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Abstract:

Reports of in-depth crash studies from Australia, UK, Europe and the USA were reviewed. Successful studies were found to have defined and explicit objectives, a sound statistical design, appropriate analysis, and a substantial report which was related to the objectives of the study. On-scene studies gather transient information, and allow development of insight into the crash process; follow-up studies are more convenient, but at the cost of lost information. The resources required for each are similar. Apart from a small rural study near Adelaide, there has been no field study of crash performance of vehicles in Australia since 1977. There is a need for a system for continual monitoring of the effects of changes in vehicles and the environment on injuries and the crash process. This should be done through on-scene studies of rural and urban crashes, and through a system of augmented police reports.

Keywords (IRRD):

on the spot accident investigation; method; accident; research; rural-area; urban-area; international; evaluation (assessment).

Notes:

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REVIEW OF IN-DEPTH CRASH RESEARCH

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EXECUTIVE SUMMARY

This report reviews in-depth studies of road crashes reported in Australia and other countries. The working definition of in-depth studies included research studies where investigators examined vehicles, injuries, and the crash site in some detail, either while the vehicles were still present, or after their removal.

Since the first on-scene studies in Adelaide (1963-66), and Brisbane (1964-66), there have been a total of 21 in-depth studies of crashes in Australia. Multidisciplinary, detailed investigations of samples of crashes have been carried out in Melbourne, Sydney, and in Adelaide (1975-79). More specialised studies of emergency medical services, seat belts, and crashes involving utility poles have been carried out in Melbourne. Studies of motorcycle crashes, seat belt performance and road tanker crashes, have been carried out in New South Wales. A small pilot study of rural crashes around Brisbane was undertaken in 1970, and a more formal study of rural crashes in the area around Adelaide has just been completed. Data on control groups of non-involved drivers and vehicles has been gathered in Adelaide, Melbourne and Brisbane.

In other countries, intensive investigations of crashes began in 1955 at the Road Research Laboratory in the UK and in Chicago and Boston in the USA at about the same time. These were followed by further multi-disciplinary studies in Michigan, Los Angeles, Buffalo, and Indiana. None of these projects used a formal sampling method for selecting crashes, and they all suffered from problems of methodology which greatly reduced the value of their results. A methodologically sound study of motorcycle crashes has been carried out in Los Angeles more recently. In the UK, in-depth crash studies have centred around the University of Birmingham,

and lately, the University of Loughborough, with support from the Transport and Road Research Laboratory. On-scene studies of car crashes are also carried out in Germany, France, and Finland.

Of the studies reviewed, only nine were deemed successful, that is, they had defined and explicit objectives, a sound statistical design, appropriate analysis, and a substantial final report which could be related to the objectives of the study. A number of common characteristics were identified which appear to be important for the ultimate success of a study. Review of these reports shows that they accumulate up to several hundred detailed case studies which can therefore be analysed statistically.

For in-depth studies the alternatives are on-scene, or follow-up methods of study. The advantage of the on-scene method is that it gathers information that changes quickly, but at the expense of out of hours work and time spent on call. The follow-up method has more convenient working hours, at the expense of losing information. The resources required are much the same for both methods. Reviews in Germany, Finland, and by the Organisation for Economic Cooperation and Development (OECD) have determined that on-scene crash studies are important and the only method of gathering certain types of information.

This review identified the need for developing a better understanding of the crash process, through on-scene investigations, and a need for monitoring the crash performance of vehicles and the man-made road side environment. The two functions of developing a basic understanding, and of system monitoring, can be fulfilled by two complementary systems. Detailed, on-scene studies of urban and rural crashes provide fundamental information on the crash and the injury processes. Less detailed data on a larger number of crashes can be obtained from a system of augmented police reports.

Apart from the recent study of rural crashes around Adelaide, there has been no systematic field study of vehicle crash performance in Australia since 1977. There have been considerable social, legal, and cultural changes, as well as changes to roads, land use and vehicles. It is therefore recommended that a formal program of monitoring road crashes be instituted, consisting of on-scene studies of rural and urban crashes, and a system of augmented police reports from one or more police jurisdictions.

CHRONOLOGY OF ROAD CRASH STUDIES IN AUSTRALIA

	Adelaide	Sydney	Brisbane	Melbourne
1962	Robertson et al		Jamieson & Tait Hospital Admissions	
1963				
1964			Jamieson et al	
1965				
1966				
1967				
1968				
1969			Jamieson et al 100 rural crashes	Ryan & Clark, Emergency Medical Services
1970				
1971				Ryan & Baldwin Seatbelts and Injuries
1972				
1973		Impact 1. Seatbelts & fatalities		
1974		Impact 2. Seatbelts & serious Injuries		MIDAS
1975	McLean et al	Impact 3. Child restraints		
1976		Fairfield. Heavy vehicles, pedestrians, motorcycles (Impact 6.)		Utility Pole Study
1977				
1978		Impact 8. Motorcycles		
1979	Side Impacts	Tankers with flammable loads		
1980				
1981				
1982				
1983				
1984	Forward Control Vans			
1985		Forward Control Vans		
1986	Rural Study			Rural Single Vehicle
1987				
1988	Head Injury Study			

Period of study ————

Field work on scene - - - - - -

Table 1.

I INTRODUCTION

This report reviews in-depth studies of road crashes reported in Australia and overseas. The working definition of in-depth studies included research studies where investigators examined vehicles, injuries, and the crash site in some detail, either while the vehicles were still present, or after their removal. Some on-scene studies had follow-up elements in their design, but not vice versa. Ryan discussed the characteristics of in-depth studies in some detail [1], while McLean traced the history and development of scientific crash investigations and provided a valuable critique of such research up to early 1972 [2]. Another valuable source used was a review of investigations of pre-crash factors in the USA, published in 1976 [3]. A third source of information was the report of an OECD working party examining the place of detailed crash investigations in the road safety system [4]. In addition to the above documents, reports of all field crash investigations that we have been able to identify have been reviewed, together with major studies and reports from Europe and USA.

