench seat has already been noted as a possible cause of injury. The arm rest on the inside of a door is far more likely to cause serious internal injuries. If an arm rest is to be located there at all it should be composed entirely of an energy-absorbing material. Similarly window winders and door handles should be recessed and also present no exposed sharp edges.

DOOR LATCHES. 16.39 The door should be regarded as a stressed part of the body frame of the car. This involves a door latch which is capable of withstanding forces acting in any direction. The panels to which the latch is attached, and also the hinges of the door, must be equally as strong as the latch itself. The exterior door handle should be recessed into the body of the car to minimise the risk of damage to the operating mechanism in the event of a side impact or of the car rolling over.

SEAT BELTS. 16.40 Seat belts should be included as original equipment in all cars. The means of adjustment on these belts should be readily accessible and should also operate in such a manner that the correct fitting of the belt is ensured at all times.

16.41 The webbing of the belt should incorporate two marks a known distance apart to enable a check to be made on the amount of stretch in the belt after the car has been involved in a collision. The maximum allowable amount of stretch should be specified by the manufacturer to enable the owner to determine when the belt should be replaced.

16.42 It is of interest to note that although seat belt mounting points are required by law in all new cars registered in South Australia, there is no standard specifying the requirements for such mounting points.

LUGGAGE COMPARTMENT. 16.43 When there is a luggage compartment inside the passenger compartment it should be so designed as to ensure that the luggage cannot encroach on the space occupied by the passengers in the event of a collision. The risk of objects carried in the boot of a car being hurled forwards through to the passenger compartment should be minimised by incorporating a sufficiently strong bulkhead between the two compartments.

BATTERY. 16.44 The battery should not be housed inside the passenger compartment. In the event of rollover the vehicle may come to rest upside down in which case acid from the battery can readily come into contact with the occupants of the car. The battery can also break away from its mounting with the attendant risk of fire from broken electrical wiring.

BODY STRUCTURE. 16.45 Recent advances in the design of pressed steel body frames have not produced significant advances in the crashworthiness of the vehicle body. In the slightly off-centre frontal impact, which is perhaps more common than the completely head-on collision, the front suspension is virtually the only structural member available to withstand the force of the collision. When this fails the front wheel is forced back into the passenger compartment. Even when the penetration by the wheel is not very great there may be sufficient derangement of the control pedals to fracture the bones of the feet and lower legs.

16.46 The side of the car presents many problems from the crashworthiness view point. There is very little space available for deformation on impact without intruding into the passenger compartment. But nevertheless, design requirements should include the effect of a side-on collision with another car at metropolitan traffic speeds. It may be that recent advances in composite cellular structural panels, for example two sheets of aluminium with a balsa wood centre core, may provide adequate strength and impact resistance without a prohibitive weight penalty.

16.47 The roof of the car should have supports which will not collapse when the vehicle rolls over. It should also be recognised that in a rollover the load is distributed over a comparatively large area of the roof. In the metropolitan area where there are many utility poles, the risk of a concentrated point impact on the roof of the car is not a remote one. It would appear to be as likely to happen as the vehicle catching fire.

16.48 The remarkable escapes by stock car drivers from very high speed crashes show that, with adequate strengthening, the passenger compartment of a car can remain survivable under extreme loadings. Rather than add a tubular steel framework inside the completed car, it would be far more preferable for the original design of the body frame to allow for all possible contingencies, and particularly those which have been shown to result in death and injury to the occupants of the vehicle.

16.49 The overall shape of the fronts of all passenger cars should be designed to minimise the injuries sustained by a pedestrian when hit by a car. Such a measure may result in a major reduction in pedestrian fatalities.

16.50 The detail shape of the front of a car should not incorporate sections which will concentrate impact forces on small areas. The bumper bar should therefore have a smooth large radius vertical section. It should be located at a standard height of fifteen inches at its horizontal centreline to avoid a direct initial impact on the knee of an adult pedestrian. It is assumed here that a fracture of the lower leg is a lesser evil than a shattered knee joint.

16.51 Mascots and protruding accessories should not be fitted to cars, even though the injuries they may inflict on a pedestrian are rarely very significant when compared to the extremely severe injuries that are frequently caused by the main impact from the front of the car.

16.52 Body panels that are frequently damaged in pedestrian accidents (the leading edge of the bonnet, the rear half of the bonnet and the windscreen surround) should be designed to crush at a controlled rate on impact, to minimise the forces involved.

MOTOR CYCLE. 16.53 There have been some suggestions that the motor cyclist might be protected from injury by being strapped to his machine (Ref. 74). To the author this appears to be very difficult to substantiate. First, the conventional motor cycle affords the rider little or no protection from direct impact. The distance available for deceleration is very small indeed. The motor cycle itself has no inherent stability or enveloping body frame to protect the rider.

16.54 Even such attempts to deflect the direct force of a collision as crash bars across the frame of the machine appear to be of little benefit in more than a minor impact. For in impacts of greater severity the rider is thrown forwards against either the crash bar or the impacting object. The inertia loading of his leg is in itself frequently sufficient to fracture the leg. If such bars are to be fitted it is apparently important to ensure that if the leg is thrown forward against it, it will strike a panel carrying an energy-absorbing material rather than the crash bar itself.

THE ROAD.

SURFACE. 16.55 This study has demonstrated the extreme variations in skid resistance between apparently similar clean dry surfaces. While it is obviously desirable that the road surface should be as skid resistant as possible, it is even more desirable that variations from one location to another should be kept to a minimum.

16.56 Skidding when braking occurred as often on loose material on the road surface as it did on wet roads. Regular road maintenance should include the removal of this loose material.

LAYOUT. 16.57 The layout of the road system, particularly in a metropolitan area, is often inherited ratherthan planned. In new areas, however, full advantage should be taken of the opportunity to avoid road layouts which are unsatisfactory at present day traffic speeds.

16.58 The uncontrolled four-way intersection must be included in this category. Sight distance at an intersection of this type naturally is closely related to the maximum safe speed of approach to that intersection. A method has been described in Chapter 15 which will permit the effect of changes in sight distance on the maximum safe approach speed to be determined.

16.59 The road layout in the area covered by this survey included very few horizontal or vertical curves. At one particular location both these features occurred together, at an underpass beneath a railway. The vertical curve restricts the motorist's sight distance, and so does not warn him of the simultaneous horizontal curve. This resulted in a head-on collision between a car and a pedal cycle in one of the accidents in this sample.

16.60 In Chapter 8 the frequency of subsequent collisions, very often with a tree or a utility pole, was presented. The author does not suggest that the trees remaining in the suburbs of Adelaide should be removed to reduce the risk of injury from these subsequent collisions. But the location and design of utility poles should make some allowance for the fact that accidents do happen and cars do run off the road. Smaller roadside objects such as guide posts should not have greater structural rigidity than is necessary for them to fulfil their main purpose.

16.61 There appear to be many advantages associated with the installation of median strips on roads such as those in the Adelaide metropolitan area. In addition to greatly reducing the incidence of one type of pedestrian accident, in which the pedestrian is 'stranded' in the middle of the road, the median also controls the manoeuvres of vehicles, particularly the U-turn.

