MONASH University
Accident Research Centre

THE FEASIBILITY OF IDENTIFYING SPEEDING-RELATED & FATIGUE-RELATED CRASHES IN POLICE-REPORTED MASS CRASH DATA

by

Kathy Diamantopoulou
Effie Hoareau
Penny Oxley
Max Cameron

MONASH UNIVERSITY
ACCIDENT RESEARCH CENTRE

March, 2003

Report No. 197

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
REPORT DOCUMENTATION PAGE

Report No.	Date	ISBN	Pages
197	March 2003	0 7326 1496 1	xvi + 62

Title and sub-title:

The Feasibility of Identifying Speeding-Related and Fatigue-Related Crashes in Police-Reported Mass Crash Data

Author(s): Kathy Diamantopoulou, Effie Hoareau, Penny Oxley and Max Cameron

Sponsoring Organisation(s):

This project was funded through the Centre's Baseline Research Program for which grants have been received from:

Department of Justice
Roads Corporation (VicRoads)
Royal Automobile Club of Victoria (RACV) Ltd
Transport Accident Commission

Abstract:

During 1999, the Transport Accident Commission suggested that Monash University Accident Research Centre undertake a project to examine the possibility of better defining crashes involving speeding and fatigue based on an analysis of Police-reported mass accident data in Victoria. Such data would enable better tracking of the relative involvement of these problem behaviours in crashes, and better assessment of the effectiveness of countermeasures aimed at each specific behaviour in crashes.

A review of the NSW Roads and Traffic Authority's (NSW RTA) procedures to identify speed and fatigue in crashes led to the recommendation that Victoria should not adapt the same procedures. This was due to the procedures' insufficient scientific basis in the derivation of identifying speed-related and fatigue-related crashes, as well as there being too many important differences between Victorian and NSW crash reports. It was therefore proposed to obtain data from recent in-depth crash investigations in which the degree of speeding and/or fatigue was determined objectively.

An in-depth crash study by the NSW RTA was intended to be used to identify fatigue but was deemed unsuitable. Consequently, the study's aim to identify fatigue in mass crash data was not feasible. A second in-depth crash study conducted by the NHMRC Road Accident Research Unit, RARU, of University of Adelaide, used accident reconstruction techniques to determine free-travelling vehicle speeds of crashed vehicles. This study was used in the development of a procedure to identify speed in Victorian Police-reported mass crash data.

The Adelaide RARU data was analysed using General Linear Modelling techniques. Two types of models were developed; one that included only main effects and assumed no interactions between factors, and a second model that allowed for interactions and modelled them explicitly. The significant factors obtained from these models were used to develop indicator functions that estimated the travelling speed of a vehicle prior to a crash. These indicator functions were applied to a subset of the Victorian Police-reported mass crash data to identify speed-related crashes for the period 1984-2000. A subset was selected to match the situation of the RARU data, i.e. urban daytime crashes in 60 km/h speed zones.

Using these indicator functions, average vehicle speeds of crashed drivers and the proportions of crashed drivers with vehicle speeds >75 km/h and >90 km/h were estimated. The aim was to see if there had been any changes in these speed measures on urban 60 km/h Melbourne roads in day-time hours during 1984-2000. The indicator functions could then be used to assess the impact of new speed enforcement and/or publicity programs - by monitoring any changes that occurred in average speeds or in the proportion of crashed drivers with speeds exceeding the speed limit as a response to the new speed initiatives.

Key Words:

Speed, fatigue, crash, general linear model, speed camera program, urban areas, 60 km/h speed zone

Monash University Accident Research Centre,
Wellington Road, Clayton, Victoria, 3800, Australia.
Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

Preface

Project Manager / Team Leader:

- Professor Max Cameron

Research Team:

- Ms. Kathy Diamantopoulou
- Ms. Effie Hoareau
- Ms. Penny Oxley

Acknowledgements:

The authors wish to acknowledge and thank the following people for their valuable assistance in this study:

- Members of the Project Advisory Committee – Mr. William Gibbons, Department of Justice; Ms. Natasha Anderson, RACV; Mr. David Healy, TAC; Ms. Kacie La & Mr. Nick Szwed, VicRoads; and Superintendent Peter Keogh, Chief Inspector David Richardson, Acting Inspector Jeff Millar & Senior Sergeant Dennis Watson, Victoria Police.

- Mr Sanjeev Narayan, Dr Karen Gelb and Ms Andrea Beel (all formerly of MUARC) for their considerable assistance in preparing sections of the report.

- Professor Jack McLean and Mr Craig Kloeden from the NHMRC Road Accident Research Unit, RARU, of the University of Adelaide for allowing MUARC to access the in-depth travel speed crash data.

- Ms Liza Reinberger of the South Australia Police (SAPOL) for granting permission to access South Australia Police vehicle collision reports.

- Ms Terrie Baker of South Australia Transport for providing MUARC with an electronic copy of South Australia Police-reported mass crash data.

- Mr Harry Vertsonis of the New South Wales Roads and Traffic Authority, NSW RTA, for his assistance and advice in assessing the suitability of the NSW RTA's crashed vehicle study in identifying fatigue-related crashes.

Contents

Tables

Figures

EXECUTIVE SUMMARY

During 1999, the Transport Accident Commission suggested that Monash University Accident Research Centre undertake a project to examine the possibility of better defining crashes involving speeding and fatigue based on an analysis of Police-reported mass accident data in Victoria. Such data would enable better tracking of the relative involvement of these problem behaviours in crashes, and better assessment of the effectiveness of countermeasures aimed at each specific behaviour in crashes.

ADOPTING NSW PROCEDURES FOR VICTORIA

The New South Wales Roads and Traffic Authority (NSW RTA) has had procedures for identifying speeding-related and fatigue-related reported crashes for many years, based on the reporting officer's opinion of the presence of the behaviour and whether the vehicle manoeuvred in a way characteristic of the behaviour. These procedures were reviewed as part of this study to determine if they were applicable to the Victorian context.

The review of the NSW RTA procedures indicated that the identification of speeding-related and fatigue-related crashes was *derived* from Police data, rather than being tested on crash data or being independent of the Police crash reports. It was thus questionable whether these procedures had sufficient scientific basis to warrant directly adopting them for the Victorian Police-reported crash data. Therefore it was recommended that Victoria **should not** adapt the same procedures for use on Victorian Police crash reports because of their insufficient scientific basis, and also because there were too many important differences between Victorian and NSW crash reports.

Because the NSW procedures were determined to be unsuitable, there was a need to investigate whether the identification of speeding-related and fatigue-related crashes directly from mass reported data is feasible at all for Victoria. It was therefore proposed to obtain data from recent in-depth crash investigations in which the degree of speeding and/or fatigue was determined objectively. These data would then be matched with Police crash reports for the same crashes, if possible. This would allow for key Police report data and appropriate functions of this information to be identified that discriminates most effectively between whether the crash involves the behaviour (speeding or fatigue, respectively) or not.

FEASIBILITY OF DISCRIMINATING SPEEDING-RELATED AND FATIGUE-RELATED CRASHES

Two in-depth crash studies, in which the degree of speeding and/or fatigue was thought to have been determined objectively, were identified as being potentially appropriate. One, a study conducted by the New South Wales Roads and Traffic Authority (NSW RTA) was believed to contain crashes where the presence or absence of fatigue had been determined using pre-defined criteria. The other, a study conducted by the NHMRC Road Accident Research Unit, RARU, of the University of Adelaide, determined the free travelling speeds of approximately 150 vehicles involved in crashes.

Fatigue-related crashes

The NSW RTA in-depth crash investigation was designed to examine the relationships between vehicle defects and road safety, and as such, the data gathered was essentially based on vehicle information such as vehicle controls, suspension, steering, tyres and chassis. Behavioural causal factors such as fatigue were not identified. On this basis the NSW RTA data was deemed unsuitable for the identification of fatigue-related crashes. Consequently, the study's objective to identify fatigue in Victoria's mass crash database of Police records was not feasible at this stage.

Speed-related crashes

The second study, conducted by RARU, examined the effect of free travelling speed on the risk of involvement in a casualty crash in a 60 km/h urban speed limit setting in Adelaide. Accident reconstruction techniques were used to determine free-travelling speeds of crashed vehicles. It was deemed feasible to use the data from this study, matched with South Australia Police crash reports, to develop a procedure to identify speed in Victoria mass crash data. The matching process of the South Australia Police crash data with the RARU case study data resulted in a database of 149 crashed vehicles for analysis.

DEVELOPMENT OF MODELS AND INDICATOR FUNCTIONS TO IDENTIFY SPEED IN MASS CRASH DATA

A statistical modelling analysis of the South Australia matched crash database identified a number of factors associated with driver speed, i.e.:

- male drivers;
- drivers aged 25 years or less;
- fatal crashes;
- extensively damaged vehicles;
- morning crashes;
- crashes in which the driver was performing a manoeuvre other than going straight ahead.

The statistical methodology used was General Linear Modelling (GLM). Two types of models were developed; one that included only main effects and assumed no interactions between factors, and a second model that allowed for interactions and modelled them explicitly.

The significant factors that were obtained from the 'main effects' and 'interactions' GLM models (listed above), were used to develop indicator functions that estimated the travelling speed of a vehicle prior to a crash. These indicator functions were then applied to Victorian Police-reported mass crash data to identify speed-related crashes for the period 1984-2000.

To apply the South Australia findings to the Victoria crash data, both data sets had to be compatible. For this to occur, certain conditions had to be selected from the Victoria data set to match the conditions inherent in the South Australia in-depth-crash study. These were selecting only:

- crashes that occurred on roads in 60 km/h speed zones;
- day-time crashes (i.e. between 08:00 – 20:00, as defined in the South Australia mass crash database);
- crashes in urban areas as defined by the Local Government Area (i.e. areas in the Melbourne Statistical division);
- drivers;

- passenger cars or passenger car-derivatives (i.e., car, station wagon, taxis, utilities, panel vans).

One of the significant factors in identifying speed, 'vehicle damage' was not available for the years 1984-1988 in the Victoria crash data. A related variable 'towed' indicating whether or not the vehicle had been towed after a crash was used as a substitute for the 'vehicle damage' variable. Because of this, two types of indicator functions were developed:

- one covering the full data period, 1984-2000, and using the 'towed' variable to estimate vehicle damage,
- the other covering the period 1989-2000 in which the 'vehicle damage' variable was readily available.

The following speed measurements were estimated:

- average vehicle speeds of crashed drivers per quarter for the periods January 1984–December 2000 and January 1989-December 2000;
- the proportion of crashed drivers with estimated vehicle speeds >75 km/h per quarter for January 1984-December 2000 and January 1989-December 2000;
- the proportion of crashed drivers with estimated vehicle speeds >90 km/h per quarter for January 1984-December 2000 and January 1989-December 2000.

The aim was to see if there had been any changes over time in average vehicle speeds of crashed drivers or in the proportion of drivers exceeding the speed limit in metropolitan (urban) areas on 60 km/h roads for crashes that occurred during daytime hours.

Initially the Victorian speed camera program occurred primarily in urban areas during low alcohol times of the week. These times of the week mainly correspond with daytime hours. Hence, trends in speed outcomes could then be compared to the Victorian speed enforcement programs to determine whether there had been a change in average speed or in the proportion of crashed drivers exceeding the speed limit as a response to these initiatives.

MAIN FINDINGS

Average vehicle speeds

The indicator functions that were based on the models that used the 'vehicle damage' variable and the 'towed' variable exhibited fairly similar trends in average vehicle speed over the time period 1989 - 2000. This was the case for both the 'main effects' and the 'interactions' models. This suggests that the variable 'towed' is a good estimate of 'vehicle damage' when determining the average vehicle speed of crashed drivers.

The 'main effects' models and the 'interactions' models showed similar trends in the estimated average vehicle speed of crashed drivers during 1984-2000 and 1989-2000. However, the actual estimates of average speed for the 'interactions' models were approximately 7 km/h lower than those estimated by the 'main effects' models. For the 'main effects' models a range of approximately 65 km/h–68 km/h was estimated compared with a range of about 57 km/h-61 km/h for the 'interactions' models.

A previous MUARC study (Rogerson et al, 1994) found that after the introduction of the speed camera program and the launch of TAC mass media speed-related publicity, there had been little change in average speeds in a 60 km/h zones during November 1989 to June 1990. This current study supports this result in the way that average vehicle speeds over time did not vary greatly, ranging from 65 km/h to 68 km/h ('main effects' models) or 57 km/h to 61 km/h ('interactions' models). However, there was a definite decline in average speed from July 1989 to July 1991.