The review has proceeded largely in chronological order, but has discussed related studies in one organisation, or geographical area, where this seemed logical.

II IN-DEPTH STUDIES IN AUSTRALIA

Table 1 sets out a chronology of in-depth studies in Australia. The hospital based study of 1,000 admissions for traffic injury carried out in 1962 and 1963 by Jamieson & Tait [5], was a precursor to the on-scene study of 400 crashes in Adelaide in 1962-66 by Robertson, McLean & Ryan [6], which concentrated mainly on injury causation and vehicle crash performance, but which also drew attention to some pre-crash factors such as the hazardous nature of uncontrolled intersections. It was the first study to be designed to provide a representative sample of crashes.

The on-scene study in Brisbane by Jamieson et al [7] from 1964 to 1966, added a sociologist to the medical-engineering team, and a control group of drivers was interviewed for comparison with the crash-involved group. They were able to show patterns of crashes and injuries similar to those found in Adelaide, but with differences related to the topography of the two cities. They also demonstrated that crash-involved drivers lead lives of conflict and turmoil in other areas as well. This study, as well as the study in Adelaide, was designed to produce a sample of crashes to which an ambulance was called. McLean has critically reviewed these studies in some detail and they will not be discussed further here [2].

A Pilot Rural Study

Jamieson, a neurosurgeon at the Royal Brisbane Hospital, enlisted a group of medical students in a study of 81 crashes occurring in an area within roughly 160 km around Brisbane during December 1969 and January 1970. The criterion for selection was a serious injury-producing or fatal accident reported to the police. The investigators visited the site of the crash, examined vehicles, and interviewed the investigating police, and drivers, where possible. Injury information was obtained from hospitals. Lack of continuity in personnel in this study, among other reasons, meant long delays in analysis of the data and the report was published in 1974 [8]. It nevertheless demonstrated that it was possible to gather detailed information on a sample of rural crashes.

Melbourne

For six months from August 1969 Ryan and Clark [9], of Monash University, carried out an on-scene study of the emergency medical services attending 100 traffic crashes in Melbourne. They independently attended crashes to which an ambulance was called and recorded details of injury and treatment provided at the scene, and then in hospital emergency departments. They found that the longest delays in treatment occurred within hospital. There were also more instances of unsatisfactory care provided in the hospitals than by the ambulance service.

Again in Melbourne, in 1971 Ryan and Baldwin [10,11] studied injuries caused by seat belts to car occupants admitted to a hospital after a car crash. The vehicle was located and examined, but the site of the crash was not visited. They found that injuries due to the seat belt were associated with loose adjustment, and faulty buckle placement. This study partly influenced changes to Australian Design Rule (ADR) specification for seat belts.

New South Wales

The Traffic Accident Research Unit of NSW Department of Motor Transport in 1973 started a series of detailed studies of various aspects of car crashes which, while using a variety of approaches, were always multidisciplinary. The first, entitled "IMPACT 1", for "In-depth Multi-Phase Analysis of Crash Trauma", was a study of deaths of occupants of 1969 model year and later cars who were thought to have been wearing seat belts [12]. Notification was by police and the ambulance service. A team would travel to the site, examine vehicles, interview police, drivers, and others, and obtain injury information from coroners' reports. Data were recorded on forms based on the NATO-Committee on the Challenges of Modern Society (CCMS) Project [13,14]. They included crashes up to 250 km from Sydney. In the 14 months from February 1973 to April 1974, 126 vehicles were examined. It was found that in general, seat belts worked satisfactorily, but occupant survival could be improved if there was less intrusion into the occupant space [15]. Part of this same group of cases was the source of a report on seat belts and side impacts [16].

"IMPACT 2" and "IMPACT 3" ran simultaneously from June 1974 to July 1975. "IMPACT 2" studied car occupants who were injured and admitted to hospital and were wearing seat belts. "IMPACT 3" was aimed at identifying children aged less than 8 years who were admitted to hospital and were wearing some form of child restraint. The car also had to have been towed away. Notification was through the ambulance and police in a defined area in the western suburbs of Sydney. "IMPACT 2" gathered 142 occupants in 127 crashes, and "IMPACT 3", 149 children in 122 vehicles.

It was found that approved child restraints generally performed well in crashes, providing much more protection than the non-approved devices examined [17]. "IMPACT 2" found the same problems of belt tension and buckle adjustment as identified by Ryan and Baldwin [10]. Some belts released at below injury levels of force, due, at times, to loading by unrestrained rear occupants. The report included brief summaries of the cases studied [18].

This series of three studies over two and a half years showed the development of a method of notification of crashes using police and ambulance services. Sufficient resources were committed to enable the field teams to reach crashes up to 250 km away within a day or two of the crash. The criteria used for selection were well defined in operational terms. The data collected were appropriate but the analysis leaves one with the feeling that the data were under-utilised.

In October 1976, a new series of field studies started. This was known as the Fairfield study after the area of western Sydney around which the study was based. This was an on-scene study of crashes involving heavy vehicles, motor cycles, pedal cycles and pedestrians. The criterion for selection was that an ambulance be called to the crash. A team of engineers and behavioural scientists attended the scene of each crash. The injury information was obtained from hospitals as required. The motorcycle component was called "IMPACT 6". The on scene study ran from October 1976 to May 1977, covering 242 crashes. The reports of this study were presented as a series of detailed case reports. No attempt was made to synthesise or otherwise analyse the data from these cases. This was a tragic waste of effort, as the study was well designed and executed, and would have provided valuable information if analysed appropriately [19,20, 21,22].

