Fifty Years of At-Scene Crash Investigations: Methodological Considerations

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ABSTRACT

At-scene investigations of road crashes for research purposes commenced in the 1950s in the United States and England. These investigations ranged from ones conducted by small multi-disciplinary teams of researchers to the use of specially trained police and medical officers, as exemplified by the Automotive Crash Injury Research program of Cornell University which laid the foundation for our understanding of the causes of injury in car crashes. The first attempt by a small team of researchers to investigate a representative sample of crashes at the scene was conducted in Adelaide in the early 1960s. The second Adelaide in-depth study, conducted in the mid-1970s, successfully investigated in great detail a sample of crashes that was representative of the population of crashes by time of day and day of week. Since then crash investigation at the scene has not been conducted on a representative basis but still with an ability to identify many factors that would otherwise be missed. At scene crash investigation has also formed the basis of case control studies such as those relating travelling speed with the relative risk of crash involvement.

This paper will provide a brief review of at-scene crash investigation over the past 50 years, noting methodological lessons that have been learnt and, in some instances, forgotten. It concentrates on research conducted in the United States and Australia.

AT-SCENE CRASH INVESTIGATIONS are a routine part of traffic policing. The aim is to make a record of who was involved, in what capacity, and with what severity of injury. The general circumstances of the crash are also recorded, as is any evidence that an offence may have been committed.

It is therefore not surprising that the first major at-scene investigation of road crashes made use of data collected at the scene by specially trained police officers, supplemented by data provided by the doctors attending those persons injured in the crash.

Founded in the early 1950s by Hugh De Haven at Cornell University Medical College in New York City, **Automotive Crash Injury Research** (ACIR) sent field staff to selected counties across the United States where they instructed Highway Patrol officers in the collection of data on every tenth casualty crash that they attended that involved a passenger car. Data collection forms were provided as were cameras with detailed instructions about what photographs were to be taken of the crashed vehicle/s. The emphasis was on injury causation rather than crash causation and so the police officers were asked to hand injury data forms to the physicians treating those car occupants who were injured. These physicians had also been trained in the completion of the data forms by the ACIR staff.

In an ACIR report published in 1954, John O. Moore and Boris Tourin found that:

> ".... regardless of the severity of accidents involved, more occupants sustain moderate through fatal injuries by being ejected than by remaining in the automobile. The opening of front doors therefore proves to be a genuine safety problem and demonstrates a need of door closures which will retain passengers <u>inside</u> the automobile in accidents." (their emphasis)

This finding, which led to the introduction of longitudinal restraint in door latches in 1956 model year cars in the United States, deserves to be recognised as one of the major advances in public health in the last 100 years.

ACIR was funded by the United States Public Health Service and the Automobile Manufacturers Association. Even though most of the initial Federal Motor Vehicle Safety Standards in the United States derived from the findings of ACIR research, funding for the program ceased in the late 1960s for a number of reasons, not all of which reflected adversely on the program itself.

One of the first attempts to investigate crashes at the scene using professionally qualified investigators was conducted by J. Stannard Baker at the **Traffic Institute of Northwestern University**, near Chicago. An engineer, a physician and a behavioural scientist were recruited from outside the traffic safety field and, in Baker's words:

> "To avoid "contamination" by conventional dogma" they were "purposely shielded from published material and courses in accident investigation at the Traffic Institute." (1961)

However, this interdisciplinary approach proved to be unexpectedly difficult:

> "The very different backgrounds of their disciplines seemed to stand in the way of a coordinated attack on a common problem. .... More than a year elapsed before members of the team successfully focussed their disciplines on case studies rather than applying case studies to their disciplines." (ibid)

A five year program of Research on Fatal Highway Collisions commenced in 1958 at **Harvard Medical School**. At that time it was the most heavily subsidised in-depth investigation of road accidents ever attempted (more than $800,000 from the US Public Health Service).

