The Benefits of In-Depth Crash Data in Crash & Injury Prevention

Brian Fildes, David Logan

Accident Research Centre

Monash University, Melbourne, Australia

Abstract –The paper set out to discuss the strengths and weaknesses of the various data collection programmes from national police data files through to in-depth data and individual case analysis. It highlighted the advantages and disadvantages of both forms of crash data. Through the ANCIS crash inspection program, the usefulness of in-depth data is illustrated with case examples as well as applications for the use of these data in addressing solutions for human, vehicle and road safety problems.

Keywords: Mass databases, In-depth crash data, Human, Vehicle, Road

1 Introduction

There are two types of crash data typically used for analyzing road crashes. The first are called "***Mass Databases***" and comprise crash details obtained from the police, hospitals, insurance or government agencies. The second are known as "***In-depth Crash Data***" or follow-up sample data, compiled by specialist crash investigators through the police, the insurance industry, vehicle manufacturers or universities. The latter type can be collected from "at-scene" investigations during the rescue and clean-up process following a crash, or retrospectively some time after the crash scene has been cleared.

Mass data are useful for analyzing the extent of the crash problem. They have the benefit of large numbers, (often state or nationwide) and hence offer statistical reliability. However, they are usually collected by large teams and are not always reliable or consistent and often are limited in the amount of details collected [1,2]. Moreover, they are typically more reliable for the serious crashes and less so for minor ones. They also only allow correlational analyses with less detail to fully understand what caused the crash or the injuries the victims sustained. Two examples of the type of mass data analyses are shown in Figures 1 and 2 below.

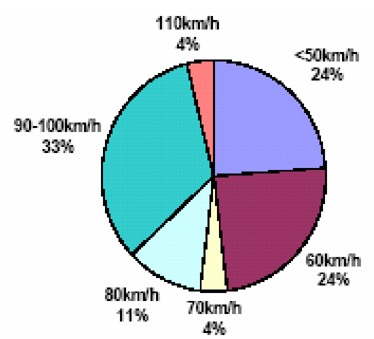

Fig 1: Crashes by speed zone; 2000-2004 (courtesy of Dept. Transport, Tasmania)

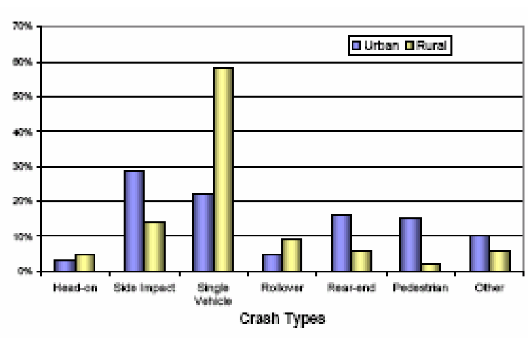

Fig 2: Crashes by crash type; 2000-2004 (courtesy of Dept. Transport, Tasmania)

In-depth data, on the other hand, are much more detailed and comprehensive in terms of the crash and injury details collected and often include details on the circumstances of the crash and injuries

Contact Email: Brian.fildes@general.monash.edu.au

sustained by the crash victims as well as the likely causes of these. There have been a number of in-depth studies undertaken around the world. These include an early 1969 UK study [3], an in-depth fatal injury study in South Australia [4], the TRL causal study [5,6], the Tri-level study of traffic accident causes in the US [7], the on-going **N**ational **A**utomotive **S**ampling **S**ystem in the US [8], and the GIDAS in-depth crash investigation program in Germany [9]. Importantly, there is worldwide acceptance of the need for such in-depth studies to help determine road safety priorities and countermeasures in the ongoing fight to reduce road carnage.

In-depth data typically provides an estimate of the impact severity of the crash (eg; delta-V or EES) and a comprehensive list of all occupant injuries, coded by classification and severity (eg; AIS and ISS). These details are usually not available in mass data. They are costly to collect, though, as it is necessary to establish specialist crash investigation teams to chase suitable crashes and collect the necessary details required. Hence, they are usually only a sample of crashes and issues of representativeness of all crashes are often involved. In larger in-depth databases in some countries, questions are often raised about their accuracy and reliability because they also involve multiple data collection teams, sometimes of varying quality.