Proportion of vehicle speeds exceeding 75 km/h and 90 km/h

When considering the proportion of crashed drivers with estimated vehicle speeds exceeding 75 km/h, the 'main effects' models produced higher estimated proportions than the 'interactions' models. For the 'main effects' models a range of approximately 15%-25% was estimated compared with a range of 9%-17% for the 'interactions' models. However, for the proportion of crashed drivers with estimated vehicle speeds exceeding 90 km/h, the 'interactions' models gave larger estimates than the 'main effects' models by about 1%.

The 'main effects' model that included the 'towed' variable showed consistently smaller estimates per quarter in the proportion of crashed drivers with vehicle speeds >90 km/h than the corresponding model that used the 'vehicle damage' variable. The proportion of speeds >90 km/h was approximately 0.2%-0.6% less in magnitude for the first model. Also, the latter model was more variable than the former model but fluctuated steadily around approximately 0.6%.

Thus the models that used the 'vehicle damage' variable and the 'towed' variable were not consistent estimators of the proportion of crashed drivers with vehicles speeds >90 km/h. However they do seem to be consistent when estimating the proportion of vehicle speeds exceeding 75 km/h in crashes.

Rogerson et al (1994) found that in response to the introduction of the speed camera program and the launch of the TAC publicity, there was a significant decrease in both the percentage of vehicle speeds exceeding 75 km/h and 90 km/h, in 60 km/h zones from November 1989 to June 1990. This decrease remained through to November 1991. These reductions were also apparent when the speed measure considered in this current study was the proportion of crashed drivers with speeds exceeding 75 km/h, but were less obvious for the corresponding proportions exceeding 90 km/h, possibly because there were too few observations. Thus the indicator functions that were developed to identify speed in mass crash data have been able to detect some changes in the speed of crashed drivers over time, particularly when considering the proportion of crashed drivers with vehicle speeds exceeding 75km/h.

Overall, both the 'main effects' and 'interactions' models exhibited similar trends during the time periods considered in the study, 1984-2000 and 1989-2000. However, the 'main effects' models produced larger estimates of the average vehicle speed of crashed drivers and the proportion of crashed drivers with vehicle speeds exceeding 75 km/h than did the 'interactions' models. Conversely, lower estimates of the proportion of crashed drivers with vehicle speeds exceeding 90 km/h were produced by the 'main effects' models compared with the 'interactions' models.

USEFULNESS OF THE INDICATOR FUNCTIONS

The indicator functions developed as part of this study can be used:

- to estimate the pre-crash travelling speeds of vehicles crashing on Melbourne roads in 60 km/h speed zones;

- as monitoring tools to assess and/or monitor changes in the average vehicle speed of crashed drivers as well as the proportion of crashed drivers exceeding the speed limit at various levels over a specified time period;

- to assess the impact of new speed enforcement programs or new publicity and education campaigns targeted at speeding drivers - this could be achieved by monitoring any changes that occurred in these speed measures during the times when these new speed initiatives were implemented.

LIMITATIONS OF THE STUDY

The indicator functions of speed that were developed are only applicable for crashes that occurred on Melbourne roads in 60 km/h speed zones, predominantly during day time hours. These constraints were placed on the analysis because it was necessary to match the Victorian crash data with the criteria used in the RARU in-depth study. The RARU study examined the effect of free travelling speeds on the risk of casualty crash involvement in 60 km/h urban speed limit setting in Adelaide.

All crashed vehicles that met the above criteria were selected from the VicRoads crash database, not just those with assumed free travelling speeds. Thus stationary vehicles involved in a crash could also potentially have been selected. A refinement of the indicator function would be to exclude vehicles which were stationary at a crash, if possible, and re-estimate the speed of drivers prior to a crash.

RECOMMENDATIONS

It is clear that the planned procedures for this study – particularly obtaining the relevant data to allow the identification of fatigue-related crashes – were not as simple and straightforward as anticipated. It is suggested that the plan to identify fatigue-related crashes (and the expansion of speed-related crashes) be re-examined.

To develop higher quality procedures for defining/indicating the presence of key behaviours in crashes, it may be necessary for MUARC to undertake special investigations of behaviours which were the precursors or precipitators of an adequate sample of crashes or at least to add such behavioural investigations to MUARC's existing crash studies. The data would be matched with Police accident reports and the correlation of the existing data with the presence of the behaviour examined. It may be necessary to recommend that additional data be collected by the Police to more accurately identify whether certain safety-related behaviours are likely to have been present in the crash.

It is also recommended that the indicator functions of speed developed as part of this study be refined to exclude crashed vehicles that may have been stationary at the time of impact.

1. INTRODUCTION

During 1999, the Transport Accident Commission suggested that Monash University Accident Research Centre undertake a project to examine the possibility of better defining crashes involving speeding and fatigue based on an analysis of Police-reported mass accident data in Victoria. Such data would enable better tracking of the relative involvement of these problem behaviours in crashes, and better assessment of the effectiveness of countermeasures aimed at each specific behaviour in crashes.

The New South Wales Roads and Traffic Authority has had procedures for identifying speeding-related and fatigue-related reported crashes for a number of years, based on the reporting officer's opinion of the presence of the behaviour.

These procedures were examined as part of this project in order to determine if they are applicable to the Victorian context. If the NSW procedures were considered to have insufficient scientific basis, the project then aimed to investigate whether such procedures were feasible at all by using information obtained from recent 'in-depth' crash investigations to determine the feasibility of discriminating both speeding-related and fatigue-related crashes.

The project was carried out in the following stages:

Stage 1: A brief review of the literature concerned with factors associated with speeding and fatigue in crashes. The literature review is presented in Chapter 2.

Stage 2: A review of the NSW procedures (discussed in Chapter 3).

Stage 3: The feasibility of discriminating speeding-related and fatigue-related crashes. The findings are presented in Chapters 4.

Stage 4: The development of statistical models and subsequent indicator functions to identify speed of drivers prior to a crash in Victorian Police-reported mass crash data. The findings are presented in Chapter 5 and Chapter 6.

2. LITERATURE REVIEW

With most traffic crashes a “chain of events” culminates in the crash, with each factor contributing to the seriousness of the crash, with some factors also possibly causing the crash. For a given set of circumstances it is generally agreed that exceeding the speed limit, termed “speeding”, is associated with an increased risk of having a crash, with this risk being exponential (Kloeden et al, 2001; Kloeden et al, 1997a). It has also been found that the likelihood of sustaining an injury given a crash has occurred also increases exponentially with speed (Fildes & Lee, 1993).

2.1 DEFINITIONS OF SPEEDING AND FATIGUE

One of the difficulties in reviewing previous research investigating speeding and crash rates is the definition of “**speeding**”. This can be a self reported measure or one inferred in a Police Accident Report as an “apparent error”. It can be judged as a “definitive cause” or “probable cause”, with cause implying that had the driver not been “speeding” the accident would most likely not have occurred. It can be judged as a “contributing factor”, usually with respect to making any damage or injuries sustained more severe than they would have otherwise been if the driver had not been speeding. In Australian studies, “speeding” has been defined as definitely present if the vehicle exceeded the speed limit by 10 km/h or more (Wundersitz et al, 2001) and “excessive speeding” as exceeding the limit by 30 km/h or more (Fildes et al, 1991).

While these operational definitions have been used to judge the causative role of speeding behaviour, it should be noted that exceeding the speed limit by any amount is speeding and is likely to increase crash risk (see section 2.2.1). In addition, VicRoads defines a speed related crash as “a crash in which the speed of the vehicle was a factor which contributed to the causation of the crash, or which could have caused the crash to be avoided, or in which, although not contributing to the causation of the crash, the speed of the vehicle in excess of a safe or legal speed on the particular stretch of road caused the severity to be greater than would have been the case if that vehicle had not been travelling in excess of the safe or legal speed” (personal communication, January 2003).

When it comes to **fatigue** there is also some difficulty in defining it. Under controlled conditions it has been shown that after sleep deprivation (i.e. 17 to 19 hours without sleep) response speeds are slower, with performance on some tests being equivalent or worse than that at 0.05 percent blood alcohol content. After longer periods without sleep, and therefore greater driver fatigue, performances further declined to match those of subjects with a blood alcohol content of 0.10 percent (Williamson et al, 2000). Often fatigue is ascribed to accidents where a single vehicle ran straight off a road because the driver fell asleep or was “drowsy”. These crashes, especially when the driver falls asleep and does not brake or avoid fixed objects, tend to be very serious, if not fatal. There are very few Australian studies investigating crashes where fatigue or “drowsy driving” may be causal or a contributing factor for vehicle drivers. Most of the research has involved truck drivers and heavy vehicles where, in some cases, drug use may also have been involved (Haworth & Heffernan, 1989; Haworth et al, 1989; Haworth et al, 1988).

2.2 LITERATURE RELATING TO SPEED

2.2.1 Speed and crash likelihood

The faster a person is driving the less time they have to react and avoid a potential crash or reduce it's severity. Fildes & Lee (1993) have reported that increases in speed cause disproportionately greater increases in stopping distance, resulting from lower braking efficiency and poor driver reactions. It was reported that an 18% increase in speed from 55 to 65 mph (99 to 104 km/h) results in a 38% increase in stopping distance.

A study undertaken in South Australia concerned with travel speed and the risk of crash involvement found that 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 (Kloeden et al. 1997a). These findings were based on a case-controlled study of cars travelling in a 60 km/h metropolitan area from 9.30 am to 4.30 p.m., Monday to Friday. It was found that cars involved in casualty crashes were generally travelling faster than cars that were not involved in a crash: 68% of casualty crash-involved cars were exceeding 60 km/h compared to 42% of those not involved in a crash. At speeds over 80 km/h the difference was far greater (14% of casualty crashes were travelling over 80 km/h compared to 1% of those that were not). From these findings it was conservatively estimated that a 10 km/h reduction in the travelling speeds of crash involved cars would probably have resulted in a reduction of at least 42% in the number of crashes (with a 5 km/h reduction in speed leading to 15 percent less crashes). The report on this study also includes a detailed discussion of the literature on speed and crash risk.

A more recent South Australian study of travelling speed and the risk of crash involvement on rural roads by Kloeden et al (2001) found that the risk of involvement in a casualty crash was 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. It was then estimated that a 5 km/h reduction in the speed of all the free travelling speed vehicles in the study would have led to a 31% reduction in casualty crashes. Further to this, it was estimated that 24% of all the casualty crashes investigated would have been avoided if none of the vehicles had been travelling above the speed limit. It was also estimated that lowering the maximum speed limit on rural undivided roads to 80 km/h could be expected to lower casualty crash frequency by 32%.

Drivers on Victorian roads who were travelling above the mean speed of the traffic, and the speed limit, were more likely to report having been involved in a crash (and multiple crashes) over the previous five years (Fildes et al, 1991).

2.2.2 Speed limit changes and crash rates

After reviewing major international studies investigating the crash rate changes associated with either decreasing or increasing the speed limit, Fildes & Lee (1993) concluded that lowering the speed limit can result in fewer serious injuries and deaths in the short-term, while increased speed limits, reported mainly in the USA, seem to have resulted in higher levels of injury severity and more fatalities. Fildes & Lee (1993) stated that the reasons for the benefits associated with reduced speed limits were not clear in most of the studies reviewed. It was not directly clear whether the reductions in crashes and injury severity could be attributed to reductions in mean speed, reductions in speed variance, reductions in traffic volumes or perhaps some increased general awareness effect (Fildes & Lee, 1993). It was also noted that changes in road safety must be attributed to changes in driver behaviour, both known and unknown, that come about as a result of the combined effects (poorly understood) of speed limit changes, publicity and surveillance.

2.2.3 Speed and injury severity

In certain types of crashes excessive speed may not have caused the accident but increased the level of injury sustained from the collision (Fildes & Lee, 1993). The likelihood of injury in a crash increases exponentially with the speed of collision. Added to this, the unprotected road users (e.g. motorcyclists, pedestrians and cyclists) can be exposed to harmful life threatening forces at relatively low vehicle speeds.

Drivers who were travelling above the mean traffic speed in both rural and metropolitan locations in Victoria were more likely to report more severe injuries in previous crashes than those below (Fildes et al. 1991). Those travelling at excessively fast speeds (defined as over 30 km/h above the speed limit) were more likely to report injuries requiring hospital or medical treatment, while nobody travelling at excessively slow speeds reported severe injuries.

2.2.4 Speed distributions

It has been found that the larger the spread of speeds around the average, the more accidents there are, with this increase also being exponential (Taylor et al, 2000). It has also been found that the crash frequency rises approximately in proportion to increases in the proportion of speeders and that the greatest benefit in reducing death and injury will be obtained by reductions in speed of the fastest drivers (Taylor et al, 2000).

