

# In-Depth Crash Investigation at the Centre for Automotive Safety Research

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**Abstract** - The Centre for Automotive Safety Research (formerly the Road Accident Research Unit) at the University of Adelaide in South Australia has a history of in-depth crash investigation going back to the 1970s. In recent years, our focus has been on studying factors that contribute to road crashes, with an emphasis on the role of road infrastructure.

Our method involves crash notification by the South Australian Ambulance Service and detailed investigation of the crash scene usually before the crash-involved vehicles have been moved. This at-scene data collection is supplemented with police crash reports, Coroner's reports including autopsy findings for fatal crashes, case notes from hospitals for all injured persons, structured interviews with crash participants and witnesses, and computerised reconstruction of the events of the crash.

One of the most notable research findings to emerge from our in-depth work has been the relationship between travelling speed and the risk of crash involvement. By comparing the calculated free speeds of crash-involved vehicles (cases) with the measured speeds of non-crash-involved vehicles travelling on the same roads at the same time of day (controls), we were able to establish that an exponential relationship exists between travelling speed and the likelihood of involvement in a casualty crash. This was the case for both metropolitan and rural areas. This research prompted the reduction of some speed limits in Australia, which has resulted in notable decreases in crash numbers.

Another finding of interest in our recent investigation of 298 mostly daytime crashes in metropolitan Adelaide was that medical conditions make a sizeable contribution to the occurrence of road crashes. We found that almost half of the drivers, riders and pedestrians involved in the collisions had at least one pre-existing medical condition, and half of these individuals had two or more such conditions. We found that a medical condition was the direct causal factor in 13% of the casualty crashes investigated and accounted for 23% of all hospital admission or fatal crash outcomes. A follow-up study of all hospital admissions for road crashes in Adelaide is now going ahead to look further at this problem.

The paper also describes studies looking specifically at pedestrian crashes. These include studies of the relationship between travelling speed and the risk of a fatal pedestrian crash, and studies utilising real crash data to validate headforms and test dummies used in the assessment of the safety of new vehicles in the event of a collision with a pedestrian.

## INTRODUCTION

In-depth crash investigation at the University of Adelaide in South Australia began with the work of Robertson, McLean and Ryan of the Department of Pathology, sponsored by the Human Factors Committee of the Australian Road Research Board. This study ran from 1963 to 1965 and collected a representative sample of crashes to which an ambulance was called between the hours of 10am and 11pm. This study was the first in the world to report that pedestrians are run under and not over, and, therefore that the design of the front of vehicles is a major determinant of the injuries suffered by pedestrians.

In 1973, the Road Accident Research Unit was formed at the University of Adelaide and a second in-depth study was conducted, with data collection running for 12 months from March 1976. This study involved a representative sample, by time of day and day of week, of crashes to which an ambulance was called. Crash investigators were on-call seven days a week. There were two teams of investigators, each including a medical doctor, an engineer and a psychologist. More than 3,000 items of information were collected in a two car crash with two occupants in each car. The detailed analysis of these crashes filled seven volumes and was recognised as a benchmark by the World Health Organisation.

In-depth crash investigation has continued since that time, usually alternating between investigation of crashes in metropolitan Adelaide and investigation of crashes in rural areas. Currently, the Centre for Automotive Safety Research (formerly the Road Accident Research Unit) at the University of Adelaide is investigating crashes in rural areas, with a boundary of 100 km from the centre of Adelaide.

The following section describes the general method we use for in-depth crash investigation. This is followed by a description of some of the specific studies we have undertaken based on in-depth crash data.

## METHOD

The Centre for Automotive Safety Research employs a specially-trained team of crash investigators that includes two engineers (one mechanical and one automotive engineer), a psychologist and a health professional. Teams of two investigate the crashes and the information collected is presented to a review panel consisting of all the crash investigators and the project management team, which consists of a psychologist and a civil engineer.

A crash is eligible for inclusion if it involves the transportation by ambulance of at least one crash participant to a hospital or if it involves a fatality. In the case of metropolitan crash studies, the crash has to have occurred within the Adelaide metropolitan area (nominally within 10 km of CASR's offices in the City centre), while for non-urban studies, the crash must occur outside of the metropolitan area but within 100 km of CASR's offices. The outer boundary is defined as such so that investigators are able to attend the scene within an hour or so of the time of the crash.