The co-principal investigators were Al Moseley, a psychologist, and Richard Ford, a forensic pathologist. The research team included a traffic engineer, an automotive engineer, a sociologist, and a psychiatrist. They were on call 24 hours a day and they attempted to attend at the scene all fatal automobile accidents in an area of about 500 square kilometres around Boston. Their emphasis tended to be on crash causation and some of their reports attracted unsympathetic attention from other researchers who believed, with some justification, that an undue attempt was being made to prove that many fatal accidents were either homicides or suicides. There also appeared to be a tendency to equate a deficiency, such as a vehicle defect, with a cause of the crash.

The most valuable reports from this program were prepared by Murray Segal, the traffic engineer. He provided a succinct expression of the raison d'etre of at-scene crash investigation:

> "It is difficult to believe that any epidemic, medical or otherwise, has ever been controlled without a first-hand look at the problem." (Segal, 1970)

In the same paper he also criticised what he perceived to be a lack of awareness of his own profession:

> "It is only the traffic and highway engineer's fault that current record systems do not contain the quality or quantity of the information which he needs. Until he takes a look at the phenomenon himself, is able to describe it, and gains an understanding of what is possible and what is not, this kind of information will not be available."

After four years about 120 fatal accidents had been investigated, a total far below the anticipated 100 cases per year, and the program was terminated by the sponsoring agency.

In the 1960s a small team of researchers at both the **University of Michigan** and **UCLA** conducted at-scene crash investigations, in each case with emphasis on injury causation. The former team consisted of an anatomist (Huelke) and, initially, a physician (Gikas), and the latter a neurosurgeon (Nahum) and an engineer (Siegel). The University of Michigan team recorded their data on a collision performance and injury report form developed by General Motors. (General Motors Corporation, 1969) Examples of the work of these two teams can be seen in Huelke and Chewning (1968), and Nahum, Siegel and Brooks (1969).

The study of Traffic Accidents in Adelaide, South Australia, which commenced in 1962, was the first attempt to investigate a representative sample of road accidents at the scene in any country. It was directed by Robertson, the Professor of Pathology at the **University of Adelaide**, and the investigators were Ryan, a doctor, and McLean, an engineer. Funded by the then newly-formed Australian Road Research Board this team investigated over 400 crashes to which an ambulance was called during the hours of 10 am to 11 pm. Weekends were not sampled at the same rate as weekdays. Crashes were investigated in the order in which they occurred, when the team was on call, to avoid the temptation to concentrate on more severe or more interesting cases. (Robertson, McLean and Ryan, 1966)

Two of the findings from this first Adelaide in-depth study had not been reported previously but have been confirmed by later research and, now, are regarded as unremarkable. The first was the observation based on the investigation of actual accidents that an adult pedestrian is run under by the striking car, not run over. In particular, it was concluded that:

> "With a larger amount of data it will be possible to describe the frontal shape of a car that will inflict minimal injuries when it strikes a pedestrian." (Ryan and McLean, 1965)

This finding was in marked contrast to that of a later paper on fatal pedestrian accidents by Huelke and Davis (1969) in which they concluded that:

> "..... in most cases no specific feature of external automotive design can be incriminated as the direct agent of injury."

The other finding, which met with vigorous opposition from established traffic engineers, was that 80 per cent of drivers approached uncontrolled four way intersections at a speed such that if a car travelling at the speed limit appeared from the road on their right it was too late to avoid a collision. In other words, the "Give way to the right" rule was impractical and urban intersections should never be uncontrolled.

Today it is often not realised how much reliance was placed on the “Give way to the right” rule. A driver on an arterial road was legally, if rarely in practice, required to give way to a vehicle crossing that road from one minor side street into another if it entered from the driver’s right and the intersection was not controlled, which it rarely was. The concept of “Priority roads” did not appear in South Australia until the mid-1970s.

The Adelaide in-depth study was followed by a similar study in Brisbane, directed by Jamieson, a neurosurgeon at the **Brisbane General Hospital**, and by a study directed by Mackay at **Birmingham University**, England. In both cases an attempt was made to obtain a reasonably representative sample of crashes.

In 1966, following a series of events resulting from the publication of a book by Ralph Nader on US automobiles entitled “Unsafe at any speed”, the Automobile Manufacturers Association funded a major at-scene study of crashes by **Cornell Aeronautical Laboratory** (CAL, now Calspan) in Buffalo, New York. (Automotive Crash Injury Research had been relocated from Cornell Medical College to CAL in 1962.)