2.2.5 Speeding information in crash data

Information collected and stored on Police reported mass crash data provides details that can be analysed to investigate the contribution of speed and fatigue in crashes, however this information is not always routinely collected or accurately recorded as it is not always possible for the police to determine, or the driver recall, at what speed they were driving when the crash occurred. An investigation of the Traffic Accident Reporting System (TARS) of Transport SA “apparent error” in the crash, as listed on the police report, revealed that “excessive speeding” was only listed in 2% of casualty crashes; with it stated that this certainly under-represents the true situation (Wundersitz et al, 2001). In a study by these authors serious casualty crashes in the Adelaide metropolitan areas were estimated to have a rate of “speeding” of 7.2%, while in rural towns the rate was 12.2%. In both locations the rate of speeding in serous casualty crashes was 2.3 times the rate for minor casualty crashes with “speeding” being defined as exceeding the speed limit by 10 km/h or more.

2.2.6 Age of driver

Overall, as drivers get older they are less likely to speed (Harrison et al, 1998). It has been determined that the transition to a “less likely to speed” driver tends to occur around 40 years of age in Australia (Fildes et al, 1991) and also in the United Kingdom (Webster & Wells, 2000). In the Australian study, drivers under 34 years of age were more likely to be excessive speeders (i.e. greater than 30 km/h above the speed limit), while those aged 55 years or older were much more likely to be excessively slow travellers. These findings were consistent in both urban and rural settings, as well as for both straight and curved roads (Fildes et al, 1991).

A recent study in South Australia investigating speeding and crash rates also found the rate of "speeding" involvement was highest for young drivers and riders (under 25 years) and decreased with increasing age (Wundersitz et al, 2001). The main "at-risk group" in terms of speed-related traffic crashes were males aged 20 to 29 years. They had been found to be more likely to be caught and fined for speeding in the last six months (14% compared to 8% for all respondents) and least likely to think they would be caught (Wundersitz et al, 2001).

2.2.7 Sex of driver

Wundersitz et al (2001) found that male drivers and riders were over-represented in "speeding" casualty crashes, however Fildes et al (1991) did not find any differences in travel speeds between male and female drivers in a study of Victorian drivers.

2.2.8 Passengers in vehicle

Fildes et al (1991) found that in general, vehicles with only a driver are more likely to exceed the speed limit and to be excessively fast drivers, i.e. driving at 30 km/hr or more above the speed limit, than vehicles with two or more occupants.

2.2.9 Driver attitudes and behaviors to speeding

A study of country drivers in South Australia found that drivers report that they would be most likely to exceed the limit on a major rural highway (Wundersitz et al, 2001) - 66% reporting that they had done so at least occasionally. The most common reasons given in this study for speeding were "in a hurry" (23%), followed by "not paying attention (21%) and "overtaking" (16%). It is presumed that the higher rates of self-reported speeding on major rural highways reflect driver's beliefs that it was "safe" to do so. It is also worth mentioning that it is likely that these rates are underestimates as people tend to have a "social response" bias and are less likely to admit to, or underestimate, any "illegal" behaviours such as speeding. Other international studies have found even higher rates of drivers admitted to speeding on occasion e.g. 85%, and that there was general agreement that everyone did it (Silcock et al, 1999).

2.2.10 Speeding and attitudes to risk

A study conducted at three sites in Victoria (1 country and 2 metropolitan) during 1997 and 1998 (Harrison et al, 1998) found that drivers who chose to drive fast:

- were more comfortable doing so,
- had a history of speeding,
- were less likely to rate travelling fast as dangerous,
- were more tolerant towards a range of illegal behaviours,
- believe themselves to be safer than other drivers,
- were more likely to be driving on a work-related trip, and
- were younger.

2.2.11 Vehicle characteristics and driving location

Drivers of newer vehicles (less than five years old) were more likely to be excessive speeders (greater than 30 km/h above the speed limit) than those in older vehicles (Fildes et al, 1991). This study also found that the type of passenger vehicle was not associated with travel speed in either rural or metropolitan locations. In addition, those travelling in vans and light commercial vehicles were more likely to be slow travellers in rural settings, but not in metropolitan areas.

2.2.12 General driver characteristics

Fildes et al (1991) found in a study of drivers in Victoria that excessive speeders (greater than 30 km/h above the speed limit in metropolitan and country regions) are more likely to be:

- younger drivers (under 34 years of age),
- drivers without occupants,
- business travellers,
- drivers travelling behind schedule,
- driving vehicles less than five years old, and
- drivers who reported travelling high distances each week.

This study found that vehicles observed exceeding the mean traffic speed and the posted speed limit on **rural roads** were more likely to have one or more of the following characteristics than drivers not speeding, in order of importance:

- Not towing a trailer,
- Young driver (under 34 years) with a high accident history,
- Drivers reporting a high safe travel speed,
- Male drivers travelling over long distances not for domestic purposes, and
- Vehicles with a driver only, travelling for business purposes, who drive high weekly mileages, and who do not own the vehicle they drive.

The **urban** analysis revealed that vehicles exceeding the mean traffic speed and the posted speed limit were more likely to have one or more of the following characteristics (also in order of importance):

- Young driver (under 34 years) with a high accident history,
- Drivers reporting a high safe travel speed,
- Drivers in vehicles less than 5 years old, and
- Business travellers (not on recreation journeys) who travel high mileages each week.

Webster and Wells (2000) in a review of a number of studies, found that many different people are speeders and a majority of drivers admit to speeding at some times. However, the research found that speeders are more likely to be:

- Younger males in non-manual occupations,
- Company car drivers,
- Drivers covering high annual mileages, and
- Younger drivers carrying young male passengers are more likely to be travelling at higher speeds.

2.3 LITERATURE RELATING TO FATIGUE

Fatigue is increasingly being recognised as a major contributing factor to road crashes in Australia. It appears to be a prevalent factor relating to high severity crashes. There has been an increase in fatigue-related fatal crashes by nearly 5% since 1996.

Fatigue information in the literature comes from two main sources. The first is that interpreted from Police data. The cause of fatigue may be directly reported or interpreted as fatigue-related due to the nature and characteristics of the crash, while following some pre-formed criteria. The second is that from surveys of self-reported fatigue. These estimates tend to be higher, suggesting that fatigue as a factor may be under estimated.

2.3.1 Definition of Fatigue

There is no single definition of fatigue found throughout the literature but all definitions relate to impaired driving performance due to feelings of drowsiness or tiredness. Any part of a driver's activity – perception, cognitive activities and movements – may be affected by fatigue (Bittner et. al., 2000). The most extreme form is actually falling asleep at the wheel. The severity of the effects of the fatigue will depend on both endogenous factors relating to the individual person, exogenous factors relating to the road environment, as well as other interaction factors.

Endogenous driver factors influencing fatigue, as identified by the Fatigue Expert Group (2001), include:

- health,
- age,
- biological factors,
- work demands or environment,
- inadequate sleep over a period of time, and
- mental or physical stress.

Exogenous factors include the:

- distance travelled by the driver,
- monotony of the road environment,
- presence of other vehicles, and
- width of the roadway.

Some of these factors will be more important than others and may interact together to give a more pronounced effect. When mixed with other factors such as speed or alcohol, the effect can again be more severe. For example, in a study by the New Zealand Land Transport Authority (1998), of 114 fatal crashes in which driver fatigue was a factor, 32% also involved alcohol.

Bittner et al (2000) found fatigue affects drivers in the following ways:

- decreases in driver reaction time and attention,
- increase in decision errors,
- important signals ignored by the driver,

- the driver may fall asleep or lapse into a 'microsleep',
- the driver's short-term memory deteriorates, and
- the driver may compensate by slowing down or be less willing to overtake.

2.3.2 Fatigue Information in Crash Data

Prior to 1993, fatigue was not identified as being a contributory factor to a crash (Data Analysis Australia, 2000). Identifying fatigue as a factor can be difficult to determine due to its subjective nature and difficulty in recognition when establishing it as a cause. Other factors are easier to detect due to the more objective, quantifiable nature of the factor. For example, alcohol can be quantified in terms of blood alcohol levels, and categorised non-subjectively as 'Pass' or 'Fail'. Fatigue on the other hand has many levels, from a feeling of 'drowsiness' to literally falling asleep at the wheel. There may also be other contributing or interaction factors related to a crash. For example, the New South Wales Roads and Traffic Authority (NSW RTA, 2001b) reported that in 2001, 19% of fatigued drivers in fatal crashes also had an illegal blood alcohol concentration (p. 64). Thus data about fatigue-related crashes might not always be reliable and may be difficult to obtain.

There have been attempts in establishing criteria that will facilitate the recognition of fatigue as a factor from Police data. Horne and Reyner (1995) came up with eight criteria to be applied to data in deciding whether the data is a fatigue-related crash. The NSW RTA (2001a) have also established a criterion for identifying fatigue as a contributing factor (p. xiv). However, these criteria differ thus there is no universal measure. Even between the operational definition constructed by the Australian Transport Safety Bureau (ATSB, 2000) and NSW RTA, there is a 'significantly different' criterion for determining fatigue involvement in crashes (NSW RTA, 2001b, p4). Furthermore, the ATSB maintain that their operational definition has its use as an index rather than an absolute measure of the number of fatigue-related crashes (ATSB, 2002).

However, even with criteria, reasoning that fatigue is the cause is almost arbitrary. It could be attributed to merely careless driving e.g. turning radio over, rather than fatigue as the 'cause'. Although fatigue could be wrongly attributed in some cases, overall, it is Fell, 1994; Horne and Reyner, 1995; Maycock, 1996; Sagberg, 1999). Maycock (1996) points out estimates derived from Police crash data will tend to be less than those derived from in depth studies. Sagberg (1999) has also found that self-reported involvement tends to give higher estimates than Police reports (p. 640). This may be due to behavioural considerations and non-recognition of fatigue as the crash cause.

2.3.3 Crash Likelihood and Injury Severity

The literature and statistics show that fatigue tends to be more prevalent as a contributing factor in high-severity crashes, that is, those that result in fatalities or serious personal injury.

The studies summarised here are two statistical reports from New South Wales (NSW) and Western Australia (WA), which use Police-reported crash data, and three other research studies. The research studies were Horne and Reyner (1999), n=606, Pack et. al. (1995), n=4,333, and Sagberg (1999), n=9,200. The estimated proportion of crashes that involved fatigue varies quite significantly throughout the literature and statistics. This may be due to the fact that the proportions are estimates only, or it may be due to the definition of terms such as 'serious crash'. The definition of this has been placed where appropriate.

Note that an ‘N/A’ has been placed where the relevant statistic was not mentioned in the study.

Between approximately 0.5% and 23% of total crashes are estimated to have fatigue-involvement, either as a primary or contributory cause (Table 1).

Table 1 Percentage of Total Crashes that involved Fatigue

Source	%
Data Analysis Australia (WA)	0.3 – 0.9
NSW RTA	7.4
Horne and Reyner	16 - 23
Pack et. al.	0.46
Sagberg	3.9

The proportion of fatal crashes that involved fatigue varied from approximately 1% to 18% (Table 2). There is a large discrepancy between the New South Wales (NSW) and Western Australia (WA) proportions which may be due to the measurement of fatigue.

Table 2 Percentage of Fatal Crashes that involved Fatigue

Source	%
Data Analysis Australia (WA)	1.2
NSW RTA	18
Horne and Reyner	N/A
Pack et. al.	N/A
Sagberg	N/A

The proportion of serious crashes that involved fatigue was estimated to be between 1% to 7%, approximately (Table 3).

Table 3 Percentage of Serious Crashes that involved Fatigue

Source	%	Definition of Serious
Data Analysis Australia (WA)	1.2	Fatal or hospital
NSW RTA	7.25	Fatal or injury
Horne and Reyner	N/A	
Pack et. al.	N/A	
Sagberg	N/A	

Between approximately 1.4% and 3.1% of fatigue-related crashes were fatal (Table 4). This appeared to be consistent across the studies.

Table 4 Percentage of Fatigue-Related Crashes that were Fatal

Source	%
Data Analysis Australia (WA)	1.9 – 3.1
NSW RTA	2.73
Horne and Reyner	N/A
Pack et. al.	1.4
Sagberg	N/A

The proportion of fatigue-related crashes that were considered serious varied from 22% to 41.5% (Table 5). Although the difference between these estimates is quite large, the magnitude of the estimates still suggests that a relatively large proportion of fatigue-related crashes involved serious injuries.