Crash investigators are alerted to the occurrence of a crash by an automatic pager system provided by the South Australian Ambulance Service. They immediately drive to the scene of the crash so that as much information and data can be collected prior to the loss of physical evidence.

The sequence of events for crash investigation is as follows:

- Notification of the crash on the SA Ambulance Service radio or pager
- Attend the crash at-scene
- Photograph the scene and involved vehicles
- Discussions with police attending the crash
- Mark the positions of the vehicles and any skid or gouge marks
- Brief introduction and discussion with participants and witnesses at-scene (where appropriate)
- Record an engineering survey of the site
- Examine the vehicle(s) at the scene and/or elsewhere
- Record video footage of the approach to the crash site from a driver's perspective

Follow-up investigations include:

- Obtain the police report on the crash
- Obtain injury information from hospitals
- Conduct a detailed interview with consenting crash participants and witnesses
- Review site design and crash history of the site
- Review crash history of the drivers
- Review Coroner's file where appropriate (fatal crashes)
- Computer aided crash reconstruction where relevant and practicable
- Perform a multidisciplinary case review

The engineering survey that is made of the site involves recording the road geometry, land marking and any traffic control measures, together with the location of any roadside objects. Engineering drawings of the road section are also obtained from the road authority. Sites may also be revisited for more detailed follow-up survey work or reassessment from a road engineering perspective.

Follow up inspections are made of the involved vehicles as needed to gather any missing information or reconfirm crash injury mechanisms. The information collected for each vehicle includes:

- Photographic record of the vehicle, including detailed photos of any visible damage and evidence of occupant (or pedestrian) contact
- Recording of VIN (Vehicle Identification Number) and current registration details
- Inspection of tyres: dimensions, tread and pressure
- Inspection of seatbelts for condition and load marks
- Measurement of vehicle deformation
- Inspection for any vehicle modifications or defects

Follow up personal interviews are conducted whenever possible with those involved in the crash and any witnesses. The information sought during these interviews includes:

- Personal details (age, sex and, for pedestrians, height and weight)
- Driving experience, traffic violation and crash history
- Familiarity with the road and the vehicle driven in the crash

- Trip details
- Possible distractions
- Alcohol and drug use, if any, prior to the crash
- Emotional and fatigue factors
- Pre-existing medical and physical disabilities
- Perception of the crash and its contributing factors
- Current state of injuries and resulting disabilities
- Clarification of vehicle/pedestrian movements, positions and the crash sequence

Our investigators are authorised to obtain data on injuries from hospital records, as noted above. Police accident reports are obtained to provide information about the crash as reported to, and interpreted by, the police. Where appropriate, Coroners files are also examined to check consistency of findings or shed further light on the case with previously unobtainable evidence. These contain full reports from the Police Major Crash Investigation Unit, autopsy and toxicology reports, together with information on any medical issues that may have been affecting the deceased individual. (All road crash fatalities are autopsied in South Australia.)

When all the evidence has been collected, a review is conducted of each case by a multidisciplinary group of CASR staff, and factors which contributed to the causation of the crash and the resulting injuries are established.

## **SPECIFIC STUDIES**

The following provides a brief account of some of the studies conducted by CASR staff based on in-depth crash investigation data. These include studies relating travelling speed to the risk of crash involvement, studies into pedestrian injuries, and studies examining the role of medical conditions in contributing to road crashes.

### **Travelling speed and the risk of crash involvement**

#### *Method*

The aim of this study [1] was to quantify the relationship between free travelling speed and the risk of involvement in a casualty crash for sober drivers of cars in 60 km/h speed limit zones in the Adelaide metropolitan area. “Free travelling speed” refers to the speed of a vehicle not constrained by other traffic and not accelerating or braking to enter or leave a road. Using a case-control study design, the speeds of cars involved in casualty crashes (cases) were compared with the speeds of cars not involved in casualty crashes but travelling in the same direction, at the same location, time of day, day of week, and time of year (controls). The pre-crash travelling speeds of the case vehicles were determined using computer-aided crash reconstruction (M-SMAC), with input consisting of tyre marks, impact points, final positions of vehicles, damage to vehicles, and participant and witness statements. The speeds of the control vehicles were measured with a laser speed device [1].