Nevertheless, these data are extremely valuable as they provide a much more detailed account of each road crash investigated and do permit a causal analysis of the crash and injuries sustained. In more recent times, they also provide sufficient details to enable a full reconstruction of the crash, using suitable computer software and modeling facilities. From this, it is possible to examine alternative countermeasure solutions in terms of their likely effectiveness and cost-benefits. More will be said of this later in the paper.

2 The ANCIS Program

The Australian National Crash Investigation Study (ANCIS) is a collaborative study involving key road safety stakeholders in Australia [10]. It comprises members of the automotive and parts manufacturing industries, the Federal Department of Transport and Regional Services, State transport authorities from Victoria, NSW and Tasmania, the Transport Accident Commission of Victoria and the Motor Accidents Authority of NSW, motoring authorities RACV, NRMA and the AAA, and IAG Insurance group. The Monash University Accident Research Centre manages the ANCIS program, undertakes crash investigations in Victoria and maintains the crash “in-depth” database.

2.1 The ANCIS Process

ANCIS utilizes a retrospective in-depth examination of a representative sample of crashes in the study areas whereby data are collected soon after the crash and the evidence is forensically ‘pieced’ together so that the important factors can be established. It is “person-based” with the crash and injured persons being identified through the trauma hospitals. Crash details are compiled through detailed inspections of the vehicles involved, the injuries sustained by the victims, a visit to the crash scene a few days after the event, and supporting documentation provided by the police and the victims or their families. The circumstances surrounding the crash are analyzed and causal information derived by detailed examination by experts.

The retrospective method cannot hope to have access to such rich and immediate information available at the scene. Nevertheless, it is capable of piecing together a reasonably detailed account of the crash and injury circumstances for most crashes and provides a reasonable account of the causal chain of events leading up to the crash. Its main advantage over the at-scene method is the reduced cost associated with greater efficiency in the collection of these data and hence the greater coverage possible using this approach.

2.2 The Three Phases of Crash Investigation

2.2.1 Phase 1 – Medical

The crash investigation starts when a crash victim is admitted to one of the 18 study hospitals in the program. The study nurse approaches the patient and seeks their agreement to participate in the program. Those judged to be unsuitable to be approached or those in unsuitable vehicles (pre-1989 models) are not recruited into the study. A questionnaire about the type and circumstances of the crash and other relevant information is administered, once the participant has been fully informed about the study and has signed a written agreement. Confidentiality and anonymity are assured for the individuals involved.

A detailed list of the injuries the participant suffered is compiled from the medical records and is coded using the Abbreviated Injury Severity scale [11]. This is a "threat to life" scale where AIS0 means the participant is not injured and AIS6, fatal or untreatable. Other relevant details from the medical and ambulance notes are often recorded to help piece together the circumstances of the crash at a later time. These details are provided to the engineers for their subsequent investigations.

Photo 1: Patient interview at study hospital

Photo 2: Engineer inspecting a crashed car

2.2.2 Phase 2 – Vehicle

Once the crashed vehicle is located (usually in a repair shop or towing or salvage yard), the vehicle inspector carries out a detailed inspection, using an inspection procedure based a combination of the USA National Accident Sampling System (NASS), the UK Co-operative Crash Injury Study (CCIS), the Standardization of Accident Information and Registration Survey (STAIRS) procedure and ATSB Accident Involvement Protocol [12]. Details of the type of crash are determined and the level of deformation and intrusion is measured using the NASS definition (shown in Photo 3). Impact severity is calculated using PC Crash and CRASH3 software. Sources of injury are determined from marks and debris inside the vehicle and a level of confidence in these judgements is ascribed. A full comprehensive photographic record of the crash and damage is also compiled for each case.