LIGHTING. 16.62 The many factors involved in seeing on the road at night do not yet appear to be fully understood. In particular the interaction between vehicle headlights and fixed street lighting is not clear. It does appear, however, that fixed street lighting should provide both uniform and high intensity illumination. The need to avoid marked differences in illumination along a given length of road, such as do occur when the lights are spaced too far apart, suggests that when the funds available for street lighting are severely restricted it may be better to light a shorter length of street to an approved standard and leave the remaining length completely unlit, rather than cover the entire length of street with sub-standard lighting.

16.63 Variations in intensity seem to be particularly critical at and near intersections. The pedestrian, who is the road user most likely to be adversely affected by poor street lighting, is often hit by a car which has just passed through an intersection at night. Street lighting at intersections is commonly very much better than on the adjoining roads The contrast between the brightly lit intersection and the darker exit road would increase the risk of the driver not seeing the pedestrian.

THE TRAFFIC SYSTEM.

TRAFFIC LIGHTS. 16.64 The symbols used and the sequence followed by traffic lights should be both standardised and also related to the reasonable expectancies of the motorist. For example, the split phase method of operation, whereby opposing streams of traffic have the green light for different periods of time, may easily confuse a motorist who is waiting to turn right and does so when his light turns to red. With split phase operation the opposing traffic stream may still have the green light, and this can of course readily result in a particularly severe type of collision.

16.65 Most drivers involved in accidents at traffic lights in this survey assumed that when they had the green light they no longer had to watch for traffic approaching from another road on their right. Unfortunately at one intersection in Adelaide conflicting traffic streams each have a green light at the same time.

This results in a right-of-way situation in which, although a driver has the green light, he must still yield to traffic approaching from his right. This situation is presented and discussed in Chapter 14.

16.66 At this same intersection the length of the amber period was insufficient to ensure that a motorist always had the opportunity of either continuing on to clear the intersection or of stopping before reaching the intersection. In a case such as this an all-red phase should follow the amber. Because many drivers seem to regard the amber phase as an extension of the green phase, both streams of traffic should each have the red light for a brief period. The length of this period should be determined by the width of the intersection.

16.67 Under certain circumstances, notably in the late afternoon, the sun's rays may shine directly into the lenses of the traffic lights. The reflection back through the lens may make it very difficult for a motorist to determine at a glance which light is in fact illuminated. A possible solution to this difficulty would be to incorporate a shutter which would cover the reflector of each light when it was not in use.

SIGNS. 16.68 There were many cases in this survey in which a vehicle failed to stop at a STOP sign. In some of these cases the STOP sign was located only on the left hand side of a very wide road. In circumstances such as these, with the sign well over to one side of the driver's field of vision, a second sign mounted on a narrow median strip in the centre of the approach to the intersection might reduce the risk of the driver not seeing the sign.

16.69 Warning signs were erected on the approaches to some of the intersections attended in this survey. At most of these locations the safe speed on entering the intersection was less than ten miles per hour. Under these circumstances it would appear more logical to install a STOP sign rather than an intersection warning sign. At any intersection where the safe crossing speed is very much less than the normal travelling speed for traffic on the approach road, a warning sign is unlikely to produce the desired change in travelling speed. A STOP sign would be more likely to be effective in this regard, but would also greatly impede the traffic flow. The conflict between facilitating the flow of traffic and ensuring maximum safety has not been resolved. Until this happens it would be well if the emphasis were to be placed on safety rather than on efficiency of traffic flow.

INTERSECTIONS. 16.70 Because the customary travelling speed of traffic in the metropolitan area is very much higher than the safe approach speeds to intersections the present give way to the right rule of the road cannot be expected to yield satisfactory results. It is possible that a major and minor road system would provide the basis for safer operation. It can also be argued that the four-way suburban intersection should never be uncontrolled.

16.71 The present legislation also states that traffic islands have no bearing on right of way. Despite this there are many locations at which traffic islands are used to change the direction from which one stream of traffic approaches another. At these locations motorists commonly assume that right of way has also been changed. In any event it is expecting too much of an already highly stressed motorist to require him to decide where the other driver originally approached the intersection from before he then decides whether or not he must yield to him.

16.72 Traffic islands can also be used to cause a sudden change of direction in one of two or more parallel streams of traffic. This was a contributory factor in two of the accidents in this sample. A motorist on an intersecting road assumed that another car was continuing with the traffic stream, when it turned off round the traffic island and crossed the path of the first to enter a third road at a point well before the anticipated conflict point where the two roads joined.

16.73 Traffic islands can also be used to determine the angle at which conflicting streams of traffic approach each other. At the present time no reliable data exists on the relative severity of collisions according to the angle and point of impact. An outline for such an investigation was presented in Chapter 8, but the amount of data available from this survey was not sufficient to enable a significant result to be obtained.

16.74 Two basic pedestrian protection measures, if widely adopted in Adelaide, could be expected to reduce the frequency of pedestrian accidents. The first of these is the pedestrian crossing, which is unlikely to have a very marked effect on accident frequency. The median strip, however, is likely to be more effective, and may also reduce the incidence of other types of accidents such as those involving pedal cyclists attempting U-turns without warning.

THE ROAD USER.

16.75 It may at first thought appear strange that the road user should be considered to have some engineering aspects. There are some factors that are of direct interest to the engineer and these can conveniently be grouped into two main categories, Biomechanics and Human Engineering.

Biomechanics.

16.76 Biomechanics is the name given to the study of the forces acting in the human body and also the body's reaction to external forces. In the present context the main concern is the impact tolerance of the human body.

IMPACT TOLERANCE. 16.77 Before design work can start on energy-absorbing structures, detailed knowledge is required of the maximum decelerations that various parts of the human body can stand without suffering injury. The head is perhaps the most critical part of the body in this regard, and concussion the most frequently occurring serious injury in road traffic accidents. Impact on the thorax (chest) can result in a rupture of the aorta. There are several conflicting theories which attempt to explain the mechanism of the rupture of this artery. Until the mechanism is more clearly understood the tolerance of the human chest to impact cannot be accurately determined.

16.78 A considerable amount of work has been done on the tolerance of the human skeleton, particularly the pelvis, to impacts from beneath. This work was done in connection with the development of ejector seats for aircraft, in which the maximum non-injurious acceleration was desired. In automobile collisions however, the impact on the pelvis is commonly from the side, and very little is known about the injury threshold for impacts from this direction.

16.79 The study of biomechanics is still in the developing stages, and there is much work yet to be done in establishing impact tolerance levels for the human body.

CRASH HELMETS. 16.80 The present safety helmet designed to British Standard 2001 is not adequate for the purpose of preventing concussion in metropolitan traffic accidents. The heavier but more enveloping helmet designed to British Standard 1869 and intended for use by racing motor cyclists appears to satisfy most of the requirements for a suitable helmet for use on the roads. In places where the use of safety helmets is compulsory, as in the State of Victoria, the standard offering the greater degree of protection should be demanded.

Human Engineering.

16.81 An understanding of human capabilities should be basic to the design of vehicles, roads and traffic systems. Unfortunately this is not always so. In some cases the particular capabilities are not yet clearly understood. In other cases they are well-known but have not been applied (Ref. 75). The following examples are by no means a complete list of the human factors relevant to road traffic accidents, but they do illustrate some of the points which arose in the course of this survey.