#### *Results*

It was found that 68 percent of casualty crash involved vehicles were exceeding the 60 km/h speed limit compared to 42 percent of control vehicles. The difference between cases and controls was greater at higher speeds, with 14 percent of case vehicles exceeding 80 km/h compared to less than one percent of controls [1].

None of the travelling speeds below 60 km/h was shown to be associated with a risk of involvement in a casualty crash that was statistically significantly different from the risk at 60 km/h. Above 60 km/h there is an exponential increase in the risk of involvement in a casualty crash with increasing travelling speed such that the risk approximately doubles with each 5 km/h increase in speed. Thus, the risk of involvement in a casualty crash is twice as great at 65 km/h as it is at 60 km/h, and four times as great at 70 km/h. Although the risk of involvement in a casualty crash increases rapidly with increasing speed, the overall contribution of speeding to crash causation is still considerable at speeds

below 75 km/h because the majority of speeding drivers are travelling in the speed range from 61 to 74 km/h. A graph showing the relative risk of involvement in a casualty crash by travelling speed is provided in Figure 1 [1].

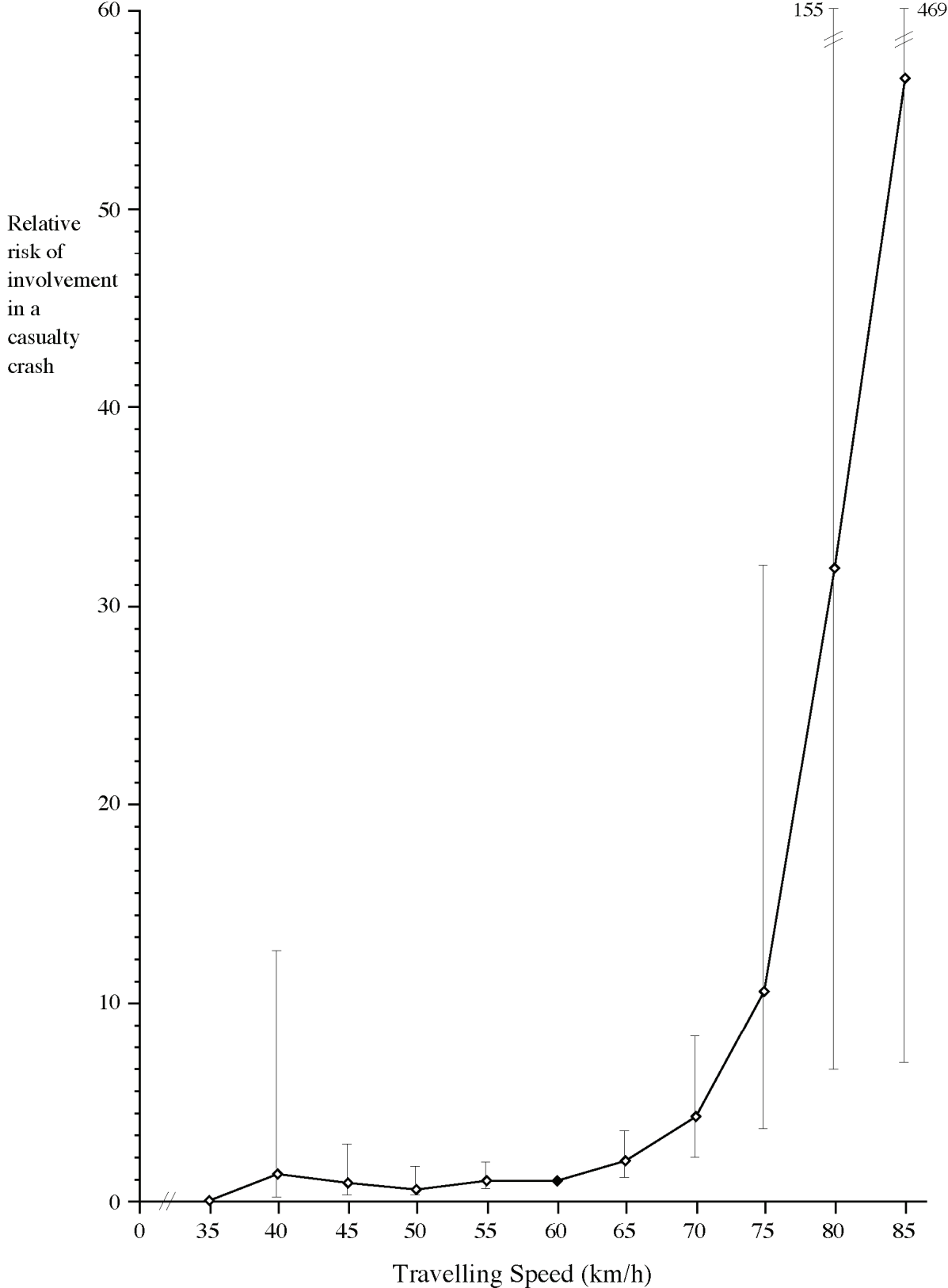


Figure 1. The relative\* risk of a casualty crash according to travelling speed

\*Relative to the risk at the 60 km/h speed limit

By working back from the risk estimates we concluded that nearly half (46 per cent) of these free travelling speed casualty crashes probably would have been avoided, or reduced to non-casualty crashes, if none of the case vehicles had been travelling above the speed limit. A more conservative estimate, based on calculation of stopping distances and impact speeds, indicates that 29 per cent of crashes would have been avoided altogether, with an average reduction of 22 percent in the impact energy of the remaining cases [1].

Using the second, more conservative, method we also estimate that a 10 km/h reduction in the travelling speeds of the crash involved cars in this study would probably have resulted in a reduction of at least 42 per cent in the number of crashes. A 5 km/h reduction showed much less effect but would still have resulted in a reduction of at least 15 per cent in the number of crashes [1].

These findings were a key factor in the decision to reduce the default urban speed limit from 60 to 50 km/h. In South Australia, the change in the speed limit occurred in March, 2003. In the following year, on local and collector roads for which the speed limit changed, there were decreases in the average vehicle speed, the average free travelling speed, the number of casualty crashes, the number of casualties, and the number of fatalities. Additionally, on arterial roads for which the speed limit remained at 60 km/h, there were also reductions in the same set of variables. Although the percentage changes were smaller on the arterial roads than on the local roads, the total effects were similar because of the higher frequency of crashes on arterial roads [2]. Similar findings have been found in studies of the speed limit reduction in other jurisdictions in Australia [3-6].