During 1978 a further study of motorcycle crashes involving serious injury (admission to hospital) or death was carried out ("IMPACT 8"). This was a mixed on-scene and followup study as it aimed to collect all eligible crashes in NSW. The investigators had developed the notification system by which police and ambulance called an answering service when eligible cases occurred, and the investigators were paged immediately. Air transport was used to visit distant country areas. Cases from the IMPACT 6 and IMPACT 8 studies were combined in a single report that outlined common patterns of crash and injury mechanisms, found in other on-scene studies [23]. The influence of the road and environment in the on-scene studied crashes was detailed in a report by Jamieson [24]. This is the only report which deals with all these cases as a whole. It provides some insight into the potential effectiveness of traffic engineering countermeasures as it was judged that in 67 per cent of cases, the applications of such a measure would have prevented the crash.

In 1979 and 1980 a study was carried out of crashes of road tankers carrying flammable loads. Using the same notification system the team attended the scene of the majority of 42 crashes of tankers occurring throughout NSW, again using air transport when necessary. Although the number of cases was relatively small, valuable information was obtained on the antecedents of the crashes and the crash performance of tankers, including such factors as lack of stability, design defects, lack of maintenance, and lack of braking capacity [25,26].

In 1985 a study of 15 crashes of forward control vans which resulted in death or serious injury was carried out using the ambulance and police notification system, plus cases collected by other means. The author eliminated several cases for reasons which were not easy to understand, leaving nine for analysis. The most important conclusion was that a frontal barrier impact did not reflect the experience of actual crashes which were usually narrow impacts (e.g., a pole) or partial engagement of the front, both resulting in considerable intrusion into the occupant space [27].

These in-depth studies conducted by the Traffic Accident Research Unit (now incorporated in the Traffic Authority of NSW) demonstrated considerable ingenuity in developing notification methods which can be used for identifying specific types of crashes. The quality of the reports are uneven but in general the conclusions relating to engineering factors appear to be soundly based. The lack of an integrated report on the Fairfield study is regrettable.

Melbourne

In Melbourne in 1974, planning began for the Multi-disciplinary In-depth Accident Study (MIDAS). This was based in the Health Commission of Victoria, and arose from the work of the Consultative Council on Road Accident Mortality. This study was supported by the Health Commission and the Road Safety and Traffic Authority. An elaborate sampling plan based on ambulance calls to crashes was developed to ensure that each accident had an equal chance of being selected. The team sampled crashes on alternate weeks, and studied fatal crashes, as well as crashes to which an ambulance was called. They also collected data from a control group of drivers passing the site of the crashes studied, twelve months later. There was considerable difficulty in obtaining and keeping suitable personnel. The field work and major part of the analysis was done by a team consisting of a physician (who was also Director), a mechanical engineer, a traffic engineer, and a sociologist, together with a research assistant. During the twelve months from March 1975, the team investigated 166 cases in the ambulance sample, and 155 fatal crashes, and in the next year interviewed 308 drivers, riders and pedestrians in the control sample. These numbers were very close to the prescribed targets in the sampling plan. When the data had been coded and the analysis just begun, the Director left. The present author (GAR) was then asked to complete the analysis and to prepare a report. The major findings were that mechanical defects to vehicles were common in both the crash and the control group, but only rarely were related to the cause of a crash [28]. Medical conditions, and use of prescription drugs were more frequently found in the control group than the crash group. A rather wide subgroup of males aged under thirty years, with low education, were found to be over-represented in crashes. This study was innovative in its sampling plan, and in the use of a control group. But it was very poorly designed and executed. The lack of continuity of staff hindered the development of expertise, the poorly defined aims and objectives meant it was lacking direction, and only the injection of large amounts of effort from external consultants enabled the data collected to be coded and analysed at all. An enterprise such as this, involving several disciplines and out of hours work, did not sit easily in the public service bureaucracy, exacerbating the above mentioned problems. The lack of direction and continuity also meant that the findings of the study were not distributed in any systematic way.

In contrast, the study of crashes involving utility poles by Fox, Good & Joubert [29] was well designed, with explicitly stated aims. These included estimating the number of collisions with poles in Melbourne each year, estimating their costs, and suggesting countermeasures, as well as developing a model for predicting hazardous sites. The study team used towing services to notify them of suitable crashes, and over eight months in 1976 and 1977 studied 879 crashes, 30 per cent of which resulted in injury. Data were gathered on the vehicle and on the site, with injury information being obtained from hospitals. A control group of randomly selected pole sites were visited. Comparison revealed that characteristics of 10 per cent of these sites were associated with about half of the crash sites. A randomly selected group of vehicles at service stations were examined, and it was found that shallower tyre tread and deviations in tyre pressure were associated with crash involvement. It was estimated that the annual cost of crashes involving utility poles amounted to $23 million. This study was based in a University department of engineering, and produced valuable results.

Adelaide

The third major detailed study of road crashes in the 1970s was undertaken by the Road Accident Research Unit at the University of Adelaide. This was an on-scene study of crashes to which an ambulance was called. It built on the experience of the first study in Adelaide and incorporated developments in methodology up to that time. Two teams, each of engineer, psychologist, and medical officer were employed, utilising a relatively simple sampling plan, and attended 304 crashes. This was an 8 per cent sample, a little below the 10 per cent aimed at. They recorded data in the pre-crash, crash and post-crash phases, on the vehicles, road users, and road and traffic environment. Photography, often using an overhead mast, was used to record vehicle damage, vehicle rest positions and roadway markings at the scene. Analysis of the vast amount of data obtained, up to 1700 items per case, involved many cross tabulations. The results of the survey were very detailed, and were presented in 10 volumes: an overview, pedestrians, pedal cycles, motorcycles, commercial vehicles, cars, road and traffic factors, a summary and recommendations, a volume of case histories of each crash, and a comprehensive code book. The findings cannot be summarized here, but they represent one of the most thorough documentations of road crashes yet published. This is particularly so when compared with the studies in Melbourne and Sydney previously described. It was a relatively simple, straight forward design, carried out with appropriate attention to detail. The seemingly protracted length of time over which the reports were published is at least in part due to the sheer volume of data to be analysed, and compares well with other studies [30, 31].