The CAL at-scene study ran for 3 years at a total cost of $800,000 US. The author of this paper was one of the two team leaders. The objectives were to:

- Obtain data concerning factors which can cause accidents.
- Develop and explore new techniques and methods for obtaining research data on accidents.
- develop procedures and techniques for handling and analyzing the mass of data obtained from intensive accident investigation. (Tharp et al., 1970)

In its early stages this study did not run smoothly; both team leaders resigned after the first year. The value of previous studies in this area was generally discounted, which reinforced the belief that this was a “pioneering effort in the fields of accident investigation” and that “Although other projects of team investigations of accidents had been accomplished, only a minimal number of accidents had been investigated in this fashion.” (ibid) In fact 408 crashes had been investigated in the Adelaide in-depth study whereas the CAL study covered 434 cases in the Buffalo area and “the final data vary in reliability, completeness and objectivity.” (ibid)

Another, separate, activity at Cornell Aeronautical Laboratory at that time has proven to be of lasting value in the interpretation of information collected at the scene of a crash. The Simulation Model of Automobile Collisions, generally referred to by its acronym SMAC, was developed by Ray McHenry with funding from the US Bureau of Public Roads. It is a computer package which, given information on the impact geometry of a two car collision and the post impact motions of the cars as revealed by tyre and gouge marks on the road surface, will provide an accurate estimate of the vehicle impact speeds and the extent of damage to each car. (McHenry, 1971) This work was published in the public domain and has been incorporated into a number of commercially available crash reconstruction packages. Today, McHenry and one of his sons continues to develop SMAC (as M-SMAC). A simpler version of SMAC, referred to as CRASH, was produced which relies solely on information on vehicle damage and is therefore less accurate, albeit easier to use.

In 1966 the United States Congress established the National Highway Safety Bureau in the Department of Commerce under the direction of William Haddon. With the establishment in the following year of the US Department of Transportation, NHSB was renamed the **National Highway Traffic Safety Administration** (NHTSA). Field accident investigation became a significant part of the research program of NHTSA. Multi Disciplinary Accident Investigation (MDAI) teams were established in selected locations around the country, mostly at university research centres. This program evolved into the National Crash Severity Study (NCSS) which was based on the study of tow away crashes from 1975 to 1977 and on police reported crashes from 1977 to 1986. It was replaced by the **National Accident Sampling Study** (NASS) which continues today, albeit with the more fashionable title of National Automotive Sampling System. Information on NASS is readily available on the NHTSA web site.

The Second Adelaide In-Depth Accident Study was conducted from 1975 to 1979 by the Road Accident Research Unit at the **University of Adelaide** under the direction of McLean. It was funded by the Commonwealth Department of Shipping and Transport and the Australian Road Research Board to a total cost of approximately $450,000 (salaries at that time were about one quarter of corresponding salaries in 2005). Three hundred and four crashes were investigated in a 12 month period from March 1996.

Two teams, each comprising a doctor, an engineer and a psychologist were on call at predetermined times to go to the scene of crashes to which an ambulance was called in the Adelaide metropolitan area. This meant that in some cases there were either no injuries sustained in the crash or those injured did not require ambulance transport. Overall, 45% of the participants in the crashes were uninjured (mostly the occupants of cars which collided with a pedestrian, cyclist or motorcyclist) whereas at the other extreme there were eight fatalities, or 0.9% of the total participants. (In the most recent at-scene study by CASR of rural crashes to which an ambulance was called, less than 10% of the crashes resulted in no one being injured.)

The on call times in the second Adelaide in-depth study were selected to yield a sample of crashes that was representative of all crashes an ambulance was called to by time of day and day of week, covering 24 hours a day, seven days a week. To the author's knowledge, this study is the only at-scene crash investigation in which this level of representativeness has been achieved.

The average time taken by the research team to reach the scene of the crash from the time an ambulance was dispatched was about 10 minutes, compared with about seven minutes for the ambulance and much longer for the police. The information collected covered factors related to the causation of the crash and to the resulting injuries. More than 3,000 data items were recorded for a typical two car crash with two occupants in each car.