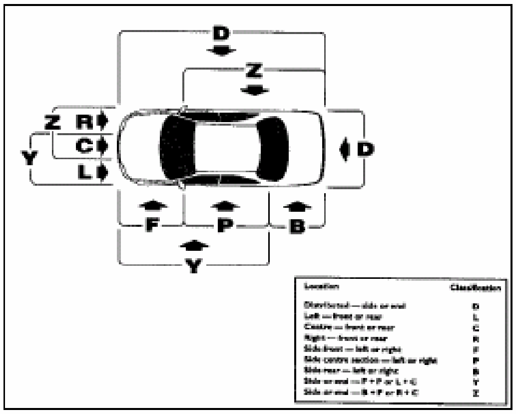

Fig 3: Crash Deformation Criteria (CDC)
(courtesy of NHTSA 1989)

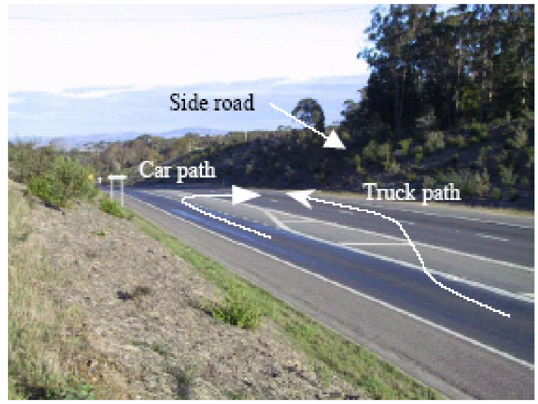

Photo 3: Crash site inspection

2.2.3 Phase 3 – Site Inspection

The final task in collecting details of the in-depth crash is to visit the crash scene and undertake a detailed investigation of the crash circumstances. While this is a retrospective action (the crashed vehicles are no longer present), a reasonable amount of the damage and crash litter is still present and where applicable, skid marks are still present on the road and damage to any abutments is often evident. Thus, the inspectors are able to put together a fairly comprehensive account of the crash from the available evidence.

In addition, the inspectors conduct a drive-through of the crash site in both directions and compile a comprehensive photographic record of the site and available crash evidence. This information is then converted into a computer reconstruction of the trajectories using PC Crash and HVE software prior to and into the crash and where necessary, a Madymo reconstruction of the occupant kinematics and injury predictions is made for comparison purposes.

2.2.4 Crash Summary & Database

The data collected in the ANCIS program comprises over 1200 relevant variables, including:

Statement of the cause of the crash;

Detailed list of participant's injuries and the source of these injuries, coded in terms of body region, most severe injury and overall severity;

Delta-V and Estimated Barrier Speed (EBS) of the crash;

Primary impact partner of the collision;

The location and amount of damage of the case, and where applicable, an other vehicle;

Pole and tree partner in single vehicle collisions;

The role that infrastructure played in the events leading up to the crash; and

Driver error and fitness to drive in precipitating the crash.

All the information is entered into an electronic database for manipulation and analysis. In general, crash studies have less interest in specific individual case information, relying more on aggregate analysis. However, in-depth crash details can highlight a problem with a particular vehicle or vehicle feature that can enable a manufacturer to respond quickly to rectify the problem.

2.3 Data Analysis

Police-based crash investigations quite correctly focus on culpability as a central objective. As such, crash and injury factors concerned with vehicle design, human factors, road and traffic engineering, emergency services, trauma management, etc., play a lesser role, thereby limiting the scope, breadth and depth of investigations. Establishment of an in-depth, systematic crash investigation resource helps to provide new knowledge on a range of crash-related dimensions, including:

Crashworthiness of the vehicle
Crash causation
Highway design influences
Road user behaviour
Human factors
Injury biomechanics
Effectiveness of countermeasures, current and proposed, and
Interaction between the above factors

The final task in completing each case in the ANCIS process, therefore, is the establishment of the range of factors associated with the crash event itself. As crashes are rarely caused by a single event (they tend to be the result of multiple factors, often in a chain of events leading up to the crash), it is more instructive to identify all factors that played a part so that intervention can take place at a number of different levels.

The ANCIS process is that the crash team (the nurse, vehicle and site inspector, the data processor, and the chief engineer) review each case to confirm the accuracy of these data and establish a consensus view on what were the causative factors. Given that these researchers have no specific interest in addressing system shortcomings, they can approach this task in a scientific manner without the pressures of intervention or policy to concern them.

These findings are then presented to the ANCIS sponsors for their interest and where they see fit, to initiate actions arising from the crash event. To aid this process, MUARC prepares electronic models of the crash event to help highlight the events leading up to the crash, the vehicle and occupant kinematics in the crash, and occasionally, some intervention alternatives and their potential benefits for added information. Experience has shown that new insights into causes and potential solutions are possible using in-depth crash data and crash reconstructions.