Comparison with data from the first Adelaide in-depth study, twelve years previously, showed that in the sample of crashes studied there were fewer pedestrians and more motorcycle crashes. Further detailed comparisons were not possible because the original case files and photographs from the first study were destroyed while in the care of the Australian Road Research Board.

This in-depth study was used as a basis for two further studies. In 1979 roadside breath testing for alcohol was carried out on drivers not involved in crashes but stopping at traffic lights close to the sites of the 304 crashes. These drivers then acted as a control group in an estimation of the effect of alcohol on crash involvement [32]. Then, in 1980, an estimate of the costs of road crashes was made by tracing persons involved in the crashes investigated in 1976 and 1977 and detailing the medical, property damage, loss of earnings and other costs in the intervening period [33].

The same Unit in 1979-1980 carried out a study of side impacts in cars using the towing services as a notification system. The aim was to assess the effectiveness of ADR29. One hundred cases were obtained and the damage recorded. Computer simulations of the impacts were performed using the CRASH II and SMAC programs. Analysis of the data stopped in 1980, and was re-activated in 1986. A report has been drafted but it is not yet published.

After a pause of some years, crash investigations resumed in 1984 with a study of forward control vans involved in crashes. This was carried out by the NH&MRC Road Accident Research Unit, which evolved from the above Unit, in Adelaide [34]. It also used the towing services as a source for finding vehicles towed away from crashes. Thirty-one crashes were studied over a five month period in 1984. It was found that intrusion into the front seat occupant space was more frequent than in passenger cars, and that there was not sufficient protection from intrusion of components in front of the front seat occupants, including the steering wheel. Comments were made about the failure of ADR3 seat anchorages, the inadequacy of bull bars, and the need for effective cargo barriers. The field study was complemented by an analysis of injury data from the Motor Accidents Board in Victoria showing that the occupants of forward control vans had more leg injuries than occupants of passenger cars.

Current Studies

Adelaide, NH&MRC Road Accident Research Unit

(a) Head Impact Reconstruction.

The aim of this study is to reconstruct head impacts to fatally injured pedestrians and motorcyclists, and combine this information with detailed neuropathological examinations of brain injury. Each post mortem examination is attended by a staff member, and injuries photographed and recorded. The vehicles are examined in detail, and the site visited, to determine the movements of the pedestrian or motorcyclist at impact. The helmets of motorcyclists are obtained for study. Computer simulations of the pedestrian-car impact are used to obtain estimates of the forces and accelerations applied to the head. These are then correlated with the results of the neuropathological examination of the brain, to gain insight into the pathological processes of injury. About 150 cases have been studied since 1984.

(b) Rural In-depth Study

For 12 months from June 1986 a two man team conducted on-scene investigations of crashes occurring on roads with an 80+ km/h speed limit outside of Adelaide, within a radius of about 100 km. These were crashes to which an ambulance was called, the team being notified by radio or by pager. At each scene, data were recorded regarding rest positions of vehicles, skid marks, and injuries, and drivers were interviewed briefly. Follow up interviews were carried out by appointment. Vehicles were examined in detail, also at a later time. Eighty crashes were obtained. A preliminary report has been prepared, and further analysis of the data is continuing.

Victoria

The Road Traffic Authority is conducting a survey of single vehicle crashes on defined roads in Gippsland. The aim of this study is to examine the road and vehicle characteristics of single vehicle crashes, a major source of deaths in rural crashes. Notification of crashes is obtained from the police and the ambulance service. A site visit is made as soon as possible, the vehicle is located and examined and a questionnaire is sent to the driver. As most drivers appear to be admitted to hospital a blood alcohol estimation is available. At each site, the geometry of the road and surroundings is mapped and skid resistance measured. Surveys of the speeds of passing vehicles are taken and questionnaires sent to a sample of these drivers. Control sites will be identified and examined in a similar way. Some 61 crashes were investigated in the six months to December 1987. Data collection will continue until June 1988 [35].

III IN-DEPTH STUDIES IN OTHER COUNTRIES

McLean reviewed the history of intensive crash investigations in some detail [2]. Briefly, in 1955 the Road Research Laboratory in the United Kingdom began investigating crashes occurring in the area around the Laboratory, using a multi-disciplinary team to study vehicle, road and injury factors. No attempt was made to obtain a statistically based sample of crashes [36]. About the same time J. Stannard Baker began a multi-disciplinary study of crashes in Evanston, Illinois, near Chicago, with limited success in terms of useful data produced, due to difficulties in getting scientists from different disciplines to work together [37]. In 1958, Mosely began a study of fatal crashes in Boston, based on Harvard University Medical School. This study produced evidence of alleged suicide and homicide in a number of instances, amid much controversy, but little in the way of useful data [38].

These three studies, while not successful in the sense of producing numerical data, nevertheless were valuable in demonstrating that scientific studies of road crashes were feasible, and that valuable information could be obtained by first hand observation at the scene of a crash. Further similar studies were undertaken at the University of Michigan [39], where they have continued since 1961, and at the University of California, Los Angeles [40], with neither group using a formal sampling method.

Cornell Aeronautical Laboratory Inc. of Buffalo NY, was the site of a number of multi-disciplinary crash investigation projects from 1966 onwards [41]. These rather elaborate studies tried techniques such as remote video cameras to explore new methods of data gathering at the crash site. However, they all suffered from poor statistical design, confused logic, and produced very little of substance for a great deal of effort.

A group at the Institute for Research in Public Safety at the University of Indiana also carried out a series of multi-disciplinary studies, primarily aimed at assessing the role of vehicle defects in crash causation [42]. These large studies also suffered from grave problems in design, execution and analysis. This study, and the Cornell studies, are valuable largely as examples of mistakes to avoid.