Virtually complete information on blood alcohol levels was obtained by methods which included team members breath testing uninjured drivers at the scene of the crash. This information on blood alcohol levels was combined with information obtained by an extensive interview with each driver which included asking about their actions immediately before the crash and it showed that intoxicated drivers were much more likely to have been involved in a secondary task than were sober crash-involved drivers. (Brewer and Sandow, 1980)

The findings from the Second Adelaide In-Depth Accident Study were reported in eight volumes plus a volume containing accident site plans and another containing the data codes. For a reference to the 10 volumes see McLean (1981).

The **Road Accident Research Unit** has subsequently conducted two at-scene studies of rural crashes within 100 km of Adelaide (see, for example, Ryan et al, 1988) and additional at-scene investigations in the Adelaide metropolitan area. This activity continues to form a major part of the work of the Centre for Automotive Safety Research.

The emphasis in this review of at-scene crash investigation has been on the earlier studies because they established many of the procedures that are now widely accepted and because it is becoming increasingly difficult to obtain reliable information on how and why many of these procedures were developed. It is also occasionally apparent that little is known or understood about work that has gone before.

METHODOLOGICAL ISSUES

Injury Scales

The first injury scale was developed by Hugh De Haven (1952) at Cornell Medical College. It ranked injury severity for an individual in categories of “minor”, “moderate”, “severe”, “life threatening” and “fatal.” It was used by ACIR and formed the basis for injury scales used by many other research groups.

The Abbreviated Injury Scale (AIS) was first proposed, as a three page document, at the 13th Stapp Car Crash Conference. (States, 1969) It was referred to as the “abbreviated” scale because it was assumed then that serious researchers would use a more complex “Comprehensive Research Injury Scale” (ibid.)

The first published version of the AIS appeared in 1971. (Anon.) It rates the severity of individual injuries by defined body region on a scale from “minor” to “untreatable”. Today the AIS manual extends over 68 pages. Despite this level of detail, no information is recorded on whether an injury is to the right or left leg, for example, which can be critical when attempting to understand the biomechanics of a given injury.

It soon became clear that rating the severity of specific injuries by body region did not readily facilitate comparisons between the overall injury severities of injured individuals. The concept of the maximum AIS rating for an individual was helpful in this regard but it did not take into account the effect of multiple injuries. The Injury Severity Score (ISS) was proposed by Baker et al (1974) in an attempt to overcome this limitation of the AIS. It comprises the sum of the squares of the highest AIS scores in three different body regions. However there is a logical inconsistency in this process in the interpretation of the numerical AIS scores.

The AIS is an ordinal scale. A ranking of 4 is more severe than a ranking of 2, but it is not twice as severe, as it would be if the AIS were a ratio scale. There is no meaningful information in the AIS severity numbers other than the simple ranking of severity. However, the ISS procedure assumes that the AIS is a ratio scale and that a moderate injury (rated 2) is twice as severe as a minor injury (rated 1), etc. It is not necessary to make such an assumption. Some statisticians may be aware of RIDIT analysis, a statistical significance test for differences between two sets of ranked data, which was developed by Irwin Bross for use by ACIR. More sophisticated tests of this type are now available but, as is often the case, there needs to be an awareness of the deficiencies in accepted practice before the need for such tests becomes apparent.

Nevertheless, the ISS is widely used and has been found to be helpful even though it is based on fallacious reasoning. Despite this, there is a need to continue to work towards a more logical and, importantly, more valid measure of a person's overall severity of injury. A sound case can also be made for a return to the conceptually simple De Haven type of whole body rating of injury severity. As noted above, most of the initial Federal Motor Vehicle Safety Standards in the United States evolved from the work of ACIR which made use of such a scale.

Vehicle Damage Scales

For more than 30 years the Society of Automotive Engineers in the United States has had a Collison Investigation Methodology Subcommittee which, inter alia, developed and continues to maintain the Vehicle Damage Index, a system of rating vehicle collision damage.