The apparently severe effects of fatigue may be confounded with some of the other contributing factors to a crash, however. Sagberg (1999) states that the higher severity of the crashes attributed to fatigue may be due to a higher prevalence of driver sleepiness on major roads, especially in rural areas, where driving speeds are higher. However, it must be remembered that the low-intensity crashes due to fatigue are less likely to be reported thus inflating the proportion of the more high-intensity related crashes and also contributing to the under estimating of fatigue-related crashes. This is supported by Horne and Reyner (1995) who agree that fatigue-related crashes are more likely to result in high-severity crashes due to the high speed of the vehicles on impact.

Table 5 Percentage of Fatigue-Related Crashes that were Serious

Source	%	Definition of Serious
Data Analysis Australia (WA)	22.3 – 34.5	Fatal or hospital
NSW RTA	41.5	Fatal or injury
Horne and Reyner	22 - 23	Fatal or hospital
Pack et. al.	37.7	Fatal or injury
Sagberg	N/A	

Fatigue-related crashes also differ according to many of the exogenous and endogenous factors mentioned in section 2.3.1, such as sex and road type.

2.3.4 Age and Sex of driver

The literature identifies males, under the age of 30, as being one of the most at risk groups for being involved in a fatigue related crash (Maycock, 1996).

In the study by Horne and Reyner (1995) it was concluded that drivers under the age of 30 seemed particularly at risk where 82% of the drivers in this group were men. The proportion of males to females involved in fatal fatigue-related crashes is significantly higher. In the five years from 1996 to 2000 the relative proportions of males to females were 79% to 21% (NSW RTA, 2001b). Sagberg (1999) also found that more males than females were involved in sleep-related crashes. In their study, a total of 10% of male drivers and 4% of female drivers reported to have fallen asleep behind the wheel during the last 12 months, with a total of 4% of these events resulting in an accident. NSW RTA

(2001a) reported 21% of the fatigued drivers and motorcycle riders involved in fatal accidents were males aged 17-25 years.

However, it is not clear as to whether men are a particularly at risk group or are simply more exposed to the situation in which the higher proportion of fatigue-related crashes occur, such as on roads with high speed limits or in the early morning (Horne and Reyner, 1995). Sagberg (1999) points out that the higher proportion could be explained by males driving relatively more than females on roads with high speed limits. In their study, when the variable 'speed limit' was entered into their logistic regression, the effect of sex was no longer significant, which suggests the relatively higher proportion of males involved in a fatigue-related crash can be attributed to their higher exposure to high-speed roads. Thus the effect of sex may be confounded with other factors, such as speed.

2.3.5 Time of Day

Fatigue-related crashes have been found to be clearly dependent on time of day and are over-represented in the early morning hours. However, the precise time of day differs slightly across the literature, but all suggest early morning and vary from early to late afternoon. In the regression model produced by Sagberg (1999), the strongest predictor variable was hour of crash ($p<0.0001$) where the odds of fatigue being related to a crash increases by about six, if the crash occurs between midnight and 06:00.

Sagberg found that fatigue was involved in 18.6% of the crashes between midnight and 06:00. Horne and Reyner (1995) concluded that there were clear time of day effects with the most prevalent times being around 02:00-07:00, especially between 2:00-3:00, and in the mid-afternoon. The NSW RTA (2001b) found that the most prevalent times were between 04:00-0:800 and 12:00-14:00. They also reported that of the fatal crashes in which fatigue was identified as a contributing factor, 32% occurred between 04:00-08:00 and 21% occurred between 12:00 and 14:00.

Time of day was also found to be related to the factor age. Pack et. al. (1995) found that there were clear time of day effects in which crashes occurred predominantly in night-time hours and late afternoon, and also found that this varied as a function of age. Younger drivers were more prevalent during night-time hours, whereas crashes involving older drivers tended to occur in the late afternoon. Horne and Reyner (1995) also found that males under the age of 30 were the most prevalent group during these hours. Pack et. al. also reported that this temporal variation was clearly different to crashes attributed to alcohol, where their frequency began to decrease after 3am, rather than increase as with fatigue. Summala and Mikkola (1994) also reported this.

2.3.6 Driving Location

It has been consistently noted that the contribution of fatigue to crashes is greater in rural areas, motorways and other monotonous-type roads where the speed limit tends to be high.

The NSW RTA (2001a) report states that of the fatal crashes, fatigue was identified as a factor in 11% of metropolitan crashes, whilst in rural areas it was identified as a factor in 24% of crashes. Of fatal crashes where fatigue was identified as a factor, 25% occurred in the metropolitan area, 12% on country urban roads and 63% occurred on country non-urban roads, defined to be rural roads with speed limits of 80 km/h or more. The proportion of fatigue-related crashes occurring on country non-urban roads has increased from 24% to 34% during 1996-2000, whilst the proportions for metropolitan and country urban areas have remained approximately the same. Crashes occurring on rural non-urban roads appear to be a key group for fatigue-related policies to be targeted.

Motorways or freeways also appear to be a prevalent type of road on which a considerable proportion of fatigue-related crashes occur (Horne and Reyner, 1995). The NSW RTA (2001a) found that 46% of fatal crashes, which involved fatigue as a factor occurred on State highways. This compares with 27% relating to all other factors being the cause. Haworth (1998) also states that fatigue-related crashes are more common on non-urban highways than on urban roads. One reason for this is that average trip lengths are likely to be longer on these roads and thus the constant speeds and monotony will bring on inattention and drowsiness.

As already pointed out, the type of road may be confounded with other factors such as 'speed limit', 'trip length' or even 'monotony of road environment'. That is, crashes are not more prevalent on non-urban roads or motorways, but on roads in which the speed limit is high, the trip is long or the road is highly monotonous, where there is little driver stimulus to keep the driver awake. The NSW RTA (2001a) found that 64% of fatal crashes identifying fatigue as a factor occurred on roads where the speed limit was 100 km/h or more. This compares with 33% of crashes within the same speed limit identifying other causes as a factor. Pack et. al. (1995) found that speed in excess of 80 km/h was also significantly higher for fatigue-related crashes (62.4%) than for alcohol-related crashes (41.6%) or crashes associated with other causes (15.0%). Haworth (1998) notes that crashes occurring in non-urban areas tend to be severe due to the high-speed roads and because fatigued drivers tend not to take evasive action. Sagberg (1999) investigated the relationship of trip length to the proportion of fatigue-related crashes. The relationship was clearly non-linear and appeared to be described quite well by a logarithmic function. Thiffault and Bergeron (2002) focused on the issue of road monotony and driver fatigue in their paper.

2.3.7 Other Studies

In Sagberg's (1999) study, the logistic regression analysis found the following factors made significant and independent contributions to increasing the odds of sleep involvement in a crash:

- Time of day - between midnight and 06:00
- Type of accident - running-off-the-road type accident
- High speed limit - 60 km/h or higher
- Type of injury - personal injury accident
- Condition of road - dry road
- Type of car - driving one's own car
- Distance driven
- Not driving the car daily
- High education
- Few years of driving experience.

The regression model showed the strongest predictor to be hour of the crash ($p<0.0001$). The variable 'car ownership' and 'frequency of driving' are not significant when considered in isolation but were significant when both were entered into the model (p. 642).

It is noted that ‘age’, ‘gender’ and ‘annual driving distance’ did not produce any additional significant effects. These were able to be explained by other factors. The effect of gender was able to be explained by the independent variable ‘speed limit’, when entered into the regression equation. The effect of age was captured by the variable ‘number of years driver’s licence was held’.

2.3.8 Drivers’ attitudes to Fatigue

Fatigue is continually being recognised as a major factor contributing to road crashes. The Australian Transport Safety Bureau (ATSB, 2000) CAS197 2000 survey (n>1000) reported fatigue as the third most often mentioned factor perceived as a causal factor in road crashes, after speed and alcohol. The proportion including fatigue as one of the top three factors was 30%, with nearly one in ten people suggesting fatigue as the main cause. Lack of concentration is mentioned as the fourth most common crash cause. In the Sagberg (1999) study, n=3239, 3.9% of drivers reported that fatigue contributed to their crash.

- **State and Territory Comparisons**

  As reported by the ATSB (2000, p18), fatigue as a crash cause is mentioned most in the ACT (37%), Queensland (35%), and NSW (34%). Significant decreases in overall mentions of fatigue have been recognised in the Northern Territory (down from 40% to 26%), South Australia (down from 34% to 25%) and Tasmania (down from 29% to 19%).

- **City: Rural**

  While speed and drink-driving are mentioned at a similar frequency in both capital cities and rural locations (p18), fatigue is more commonly recognised as a crash cause by the rural community (38% compared with 26% in the cities).

- **Age**

  The 60 and over age group is significantly less likely than younger people to mention driver fatigue (p16) as a factor associated with crashes.

2.3.9 Crash Characteristics (identifying a crash as fatigue-related)

- **Driving off road**

  Pack et. al. (1995) found that 78.5% of the total fatigue-related crashes were where the driver drove off the road, either to the left or right. This compares with 48.4% of alcohol- related crashes and 9.0% crashes caused by other factors. Sagberg (1999) found that the most frequent consequence of falling asleep was crossing the outer-line before awakening (40%), whereas crossing the centre line was reported by 16%.

- **Single Vehicle**

  Pack et. al. (1995) found that amongst fatigue-related crashes, 77.5% involved a single vehicle, compared with 50.7% for alcohol-related and 8.7% crashes caused by other factors.

- **Type of Car**

  In the Horne and Reyner study (1995), of the vehicles involved (in Study 1), 81% were cars while 9% were light trucks. Sagberg (1999) found that driving one's own car is associated with fatigue-related crashes.

2.3.10 Summary of factors relating to fatigue

In summary, the typical features found in a fatigue-related crash were :

- Male drivers, aged under 30 years;
- Early morning (normal sleeping hours) and afternoon occurrence;
- Country, especially non-urban roads occurrence;
- Motorways, freeways or high-speed roads occurrence;
- High impact or high severity crashes, and
- Single vehicle crashes.

The following chapter reviews the procedures that were put in place by the NSW RTA regarding the identification of speeding-related and fatigue-related crashes, and assesses their suitability for application to the Victorian situation.

3. REVIEW OF NSW PROCEDURES

The New South Wales Roads and Traffic Authority (NSW RTA) has had procedures for identifying speeding-related and fatigue-related reported crashes for many years, based on the reporting officer's opinion of the presence of the behaviour and whether the vehicle manoeuvered in a way characteristic of the behaviour. These procedures were examined as part of this study to determine if they were applicable to the Victorian context.

3.1 METHOD

The NSW RTA were contacted to determine the rationale underlying their identification procedures, e.g. whether the procedures had been derived or tested on crash data, independent of NSW Police crash reports, in which the role of speeding and fatigue has been determined, or whether other methods were used.

Information was provided as to how NSW Police data was used to determine speed-related and fatigue-related crashes. The following section describes the identification criteria.

3.2 CRITERIA FOR DETERMING SPEEDING AND FATIGUE INVOLVEMENT

3.2.1 Speeding

The identification of speeding (excessive speed for the prevailing conditions) as a contributing factor in road traffic crashes cannot always be determined directly from Police reports of those crashes. Certain circumstances, however, suggest the *involvement* of speeding. The NSW RTA has therefore drawn up criteria for determining whether or not a crash is to be considered as having involved speeding as a contributing factor.

Speeding is considered to have been a contributing factor to a road traffic crash if that crash involved at least one speeding motor vehicle.

A motor vehicle is assessed as having been speeding if it satisfies the conditions described below under (a) or (b) or both,

(a) The vehicle's controller (driver or rider) was charged with a speeding offence; or the vehicle was described by Police as travelling at excessive speed; or the stated speed of the vehicle was in excess of the speed limit.

(b) The vehicle was performing a manoeuvre characteristic of excessive speed, that is:

- while on a curve the vehicle jack-knifed, skidded, slid or the controller lost control; or
- the vehicle ran off the road while negotiating a bend or turning a corner and the controller was not distracted by something or disadvantaged by drowsiness or sudden illness and was not swerving to avoid another vehicle, animal or object and the vehicle did not suffer equipment failure.

3.2.2 Fatigue

The identification of fatigue as a contributing factor in road traffic crashes similarly cannot always be determined directly from Police reports of those crashes and the following criteria are used to assess its involvement. Fatigue is considered to have been involved as a contributing factor to a road traffic crash if that crash involved at least one fatigue motor vehicle controller.

A motor vehicle controller is assessed as having been fatigued if the conditions described under (c) or (d) are satisfied together or separately.

(c) The vehicle's controller was described by Police as being asleep, drowsy or fatigued.