3 Case Studies

The two case studies presented in this section highlight the multi-causal nature of road crashes and the value in carrying out in-depth investigations to gain a far more comprehensive understanding of the importance of the complex interactions between the road user, their vehicle and the road and roadside setting.

3.1 Case 1 – Crash Summary

This crash occurred early in the morning on a public holiday Monday. The case vehicle ran off the road in a medium sized rural town in Victoria (pop. 90,000 approx). The case vehicle, with four people onboard, was travelling down a long straight section of road until a sharp right-hand bend, which it failed to negotiate. The car impacted two trees before rolling several times, finally coming to rest on its roof. The two back seat occupants were uninjured, while the front passenger was taken to a local hospital with minor injuries. The driver was injured more severely and was transported by helicopter ambulance to one of

Melbourne's main trauma hospitals, remaining there for 12 days. Key aspects of each of the human, vehicle and road/roadside setting are listed below.

3.1.1 Case 1 - Human

In the interview with the research nurse, the driver, a 27-year-old male, revealed that he had been very busy prior to the crash, working 16 hours the day before after just four hours sleep. On the day of the crash he had been drinking until late in the night and only had three to four hours of sleep. He stated that his friends pressured him to drive them home. They were 25 minutes into the one-hour journey at 07:30 when the crash happened. The driver claimed he fell asleep.

The most severe injury sustained by the driver was a compound fracture of the right radius. Fractures to the styloid processes of the radius and ulna on the right side were also recorded, along with degloving of the temporal-parietal region and right forearm. His blood-alcohol concentration was measured at 0.13% (compared with the Victorian legal limit of 0.05%) after arrival in hospital, around 2½ hours post-crash.

3.1.2 Case 1 - Vehicle

The vehicle was a locally manufactured sedan, less than one month old. The vehicle was fitted with Electronic Brake Force Distribution, Brake Assist, traction control, dual front airbags and seat-mounted head-thorax airbags for side-impacted front seat occupants. Based on a detailed examination of the vehicle, crash site and police report, the team concluded that the driver had attempted to negotiate the corner, but run wide. The first impact was a narrow offset frontal with a 450mm diameter tree. The vehicle then rotated clockwise, striking the second tree on the left rear quarter. It then performed a minimum of a half lateral roll, evidenced by scratch marks on the roof and A-pillars, before coming to rest. There was no evidence of braking, although the vehicle was equipped with an antilock braking system, which prevents wheel lock. All occupants were wearing their seatbelts. None of the airbags fitted to the vehicle deployed.

Crashed vehicle LH side

Crashed vehicle RH side

3.1.3 Case 1 - Road/Roadside Setting

The road was an 8m wide rural road, recently resurfaced. Markers were in place defining the location of edge and centre lines, but they had not been painted at the time of the crash. A 100 km/h limit was in force, with an advisory sign of 40 km/h located 175m prior to the corner. There was a single black and white chevron sign indicating the presence of the corner. One previous crash was on record as occurring at the same bend, some 10 years earlier.

View in direction of travel

Reverse view

3.1.4 Case 1 - Contributing Factors

The major contributing factors leading to the occurrence of this crash were undoubtedly the level of driver alcohol impairment, coupled with significant fatigue effects. However, there were a number of other issues primarily concerned with the road and roadside setting that clearly influenced the occurrence of this crash. The most important of these was the prevailing speed limit of 100 km/h heading straight into a tight corner (40 km/h), particularly in the absence of prominent warnings for the curve. Under moderate deceleration (2 ms^{-2}), a vehicle will take 160 m to slow down from 100 km/h to 40 km/h and the advisory sign was only 175 m from the corner. A video drive-through made of the crash site indicated that the location of the corner was not at all obvious.

3.1.5 Case 1 - Countermeasures

Given that the road ended at a main highway 200 m further on from the crash location, one important countermeasure identified was to reduce the speed limit around the location. This may have helped avoid the crash occurring, as well as reducing its severity had it taken place. Also identified were enhanced curve warning measures, including tactile edge lines, improved visual delineation (larger or more numerous chevron signs). Crash severity would have been greatly reduced with the provision of a run-off-road barrier.