A more recent study was conducted in which the methodology for the urban speed study was repeated in rural areas in South Australia [7]. In this study, because of the speed limits ranging from 70 to 110 km/h at the different crash sites, the relative risk of crash involvement by travelling speed was calculated using deviation from the average speed of control vehicles at each site. This ensured that the data were appropriately normalised for the analysis. It was found, again, that higher travelling speeds are associated with an exponential increase in the risk of crashing, and that there is no evidence of an increased risk for slow moving vehicles. Specifically, it was found that the risk of involvement in a casualty crash is more than twice as great when travelling 10 km/h above the average speed of non-crash involved vehicles and nearly six times as great when travelling 20 km/h above the average speed [7]. This study was also followed by reductions in speed limits, in this case on South Australian rural roads.

## **Pedestrian injury**

The relationship between travelling speed and crash involvement has also been analysed with respect to urban pedestrian collisions [8]. This study analysed 118 fatal pedestrian crashes in which the striking vehicle was travelling at a free speed and there was sufficient information available to obtain a measure of that speed. The information required was comprised of physical evidence from the vehicle and the crash scene, and witness and driver statements. Combining the calculated travelling speeds and calculated impact speeds with previously established relationships between impact speeds and the likelihood of a fatality, Anderson et al. were able to determine the likely reductions in fatal crashes associated with various scenarios of reductions in travelling speed. It was found that if all vehicles had been travelling 5 km/h slower, there would have been a 32 percent reduction in fatalities, including 10 percent of crashes avoided altogether (i.e. the vehicle would have stopped prior to striking the pedestrian). If all vehicles had been travelling 10 km/h slower, there would have been a 48 percent reduction in fatalities, with 22 percent of crashes avoided altogether. If the speed limit had been 50 km/h instead of 60 km/h, and assuming a similar level of compliance with the speed limit, there would have been a 30 percent reduction in crashes, with 14 percent of crashes not occurring. The finding that a large proportion of the reductions in fatalities was associated with elimination of the crash altogether also suggests likely savings in serious injuries with reductions in travelling speed [8].