(d) The vehicle performed a manoeuvre which suggested loss of concentration of the controller due to fatigue, that is:

- the vehicle travelled onto the incorrect side of a straight road and was involved in a head-on collision (and was not overtaking another vehicle and no other relevant factor was identified); or
- the vehicle ran off a straight road or off the road to the outside of a curve and the vehicle was not directly identified as travelling at excessive speed and there was no other relevant factor identified for the manoeuvre.

3.3 FEASIBILITY OF ADOPTING NSW PROCEDURES FOR VICTORIA

These criteria indicate that the identification of speeding-related and fatigue-related crashes is *derived* from Police data, rather than being tested on crash data or being independent of the Police crash reports. It is thus questionable whether these procedures have sufficient scientific basis to warrant directly adopting them for the Victorian Police-reported crash data.

It is therefore recommended to not adopt the same procedures described in section 3.2 for use on Victoria Police crash reports because of their insufficient scientific basis, and also because there are too many important differences between Victorian and NSW crash reports.

Because the NSW procedures were determined to be unsuitable, there was a need to investigate whether the identification of speeding-related and fatigue-related crashes directly from mass reported crash data is feasible at all for Victoria. It was therefore proposed to obtain data from recent in-depth crash investigations in which the degree of speeding and/or fatigue was determined objectively. These data would then be matched with Police crash reports for the same crashes, if possible. This would allow for key Police report data and appropriate functions of this information to be identified that discriminates most effectively between whether the crash involves the behaviour (speeding or fatigue, respectively) or not.

The next chapter describes the process, data issues and difficulties associated with obtaining the speed-related and fatigue-related crash data from the in-depth crash investigations.

4. FEASIBILITY OF DISCRIMINATING SPEEDING-RELATED AND FATIGUE-RELATED CRASHES

To conduct this component of the project, it was necessary to obtain data from recent in-depth crash investigations in which the degree of speeding and/or fatigue had been determined objectively. Two studies were identified as being potentially appropriate. One, a study conducted by the New South Wales Roads and Traffic Authority (NSW RTA) was believed to contain crashes where the presence or absence of fatigue had been determined using pre-defined criteria. The other, a study conducted by the NHMRC Road Accident Research Unit, RARU, of the University of Adelaide, determined the free travelling speeds of approximately 150 vehicles involved in crashes. The data issues associated with both these studies are described in the following sections.

4.1 FATIGUE DATA

The NSW RTA has undertaken a detailed Crashed Vehicle Study primarily to determine the role of the vehicle condition in crashes. The NSW RTA'S Crashed Vehicle Study involved a detailed examination of approximately 4,500 vehicles involved in crashes throughout New South Wales from 1995 to 1998. Details of this study can be found in Holgate, Harkness and Vertsonis (1999).

This study was designed to examine the relationships between vehicle defects and road safety, however it was understood by MUARC, based on earlier correspondence with the NSW RTA, that this data may also identify the presence of other causal factors, in particular fatigue. Although about 4,500 vehicles were included, it was expected that only in some cases would the investigators state that fatigue was or was not present. It was therefore hoped that it would be feasible to match this sub-set of cases with NSW Police crash reports already held by MUARC for use in other research studies. The matched data could then be used to test the existing NSW procedures for identifying fatigue in mass crash data and, if necessary, develop a new procedure.

In an effort to obtain the data used in the study, further correspondence with the NSW RTA revealed that behavioural causal factors were in fact not identified. The NSW RTA in-depth crash investigation was designed to examine the relationships between vehicle defects and road safety, and as such, the data gathered was essentially based on vehicle information such as vehicle controls, suspension, steering, tyres and chassis.

On this basis the NSW RTA data was determined to be unsuitable for the identification of fatigue-related crashes. Consequently, the study's objective to identify fatigue in Victoria's mass crash database of Police records was not feasible at this stage.

It should also be noted that the NSW Police crash data contains some highly sensitive information, in the form of a narrative that describes what happened in the crash and also lists personal details about the people involved. However, this information was not made available to MUARC and thus could also not be used in the identification of fatigue-related crashes.

4.2 SPEED DATA

The NHMRC Road Accident Research Unit, RARU, of the University of Adelaide, completed a study into the effect of free travelling speed on the risk of involvement in a casualty crash in a 60 km/h urban speed limit setting in Adelaide (Kloeden et al, 1997a & 1997b).

This study involved determining the travel speed of approximately 150 vehicles involved in crashes during 1995-1997 using accident reconstruction techniques. Travelling speed was defined as 'the speed of a vehicle moving along a mid-block section of road, or with right of way through an intersection, and not slowing to join, or accelerating away from, a traffic stream'.

Travelling speeds were determined only for those vehicles that had a free travelling speed prior to the crash, using computer-aided reconstruction techniques. These vehicles were identified as case vehicles and comprised only of passenger cars or passenger car derivatives. Inclusion of a case vehicle was also limited to one whose driver had a Blood Alcohol Concentration (BAC) reading of zero to eliminate confounding the results of the study with alcohol impairment. Each crash reconstruction conducted is documented in Kloeden et al (1997b). The case vehicle criteria used in RARU's study are set out in Appendix A.

MUARC was able to obtain the vehicle speed data from RARU. To allow for the development of a procedure to identify speeding in mass crash data, the feasibility of matching this vehicle speed information with South Australia Police crash reports was examined. The methodology used in this matching process is described in the next section.

4.3 MATCHING VEHICLE SPEED DATA WITH POLICE CRASH REPORTS

Initial efforts to acquire RARU's vehicle speed data, involved seeking permission from the South Australia Police (SAPOL) to obtain the 148 South Australia Police vehicle collision reports used in the *Travelling Speed and the Risk of Crash Involvement* study (Kloeden et al, 1997a & 1997b). This entailed a written request to the manager of the Information Services Branch of SAPOL outlining detailed confidentiality and security procedures that MUARC would observe in handling the data. Access to the collision reports was granted on the understanding that certain conditions outlined by SAPOL would be adhered to whilst carrying out the study.

Once permission from SAPOL had been granted, RARU supplied hard copies of 146 of the 148 vehicle collision reports to MUARC for crashes that occurred between January 1995 and January 1997. Two collision reports could not be provided at the time of the data request.

In the course of their crash investigations, RARU researchers assigned a separate identification number to each Police collision report used in their study. Only these RARU identification numbers identify each crash reconstruction in Kloeden et al (1997b). To facilitate the merging of crash information in the electronic SA crash database with that in Kloeden et al (1997b), a document matching the Police collision report numbers with the RARU identification numbers was also supplied with the collision report forms.

The Police collision report numbers for the 146 crashes were used as identifiers to extract information from the South Australia crash database that was provided to MUARC by SA Transport. The corresponding information was extracted for 144 crashes. Two SA Police collision numbers could not be found in the SA crash database, hence information from these reports was keyed directly into the database. Four items not included in the crash database but available on the collision report forms were added. These variables were:

- Total damage (of crash)
- Residential postcode
- Crash site postcode
- RARU accident number

The following variables, obtained from the *Volume 2 – Case and Reconstruction Details* of RARU's *Travelling Speed and the Risk of Crash Involvement* report (Kloeden et al, 1997b), were also added to the database:

- RARU identification numbers (e.g. CN065)
- Pre-crash travelling speed
- Impact speed
- Delta V[1]

Transferring the pre-crash travelling speeds from RARU's reconstruction details was a lengthy, and at times, difficult process. This was because the *vehicle unit* labelling system differed between that in the Police collision reports and that in RARU's diagrammatic explanations. Therefore, each Police crash summary had to be read in conjunction with RARU's crash summary to ascertain which of the vehicle unit numbers in the Police collision reports corresponded to the case vehicle in RARU's crash reconstructions. Once the corresponding Police-assigned vehicle unit number was established, the travelling speeds for each vehicle were then incorporated into the database.

In carrying out this process, confirmation of crash locations (obtained from the Police collision reports) was made using an Adelaide street directory. Street names and 'north arrows' were added to the RARU diagrammatic maps to better follow the narrative in the Police collision reports, as many of the 'north arrows' in the diagrammatic explanations were inconsistent with those in the street directory.

Difficulties in ascertaining the vehicle unit numbers were experienced with two crashes. This arose in crashes involving three vehicles where it was not specified for *which* vehicle the crash reconstruction had occurred. However, for most of the reconstructions in *Volume 2 – Case and Reconstruction Details*, information from the hypothetical scenarios specified the unit number for each vehicle involved in each crash. This therefore made it relatively easy to distinguish which vehicle unit was the case vehicle.

Through a process of elimination and careful judgement, the vehicles most likely to be the case vehicles in the two three-vehicle crashes were established and added to the database.

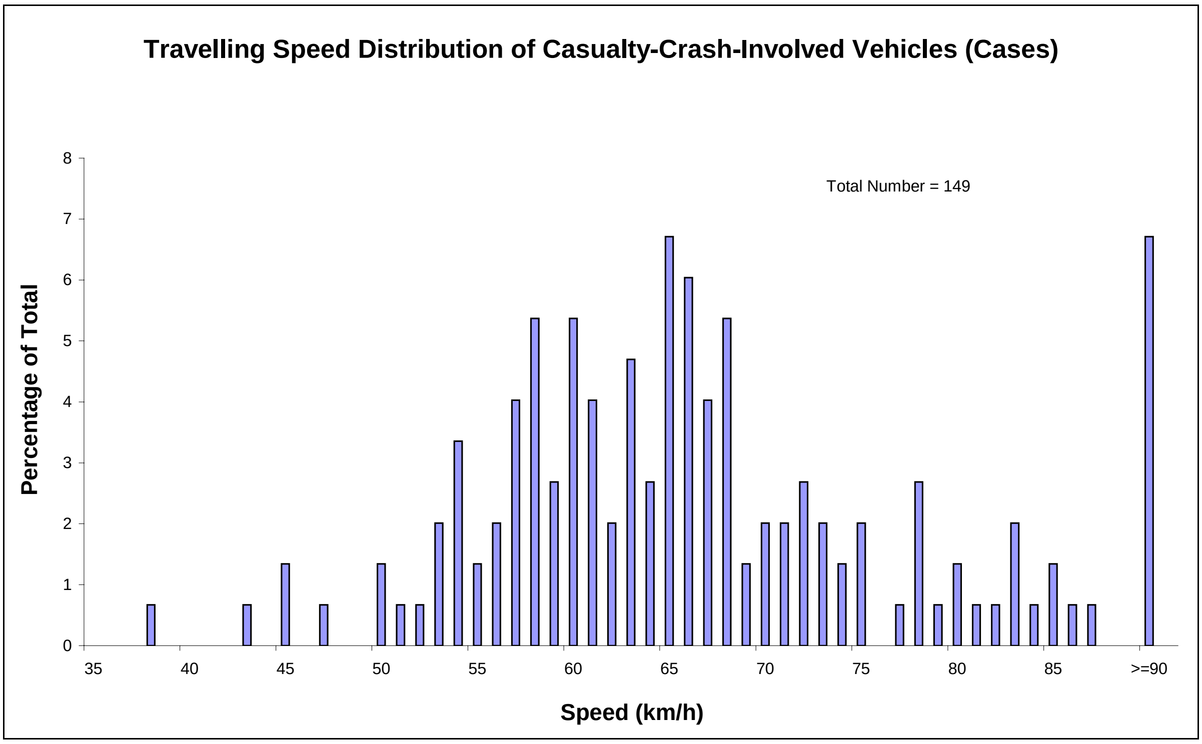
4.3.1 Distribution of speeds

The above matching process of the S.A. Police crash data with the RARU case study data resulted in a database of 149 *crashed vehicles* for analysis.

The pre-crash travelling speed distribution of the casualty crash-involved vehicles is shown below. The mean travelling speed was 67.5 km/h, and 6.7% of the crashed drivers had speeds of at least 90 km/h.

---

[1] The change in velocity at impact for those injured in a crash .



4.3.2 Distribution of Variables in Database

Frequency distributions for each of the variables in the matched database of the 149 crashed vehicles are given in Appendix B. The variables contained in the database included: age and sex of driver; total vehicle damage sustained in crash; unit damage; unit movement; crash severity; crash type; apparent driver error; number of vehicle occupants; crash location; time of day of crash; traffic control type; day of week of crash and road alignment.

The characteristics of the crashes and drivers were predominantly:

- Male drivers;
- Drivers aged 26-59 years;
- Two-unit crashes;
- Travelling vehicle speeds of 60-69 km/h;
- Single occupant crashes;
- Right-turn or right-angle crashes, and
- Total Vehicle damage between $5001-$10,000.
- No apparent driver error recorded.

Using the available variables in the matched database the next chapter gives the results of a statistical analysis of the data to identify the characteristics that may discriminate speeding in Police-reported crash data.