VISION. 16.82 The colour of each car was recorded and an attempt was made to judge its contrast with the background. Because of great variations in the backgrounds this did not seem to be likely to produce significant results and no analysis of the data was attempted. The following questions did present themselves however. What is the effect of colour (of a car) on a person's ability to distinguish it from this great range of backgrounds? What is the effect of various types of illumination at night on the contrast between a car and its background? What is the interaction between monochromatic street lighting and the colour of a car?

16.83 Illumination of suburban streets is by many possible sources, including fixed street lights, extraneous lights such as advertising signs and floodlights, and vehicle headlights. The interaction of these light sources and the possibilities of disability glare are but two of many factors which merit further study.

16.84 The general nature of the background, and the objects that drivers look for (e.g. when approaching an intersection) may interact. If, as is probable, drivers look for other cars, then a background of parked cars may make the task of perception harder, and so increase the risk of failure.

EXPECTANCIES. 16.85 This leads on to the question 'What does a driver look for at an intersection?' The fact that the car driver rarely sees a motorcyclist, before a collision, suggests that he looks for other cars or objects the size of a car.

16.86 The alarming results obtained from the investigation into safe speeds at intersections bring forward two issues. The first relates to the factors that affect a driver's estimate of a reasonable travelling speed (which was consistently much higher than the safe approach speed in this investigation).

16.87 The second factor is the driver's attitude to the right of way law. Many drivers either ignore or are unaware of the possibility of a collision at an intersection, or they assume that they are on a 'major' road. Could it be that the concept of major and minor roads is more in keeping with driver behaviour than the present give way to the right system?

16.88 Behaviour at traffic lights also appears to be based on certain assumptions of what 'normally' happens. Hence the dangers associated with split-phase operation. The effect of other cars moving off or stopping was significant in several accidents in this survey. Do drivers in some way wait for another driver to make the decision for them?

16.89 The high frequency of accidents to elderly pedestrians raises the question of adaptation to changing traffic conditions. To what extent do we assume that all road users have driven a car and understand that pedestrians are difficult to see and not easy to avoid under many circumstances?

CONTROLLABILITY. 16.90 Driver/vehicle fit would appear to be such a basic point that it could be taken for granted. This is not always so, even for persons of 'average' build. For the fifth and ninetyfifth percentile groups many cars are extremely difficult or even impossible to drive. Vision, both to the front and the rear, may be severely restricted. Controls may be poorly located. It is by no means uncommon to find that a driver cannot reach the handbrake when he is wearing a seat belt.

16.91 The identification of control knobs on the instrument panel can reliably be done by touch in only a few models. In others the driver must look away from the road, at the knobs, or risk turning his lights off in mistake for starting the windscreenwipers.

TABLE A3.1

TRAFFIC ACCIDENT RESEARCH UNIT WORKING SCHEDULE BASED ON A 20 WEEK CYCLE

Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mon.	L	O	E	L	E	E	L	E	L	O	L	L	E	L	E	E	L	E	L	E
Tues.	E	E	L	O	L	E	L	L	E	E	L	E	L	O	L	E	L	E	E	L
Wed.	L	E	L	L	E	O	E	E	L	E	L	E	L	E	L	O	L	E	E	L
Thurs.	E	L	E	E	L	E	L	O	L	L	E	L	E	E	E	L	E	L	L	O
Frid.	L	E	L	E	L	L	E	L	E	E	E	O	L	E	L	L	E	O	L	E
Sat.	O	L	O	E	O	L	O	E	O	L	O	E	O	L	O	E	O	L	O	E
Sun.	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

E = Early = 10.00 a.m. - 5.45 p.m.
L = Late = 5.45 p.m. - 11.00 p.m.
O = Off. Duty

TABLE A3.2

Regional Distribution of Accidents

Number of Accidents	North of the River		South of the River	
	Early Period	Late Period	Early Period	Late Period
0	53	81	41	72
1	61	52	52	49
2	46	34	56	32
3	11	13	18	15
4	10	0	11	10
5	0	1	1	3
6	0	0	2	0
Mean	1.249	0.906	1.540	1.117
Variance	1.226	1.002	1.560	1.638

TABLE A.3.3

Expectations (Poissonian) for at least one accident.

	North of the River		South of the River		Whole City	
	Early	Late	Early	Late	Early	Late
Monday	0.65	0.50	0.74	0.61	0.91	0.81
Tuesday	0.67	0.48	0.69	0.51	0.90	0.75
Wednesday	0.65	0.50	0.75	0.55	0.90	0.77
Thursday	0.69	0.70	0.71	0.60	0.90	0.88
Friday	0.64	0.72	0.81	0.85	0.93	0.95
Saturday	0.85	0.75	0.91	0.88	0.98	0.96
Sunday	0.72	0.30	0.80	0.47	0.94	0.64

TABLE A3.4

NUMBER OF ACCIDENTS ATTENDED

Day of Week	Early Period							Late Period							Grand Total of Accidents	Total Working Periods
	Number of accidents attended					Sub-Total of Accidents	Sub-Total of Working Periods	Number of accidents attended					Sub-Total of Accidents	Sub-Total of Working Periods		
	0	1	2	3	4			0	1	2	3	4				
Monday	5	16	4	0	0	24	25	8	8	8	0	0	24	24	48	49
Tuesday	5	12	8	3	0	37	28	9	12	2	1	0	19	24	56	52
Wednesday	0	15	9	2	0	39	26	6	16	9	0	0	34	31	73	57
Thursday	4	7	7	2	0	27	20	8	11	8	3	1	40	31	67	51
Friday	2	10	11	5	2	55	30	1	10	9	2	0	34	22	89	52
Saturday	0	6	4	3	0	23	13	0	2	8	7	0	39	17	62	30 *
Sunday	0	2	2	0	0	6	4	0	2	1	1	0	7	4	13	8 *
Total Accidents:	0	68	90	45	8	211		0	61	90	42	4	197		408	
Total Working Periods:	16	68	45	15	2		146	32	61	45	14	1		153		299

* Note: After a short initial period only alternate Saturdays were "on duty", and no Sundays.

TABLE A3.5

ACCIDENTS ATTENDED IN THE PERIOD FEBRUARY 3RD - AUGUST 28TH, 1964.