3.2. Case 2 - Crash Summary

The participant, a 50-year-old motorcyclist, was travelling north along a semi-rural arterial road. As he approached the entrance to a golf club, an oncoming vehicle driven by an 80-year-old female, made a right-hand turn across his path. The motorcyclist hit the left front quarter of the car, was thrown from his bike and ended up approximately 30 m from the initial impact point. He was taken to a major Melbourne trauma hospital, where he remained for more than three weeks. Pertinent details of the crash are listed below.

3.2.1 Case 2 - Human

The rider had been road-testing his motorcycle after fitting some new parts. Immediately prior to the crash, he had been heading back home, but could not recall anything beyond this point. The driver of the sedan was not available for interview. The motorcyclist had held his licence for 32 years and had ridden regularly throughout that period, covering 15000-20000 km each year. He had used the road about 2-3 times each year and recalled that it was a 100 km/h zone and that he was travelling at about that speed. He told the research nurse that he was wearing a full-face helmet, a dark green full length rain jacket, jeans and steel-capped motorcycle boots. None of the items of clothing were reflective and he did not have his headlight on.

The 95 kg, 168 cm rider suffered severe lower leg injuries, including an 80% degloving below the right knee (AIS3), compound fractures of both the right tibia and fibula bones (with torn medial ligament) and two fractured right metatarsals. The crash investigation team concluded that these injuries were most likely the result of his leg being crushed between the motorbike and road. He also received a right pelvic fracture (with dislocation) and a splenic laceration. No alcohol was found in his blood.

3.2.2 Case 2 - Vehicle

The motorcycle had structural damage to the front wheel assembly and surface damage elsewhere. The 1985 Harley Davidson was in fair condition for its age and had adequate tyre tread remaining. The car was believed to have been only lightly damaged and was repaired quickly.

Crashed motor cycle

View from rider position

3.2.3 Case 2 - Road/Roadside Setting

The crash site was at the crest of a gentle hill. There was a single travel lane each way, along with a left-turn slip lane in the motorcycle travel direction and a dedicated right turn lane in the opposite direction. More significantly, a thick stand of trees lined the road where the motorcycle was, while the right-turning car was in bright midday sunshine. Sight distance for the car was estimated to be 250-300 m. There had been two crashes in the previous five-year period at the intersection, neither of which resulted in a serious injury outcome.

View in motorcycle direction of travel

Reverse direction, showing right-turn lane

3.2.4 Case 2 - Contributing Factors

Reverse direction, showing right-turn lane A number of factors came together and led to this crash occurring. The car driver either did not see the motorcycle in time or made a gap judgement error in executing her turn. High approach speeds to the intersection (100 km/h), coupled with heavy shading by the trees and the motorcycle's lack of visibility (dark, non-reflective clothing and no headlight) all contributed to the occurrence of this crash. Furthermore, the age of the car driver is likely to have resulted in worse performance in terms of both seeing the motorcyclist as well as making a correct and timely turning decision once she had.

3.2.5 Case 2 - Countermeasures

As for the previous case study, a significant reduction in travel speed would have both decreased the likelihood of the crash occurring or, given that it had still taken place, reduced its severity. At the time of presentation of this case, a review was underway by the relevant authorities. Better signage of the golf club access road would have helped the motorcyclist to be more aware of the approaching intersection, while improved visibility of the motorcyclist would have greatly assisted the car driver. Other possible countermeasures that were considered included reviewing the geometric design of the intersection, thinning/removing the trees or changing the color of the road surface to improve the vehicle-road contrast.

4 Expected Benefits From ANCIS

The collection of in-depth crash data has the very real potential to provide substantial benefits in improved road safety for all motorists. The thorough and systematic investigation of a representative sample of fatal and serious injury crashes enables a greater understanding on the causes of severe harmful road crashes and the level of protection offered by today’s vehicles. These data offer new knowledge and insights in areas not traditionally covered by police investigations and elevate our understanding of the road crash problem and solutions to a more mature level. This information identifies new road safety initiatives for the agencies responsible for providing new and innovative road safety initiatives.