5. STATISTICAL ANALYSIS

5.1 METHODS

General linear modelling (GLM) and logistic regression analysis were the statistical methodologies used to analyse the data. GLM performs an analysis of variance for dependent variables (i.e. travel speed) by one or more factor variables or covariates. The factor variables divide the population into groups. Using the general linear model procedure, the hypotheses about the effects of factor variables on the means of various groupings of the dependent variable can be tested. GLM allows for the testing of both balanced and unbalanced models, which is useful when each cell in the model does not contain the same number of cases. It is assumed that for the dependent variable (speed) the data are from a multivariate random population.

Logistic regression analysis models the proportion of crashed drivers in the data set in which the presence of speeding was present or absent.

The aim was to develop statistical models using these variables as potential factors in the identification of speed-related crashes.

The data was prepared for analysis by matching the South Australia Police crash data with RARU's in-depth case study data. The data was analysed using the procedure PROC GLM in the statistical software package SAS, Version 8.02 (Cody & Smith, 1997), the GLM Univariate procedure in the statistical package SPSS Version 10.0.5, and the LOGISTIC REGRESSION procedure in the statistical package SPSS Version 10.0.5.

5.2 DATA

The dependent variable used in the general linear model (GLM) was the travelling speed of each vehicle. The categorical factors considered for the analysis are given in Table 6.

Table 6 Categorical Factors used in the General Linear Model (GLM)

FACTOR	CATEGORY
Driver age	≤ 25 years (young) 26-59 years (middle) ≥ 60 years (old)
Driver sex	Male or female
Crash severity	Fatal or injury
Crash type	Rear-end Head-on Right angle Hit pedestrian/fixed object/parked vehicle Right turn Side-swipe
Total vehicle damage cost in crash	≤ $5,000 $5,001-$9,999 $10,000-$14,999 ≥ $15,000
Day of week	Sunday; Monday; Tuesday; Wednesday; Thursday; Friday; Saturday
Apparent driver error	Error or no error
Licence type	Full Learner/probationary
Locational Region of crash	Inner city or Other Metropolitan
Time of crash	8:00 a.m.-10:59 a.m. 11:00 a.m. – 1:59 p.m. 2:00 p.m. –4:59 p.m. 5:00 p.m. – 7:59 a.m.
Traffic control	Control or No control
Vehicle damage	Extensive/unrepairable Major towed away Moderate towed away Moderate driveable/minor/nil
Vehicle movement	Straight ahead or Other manoeuvre

5.3 MODELLING RESULTS

5.3.1 General Linear Models

The matched data initially consisted of 149 cases in which the travelling vehicle speed was estimated for crashes occurring in the Adelaide metropolitan area during 1995-1997. The general linear modelling analysis was performed on 148 of these cases because of missing values associated with the explanatory factors.

Two models were fitted to the data. The first 'The Main Effects Model' included only the factors given in Table 6, whilst the second "The Interactions Model" also considered possible interactions between these factors.

5.3.1.1 The Main Effects Model

A general linear model was estimated using the variables given in section 5.2 as potential explanatory factors of speed without considering any possible interactions effects between these factors.

The statistical analysis of the matched data identified driver age, driver sex, crash severity, vehicle damage as statistically significant factors associated with speed ($p<0.05$). The time of day of the crash was marginally significant ($p<0.07$), as was the movement of the vehicle prior to the crash ($p<0.15$). The other potential explanatory factors in the matched database were not found to be statistically significant. Table 7 displays the statistically significant main effects from the estimated general linear model.

Table 7 MAIN EFFECTS MODEL: Significant factors estimated from the GLM analysis

Factor	Degrees of freedom	Sum of Squares	Mean Sum of Squares	F-value	p-value
Driver age	2	1386.9	693.4	4.30	0.0155***
Driver sex	1	2002.8	2002.8	12.41	0.0006***
Crash Severity	1	1560.4	1560.4	9.67	0.0023***
Vehicle damage	3	2512.6	837.5	5.19	0.0020***
Time of day	3	1200.3	400.1	2.48	0.0638**
Vehicle movement	1	349.3	349.3	2.16	0.1435*
R^2 value	*32.0% (unadjusted); 26.5% (adjusted)*				

****Statistically significant at the 5% level*
***Statistically significant at the 7% level*
**Statistically significant at the 15% level*

For each level of the significant factors displayed in Table 7, the least-squares adjusted mean travel speeds were estimated (Table 8).

Driver Age

The pairwise comparisons between the three age-groups found statistically significant differences in mean travel speeds between:

- Drivers involved in crashes aged ≤ 25 years and those aged ≥ 60 years (Bonferroni adjustment for multiple comparisons, p=0.030), i.e. a difference in average speed of 9.3 km/h, and
- Drivers involved in crashes aged ≤ 25 years and those aged 26-59 years (Bonferroni adjustment for multiple comparisons, p=0.057), i.e. a difference in average speed of 5.9 km/h.

Thus crash-involved drivers aged ≤ 25 years have significantly greater travelling speeds on average (80.3 km/h) than crashed drivers aged ≥ 60 years (71.0 km/h) and those aged 26-59 years (74.4 km/h).

Driver Sex

The pairwise comparison between the two genders showed that male drivers involved in crashes have statistically significantly greater average vehicle speeds than female drivers (79.3 km/h and 71.2 km/h, i.e. a difference of 8.1 km/h).

Crash Severity

Fatal crashes were associated with significantly larger average vehicle travel speeds than injury crashes (82.8 km/h and 67.7 km/h, i.e. a difference of 11.6 km/h).

Vehicle Damage

The pairwise comparisons between the **vehicle damage** levels found statistically significant differences in mean travel speeds between:

- Crash-involved drivers with extensively damaged vehicles and those with minor vehicle damage (Bonferroni adjustment for multiple comparisons test, p=0.001);
- Crash-involved drivers with major damage towed-away vehicles and those with minor vehicle damage (Bonferroni adjustment for multiple comparisons test, p=0.042), and
- Crash-involved drivers with moderate damage towed-away vehicles and those with minor vehicle damage (Bonferroni adjustment for multiple comparisons test, p=0.039).

Thus the level of vehicle damage sustained in the crash is associated with travel speed. Extensively damaged, unrepairable vehicles had statistically significantly larger mean travel speeds (81.5 km/h) than those with minor damage (67.1 km/h).

Time of day of crash

The pairwise comparisons between the **time of day** categories found a marginally statistically significant difference in mean travel speed between:

- Drivers who crashed during the morning period of 8:00 a.m.-10:59 a.m. and those who crashed during the middle of the day 11:00 a.m-1:59 p.m. ((Bonferroni adjustment for multiple comparisons test, p=0.064).

Based on this sample of crashed drivers, mean travel speeds were greater for crashes occurring during morning hours than for crashes occurring during the middle of the day. It should be noted however, that the data obtained from the RARU crash study mainly consisted of crashes occurring during the daylight hours. There were few night crashes in which the travel speed of the crash-involved vehicle was estimated.

Vehicle movement

Crash-involved vehicles that were *not* travelling straight ahead prior to the crash had larger average travel speeds than those travelling straight ahead (78.3 km/h and 72.2 km/h, respectively). The differences in these average travel speeds were only statistically significant at the 15% level, however.

Table 8 Least squares adjusted mean travel speed for significant main effects together with 95% confidence intervals

SIGNIFICANT FACTOR	MEAN TRAVEL SPEED (km/h)	95% confidence interval for mean travel speed	
Driver age		**Lower bound**	**Upper bound**
≤ 25 years	80.3	73.7	86.9
26-59 years	74.4	67.9	80.8
≥ 60 years	71.0	62.8	79.3
Driver sex			
Male	79.3	73.2	85.4
Female	71.2	64.1	78.3
Crash severity			
Fatal	82.8	72.8	92.8
Injury	67.7	63.0	72.4
Vehicle movement			
Straight ahead	72.2	66.8	77.7
Other manoeuvres	78.3	69.3	87.2
Vehicle damage			
Extensive – unrepairable	81.5	74.3	88.6
Major – towed away	76.3	69.2	83.5
Moderate – towed way	76.0	69.0	83.1
Minor – driveable/nil	67.1	59.1	75.1
Time of crash			
8:00am – 10:59am	79.0	71.4	86.7
11:00am – 1:59pm	71.0	64.8	77.3
2:00pm – 04:59pm	75.5	68.7	82.2
5:00pm – 07:59am	76.4	65.3	85.4

Summary of GLM findings for the 'main effects' model

Based on the matched database of South Australia Police crashes and the RARU in-depth crash study, crashes with larger average vehicle speeds were more likely to:

- involve young drivers aged ≤ 25 years;
- involve male drivers;
- involve a fatality;
- have extensive, unrepairable vehicle damage;
- occur between 8:00 a.m-11:59 a.m.;
- involve vehicle manoeuvres other than 'straight-ahead' (e.g. left or right turn, swerving manoeuvres).

All other available variables in the matched database (i.e. crash type, driver error, location, day of week) were not statistically significantly associated with speed.

5.3.1.2 The model with interactions

The statistical analysis identified the following combination of interactions to be statistically significant in predicting vehicle speed, when combined with the main effects model from section 5.3:

- Time of Day * Vehicle Damage
- Time of Day * Vehicle Movement
- Time of Day * Crash Severity.

When these interactions were considered in the model, the vehicle movement variable was no longer significant (p- value = 0.703), as its contribution in predicting vehicle speed was now captured by the interaction effects. Therefore this variable was redundant and removed from the model. Table 9 displays the statistically significant main effects and interactions obtained from the general linear model.

Table 9 INTERACTIONS MODEL: Significant Factors and Interactions estimated from the GLM Analysis

Factor	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F-value	p-value
Driver Age	2	1751.8	875.9	6.38	0.0023 ***
Driver Sex	1	1823.8	1823.8	13.29	0.0004 ***
Time of Day	3	2463.0	821.0	5.98	0.0008 ***
Vehicle Damage	3	859.7	286.6	2.09	0.1052 *
Crash Severity	1	463.0	463.0	3.37	0.0686 **
Time of Day * Vehicle Damage	9	2318.8	257.6	1.88	0.0614 **
Time of Day * Vehicle Movement	3	1101.6	367.2	2.68	0.0502 **
Time of Day * Crash Severity	3	1102.8	367.6	2.68	0.0500 ***
R^2 value	*48.2% (unadjusted); 37.5% (adjusted)*				

**** Statistically significant at the 5% level*
*** Statistically significant at the 7% level*
** Statistically significant at the 11% level*

5.3.2 Logistic Regression Analysis

5.3.2.1 Drivers with vehicle speeds of at least 60 km/h

In addition to the “main effects” general linear model estimated in section 5.3.1.1, a logistic regression model was fitted to the matched data to ascertain what factors were associated with the presence of speeding (at least 60 km/h) or the absence of speeding (below 60 km/h).

The forward stepwise selection procedure only identified the **location** of the crash as associated with speeding above 60 km/h. It was found that crashes occurring in metropolitan areas of Adelaide outside the CBD were about four times as likely to be speed-related than those occurring in the inner city area (estimated odds ratio of 4.29; p=0.012).

5.3.2.2 Drivers with vehicle speeds of at least 70 km/h

Another logistic regression model was fitted to the matched data to ascertain what factors were associated with the presence of speeding at or above 70 km/h. This analysis identified only the sex and age of the driver as significantly associated with being in a speed-related crash. **Male** drivers were almost five times as likely as female drivers to be in a crash in which their travel speed was at least 70 km/h (estimated odds ratio of 4.85; p=0.001).

Similarly young drivers aged ≤ 25 years were about **four** times as likely to be involved in a speed-related crash (at least 70 km/h) than drivers aged ≥ 60 years (odds ratio of 4.2; p=0.027), and almost three times as likely as drivers aged 26-59 years (odds ratio of 2.89; p-0.010).

Because only two factors, the location of the crash and the sex of the driver, were found to be significant identifiers of the proportion of speeding drivers, the results obtained from the logistic regression analysis were not used in the development of the speed indicator functions presented in the next chapter.

Chapter 6 uses the significant factors obtained from the 'main effects' and 'interactions' GLM models to develop indicator functions to identify speed-related crashes in Police-reported mass crash data.

6. DEVELOPMENT OF INDICATOR FUNCTIONS TO IDENTIFY SPEED

The matching of the in-depth crash study with South Australia Police crash reports identified a number of factors associated with driver speed, i.e.:

- male drivers;
- drivers aged 25 years or less;
- fatal crashes;
- extensively damaged vehicles;
- morning crashes;
- crashes in which the driver was performing a manoeuvre other than going straight ahead.

These factors were used to identify speed-related crashes in Victoria Police-reported mass crash data via functions based on the general modelling analyses (GLM) described in section 5.3.1.