		Early Period								Late Period					Total
		10-11 a.m.	11-12 a.m.	12- 1 p.m.	1 - 2 p.m.	2 - 3 p.m.	3 - 4 p.m.	4 - 5 p.m.	5-5.45 p.m.	5.45-7 p.m.	7 - 8 p.m.	8 - 9 p.m.	9 -10 p.m.	10-11 p.m.	
Monday	All accidents	5	1	3	0	0	3	11	7	13	9	7	3	2	64
	Accidents attended	4	1	1	0	0	3	4	4	5	3	5	2	0	32
	Percentage	80	100	33	0	0	100	36	57	38	33	71	67	0	50
Tuesday	All accidents	2	2	4	6	2	1	8	11	6	5	9	2	2	60
	Accidents attended	2	1	2	4	0	1	4	6	2	3	4	2	1	32
	Percentage	100	50	50	67	0	100	50	55	33	60	44	100	50	53
Wednesday	All accidents	1	4	5	2	2	5	8	11	8	9	3	1	2	61
	Accidents attended	1	4	5	0	0	4	4	7	3	4	2	0	2	36
	Percentage	100	100	100	0	0	80	50	64	38	44	67	0	100	59
Thursday	All accidents	2	1	2	4	1	3	3	6	14	10	7	3	4	60
	Accidents attended	2	1	1	3	1	2	1	5	5	2	3	2	2	30
	Percentage	100	100	50	75	100	67	33	83	36	20	43	67	50	50
Friday	All accidents	2	2	8	3	1	7	16	12	15	14	8	6	5	98
	Accidents attended	1	1	6	2	1	5	6	4	7	4	5	3	1	47
	Percentage	50	50	75	67	100	71	38	33	47	29	63	50	20	48
Saturday	All accidents	4	1	6	1	7	2	1	5	15	10	5	3	1	61
	Accidents attended	0	1	3	1	4	1	0	5	5	5	2	2	1	30
	Percentage	0	100	50	100	57	50	0	100	33	50	40	67	100	49
Total:	All accidents	16	11	28	16	13	21	47	52	71	57	39	18	16	404
	Accidents attended	10	9	18	10	6	16	19	31	27	21	21	11	7	207
	Percentage	73	82	64	63	46	76	40	60	38	37	54	61	44	51

Appendix A 4.1

Adult Pedestrians Struck by the Fronts of Passenger Cars.

A 4.1.1 Analysis of variance and derivation of injury/speed curves.

X = impact speed (m.p.h.)

Y = injury severity: fatal injury: Y = 5

minor injury: Y = 1

(a) All 32 cases

Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio
Regression	1	0.506353	0.506353	17.172***
Deviation	30	0.884608	0.029486	
Total	31	1.390961		

$$\log Y = -0.249281 + 0.516291 \log X$$

$$R = 0.6033$$

(b) Six cases each involving a Volkswagen 1200 car

Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio
Regression	1	0.244628	0.244628	7.843*
Deviation	4	0.124749	0.031187	
Total	5	0.369377		

$$\log Y = -1.415187 + 1.324670 \log X$$

$$R = 0.8138$$

(c) Six cases each involving a Ford Falcon Car

Variation	Degrees of Freedom	Sums of Squares	Mean Square	Variance Ratio
Regression	1	0.000354	0.000354	0.008 N.S.
Deviation	4	0.174682	0.043670	
Total	5	0.175036		

$$\log Y = 0.310145 + 0.026359 \log X$$

$$R = 0.0450$$

The values of R (the correlation coefficient) and the variance ratio suggest that the number of cases is too small for a firm conclusion to be drawn.

A 4.1.2 Check on the significance of the difference between the slopes of the speed/injury curves for VW1200 and Ford Falcon.

(a) VW 1200

$$\text{s.e. (b)} = \sqrt{\frac{\text{residual variance}}{(\log \bar{X} - \log X)^2}} = \sqrt{\frac{0.03119}{0.1394}} = 0.47$$

$$b_{VW} = 1.32 \pm (2.78 \times 0.47) = 1.32 \pm 1.31$$

(b) Ford Falcon

$$\text{s.e. (b)} = \sqrt{\frac{0.04367}{0.5103}} = 0.29$$

$$b_F = 0.026 \pm (2.78 \times 0.29) = 0.026 \pm 0.85$$

$$\text{s.e. } (b_{VW} - b_F) = \sqrt{\text{var}(b_{VW}) + \text{var}(b_F)}$$

$$= \sqrt{0.223 + 0.0856}$$

$$= 0.555$$

$$t_8 = \frac{b_{VW} - b_F}{s.e.\ (b_{VW} - b_F)} = \frac{1.299}{0.555}$$

$$t_8 = 2.34$$

Significant at 5% level; $t_8 = 2.31$

TABLE A8.1

Car Occupants: Age x Sex x Seated Position

Age in Years	Drivers		Front Seat Passenger		Rear Seat Passenger	
	Male	Female	Male	Female	Male	Female
0- 4			11	11	11	10
5- 9			8	4	14	12
10-14			5	7	10	22
15-19	60	9	26	31	18	13
20-24	97	11	21	16	10	7
25-29	47	4	9	13	9	5
30-34	53	5	10	11	1	4
35-39	61	13	9	15	4	0
40-44	37	6	9	17	3	7
45-49	32	8	4	15	6	3
50-54	27	3	3	7	1	3
55-59	15	5	1	5	1	2
60-64	13	1	0	6	1	5
65-69	12	3	2	6	0	2
70-74	7	1	2	2	0	2
75-79	6	1	1	4	1	0
80+	0	0	1	2	0	2
Total	467	70	122	172	90	99

TABLE A 9.1

Cost of Repair (Cars only)

Accident No.	Make and Model	Year of Manufacture	Section Damage	Cost of Repair (A)	Market Value (B)	A/B	Time to Repair
MINOR DAMAGE:							
0264	Holden EJ sedan	1963	2.1.1	£ 30	£ 900	0.03	2 days
0286	Holden EK utility	1962	2.1.1	£ 55	£ 700	0.08	2 days
Totals and Average:				£ 85	£1600	0.05	2 days
MODERATE DAMAGE:							
0232	Vauxhall Cresta sedan	1961	1.2.3	£186	£ 925	0.20	2 weeks
0233	Holden FJ sedan	1956	2.3.3	£ 80	£ 350	0.23	-
0249	Ford Zephyr sedan I	1955	1.3.2	£ 90	£ 300	0.33	3 weeks
0257	Holden FB taxi	1961	3.2.1	£200	£ 650	0.31	-
0264	Bedford panel van	1947	2.2.2	£ 15	£ 30	0.50	-
0267	Holden FJ van	1955	3.2.3	£258	£ 300	0.86	-
0269	Holden FE sedan	1957	3.2.1	£200	£ 475	0.42	-
0272	Holden EJ sedan	1963	3.1.1	£152	£ 900	0.17	1 week
0284	Morris Oxford Utility	1952	3.2.1	Write off	£ 100	-	-
0286	Morris '850' sedan	1964	3.2.3	£195	£ 690	0.28	3 weeks
0288	Austin A50 sedan	1955	3.2.2	£160	£ 275	0.58	3 weeks
0288	Volkswagen 1200 sedan	1962	3.1.1	£ 93	£ 795	0.12	2 weeks
0288	Holden EH station sedan	1963	3.1.1	£133	£1000	0.13	2 weeks
0290	Holden FB sedan	1960	3.1.1	£ 66	£ 675	0.10	1 week
0291	Standard Vanguard sedan	1950	3.1.1	£ 47	£ 125	0.38	2 weeks
0295	Holden FB St. sedan	1959	3.1.1	£177	£ 700	0.25	1 week
0307	Mercedes 220 SE	1963	3.1.1	£450	£2400	0.19	1 month
0308	Vauxhall Wyvern	1953	3.2.1	£126	£ 200	0.63	5 weeks
0322	Volkswagen 1200 sedan	1963	3.1.1	£115	£ 775	0.15	2 weeks

TABLE A 9.1 (Contd.)