The principal benefits from a comprehensive program of in-depth crash investigations, spanning the full range of fatal and serious road crashes, including:

a) the level of protection offered by today’s vehicles and any emerging problems;

b) new countermeasure programs and initiatives, covering road infrastructure development, education and behavior change, vehicle design, trauma management, enforcement and various combinations of these disciplines;

c) more sharply focused road safety strategies for future investment in road trauma reduction, in line with current state and national targets;

d) more comprehensive investigations for Coronial Inquiries;

e) “time-stamping” a country’s fatal and serious injury crash problem and its characteristics, early in the new decade, thereby enabling comparisons and evaluations to be made at critical times in the future, as well as providing an objective basis for adjusting and strengthening the State’s strategic effort over the period 2001 to 2005; and

f) enhancing the effectiveness of crash investigation and countermeasure development methods by drawing on new and innovative treatment models.

4.1 Who Will Benefit?

Obviously, the principle benefactor from the collection of in-depth data, used to help address road safety problems, is society. Many lives have been saved over the last 30-40 years in Western countries from adopting a systematic approach to road safety driven by detailed crash data; an initiative that had its foundation in the 1960s in the USA [13]. In spite of this, approximately 1.2 million people are likely to lose their lives this year and around 50 million will be seriously injured from road crashes around the world. As noted in the World Report on Road Traffic Injury Prevention [14], “without increased efforts and new initiatives, the total number of road traffic deaths and injuries worldwide is forecast to rise by some 65% between 2000 and 2020”.

These data are particularly useful for various industry groups, governments and consumer advocates in their on-going quest to find these new initiatives.

4.1.1 Governments

The biggest user of in-depth data for developing road safety initiatives is government. In general, they have the responsibility for the transport system and supporting infrastructure. In-depth data can show government officials the types of hazards on our roads and the consequences for those who happen to be involved in a crash with the infrastructure. Poles and trees are involved in particularly severe crashes and through the use of in-depth data, it is possible to demonstrate how these collisions can be either avoided or the damage mitigated.

In-depth data offers the opportunity to extend knowledge and treatment options for crash reduction and evaluate the effectiveness of countermeasures. It provides detailed information not currently available on crash severity and the level of injury beyond that currently available in most police databases (limited to ‘killed’, ‘seriously injured’, ‘minor injuries’ or ‘not injured’). It is useful for targeting police enforcement initiatives and so gain the maximum benefit from road safety campaigns.

Government is usually responsible for vehicle regulations that specify the level of safety for vehicle manufacturers to provide in order to sell vehicles in their country. In-depth data demonstrates to governments the types of injuries people are suffering in crashes and highlights priorities needing to be addressed [15]. These data can also be used to illustrate what the potential costs and benefits would be if certain new regulations were to be introduced into their countries [16].

4.1.2 Vehicle Manufacturers

Those responsible for building our cars need accurate and timely information on the crash performance of their vehicles. In-depth data provides information on vehicle crashworthiness and areas that require further improvement. It can identify particular emerging safety problems in vehicles and the benefits and disbenefits of new safety technology to their customers.

In-depth data can also be used to evaluate the effectiveness of new vehicle safety features such as airbags, structural design modifications, improved braking systems, and so on. In many instances, these data will provide indicative answers much quicker and more comprehensively than it takes to assemble large-enough mass databases to attempt to do the same task.

Finally, these data provide manufacturers with the means to enter into knowledgeable discussions with governments and consumer groups on relevant safety issues. In the past, the initiative for improving safety was very much driven by government. Today, with increased knowledge about the safety performance of their vehicles, manufacturers play a major role in improved vehicle safety and can usually act much faster in introducing safety improvements than government can.

4.1.3 Consumer Organizations

Vehicle safety is an important marketing feature these days in the sale of new vehicles. Most manufacturers will include information on the level of safety technology in their vehicles and if successful, how well they perform in the various prospective and retrospective consumer-rating systems their vehicles are exposed to. In-depth data can assist this process by adding real crash experience to the somewhat artificial laboratory environments that crash testing employs.

The accumulation of a number of in-depth crashes that align with a particular crash test configuration can be a powerful means of adding some realism to their relative make/model comparisons and add more credibility to their claims in the media.

5 Conclusions

Current crash data systems fulfill many of the requirements required for examining the extent of the road safety problem and for prioritizing areas requiring intervention. However, these mass databases are generally less adequate for identifying crash and injury causation factors and countermeasures. The extensive information available in in-depth studies can provide much greater detail on the events leading up to a crash and the vehicle factors associated with the causes of injuries.