In sharp contrast is a study of motorcycle crashes by Hurt, Ouellet & Thom at the University of Southern California, Los Angeles [43]. This study ran over 5 years, was well designed, the field work was careful and conscientious, and a very valuable report produced. A formal sampling technique was used, the notification system was closely monitored to determine its performance, and alterations made to ensure a meaningful sample. A control group of riders and machines passing the sites of the study crashes was obtained. The conclusions regarding factors predisposing to involvement in crashes were soundly based on the data gathered. The report is a very impressive document, illustrating that trustworthy results can only be obtained with good design, field work, and analysis.

In the mid 1960s, Mackay at the University of Birmingham carried out an on-scene study of crashes in and around Birmingham [44]. This team attempted to determine the role of human, vehicle and environmental factors in the pre-crash phase, as well as the causes of injury in the crash phase. This was one of the first studies to follow the Adelaide example of being based on a defined sampling plan, so some confidence could be placed in its conclusions. The chief among these was that combinations of factors were associated in producing crashes, the human and environment being the most common. The injury patterns found were similar to those in Adelaide.

Since this study, there has been a continuing series of studies carried out at this unit. The most significant were an on-scene detailed study of car and pedestrian collisions [45] and a follow-up study of fatal motorcycle crashes [46,47]. These studies elucidated the mechanisms of injury in some detail, and demonstrated the common patterns of collisions. An important element in these investigations was the notification system which had been developed over time with the police forces of Birmingham and the surrounding counties. The good functioning of this system meant that the rate of notification of eligible cases was very high. The unit also developed a good relationship with the hospitals, medical authorities and coroners, enabling information on injuries to be obtained relatively easily.

In the USA in the 1970's there was a large expansion of multi-disciplinary accident investigation teams sponsored by the National Highway Traffic Safety Administration. These teams were largely based on universities throughout the country, and each investigated 20 to 50 cases per year, concentrating on severe crashes. Much information was obtained on mechanisms of injury in individual cases. However, due to the lack of a sampling strategy, the uncertainties involved in aggregating the data from different teams meant that it was not possible to place any faith in conclusions drawn from the data.

This problem is best illustrated with the NATO-CCMS international accident investigation project. With sponsorship from the US Department of Transportation, a common Collision Analysis Report Form was developed and used by multi-disciplinary teams from several countries in Europe, UK and the USA. Even with intensive editing efforts, the differences in interpretation of data items, case selection, and operating procedures were so great, that the data could not be analysed in any useful way. The useful outcome of the exercise was the report form, and the realisation of the difficulties arising in such an exercise [13,14].

In Europe, on-scene investigations of crashes have been carried out systematically in Germany for many years, in Heidelberg, at first, and then in Berlin and Hanover. The latter is an on scene study with a statistical sampling plan, using a multi-disciplinary team based on the Medical University of Hanover, and the Technical University of Berlin. From 1973 to 1984 two teams were used, since 1984 only one [48]. Data is collected on all phases of the crash process. A cost effectiveness review of such studies (unfortunately in German) concluded that "at the scene accident investigations are an indispensable instrument of obtaining empirical accident data, especially for accident research" [4].

The insurers association, HUK-Verband, carries out followup investigations of different categories of crashes, with the objectives changing from time to time, as required. Analysis of the data obtained is continuous [4].

In France, all fatal accidents have been studied since 1983 by Direction de la Securite et de la Circulation Routiere on a follow-up basis, by inspectors of the department. A more research oriented study is carried out by Institute National de Recherche sur les Transports et leur Securite (INRETS). This is a multi-disciplinary on scene study of crashes in a 30 km radius around the town of Salon-de-Provence, using a hospital admission criterion. The study is focussed primarily on pre-crash factors, using a method of detailed reconstruction of events. Results are not analysed statistically [4].

All European car manufacturers have carried out investigations of crashes involving their own cars, but not on any sampling basis. Volvo, in Sweden, maintains a continuing study of crashes involving their vehicles, through their insurance arrangements [4].

Since 1971 there has been developed, in Finland, a network of multi-disciplinary teams which investigate all fatal crashes in the country. These are based on the police information system, but work independently. The focus is on pre-crash variables, but some attention is paid to injury production. In 1978 the system was evaluated, and modified so that each team concentrates on a specific type of crash, not all of which are fatal [49,50]. One of the benefits of these teams, it was stated, was an increase in awareness of the importance of the various human, vehicle and road environment factors in personnel from the agencies involved in these teams, and an increase in the ability of police to determine the actual course of events in crashes, rather than solely attempt to determine who was to blame. The review concluded that maintaining these teams had many benefits.

The current position with regard to detailed crash studies in Europe is that, as mentioned above, on scene investigations are in progress in Germany, France, and Finland. In the UK, the Transport and Road Research Laboratory, together with the motor manufacturers is sponsoring two teams collecting data on recent model car crashes, one at the University of Birmingham, and one at the University of Loughborough. These are follow-up studies, based on police notifications, and concentrating on injury causation in the crash phase. Each unit has a set quota of crashes to obtain. The reports are sent to TRRL for editing and analysis. Little analysis of data is performed by the investigating teams. The intent is to obtain an overall sample of crashes which represents the nation as a whole, Birmingham being largely urban, and Loughborough, rural [4].

In the USA the Multi-Disciplinary Accident Investigation (MDAI) teams have largely been abandoned in favour of the National Crash Sampling System (NCSS) [51]. Teams of investigators are stationed at 50 sites around the country. They carry out follow-up studies of police reported crashes, examining the vehicles and visiting the site, and obtaining injury information from medical sources. The sites are chosen to provide a geographically balanced sample of crashes. Then the data is weighted to produce national estimates, e.g. 10 million car occupants are involved in crashes annually. However, few of the crashes and injuries are severe, therefore the weighting factors for these cases are large, and consequently the statistical uncertainty is large also. One or two cases can distort the results remarkably [52]. It is uncertain what use is being made of the unweighted data, which could be very useful, given its limitations, e.g. only two-thirds of personal injury crashes are reported to police.