Accident No.	Make and Model	Year of Manufacture	Section Damage	Cost of Repair (A)	Market Value (B)	A/B	Time to Repair
MODERATE DAMAGE (Contd.):							
0326	Triumph Mayflower sedan	1951	3.2.1	Write off	£ 100	-	-
0327	Holden EK sedan	1962	3.2.1	£275	£ 825	0.33	3 weeks
0338	Morris 1100 sedan	1964	1.3.3	£150	£ 900	0.17	2 weeks
0340	Holden EJ taxi	1963	3.1.1	£ 75	£ 875	0.09	-
0340	Ford Falcon St. sedan	1960	2.3.1	£100	£ 650	0.15	-
0342	Riley sports convertible	1951	3.1.1	Write off	£ 225	-	-
0346	Holden FJ panel van	1956	3.1.1	Write off	£ 300	-	-
0372	Holden FB sedan	1960	3.1.1	£120	£ 675	0.18	1.1/2 weeks
0378	Holden FB sedan	1960	2.3.1	£150	£ 675	0.22	3 weeks
0387	Holden EK sedan	1961	1.3.3	£ 94	£ 775	0.12	1 week
0400	Morris '850' sedan	1961	3.2.1	£177	£ 500	0.35	3 weeks
0404	Ford Zephyr II sedan	1959	3.2.1	£ 70	£ 640	0.11	-
0411	Holden EH sedan	1963	3.1.1	£150	£ 950	0.16	1 week
0416	Renault R4	1963	3.3.1	£180	£ 600	0.30	5 weeks
0429	Holden EH taxi	1964	3.2.2	£186	£ 925	0.20	2.1/2 weeks
0431	Holden FB sedan	1960	3.1.1	£ 91	£ 675	0.13	3.1/2 days
Total and Average:				£5286	£21955	0.24	2+ weeks

Section damage code:

Nil	1
Minor	2
Moderate	3
Severe	4
Extremely severe	5

(e.g.: 4.2.1 represents severe frontal damage, minor passenger compartment damage nil damage to rear section.)

TABLE A 9.1 (Contd.)

Accident No.	Make and Model	Year of Manufacture	Section Damage	Cost of Repair (A)	Market Value (B)	A/B	Time to Repair
SEVERE DAMAGE:							
0227	Holden FE sedan	1957	2.3.4	£325	£475	0.68	-
0228	Rover	1951	4.2.2	£200	£200	1.0	-
0235	Morris Minor sedan	1950	2.4.3	Write off	£125	-	-
0240	Standard Vanguard II	1955	4.3.2	Write off	£275	-	-
0244	Ford Zephyr II taxi	1959	2.4.2	£263	£600	0.44	-
0246	Ford Zephyr II utility	1960	2.4.3	£300	£650	0.46	-
0246	Holden FE sedan	1957	4.2.1	£233	£475	0.49	-
0261	Jaguar Mk VII	1954	4.4.1	Write off	£450	-	-
0261	Holden FB sedan	1960	4.3.1	£450	£675	0.67	-
0266	Skoda station sedan	1950	2.4.2	Write off	£ 40	-	-
0269	Jaguar Mk V	1949	4.2.1	£150	£200	0.75	-
0269	Austin A40 panel van	1954	4.3.2	Write off	£180	-	-
0270	Hillman	1951	3.4.1	Write off	£ 90	-	-
0272	Hillman station sedan	1958	3.3.3	£230	£425	0.54	3.1/2 weeks
0275	Ford Falcon sedan	1963	4.3.1	£227	£825	0.28	-
0275	Ford Customline	1954	4.3.2	Write off	£350	-	-
0275	Holden FC sedan	1958	4.4.1	£480	£550	0.87	1 month
0277	Ford Falcon sedan	1964	4.2.2.	£290	£900	0.32	1 month
0277	Ford Customline	1953	4.2.2	Write off	£225	-	-
0278	Standard Cadet	1955	4.3.1	Write off	£150	-	-
0280	Ford Customline	1953	4.3.3	Write off	£225	-	-
0282	Rover	1951	4.2.1	£ 85	£170	0.50	4 weeks
0283	Holden FE sedan	1957	2.4.2	£303	£475	0.65	17 days
0286	Austin A30 sedan	1955	3.3.3	£116	£190	0.61	3 weeks
0287	Pontiac sedan	1951	3.4.1	Write off	£200	-	-
0291	Ford Anglia	1956	2.4.3	£182	£240	0.76	1 month

TABLE A 9.1 (Contd.)

Accident No.	Make and Model	Year of Manufacture	Section Damage	Cost of Repair (A)	Market Value (B)	A/B	Time to Repair
SEVERE DAMAGE (Contd.):							
0293	Vauxhall Velox	1962	4.3.1	£257	£925	0.28	3 weeks
0300	Holden FC sedan	1959	4.2.3	£450	£625	0.72	4 weeks
0307	Holden EK sedan	1961	2.4.1	£300	£775	0.39	1 month
0312	Standard '8'	1954	2.5.1	Write off	£100	-	-
0319	Ford Zephyr II	1959	4.2.1	£450	£640	0.70	3 weeks
0326	Dodge sedan	1950	2.4.3	Write off	£130	-	-
0327	Vauxhall Victor	1960	3.4.3	£209	£600	0.35	1 week
0345	Ford Customline	1953	4.3.1	Write off	£225	-	-
0345	Pontiac	1937	1.4.3	Write off	£ 30	-	-
0346	Morris Minor	1957	3.4.1	Write off	£375	-	-
0355	Volkswagen 1200 sedan	1960	4.3.3	£304	£650	0.47	3 months
0357	Holden FB sedan	1960	4.3.1	£400	£675	0.59	--
0373	Austin A40 sedan	1950	2.4.2	Write off	£ 90	-	-
0394	Morris 850 sedan	1961	4.3.2	£300	£500	0.60	4 weeks
0405	Ford Prefect sedan	1950	4.2.1	Write off	£ 60	-	-
0408	Chrysler sedan	1937	4.2.1	Write off	£ 30	-	-
0412	Holden FC taxi	1959	2.4.3	£300	£575	0.52	3 weeks
0417	Holden EK utility	1962	4.2.3	£286	£795	0.36	1.1/2 weeks
Totals and average				£10159	£16365	0.62	3.1/2 weeks

TABLE A 9.1 (Contd.)

Accident No.	Make and Model	Year of Manu-facture	Section Damage	Cost of Repair (A)	Market Value (B)	A/B	Time to Repair
EXTREMELY SEVERE DAMAGE:							
0252	Holden FE sedan	1957	4.4.3	Write off	£475	-	-
0279	Holden FC sedan	1958	4.4.2	Write off	£550	-	-
0289	Fiat 1100 sedan	1959	2.5.4	£550	£550	1.00	2 months
0314	Holden FJ panel van	1955	3.5.4	Write off	£250	-	-
0364	Sunbeam Talbot '80'	1949	2.4.4	Write off	£100	-	-
Totals and average:				£1875	£1875	1.00	2 months

Appendix A 15.1

The following method is an alternative to the graphical solution shown in Figure 15.2. Substitute for V_X in equation (15.2),

$$-RT + \sqrt{R^2T^2 + 2RX} = (X + S) \cdot \frac{(X - B)}{(AX))} \cdot \frac{22C}{15}$$

This is a quartic in X and is most easily handled by the following method. Take a larger value, C_1, for the approach speed of D_2, e.g.