A less well known, but potentially more valuable, system of rating vehicle damage is known as the TAD Scale, where the acronym referred to the Traffic Accident Data project of the National Safety Council. (Rouse and Gendre, 1969) This scale was developed for use by police officers when reporting on a traffic accident and it has been in routine use by the police in North Carolina since the late 1960s. The scaling is done by comparing the damage to the case vehicle with a series of photographs of vehicles damaged to various degrees in similar locations on the vehicle. The author has observed police officers in North Carolina reciting the TAD scale rating for a crashed car as they walked towards it from their patrol car. This simple measure, combined with routine recording of the Vehicle Identification Number of the crashed vehicle, has rendered the mass accident data system in North Carolina into a very valuable source of data on the crashworthiness of vehicles.

Selection of Cases

The information available from any investigation, and the validity of the conclusions that can be drawn from it, will be determined in large part by the criteria used in selecting the cases to be studied. For example, the investigations of crash injury by the Crash Injury Research and Engineering (CIREN) teams funded by NHTSA are based on trauma centres which deal only with a comparatively narrow segment of the injury spectrum. Crash involved occupants who die before reaching hospital do not appear at a trauma centre, nor do occupants whose injuries do not require treatment at a trauma centre but which can be treated by a doctor at a conventional hospital or even at a doctor's consulting rooms.

Consequently, a study of rollover dynamics and injury causation by the San Diego CIREN team was based on a sample of severely injured occupants of vehicles which had rolled over. The incidence of head and spinal injuries among these occupants was as follows : head 35%, spine 16%, head and spine 18%, neither 31%. Clearly, this study has provided information which may be useful in describing those factors in vehicle rollovers which result in serious head and/or spinal injuries. While some occupants may have died after reaching the trauma centre they may not have been representative of all fatalities in rollover crashes. Similarly, as the study only included cases resulting in serious injuries it can not be expected to identify those factors that may be protective against serious injury in a rollover.

As the level of crashworthiness of new cars continues to improve, it will become even more important to ensure that any study of crash injury protection includes the full range of injury severity outcomes, from nil to fatal. This may mean relying on towing services, as well as ambulance calls, for notification of crashes in rural areas.

There are many other matters which could be considered in relation to avoiding bias in the selection of the crashes to be studied. Perhaps the most common, and hence important, of these is the temptation to give preference to the investigation of "interesting" cases. The author has experienced the incredulity of an ambulance radio operator on learning that our research team continued to go to the scene of a collision between a pedal cycle and a car when a call had just come in for ambulances to attend a level crossing crash. In an ideal world, another team would also be on call to respond to "interesting" cases.

If road accident investigation has a "Holy Grail" it is surely the belief that there must be an all-purpose data recording system that will be suitable for all needs and to which all researchers should subscribe. Thirty six years ago Herbert Jacobs (1969) remarked that:

> "All of these issues of sample selection and control lead me to question the recent demand for large-scale, massive, general accident data systems which can be tapped by any investigator. I believe that this represents a false direction, and that a much stronger case can be made for the development of specialised data systems to meet the needs of particular research strategies and particular experiments.

SUMMARY

Baddeley (1981), in commenting on the previously-referred-to paper by Brewer and Sandow (1980) which was based on the data from the second Adelaide in-depth study, observed that:

> "... studies based on naturalistic observations are liable to be very expensive as this obviously was, and to provide data which are open to more than one interpretation. This does not mean that such observations are not important, but does imply that both observational and experimental approaches have their limitations and that an adequate understanding of phenomena in the real world will require us to use both."

The aim of this paper has been to draw attention to some aspects of approaches that have been used in at-scene crash investigation in the past in the hope that their benefits and limitations might be more widely recognised when future work of this type is being planned.

Finally, the essential characteristics of at-scene crash investigation are not readily presented in a compartmentalised manner under headings such as "Injury severity scales" or "Selection of cases." They were expressed in the following way by Haddon et al (1964) in one of the best books ever published on accident research:

> "the open-ended observation and description of phenomena to discover variables which deductively seem to be of importance", and
>
> "The productive synthesis of material not previously recognised as related."

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