The other mass data file is the Fatal Accident Reporting System (FARS) [53]. A staff of FARS personnel in each State process police reports on fatalities, augmenting them with coroners' reports. Again, gross differences in interpretation of data items, and in the content of each State's forms and procedures, limit the usefulness of this collection.

In Canada from 1970-1979 there were 10 MDAI teams at universities across the country, carrying out on-scene investigations of fatal or injury producing crashes, to no particular sampling plan. This system was changed in 1981 to 10 similar teams carrying out followup studies of police reported crashes to a sampling plan intended to produce a national estimate, after suitable weighting. This scheme has the same drawbacks as the similar NCSS operation in the USA. However, in Canada, there is more uniformity between provinces in the content and quality of police reports than there is between States in the USA. Light truck and van crashes were studied from 1981-1984, and passenger vans from 1985 to date [4].

It is obvious that in Australia we are fortunate to have the national Australian Bureau of Statistics collections of casualty (hospital admissions) data, for which there is no equivalent in the USA.

IV GENERAL COMMENTS ON IN-DEPTH STUDIES

Of the studies reviewed only a few could be deemed successful, in terms of having defined and explicit objectives, a sound statistical design, appropriate analysis, and a substantial final report which could be related to the objectives of the study. The nine studies meeting these criteria are listed below in Table 2.

A number of points become evident from examination of the table. Seven of the studies were sited in a university, one in a teaching hospital, and one in a traffic organisation. The majority had a time span of four or five years. In Hanover this research appears to be ongoing, with periodic reviews. Eight of the nine were on-scene studies, all were multi-disciplinary. The total sample of cases ranged from 45 upwards. Three studies obtained control samples of drivers and/or vehicles. This is important for evaluation of pre-crash factors. The subjects of three studies were specialised: motorcycles, pedestrians, and road tankers, while the remainder studied all crashes. The Australian studies used an ambulance service based notification system, the remainder used the police.

Characteristics of a "good" study

After considering the review of previous "in-depth" or detailed road crash investigations in Australia and other countries it is possible to list the most important characteristics of a study design. While the presence of these characteristics will not guarantee success, their absence will make failure a very high probability. Studies that are well designed and executed produce valuable results that can be trusted.

1. There must be an identified sampling frame.
2. The sampling method must be defined operationally, practical, and obtain a specific percentage of the population of crashes under study.
3. There must be an explicit or implied theoretical base for identifying data to be collected, based on known psychological, physiological, biological or sociological processes.
4. Data items must be defined in objective and operational terms, and not be opinion or judgement.
5. There must be quality control measures at each stage, to provide for completeness and accuracy of data and completeness of case identification and collection.
6. There should be case review sessions to combine and review all aspects of each case to provide a structured narrative or summary which could be electronically stored for text retrieval. The use of free text and keywords has been found valuable in analysis of items or groups of items not coded.
7. For the recording and coding of data, there is now a fair amount of agreement internationally on vehicle and injury data: NATO/CCMS forms, General Motors "long form"; use of the Abbreviated Injury Severity (AIS) scale for injury; the Vehicle Deformation Index (VDI) or Collision Damage Classification (CDC) for vehicle damage; Delta V, or Equivalent Barrier Speed or other estimates of impact severity.
8. Estimates of severity can be aided by collision simulation programs, remembering that the accuracy of the output is determined by the accuracy, or otherwise, of the input.
9. The analysis and report writing should be done by those who collect the data, and do the field work.

10. Data processing, analysis, and report writing should take as long as the field work to achieve adequate thoroughness, and may even take longer.

11. Statistical methods used should progress from simple cross tabulation to more complex techniques as required.

12. Detailed design, preparation, selection and training of staff take longer than imagined. Roughly 1/3 preparation, 1/3 field work, 1/3 analysis and report writing.

13. Personnel - professional qualifications are essential, e.g. in behavioural sciences, engineering, medicine, psychology. Working in a multidisciplinary team takes adjustment. It takes time before a professional stops applying the study to his discipline and starts applying his discipline to the study. Commitment and motivation are important for a long term study. Several studies have had difficulties because staff saw the period of the study as an interruption to their career.

14. The details of a study design depends on its particular aims and objectives. Therefore the aims and objectives should be explicitly stated in as much detail as possible. This statement guides the direction, structure, and development of the study. Studies may be broad and exploratory (Adelaide, Brisbane) or more defined (utility pole study, tankers or motorcycles).

McLean discusses at length the issues involved in designing and carrying out such studies to a successful conclusion. He comments: p. 116, "Far from being a matter of simply going to accidents to collect information, an efficient in-depth study demands a quality of planning, execution and analysis that is the equal of that in any other research endeavour" [2].

TABLE 2

"SUCCESSFUL" IN-DEPTH STUDIES

Site	Time Period	Organisation	Type of Study	No. Cases	Types of Crash	Criterion	Control Group	Authors	Reference No.
Adelaide	1962-66	Dept. Pathology University of Adelaide	on scene	403	all	ambulance	no	Robertson, Ryan, McLean	6
Brisbane	1964-66	Royal Brisbane Hospital	on scene	300	all	ambulance	drivers, household survey	Jamieson et al	7
Birmingham	1965-69	Univ. of Birmingham	on scene	425	all	police	vehicles	Mackay GM	44
Adelaide	1975-79	Road Accident Research Unit, Univ. of Adelaide	on scene	300	all	ambulance	no	McLean et al	30,31
Birmingham	1973-76	Univ of Birmingham	on scene	318	pedest.	police	no	Ashton	45
Hannover FDR	1973-	Medical Univ. Hannover, Technical Univ. of Berlin	on scene	2000+	all	police	no	various	48