In-depth investigation of pedestrian crashes has also been used to validate the pedestrian subsystem testing methods used in vehicle design safety assessments. For example, one study involved the simulation of three fatal pedestrian crashes using MADYMO and the Polar-II dummy developed by Honda R&D in conjunction with GESAC [9]. The head kinematics of the computer simulation and the Polar-II test were compared with the vehicle-pedestrian contacts known to have occurred in the actual cases. The cases selected for the study involved pedestrians whose height and weight were close to the 50<sup>th</sup> percentile adult male. The investigation of the cases had provided good estimates of impact speed and complete injury data, which was obtained from attendance at autopsies, and all contact points between the pedestrian and the vehicle had been recorded. MADYMO simulations were made to determine the kinematics of the pedestrian during the collision, and a full-scale Polar-II dummy and the same make and model of the vehicle in each case were then used to reconstruct the crash. The results showed good agreement between some aspects of the different measures of head kinematics but also some discrepancies. The Polar-II head impacts tended to be closer to vertical and the impact location more forward on the car than those found with the MADYMO simulations and the actual cases. Leg kinematics were noticeably different, with the Polar-II legs remaining engaged with the front of the vehicle for a longer period of the collision. In contrast to the simulations, the Polar-II legs were in some instances still engaged as the head stuck the vehicle. The behaviour of the model and/or the Polar-II will be the focus of further validation and refinement [9].

Another example of such a study involved validation of the headform impactors designated by the European Enhanced Vehicle-safety Committee (EEVC) Working Group 10 for assessing pedestrian head protection [10]. This study compared data collected from real crashes with the outcomes of computer simulations and laboratory reconstructions of the crashes using the headforms specified by the EEVC. It was found that the EEVC headform results correlated well with the severity of head injuries, as measured by the AIS, in the real crashes. Specifically, head impacts exceeding a HIC value of 1,000 were positively associated with head injuries of AIS3 and above [10].

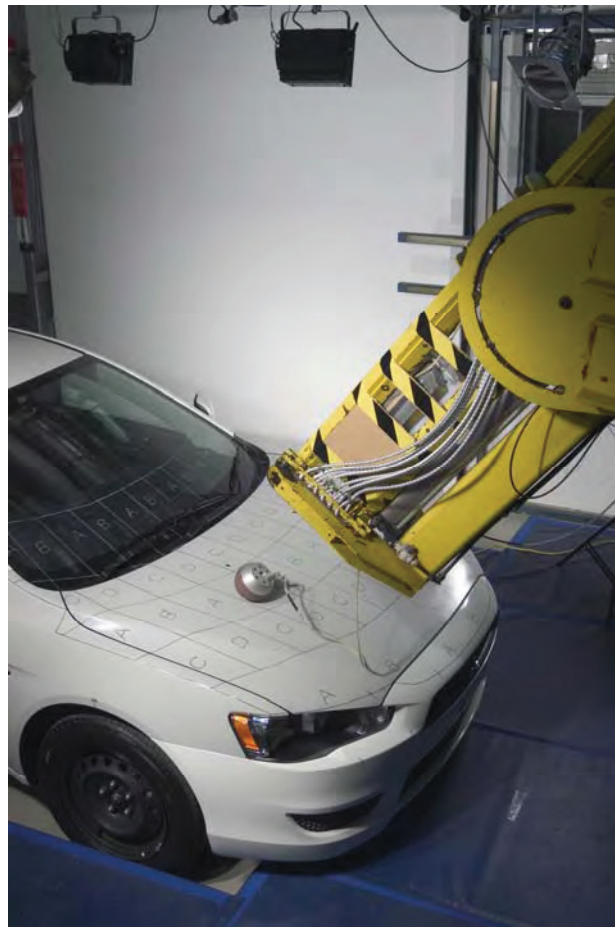


Figure 2. Headform launcher at the Streeter Impact Laboratory, CASR.



## Medical conditions

A sample of 301 metropolitan crashes was analysed for the contribution of medical conditions to crash causation [11]. These 301 crashes involved a total of 607 active participants (493 drivers, 83 pedestrians, 20 motorcyclists, and 11 pedal cyclists). Of these, 325 required either medical treatment at a hospital or admission to a hospital, or were fatally injured. The medical records of these crash participants were analysed for the following:

- Documentation related to existing medical conditions
- Medication use at the time of the crash
- Results of blood screening for alcohol and other drugs
- Medical documentation that gave support to or refuted medical conditions as a contributing factor in crash causation
- Injuries incurred as a result of the crash
- Length of hospitalisation as a result of injuries
- Long term health outcomes as a result of involvement in the crash.