The purpose of this part of the study was to develop indicator functions to predict travelling speed prior to a crash from the GLM analyses, which could be applied to Victoria Police-reported mass crash data. The analysis considered Police-reported Victoria crashes for the period 1984 – 2000.

6.1 DEVELOPING THE INDICATOR FUNCTIONS

The indicator functions were developed based on the significant predictor variables of travelling speed of drivers, that were found in the modelling analyses of the matched South Australia crash data (Section 5.3, Table 7 and Table 9).

To apply the South Australia findings to the Victoria crash data, both data sets had to be compatible. For this to occur, certain conditions had to be selected from the Victoria data set to match the conditions inherent in the South Australia in-depth-crash study. These were selecting only:

- crashes that occurred on roads in 60 km/h speed zones;
- "day-time" crashes (i.e. between 08:00 – 20:00, as defined in the South Australia mass crash database);
- crashes in urban areas as defined by the Local Government Area (i.e. areas in the Melbourne Statistical division);
- drivers;
- passenger cars or passenger car-derivatives (i.e., car, station wagon, taxis, utilities, panel vans).

This selection process allowed the data sets to be comparable so that variables found to be statistically significant predictors of driver speed in the South Australia data could be transferred to the Victoria Police-reported mass crash data. However, not all of the significant variables in the South Australia data were readily available in the Victoria mass crash data. Some of the variables had to be slightly adjusted and their coefficients (i.e.

parameter estimates) re-estimated to match the categories of the variables in the South Australia data (as defined in Table 6). The variables that were adjusted were:

Vehicle Movement

The variable 'Vehicle Movement' was found to be a significant factor in identifying speed in the South Australia crash data and consisted of the binary vehicle movements 'Straight Ahead' and 'Other Manoeuvre'. The Victoria Police-reported mass crash data, that was available to MUARC, did not have a directly matching variable. Hence, the vehicle movements were subjectively defined on the basis of the VicRoads Definition of Classifying Vehicles (DCA) categories. The reclassification used can be found in Appendix C.

Crash Severity

The South Australia crash severity variable had a binary outcome, either a fatal or injury crash. However, the Victoria data variable provided more information with the 'Crash Severity' level 'Injury' further divided into 'Serious' or 'Other'. To make use of the additional categorisation of the injury variable into serious and other, a weighting procedure was used on the South Australia crash severity variable to obtain appropriate parameter estimates for the serious and other injury levels.

Vehicle Damage

The 'vehicle damage' variable in the Victoria Police-reported data consisted of the following levels:

1. Nil
2. Minor
3. Moderate (driveable vehicle)
4. Moderate (unit towed away)
5. Major (unit towed away)
6. Extensive (unrepairable).

These levels did not directly match the South Australia 'vehicle damage' levels. However, the first three levels (i.e. nil, minor and moderate/driveable) were pooled together into one level to correspond with the South Australia variable levels. In addition, the 'vehicle damage' variable was not available for the years 1984-1988 in the Victoria crash data. Thus a related binary variable, *'towed'*, indicating whether the vehicle had been towed or not, was used in the regression model as a substitute for the 'vehicle damage' variable. Its coefficient was estimated using a weighted average of the parameter estimates from the variable 'vehicle damage'. Its calculation is shown in Appendix D. From 1989 onwards, this variable became readily available, and so was used for the 1989 – 2000 crashes.

Two main types of indicator functions were considered based on the models given in section 5.3. The first type of indicator function was based on a main effects model that assumed no interactions between factors (i.e. Table 7). The second model allowed for interactions and modelled them explicitly (i.e. Table 9).

6.2 THE MAIN EFFECTS MODELS

Two indicator functions to identify speed in mass crash data were created for analysis based on the main effects model. Model MAIN1 covered the full data period, 1984-2000. This model used the 'towed' variable to substitute for the 'vehicle damage' variable. Thus the coefficients for this related variable had to be approximated from the coefficients of the 'vehicle damage' variable. This process is described in Appendix D. Model MAIN2 included the 'vehicle damage' variable, but covered the data period 1989-2000 only. Therefore the two models were:

Model MAIN1: - Data range 1984 – 2000
- Uses the variable 'towed' to approximate vehicle damage.

Model MAIN2: - Data range 1989 – 2000
- Uses the original estimated variable 'vehicle damage'.

Table 10 gives the variables and their associated parameter estimates that were used to develop the indicator functions of driver speed based on the 'main effects' model. The differences between the two models with respect to each factor are shown in italics.

Table 10 Regression Models from the 'Main effects' GLM/ANOVA analysis

FACTOR OR VARIABLE	Coefficients or Parameter Estimates (km/h)	
	Model MAIN1 (1984-2000)	**Model MAIN2 (1989-2000)**
Intercept	54.4733	54.4733
Age Group (old)		
Young	9.2615	9.2615
Middle	3.3190	3.3190
Sex (female)		
Male	8.0933	8.0933
Time of Day (evening)		
Morning	3.6646	3.6646
Midday	-4.3240	-4.3240
Late Afternoon	0.1114	0.1114
Vehicle Movement (other)		
Straight Ahead	-6.0364	-6.0364
Crash Severity (Injury)		
Fatal	15.0848	15.0848
Serious	7.5424	7.5424
Towed (no)		
Yes	*10.2125*	n.a.
Vehicle Damage (Minor)		
Extensive		*14.3584*
Major - towed	n.a.	*9.2434*
Moderate - towed		*8.9233*

Note: Variable Level in brackets denotes reference group.

The reference groups, denoted in brackets, are the groups to which the other variable levels are compared. For example, age is referenced to 'old' drivers. If a particular observation consisted of a 'young' driver, the model from table 10 would predict this driver to be travelling 9.26 km/h faster than an 'old' driver. An observation with an 'old' driver would not have any additional speed added to it, as it is the reference group.

A numerical example of the indicator function is given below for both time periods:

For a crash having the following characteristics:

- Driver was *young* and *male*
- *Fatal* crash occurred in the *morning* while driving *straight* ahead
- *Extensive* vehicle damage, vehicle *towed*.

The average vehicle speed of the above crashed driver would be estimated as follows from the two 'main effects' models:

<u>Model MAIN1 (1984-2000)</u>:
Vehicle Speed of crashed driver
= (54.47 + 9.26 + 8.09 + 3.66 – 6.04 + 10.21) km/h = **79.65** km/h

<u>Model MAIN2 (1989-2000)</u>:
Vehicle Speed of crashed driver
= (54.47 + 9.26 + 8.09 + 3.66 – 6.04 + 14.36) km/h = **83.80** km/h

The average vehicle speed of crashed drivers falling into other demographic groups can be similarly estimated.

6.3 THE INTERACTIONS MODEL

Similarly two indicator functions were also developed based on the 'interactions model' obtained from the GLM analysis. These models were:

<u>Model INT1</u>: - Data range 1984 – 2000
- Uses the variable 'towed' to approximate vehicle damage.

<u>Model INT2</u>: - Data range 1989 – 2000
- Uses the original estimated variable 'vehicle damage'.

The variables and their associated parameter estimates based on the 'interactions' models are given in Table 11. The parameter estimates in this table were used to develop the indicator functions of driver speed. The differences between the two above models with respect to each factor are shown in italics.

Using the similar example as for the 'main effects' model, that is, for a crash having the following characteristics:

- Driver was *young* and *male*
- *Fatal* crash occurred in the *morning* while driving *straight* ahead
- *Extensive* vehicle damage, vehicle *towed*.

The average vehicle speed of the above crashed driver would be estimated as follows from the two 'interactions' models:

Model INT1 (1984-2000):
Vehicle Speed of crashed driver
= (22.41 + 11.61 + 7.98 + 35.99 +19.78+15.39-7.60-32.99) km/h = **72.57** km/h

Model INT2 (1989-2000):
Vehicle Speed of crashed driver
= (22.41 + 11.61 + 7.98 + 35.99 +19.78+11.99-13.35-32.99) km/h = **63.42** km/h

Table 11 Regression Models with 'INTERACTIONS'

FACTOR or VARIABLE	**Coefficients or Parameter Estimates (km/h)**	
	Model INT1	**Model INT2**
Intercept	22.413	22.413
Age Group (old)		
Young	11.6090	11.6090
Middle	4.8297	4.8297
Sex (female)		
Male	7.9837	7.9837
Time of Day (evening)		
Morning	35.9882	35.9882
Midday	22.6396	22.6396
Late Afternoon	38.8523	38.8523
Crash Severity (Injury)		
Fatal	19.7793	19.7793
Vehicle Damage (Minor)		
Extensive		*11.9918*
Major – towed		*19.9946*
Moderate – towed		*13.2207*
Towed (No)		
Towed	*15.3939*	
Time of Day * Vehicle Damage (Morning and Minor)		
Morning and Extensive		*-13.3499*
Morning and Major		*-20.2361*
Morning and Moderate		*-7.4924*
Time of Day * Vehicle Damage (Midday and Minor)		
Midday and Extensive		*-3.0489*
Midday and Major		*-11.3468*
Midday and Moderate		*-4.0059*
Time of Day * Vehicle Damage (Afternoon and Minor)		
Afternoon and Extensive		*12.7972*
Afternoon and Major		*-10.0233*
Afternoon and Moderate		*-7.9386*
Time of Day * Towed (Evening and No)		
Morning and Towed	*-7.5984*	
Midday and Towed	*-7.0846*	
Afternoon and Towed	*-2.2208*	
Time of Day * Vehicle Movement (Evening and Other)		
Midday and Straight	0.1784	0.1784
Afternoon and Straight	-15.8018	-15.8018
Evening and Straight	21.7738	21.7738

FACTOR or VARIABLE	Coefficients or Parameter Estimates (km/h)	
	Model INT1	Model INT2
Time of Day * Crash Severity (Evening and Injury)		
Morning and Fatal	-32.9936	-32.9936
Midday and Fatal	-11.6192	-11.6192
Afternoon and Fatal	10.7283	10.7283

Note: Variable level in brackets denotes reference group.

6.4 TESTING THE INDICATOR FUNCTIONS

The Victoria mass crash data consisted of Police-reported crashes from 1984 to 2000. The two 'main effects' models (Table 10) and the two 'interactions' models (Table 11), were applied to each observation in the subset of the Victoria data (i.e. considering only urban Melbourne, 60 km/h speed zones, day-time crashes) to give an estimate of the predicted vehicle speed of each crashed driver. The following speed measurements were obtained:

1. Monthly, Quarterly and Yearly Estimated Average Vehicle Speeds of crashed drivers for the periods January 1984–December 2000 and January 1989-December 2000.
2. The proportion of crashed drivers with estimated vehicle speeds >75 km/h per month and per quarter for January 1984-December 2000 and January 1989-December 2000.
3. The proportion of crashed drivers with estimated vehicle speeds >90 km/h per month and per quarter for January 1984-December 2000 and January 1989-December 2000.

The aim was to see if there had been any changes over time in average vehicle speeds of crashed drivers or in the proportion of drivers exceeding the speed limit in metropolitan (urban) areas on 60 km/h roads for crashes that occurred during daytime hours.

Initially the Victorian speed camera program occurred primarily in urban areas during low alcohol times of the week. These times of the week mainly correspond with daytime hours. Hence, trends in speed outcomes could then be compared to the Victorian speed enforcement programs to determine whether there had been a change in average speed or in the proportion of crashed drivers exceeding the speed limit excessively as a response to these initiatives.

6.4.1 Trends in Average Vehicle Speeds

6.4.1.1 Models for the period 1984-2000

Figure 1 displays the estimated average vehicle speed of drivers per quarter for the period 1984-2000 based on the 'main effects' model (MAIN1) and the 'interactions' model (INT1). This chart also displays the 95% confidence limits placed on each average vehicle speed estimate.

<u>MAIN1 Model</u>

Using the results of the 'main effects' model, between 1984 and 2000, the estimated average speed fluctuated between approximately 65km/h and 68 km/h. From January 1984 to December 1985 there appears to have been a relatively steady upward trend towards 68 km/h until a decrease in estimated average speed towards the end of 1985 and the beginning of 1986. The rate appears to remain relatively steady around 66.5 km/h from early 1986 to late 1990 where there is another decrease in estimated average speed to about 65 km/h.

A small number of visible speed cameras with advance warning signs were first trialled at high crash frequency sites in Melbourne in 1985 and may have had a small effect, or at least arrested the increase in average speed (Portans, I., 1988). The initial trial of speed cameras corresponds with the first reduction in average speed of crashed drivers shown in Figure 1, whilst the second decrease in average speed corresponds to the time when the speed camera program was launched.