$C_1 = C + 10$ m.p.h. Then in (15.1)

$$V_X = \frac{X.(X - B)}{(AX)} \cdot \frac{22C_1}{15} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15.4)$$

for the clearance distance to be S as stipulated we must have

$$V_X = (X + S).\frac{(X - B)}{(AX)} \cdot \frac{22C_1}{15} \quad \ldots\ldots\ldots\ldots\ldots (15.3)$$

The procedure is therefore to choose $C_1 = C + 10$, solve (15.4) for X and hence V_X. Then calculate $C_2 = \frac{15\ AXV}{22(X-B)\ (X+S)}$

Should $C_2 = C$ then the problem is solved and the value obtained for V_X is the required one. If $C_2 \neq C$, then we multiply C by $\frac{C}{C_2}$ obtaining a new "corrected" value of C_1.

Repetitions of this procedure will result in C_2 approaching the value of C. When $|C_2 - C| \leqslant 0.5$, the corresponding values of X and V_X have been taken to be sufficiently accurate for the present purpose. Any error in V_X will be less than 0.5 m.p.h.

The following programme has been used to solve for V_X on an IBM 1620 computer.

```
PUNCH 2

 2 FORMAT (3X1HJ6X1HA6X1HB6X2HAC5X2HC15X1HR6X1HT6X1HX6X1HV)
   M = 1
   READ, K
 4 READ, J,A,B,AC,R,T,SD
   N = 1
   C = AC + 10
 9 N = N + 1
   IF(50 - N) 12,10,10
10 D = (22.*C/(15.*A))**2*B-22.*R*C*T/(15.*A)+R
   E = (22.*C/(15.*A))**4*B**2
   G = (22.*C/(15.*A))**3*2.*B*R*T
   X = (D+SQRTF(D**2-E+G))*(15.*A/(22.*C))**2
   V = (-R*T+SQRTF((R*T)**2+2.*R*X))*15./22.
   C1= A*X*V/((X-B)*(X+SD))
   ER= ABSF(C1-AC)
   IF(ER-0.5)7,7,8
 8 C = C*AC/C1
   GOTO9
 7 PUNCH 3,J,A,B,AC,C1,R,T,X,V
 3 FORMAT(17,8F7.1)
 6 M = M+1
   IF(K-M)5,4,4
12 PUNCH 14
14 (FORMAT(17HDOES NOT CONVERGE)
   GOTO6
 5 STOP
   END
```

Appendix B.

Code 2. Accident Circumstances and Vehicle Data

1-4 **Accident No.**

0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

5 **Type of card**

2	Accident circumstances and vehicle data

6 **No. of this unit**

1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	Not elsewhere classified

7 **Natural lighting**

1	Day
2	Night
3	
4	
5	
6	
7	
8	
9	Not recorded

8. <u>Type of artificial lighting on this unit</u>
(approaching scene)
1 Incandescent
2 Mercury vapour
3 Sodium vapour
4 Fluorescent
5 Primarily extraneous (shop windows, signs, etc.)
6. None
7 Not elsewhere classified
8 Not applicable
9 Not recorded

9 <u>Colour of this unit, if vehicle</u>
1 Grey, light green, light blue
2 White, cream
3 Orange, bright red
4 Dark red, purple, brown
5 Black, dark blue
6 Dark grey, dark green
7 Not elsewhere classified
8 Not applicable
9 Not recorded

10 <u>Contrast of vehicle colour with background</u>
1 Good
2 Fair
3 Poor
4 Not able to assess
5
6
7
8 Not applicable
9 Not recorded

11 <u>Location of accident: traffic control for this vehicle</u>
1 Not at an intersection
2 At an intersection, no traffic control for this vehicle
3 At an intersection, stop sign for this vehicle
4 At an intersection, traffic lights for this vehicle
5 At an intersection, police control for this vehicle
6 At an intersection, not elsewhere classified
7 Not at an intersection, traffic control for this vehicle (traffic lights, police, etc.)
8 Not applicable
9 Not recorded

12 Road alignment (for this vehicle)

1	Straight
2	Curved
3	
4	
5	
6	
7	
8	Not applicable
9	Not recorded

13 Road surface conditions for this unit

1	Dry
2	Wet
3	
4	
5	
6	
7	
8	
9	Not recorded

14 Road surface conditions for this unit

1	Smooth
2	Rough (holes, deep ruts)
3	Major irregularity (spoon drain, etc.)
4	
5	
6	
7	
8	Not applicable
9	Not recorded

15 Road surface conditions for this unit

1	Clean
2	Loose material
3	
4	
5	
6	
7	
8	Not applicable
9	Not recorded

16 Type of road surface for this unit

1	Bitumen
2	Concrete
3	Gravel
4	Earth
5	
6	
7	Not elsewhere classified
8	Not applicable
9	Not recorded

17 Type of accident for this unit

1	Single impact; non-rollover
2	Multiple impact; non-rollover
3	Rollover secondary to single or multiple impact
4	Rollover principal
5	No impact
6	
7	
8	Not elsewhere classified
9	Not recorded

18 Type of collision for this unit

1	With moving vehicle)	excluding cycles, motor-cycles
2	With stationary vehicle)	
3	With pedestrian	
4	With cycle, motor-cycle	
5	With movable object	
6	With immovable object	
7	Combinations of the above	
8	Not elsewhere classified	
9	Not applicable	

19 Type of this unit

1	Car and car-type station sedans, vans, utilities
2	
3	Motor-cycle, motor-scooter
4	Pedal cycle
5	Light truck, jeep type vehicle, small bus
6	Heavy truck (over 2 ton tare weight), bus, semi-trailer
7	Car with trailer
8	3-wheeled car, motor-cycle with sidecar
9	Other

20 No. of occupants in this unit

0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	More than 7
9	Not recorded

21 Type of this unit if car

1	Four-door (neglect rear openings unless used by passengers)
2	Two-door
3	
4	
5	
6	
7	
8	Not elsewhere classified
9	Not recorded

22 Type of this unit if car

1	Hard top
2	Soft top (erected)
3	Soft top (folded)
4	
5	
6	
7	
8	Not elsewhere classified
9	Not recorded

23 Type of this unit if car

1	Engine at front
2	Engine at rear
3	
4	
5	
6	
7	
8	Not elsewhere classified
9	Not recorded

24-26 Make of this unit if car

001	Holden FE, FC, FB, EK
002	Holden FJ, FX
003	Holden EJ, EH
004	
005	Ford Zephyr
006	Ford Prefect, Anglia
007	Ford Customline, Mainline
008	Ford Consul
009	Ford Falcon
010	Volkswagen 1200
011	Vauxhall Wyvern
012	Vauxhall Velox, Cresta
013	Vauxhall Victor
014	Standard Vanguard
015	Morris Minor, Minor 1000
016	Morris 850
017	Morris Oxford
018	Morris 8/40
019	Morris '6'
020	Chrysler Valiant
021	Simca Aronde
022	Austin A50, A55
023	Austin A95, Westminster; A90 Atlantic
024	Austin A30
025	Austin A40
026	Austin '8'
027	Jaguar
028	Humber Hawk
029	Humber Super Snipe
030	Riley 1.1/2 litre
031	Riley 2.1/2 litre
032	Plymouth, Dodge, De Soto
033	Wolseley
034	Mercedes 180, 190
035	Hillman
036	Chevrolet
037	Ford 'V8', pre-1949
038	Singer 'Gazelle'
039	Buick
040	Chrysler Royal
041	Simca 'Vedette'
042	Renault '760'
043	Austin-Healey
044	Fiat