It was found that there were 138 crashes in which at least one active participant was identified as having a pre-existing medical condition. Half of these cases had two or more medical conditions, while nine participants had four or more. The most common pre-existing medical conditions were hypertension (36 cases), depression (24) and Non-Insulin-Dependent Diabetes (21). In 39 of the 301 crashes (13%), there was medically documented evidence to support a pre-existing medical condition as a direct causal factor in the crash. Fourteen of these 39 were pedestrians, with the remainder being drivers of cars. Seven cases involved cardiac events, seven involved crash participants with psychiatric conditions making deliberate suicide attempts, six involved non-suicidal mental health related events such as psychotic episodes, and five involved epileptic events. The most common outcome of the medical events for drivers was loss of control of the vehicle, either running off the road or crossing the centre line and into the path of oncoming traffic. In 11 of these cases, there were licensing decisions taken on the basis of the crash. These included five licence suspensions pending investigation, three suspensions for an undefined time, one driving assessment advised, one two-year suspension, and one single-year suspension. There were also a number of crashes in which the involvement of medical conditions was highly probable. These crashes were not explicitly identified by treating medical practitioners as being due to medical conditions of the crash participants but were judged to be probably due to these conditions by our investigators [11].

The study demonstrates a significant role played by medical conditions in crash involvement. It is also important to note that 57 percent of the drivers in the crashes were uninjured and did not undergo medical scrutiny. Therefore, the extent of medical conditions contributing to crashes is likely to be greatly under-estimated by the study. Additionally, the figures here exclude cases in which the contributing factors were related to alcohol, medication or illicit drug use. A limitation of the study is that 95 percent of the crashes investigated occurred between 0800 and 2000 hours, and so the sample is not truly representative of all metropolitan crashes [11].

In response to the findings of the study, and in order to address this limitation, a follow-up study is being conducted by CASR in which the role of medical conditions is being examined in all crashes involving admission of a crash participant to the major metropolitan emergency hospital. All drivers and motorcycle riders who are treated at, or admitted to, a major metropolitan hospital in Adelaide over a 24 month period will be included in the study. The study will involve analysis of the following:

- Driver/rider hospital medical records
- Police reports on the actual crash
- Driver/rider crash histories, as recorded in the Traffic Accident Reporting System maintained by the South Australian Department for Transport, Energy and Infrastructure
- Driver/rider licensing records maintained by the Registrar of Motor Vehicles

Drivers or riders who are judged to have had a medical condition that may have contributed to the occurrence of the crash will be contacted for an in-depth interview.

## TEACHING

In addition to our on-going research, we have been able to train researchers from other countries. In 2005, we described the benefits arising from in-depth crash investigation at a seminar we convened in Bangkok in collaboration with Khon Kaen University, and sponsored by Takata Corporation. This led to the Thai Government Office of Transport Planning (OTP) decision to fund crash investigation teams at five universities in Thailand and a request for CASR to conduct a one week training course in Adelaide in March 2006. This course was attended by 18 engineers from these universities and Thai government agencies.

The Director General of the newly formed Malaysian Institute for Road Safety Research (MIROS) recently requested that CASR train two engineers in at-scene crash investigation. The two engineers trained with CASR for a period of two months in late 2007/early 2008, and have returned to MIROS to co-ordinate crash investigation activities there.

## CONCLUSIONS

The Centre for Automotive Safety Research at the University of Adelaide has a proud history of in-depth at-scene road crash investigation, and continues to undertake this activity to add to road safety knowledge. Studies have been conducted into many aspects of road crashes using the data we have collected using in-depth crash investigation and this paper has outlined just a few of these. We have also been active in training researchers from South East Asia to assist in the use of in-depth crash investigation to identify the key road safety problems that need to be addressed in those countries.

## ACKNOWLEDGEMENTS

The Centre receives funding for this activity from the South Australian Department for Transport, Energy and Infrastructure, and the compulsory third party insurer in South Australia, the Motor Accident Commission.

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