TABLE 2 (cont)

Site	Time Period	Organisation	Type of Study	No. Cases	Types of Crash	Criterion	Control Group	Authors	Reference No.
Los Angeles	1975-80	Traffic Safety Center, Univ. of Southern California	on scene	900	motor-cycle	police	riders & motor-cycles	Hurt, Ouellet, & Thom	43
Sydney	1979-80	Traffic Authority of NSW	on scene	45	road tankers	police	no	Griffiths	76
Melbourne	1976-78	Univ. of Melbourne	followup	800	car v pole	tow service	yes	Fox, Good, Joubert	29

V ADVANTAGES OF ON-SCENE DETAILED CRASH INVESTIGATIONS

It is often stated, particularly in the American literature, that the two main methods of research into road traffic crashes are the case study, in which a few cases are investigated in detail by a multi-disciplinary team, and mass data, or analysing aggregations of police accident reports. It is obvious from reviewing the literature that this dichotomy holds only in North America. In Australia and Europe the successful and useful studies have each accumulated several hundred cases, chosen in a systematic way, and used sound statistical methods of analysis.

The distinction should lay, not between case study and mass data, but between on-scene and follow-up methods of 'case study'. Attending the scene of a crash before the vehicles involved are removed has a number of advantages. Investigators can identify drivers and others involved in the events and interview them while memories are still very fresh. Indeed, some people have a strong need to talk, and having a sympathetic, interested listener can be quite therapeutic. Information about conditions, states, or position of components of the crash can be identified and recorded at the scene. This is particularly important if pre-crash, causal or contributing conditions are being studied. The destination of the injured persons and damaged vehicles can be obtained quickly. This is very important for follow-up interviews and examinations. If medical personnel are part of the on-scene team, on occasions they can assist the emergency medical services in resuscitation measures. A further advantage of attending the scene is the insights it can provide into the processes involved in events of a crash. This is something that does not come from studying reports in an office. This educative component is particularly important for vehicle, highway, and traffic engineers, who normally do not see the results of their mistakes first hand.

The disadvantages of attending on-scene are relatively few. The work is mostly out of normal office hours, at night and on weekends, and therefore disruptive of family and social life. It requires some form of notification system which relies on the goodwill and memory of despatchers or controllers in an emergency service, and hence needs to be operating more or less continuously for long periods for maximum efficiency. The system is unlikely to work satisfactorily for short term projects. The necessity for combining on-scene work with followup interviews and vehicle examinations can overload a team at times, invading their free time to a considerable extent.

Whether the team relies on a police or ambulance service for notification, the nature of the event is usually not known with any accuracy until arrival at the scene. Therefore, many unnecessary trips can be made if only one particular type of event is being studied, e.g. side impacts, or pedestrians. This leads to frustration on the part of the team and misunderstanding and confusion on the part of the emergency service controllers, if they do not understand the aims of the study.

In the alternative method, the components of the crash are 'followed-up' on the next or subsequent days. In this case the notification system is largely 'active', i.e. the study team seeks cases that meets its selection criteria from police, ambulance, or towing service sources, and does not wait to be notified. This method is particularly suitable for investigations of particular types of event, e.g. fatal motorcycle crashes, crashes involving late model cars, crashes involving heavy goods vehicles, or of rare events, e.g. passenger bus crashes. The investigations can be carried out largely within normal office hours, except perhaps for interviews of persons involved. However, locating vehicles, drivers and riders, and other participants is time-consuming and involved. Locating the site and establishing the point of impact and rest position of vehicles can present problems when markings have disappeared and no-one is available to point out the important positions. There can also be difficulty in obtaining information about injuries, particularly minor injuries, some time after the crash.

Therefore, there is a loss of accuracy of information when using this method. This may not be of importance, depending on the aims or objectives of the study. Accurate information about the rest positions of vehicles is important if collision simulation programs such as SMAC are to be used with any accuracy or confidence in the results. This may be one factor to be taken into account when determining which method of study is appropriate. The requirements for vehicles, equipment, office space, and computing capacity remain much the same whichever method is used.

The number of cases, and therefore, the time required to accumulate them depend to a large extent on the objectives of the study, and calculations of sample size and statistical power are required to provide an indication.

The choice between on-scene and followup study methods really depends on the type of event under review and the aims and objectives of the study. The resources and time required are very similar for both.

The virtue of the in-depth, or detailed, study of crash events is the wide range of detailed information which can be obtained. This serves as a base for "the productive synthesis of material not previously recognised as related" and for "the open ended observation and description of phenomena to discover variables which deductively seem of importance" [54].

Reviews of in-depth crash studies in Germany, and Finland, have concluded that they provide essential information that is not possible to obtain in other ways. The Finnish report maintains that there are indirect the roads and land use patterns since 1977. The introduction of random breath testing, and changes to licence conditions for probationary drivers, are some examples of relevant changes.

Police accident reports provide generally reliable data on the time and place of crashes, and on the number and type of vehicles involved, but they are poor on detailed injury data, on the extent of vehicle damage, and the configuration of the impact. They are very poor on establishing relevant pre-crash factors. For these reasons examination of mass police accident data is not able to reveal the effects of the changes mentioned above, unless the effect is very large indeed.

If Adelaide were selected as the site for an on-scene study of road traffic crashes there would be an unprecedented opportunity to trace the effects of the changes outlined above, through the records of the 1975-77 on scene study and to a much lesser extent, unfortunately, the 1962-66 study. These representative samples of crashes would reflect the environmental changes, as well as changes to the vehicles. A comparison of a succession of such samples in a single city would be unique. The same basic methods of investigation could be used, together with the selection of appropriate control groups of drivers, riders and pedestrians, to study further specific pre-crash factors, such as the interaction between driver and environment, which has been shown to be important in a number of studies [24,31].