045	Singer 1500
046	Studebaker
047	Skoda
048	Hudson
049	Mercedes 220, 220SE
050	DKW
051	Morris Elite, Morris Major, Austin Lancer
052	Triumph Herald
053	Ford Cortina
054	Rover
055	Standard 10, 8
056	Austin A70
057	Peugeot 403
058	Bedford
059	Pontiac
060	Triumph Mayflower
061	Renault Dauphine
062	Morris 1100
063	Austin Freeway
064	Renault Floride
065	Sunbeam Talbot
066	Renault R4
067	MG Magnette

Code 'not recorded' as '999'

24-26 Make of this unit if motor-cycle or scooter, motor-cycle with sidecar or three-wheeled car

001	Honda 250 cc motor-cycle, 125 cc
002	Honda Cub motor-cycle
003	Vespa motor-scooter
004	Lambretta L 125, L 150 motor-scooter
005	Triumph 650 motor-cycle
006	ISO motor-scooter
007	Harley Davidson motor-cycle with sidecar
008	James motor-cycle
009	B.S.A. 250 cc motor-cycle
010	B.S.A. 650 cc motor-cycle
011	B.S.A. 125 cc 150 cc motor-cycle
012	B.M.W. R60 motor-cycle
013	Triumph 500 cc motor-cycle
014	Harley Davidson motor-cycle
015	A.J.S. 350 cc motor-cycle, Matchless 350 cc motor-cycle
016	Heinkel motor-scooter
017	B.S.A. 350 cc motor-cycle

018	Jawa 250 cc, 350 cc motor-cycle
019	Messerschmitt 3-wheeled car
020	Puch 250 cc motor-cycle
021	Durkopp Diana motor-scooter

Code 'not recorded' as '999'

24-26 Make of this unit if truck, jeep type vehicle, bus, semi-trailer

001	Austin 10-ton truck
002	International truck
003	International - semi-trailer
004	Ford Thames van
005	Austin 3-ton truck, 5-ton truck
006	Chevrolet truck
007	Dodge utility, van
008	V.W. Combivan, pickup, etc.
009	Dodge truck
010	Bedford truck
011	Ford truck, utility
012	Bedford van
013	M.T.T. bus
014	Foden heavy truck
015	Commer van
016	International utility
017	Leyland bus
018	Ford semi-trailer
019	Diamond 'T' truck
020	Austin van
021	A.E.C. semi-trailer
022	Land Rover

27-28 Year of manufacture of this unit (code last two digits of year)

0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

Code 'not recorded' as '99'

29 Weight of this unit, if car

1	Less than 1,000 lb
2	1,000 to 1,499 lb
3	1,500 to 1,999 lb
4	2,000 to 2,499 lb
5	2,500 to 2,999 lb
6	3,000 to 3,499 lb
7	3,500 to 3,999 lb
8	Over 3,999 lb
9	Not recorded

Weight of this unit, if truck, jeep type, etc.

1	Less than 1 ton
2	1 ton but less than 2 tons
3	2 tons but less than 3 tons
4	3 tons but less than 4 tons
5	4 tons but less than 5 tons
6	5 tons but less than 6 tons
7	6 tons but less than 7 tons
8	7 tons or more
9	Not recorded

Note: include weight of load

30 Speed of this vehicle prior to accident

0	Stationary
1	1-10 m.p.h.
2	11-20 m.p.h.
3	21-30 m.p.h.
4	31-40 m.p.h.
5	41-50 m.p.h.
6	51-60 m.p.h.
7	61+ m.p.h.
8	Reversing
9	Not recorded

31 Speed of this vehicle at impact or on rollover

0	Stationary
1	1-10 m.p.h
2	11-20 m.p.h.
3	21-30 m.p.h.
4	31-40 m.p.h.
5	41-50 m.p.h.
6	51-60 m.p.h.
7	61+
8	Reversing
9	Not recorded

32 Skidding due to braking

1 No
2 Yes
3
4
5
6
7
8 Not applicable
9 Not recorded

33 Movement of this unit prior to accident

1 Proceeding straight ahead, not overtaking vehicle on traffic lane
2 Proceeding straight ahead, overtaking vehicle on traffic lane
3 Turning right
4 Turning left
5 Stationary on traffic lane
6 Parked off traffic lane
7 Performing U-turn
8 Entering traffic lane
9 Not elsewhere classified

Note: Consider movement on smooth curves as for straight roads

34-35 Alignment of principal other vehicle: or direction of principal impact if no other vehicle

0 0
1 1
2 2
3 3
4 4
5 5
6 6
7 7
8 8
9 9
77 Not elsewhere classified
88 Not applicable
99 Not recorded

Code: Rollover only as 13
Top impact as 14
Bottom impact as 15

36-37 Point of principal impact

1 1

2 2
3 3
4 4
5 5
6 6
7 7
8 8
9 9
Note: Code wheels as being in areas 2, 4, 8 and 10
Code area between wheels as 3, 6, 9 and 12
Code top as 13, 14, 15 and 16, for corners with the front right corner as 13 and then clockwise round the car; 18, 19 for front or rear.
77 Not elsewhere classified
88 Not applicable
99 Not recorded

38 Permanent deformation at point of principal impact

1 Nil
2 0-3 in.
3 3.1/2 to 9 in.
4 9.1/2 to 15 in.
5 15.1/2 to 30 in.
6 More than 30 in.
7
8 not applicable
9 Not recorded
Note: Deformation measured on a line from the point of impact to the centre of the vehicle.

39 Region of maximum deformation of passenger compartment

1 No deformation
2 Left side
3 Right side
4 Top
5 Front
6 Rear
7 Other
8 Not applicable
9 Not recorded

40 Movement of this unit during the accident

1	Did not roll over
2	Did roll over
3	
4	
5	
6	
7	
8	Not applicable
9	Not recorded

41 Sequence of rollover, if applicable

1	Before collision
2	After collision
3	Before and/or after collision
4	Rollover only, no collision
5	
6	
7	Not elsewhere classified
8	Not applicable
9	Not recorded

42 Type of rollover

1	Side over side to the right
2	Side over side to the left
3	Side over end
4	End over end
5	Roll in mid-air
6	
7	Not elsewhere classified
8	
9	Not recorded

43 Degree of rollover

1	1/4 roll
2	1/2 roll
3	3/4 roll
4	1 roll
5	1.1/4 roll
6	1 1/2 roll
7	1.3/4 roll
8	2 or more
9	Not recorded

44 Rollover surface

1 Hard, smooth
2 Hard, rough
3 Soft
4 Irregular surface, with some hard rough material
5 Irregular surface, with no hard rough material
6
7
8 Not applicable
9 Not recorded

45 Spin

1 Negligible spin
2 Clockwise, before accident
3 Anticlockwise, before accident
4 Clockwise, after collision and/or during rollover
5 Anti-clockwise, after collision and/or during rollover
6 'Jack-knifed'
7 Not elsewhere classified
8 Not applicable
9 Not recorded

46-47 Condition of tyres fitted to this unit

Front Wheel/s

1 Both good
2 Both poor
3 R.H. good, L.H. poor
4 R.H. poor, L.H. good
7 Not elsewhere classified (collision damage, etc.)
9 Not recorded