A small sample of in-depth crashes was reviewed to illustrate the level of detail available in the ANCIS collaborative research program. These cases showed the depth of information available on human, vehicle, road and roadside conditions, contributing factors to the crash and injuries sustained and possible countermeasures to prevent the crash or mitigate the injuries suffered by the victims. These data are valuable for supplementing mass crash databases and provide a much more full description of the crash.

It was argued that these data are of potential use for governments, vehicle manufacturers and consumer groups and provide a means for greater insights into the need for vehicle regulation and road and roadside initiatives, new on-board vehicle safety technology and improved vehicle design, as well as evidence for consumers on what constitutes a safe vehicle and roadway. These data also provide the means of sophisticated computer modeling of each crash to illustrate to key stakeholders the need for further interventions.

6 Acknowledgments

The authors would like to thank the sponsors for funding the study and the crash research teams in Victoria, NSW and Tasmania who collected these data, namely Louisa Lam, Lisa Sharwood, Julie Brown, Michael Fitzharris, David Kenny, Ron Laemmle, Mary Michaelopoulos, James Scully, David Sheppee, Andrew Stanley and Vicki Xafis. We acknowledge the assistance of the study hospitals in providing access to patients and to all the patients who generously agreed to be part of the ANCIS program.

7 References

1. Estimating Global Road Fatalities, Romania Fact Book, 2005 www.factbook.net/EGRF_Introduction.htm

2. Calspan (1999). Expert Systems for Crash Data Collection, Publication No. FHWA-RD-99-052, Contract DTFH61-95-0007, Office of Safety and Traffic Operations R&D, Federal Highway Administration, McLean VI.

3. Mackay G.M. "Some collision aspects of British road accidents", Automotive Engineer, pp500-503, December 1969.

4. McLean A.J., Aust H.S., Brewer N.D. & Sandow B.L. "Adelaide In-depth accident study – 1975-1979: Part 6; car accidents", NH&MRC Road Accident Research Unit, The University of Adelaide, Adelaide, Australia, 1979.

5. Sabey B.E. & Straughton G.C. "Interacting roles of road environment, vehicle and road user in accidents", Paper presented at the 5th International Conference of the Association for Accidents and Traffic Medicine, London, UK, 1975.

6. Sabey B.B. Road safety and value for money, Transport & Road Research Laboratory (now TRL) Supplementary Report SR 581, Crowthorne, Berkshire, UK, 1980.

7. Treat J.R., Tumbas N.S., McDonald S.T., Shinar D., Hume R.D., Mayer R.E., Stansifer R.L. & Castellan N.J. (1977). Tri-level study of the causes of traffic accidents, Report DOT-HS-034-3-535-77 (TAC), Indiana University, March 1977.

8. NHTSA, National Automotive Sampling System 1989 crashworthiness data system, U.S. Dept. Transportation, National Highway Traffic Safety Administration, Washington DC, 1989.

9. Kühnel A., Wanderer U & Otte D. "Ein Verleich von realen mit nachgefahrenen Fuβgängerunfällen", International Research Conference on the Biomechanics of Injury, 1975

10. MUARC (2003). Australia's National Crash Investigation Study (ANCIS), Informative leaflet, Monash University Accident Research Centre, Clayton, Australia.

11. AAAM,The Abbreviated Injury Scale 1990 Revision (Update 98), Association for the Advancement of Automotive Medicine, Barrington IL, 2001.
12. ATSB. Site inspection criteria, fatal file, Australian Transport Safety Bureau, Department of Transport and Regional Services, Canberra, Australia, 2000.
13. Haddon W. Advances in the epidemiology of injuries as a basis for public policy, Public Health Reports 1980; 95: pp411-421.
14. WHO (2004). World Report on Road Traffic Injury Prevention, World Health Organisation, Geneva.
15. Fildes BN, Lane JC, Lenard J & Vulcan AP. (1991). Passenger cars and occupant injury, Australian Transport Safety Bureau (formerly the Federal Office of Road Safety), Department of Transport & Regional Services, Canberra, Australia.
16. MUARC (1992). Feasibility of occupant protection measures, Australian Transport Safety Bureau (formerly the Federal Office of Road Safety), Department of Transport & Regional Services, Canberra, Australia.