Other advantages of Adelaide are that it is small enough to be studied in this way but large enough to generate enough crashes to permit maximum utilization of the field teams. The necessary goodwill and cooperation of the police, ambulance, and medical services have been built up over the past 25 years. The topography of Adelaide and its surrounding areas varies from flat plains to hilly terrain, from urban to rural, and includes a number of major highways.

On-scene, Rural Study

The rural study around Adelaide for which field work has been recently completed, has shown on preliminary analysis several patterns of crash events, which are very dissimilar to urban crashes. There is a high incidence of vehicles leaving the road for a variety of reasons, often due to interactions between driver and elements in the environment, such as gravel shoulders. The severity of impacts is greater than in urban crashes. The relatively small number of cases studied (80) means that the analysis of individual items of data is limited. Therefore, if additional cases were obtained the characteristics of rural crashes could be delineated in detail, for the first time. It is suggested that 100 more cases should be studied over a two year period. The notification system, the equipment, and most of the personnel are still in place. It would take very little time for this study to be made operational again. Hence, data on the crash performance of vehicles would become available earlier than from an urban study.

An Augmented Police Accident Report

This study would be similar to the Automotive Crash Injury Research program of Cornell University, which operated in the 1950s and 1960s. In selected areas and states of the USA, highway patrolmen were trained to complete, for every tenth injury-producing crash, an additional form describing damage to the vehicle with particular attention paid to signs of occupant contact. When an injury occurred the patrolmen took another form to the hospital where, by arrangement, injury details were completed. They also took photographs of the vehicle and the scene. The completed forms and photographs were forwarded to the ACIR headquarters, for checking, coding, and analysis. Over the years of its operation, reports from ACIR benefits in the sense of educating agency personnel and the public about the realities of the crash process. The OECD report sets studies of this type in an integrated framework of action on road safety, involving all relevant agencies. It is noteworthy that in Germany, Finland and France, in-depth studies are continuing, with periodic review and re-direction. In Australia, they can best be described as sporadic, of limited duration, with circumscribed aims, i.e. a series of 'one shot' studies. The best value would be obtained from in-depth studies if they were part of such an integrated system, with the objectives of evaluating present countermeasures, and of developing new insights into the crash event process.

VI PROPOSED PLAN OF WORK

The foregoing review of research in Australia and other countries indicates that the on-scene study of crashes provides valuable information which can not be obtained any other way, and which is essential to developing an understanding of the crash process. In addition, there is a need for an on-going monitoring of the crash performance of vehicles and the man-made roadside environment.

These two functions, developing a basic understanding and system monitoring, can be fulfilled by two complementary systems. Detailed, on-scene investigations of urban and rural crashes provide fundamental information on the crash and injury processes. Less detailed data on a larger number of crashes can be obtained from a system of augmented police reports, modelled on the Automotive Crash Injury Research program (ACIR) which was conducted by Cornell University in the USA from the early 1950s to the late 1960s.

These two components would provide a formal mechanism for evaluating the effects of changes in the construction of vehicles, as well as changes in the legal and road environment. At present there is no method of detecting the effects of changes in the road-vehicle-driver system, except through anecedotal evidence, or from study of police accident reports of injury and fatal crashes. This is a very crude and unsatisfactory method.

On-scene Urban Study

Apart from the recent rural crash study around Adelaide there has been no systematic field study of vehicle crash performance since 1977, and no study of pre-crash factors. There have been changes to the social, cultural and legal aspects of Australia, as well as continuing changes to identified, inter alia, the importance of ejection as a cause of death, the failure of door latches as a prime cause of ejection, and the leading causes of injury to car occupants [54-59]. Most of the initial safety standards for passenger cars evolved from the work of ACIR.

An ACIR-type program could be developed in Australia, initially in one police district, such as in the ACT. Subsequent development should include police districts in other States.

Hospital based injury surveillance systems which are being developed are not satisfactory for this purpose because, although injury information may be accurate, data relating to the injury producing incident is not of sufficient detail, nor does it encompass all persons involved in the crash, whether injured or not. This is an essential item of information for determining rates of injury, e.g. for seating positions. The Federal Office of Road Safety Fatal File overcomes some of these deficiencies but collects less information on vehicle crashworthiness than is envisaged in an ACIR-type program and is, by definition, restricted to fatal crashes.

Road Crash Monitoring System

A formal system for monitoring the vehicle, human and environmental components of road traffic crashes is proposed, consisting of on-scene, detailed studies of crashes in urban and rural environments, together with less detailed information on a much larger sample of crashes obtained from the augmented police reports.

The focus of each component would change from time to time as the need arose. There would also be periodic review of the functioning and effectiveness of each part, and of the whole. The on-scene study would have an important training function, as personnel from other organisations could be seconded for periods of say, 3 to 6 months, thus providing a continuing source of expertise for the development of methods of crash investigation. This team could also investigate crashes of particular interest in its own, or other states, e.g. buses, or heavy trucks.

It is proposed that, in the short term, on-scene urban and rural studies be conducted in and around Adelaide, to fulfil the immediate needs for information. The augmented police accident report program should be initiated in the short term. The longer term aim should be to develop an on-going system for the detailed and comprehensive monitoring of road traffic crashes in Australia based on the experience gained in the proposed short-term activities.

VII RECOMMENDATIONS

1. Establish a formal system to monitor in detail the performance of the human, vehicle and road system in crashes, by means of:
   - a program of on-scene, in-depth studies of crashes according to the scheme outlined in this report;
   - follow-up studies to investigate particular problems, where appropriate;
   - an augmented police report system.

2. Develop in one police district, an augmented police report system, with a view to possible extension to other jurisdictions as part of the monitoring system.

3. In the short term, conduct a further on-scene study of rural crashes. This could usefully be conducted in South Australia to complement that just completed.

4. A third on-scene study of crashes in Adelaide be conducted to take advantage of the unique opportunity to monitor the effects of vehicle, road, and environmental changes over 30 years.

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