Rear wheel/s

1 Both good
2 Both poor
3 R.H. good, L.H. poor
4 R.H. poor, L.H. good
7 Not elsewhere classified (collision damage, etc.)
8 Not applicable
9 Not recorded

48 Overall vehicle damage (other than car)

1	Nil
2	Minor
3	Moderate
4	Severe
5	Extremely severe
6	
7	
8	Not applicable
9	Not recorded

48,49,50 Overall car damage (multiple areas of damage)

col.48 - front	col. 49 - compartment	col. 50 - rear	
1	1	1	Nil
2	2	2	Minor
3	3	3	Moderate
4	4	4	Severe
5	5	5	Extremely severe
6	6	6	
7	7	7	
8	8	8	Not applicable
9	9	9	Not recorded

51-54 Vehicle doors (after accident)

	Front right col.51	Front left col.52	Rear right col.53	Rear left col.54
Remained closed, operate normally	1	1	1	1
Open, cannot shut; no damage to door	2	2	2	2
Open, cannot shut; damage to door	3	3	3	3
Open, operate normally	4	4	4	4
Jammed shut; cannot open	5	5	5	5
Remained closed, do not operate normally	6	6	6	6
Not elsewhere classified	7	7	7	7
Not applicable	8	8	8	8
Not recorded	9	9	9	9

55 Vehicle door locks
1 Longitudinal restraint
2 No longitudinal restraint
3
4
5
6
7 Not elsewhere classified, e.g. locks on rear doors differ from those on front
8 Not applicable
9 Not recorded

56 Type of windscreen glass
1 Tempered
2 Laminated
3 Plate
4 Tempered (tinted)
5 Laminated (tinted)
6 Plate (tinted)
7 Not elsewhere classified
8 Not applicable
9 Not recorded

57 Form of windscreen glass
1 Curved, one piece
2 Flat, one piece
3 Curved, two piece
4 Flat, two piece
5
6
7 Not elsewhere classified
8 Not applicable
9 Not recorded

58 Damage to windscreen
1 No damage
2 Tempered glass broken, probable occupant contact
3 Tempered glass cracked or broken, no occupant contact
4 Laminated glass cracked or broken, probable occupant contact
5 Laminated glass cracked or broken, no occupant contact
6 Not elsewhere classified; but occupant contact probable
7 Not elsewhere classified; no occupant contact
8 Not applicable
9 Not recorded

59 Damage to window glass (other than windscreen)

1	No damage
2	Damage, probable occupant contact
3	Damage, no occupant contact
4	No damage, probable occupant contact
5	
6	
7	
8	Not applicable
9	Not recorded

60 Steering wheel damage

1	No damage
2	Minor damage, probable occupant contact
3	Severe damage, probable occupant contact
4	Damaged, not due to occupant contact
5	No damage, probable occupant contact
6	
7	Not elsewhere classified
8	Not applicable
9	Not recorded

61 Dash panel damage

1	No damage
2	Minor damage, probable occupant contact
3	Moderate or severe damage, probable occupant contact
4	Damaged, not due to occupant contact
5	No damage, probable occupant contact
6	
7	Not elsewhere classified
8	Not applicable
9	Not recorded

62 Rear vision mirror damage

1	Nil
2	Damaged, probable occupant contact
3	Damaged, no occupant contact
4	No interior mirror
5	No damage, probable occupant contact
6	
7	
8	Not applicable
9	Not recorded

63 Seat belts fitted (car, truck, etc.); safety helmet worn (motor-cycle)

1	No
2	Yes
3	
4	
5	
6	
7	
8	Not applicable
9	Not recorded

64 Front seat damage

1	No damage
2	Damaged, due to inertia of seat and/or occupants
3	Damaged, resulting from damage to vehicle body
4	No damage, probable occupant contact
5	
6	
7	
8	Not applicable
9	Not recorded

65 Engine mounting damage

1	Undamaged
2	Damaged; one or more partly torn free
3	Damaged; one or more completely torn free
4	
5	
6	
7	Not elsewhere classified
8	Not applicable
9	Not recorded

66 Number of principal other unit

0	No other unit involved
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	Not elsewhere classified

67 Type of principal other unit

1	Car, and car type station sedans, vans, utilities
2	Pedestrian
3	Motor-cycle, motor-scooter
4	Pedal cycle, motor-assisted cycle
5	Light truck, jeep type vehicle, small bus
6	Heavy truck (over 2 tons tare weight), bus, semi-trailer
7	Car with trailer
8	3-wheeled car, motor-cycle with sidecar
9	Other

68,69,70 Make of principal other unit if car

001	Holden, FE, FC, FB, EK
002	Holden FJ, FX
003	Holden EJ, EH
004	
005	Ford Zephyr
006	Ford Prefect, Anglia
007	Ford Customline, Mainline
008	Ford Consul
009	Ford Falcon
010	Volkswagen 1200
011	Vauxhall Wyvern
012	Vauxhall Velox, Cresta
013	Vauxhall Victor
014	Standard Vanguard
015	Morris Minor, Minor 1000
016	Morris 850
017	Morris Oxford
018	Morris 8/40
019	Morris '6'
020	Chrysler Valiant
021	Simca
022	Austin A50, A55
023	Austin A95, Westminster; A90 Atlantic
024	Austin A30
025	Austin A40
026	Austin '8'
027	Jaguar
028	Humber Hawk
029	Humber Super Snipe
030	Riley 1.1/1 litre
031	Riley 2.1/2 litre
032	Plymouth, Dodge

033	Wolseley
034	Mercedes 180
035	Hillman
036	Chevrolet
037	Ford 'V8', pre-1949
038	Singer 'Gazelle'
039	Buick
040	Chrysler Royal
041	Simca 'Vedette'
042	Renault '760'
043	Austin-Healey
044	Fiat
045	Singer 1500
046	Studebaker
047	Skoda
048	Hudson
049	Mercedes 220, 220SE
050	D.K.W.
051	Morris Elite, Morris Major, Austin Lancer
052	Triumph Herald
053	Ford Cortina
054	Rover
055	Standard 10, 8
056	Austin A70
057	Peugeot 403
058	Bedford
059	Pontiac
060	Triumph Mayflower
061	Renault Dauphine
062	Morris 1100
063	Austin Freeway
064	Renault Floride
065	Sunbeam Talbot
066	Renault R4
067	M.G. Magnette

71 Type of principal other unit (if car)

1	Front
2	Rear engine
3	
4	
5	
6	

7	
8	Not elsewhere classified
9	Not recorded

76 Overall vehicle damage - car

1	Nil
2	Minor
3	Moderate
4	Severe
5	Extremely severe
6	
7	
8	Not applicable
9	Not recorded

77 Weight of principal other unit, if car

1	Less than 1,000 lb
2	1,000 to 1,499 lb
3	1,500 to 1,999 lb
4	2,000 to 2,499 lb
5	2,500 to 2,999 lb
6	3,000 to 3,499 lb
7	3,500 to 3,999 lb
8	Over 3,999 lb
9	Not recorded

78 Speed on impact of principal other unit (m.p.h.)

0	Stationary
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61 and over
8	reversing
9	Not recorded

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