The estimated average speed appears to then slowly but steadily increase from January 1994 until December 2000. This steady increase suggests a ‘speed creep’ effect in which vehicle speeds slowly increase over time by a small km/h amount because of improvements in vehicles and the road system.

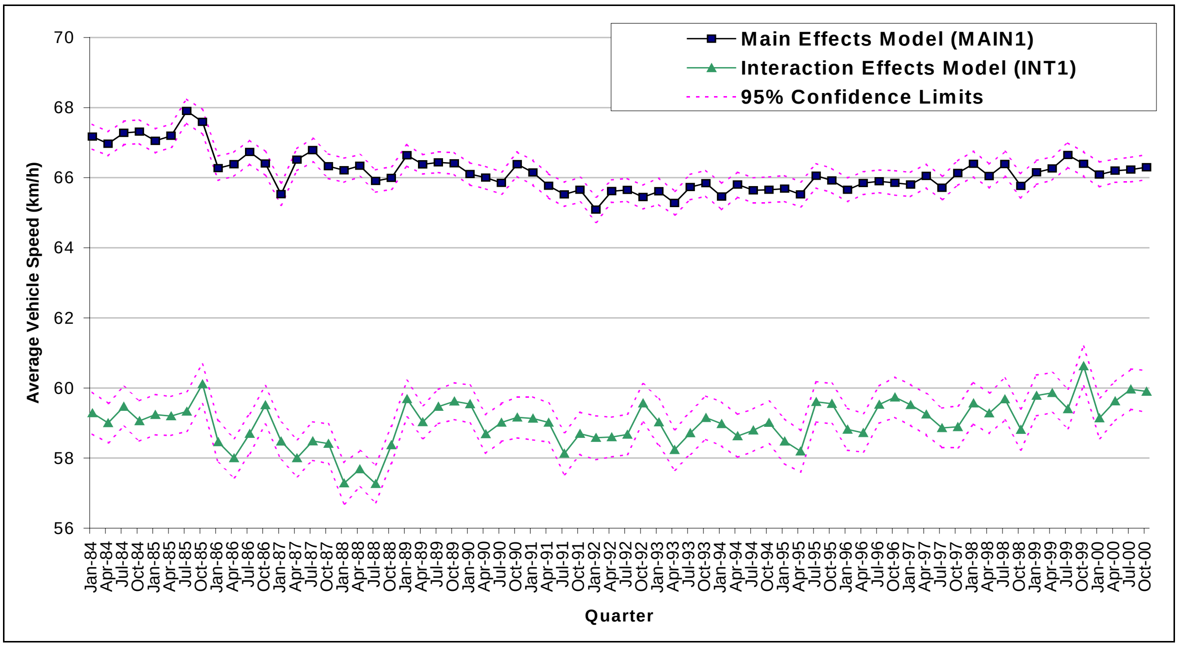
Although the speed estimates shown in Figure 1 fluctuate throughout the range, the range itself is not very large, i.e. between 65 km/h to 68 km/h throughout 1984-2000.

INT1 Model

The average vehicle speed of crashed drivers, as estimated by the ‘interactions’ model was approximately 7 km/h lower than that estimated from the ‘main effects’ model, fluctuating between 57 km/h and 61 km/h. From January 1984 to July 1988 there appears to have been a downward trend in average speed towards 57 km/h. This sharply increases at the end of 1988 and beginning of 1989 towards 60 km/h – back to the levels exhibited in late 1985. The trend in average speed decreases slightly through to the middle of 1991. From this point, the average speed remains fairly steady, fluctuating at around 59 km/h, until April 1995 where a gradual increase in average speed can be detected during the next five years.

Although the ‘interactions’ model produced lower average vehicle speeds than the ‘main effects’ model, the trends shown by both models during 1984-2000 were similar.

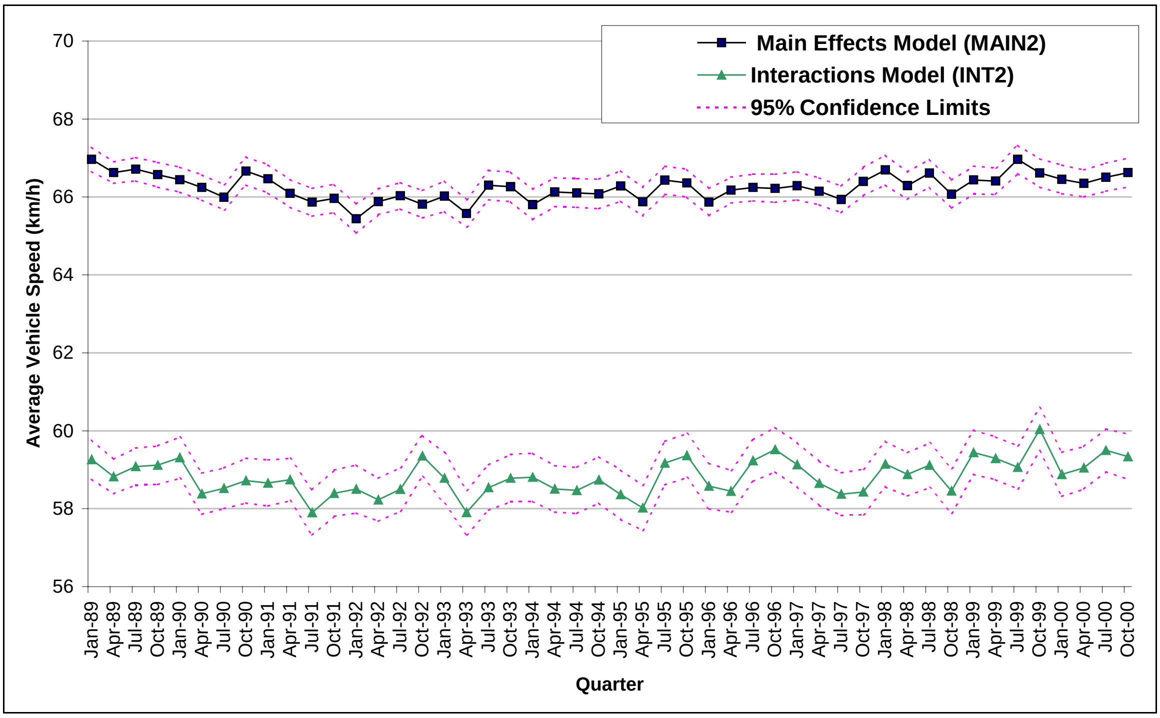
Figure 1 ***‘MAIN EFFECTS’ (MAIN1) & ‘INTERACTIONS’ (INT1) MODELS :***
Estimated Average Vehicle Speeds of crashed vehicles on Melbourne roads in 60 km/h speed zones per quarter, 1984-2000



6.4.1.2 Models for the period 1989-2000

Figure 2 shows the estimated average vehicle speed of drivers per quarter for the period 1989-2000 based on the second 'main effects' model (MAIN2) and the second 'interactions' model (INT2). These models have used the 'vehicle damage' variable rather than the 'towed' variable. Figure 2 also displays the 95% confidence limits that have been placed on each average vehicle speed estimate.

Figure 2 'MAIN EFFECTS' (MAIN2) & 'INTERACTIONS' (INT2) MODELS : Estimated Average Vehicle Speeds of crashed vehicles on Melbourne roads in 60 km/h speed zones per quarter, 1989-2000



MAIN2 Model

The second 'main effects' model, MAIN2, which uses the 'vehicle damage' variable instead of the 'towed' variable, appears to have similar estimates of average speed as the MAIN1 Model over the time period 1989 – 2000. Average vehicle speeds of crashed drivers decreased from January 1989 to January 1992, then stabilised somewhat between January 1992-December 1997, before increasing again during 1998-2000.

A previous MUARC study (Rogerson et al, 1994) found that after the introduction of the speed camera program and the launch of TAC mass media speed-related publicity, there had been little change in average speeds in a 60 km/h zones during November 1989 to June 1990. This current study supports this result in the way that average vehicle speeds over time did not vary greatly, ranging from 65 km/h to 68 km/h. However, there was a definite decline in average speed from July 1989 to July 1991.

INT2 Model

For the second 'interactions' model, INT2, from January 1989 to July 1991, there has been a reduction in average vehicle speed towards 58 km/h before increasing again through to the end of 1992. The average vehicle speed then stabilised somewhat until 1995 before steadily increasing towards the year 2000.

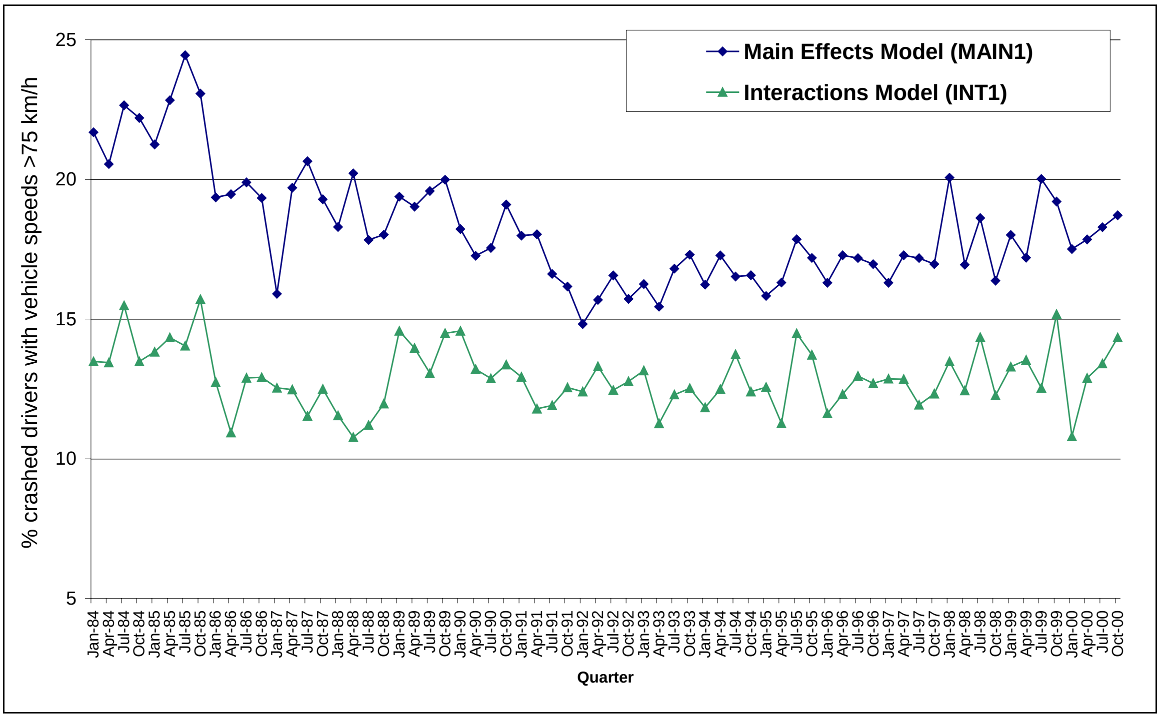
The ‘interactions’ models, INT1 and INT2 have exhibited fairly similar trends in average vehicle speed over the time period 1989 - 2000. This suggests that the variable ‘towed’, used in the first model INTI, is a good estimate of ‘vehicle damage’. This also applies for the two ‘main effects’ models.

6.4.2 Trends in Proportions of Drivers with Vehicle Speeds >75 km/h

6.4.2.1 Models for the period 1984-2000

The proportion of crashed drivers with vehicle speeds exceeding 75 km/h based on the ‘main effects’ model, MAIN1, and the ‘interactions’ model, INT1, are shown in Figure 3 for the period 1984-2000. Ninety-five percent confidence limits placed on these proportions are shown in Appendix E (Figure E1).

Figure 3 ‘MAIN EFFECTS’ (MAIN1) & ‘INTERACTIONS’ (INT1) MODELS: Percentage of crash-involved drivers on Melbourne roads in 60 km/h speed zones with estimated Vehicle Speeds >75 km/h per quarter, 1984 – 2000.



<u>MAIN1 Model</u>

For the ‘main effects’ model, generally the percentage of drivers with vehicles speeds exceeding 75 km/h fluctuated between 15% and 25%. From January 1984 until December 1985 there appears to be have been a relatively steady trend with between 20% and 25% of driver speeds exceeding 75 km/h. There seems to have been a drop in 1986 with a steady rate of approximately 18%-19% until 1992 where there appears to have been another decrease. From the beginning of 1992 to the end of 1997 the trend is relatively steady with approximately 17% of drivers exceeding the speed limit by 15 km/h. From 1998 to 2000, a steady increase in the proportion of drivers with vehicle speeds exceeding 75 km/h (i.e. approaching 20%) was detected.

INT1 Model

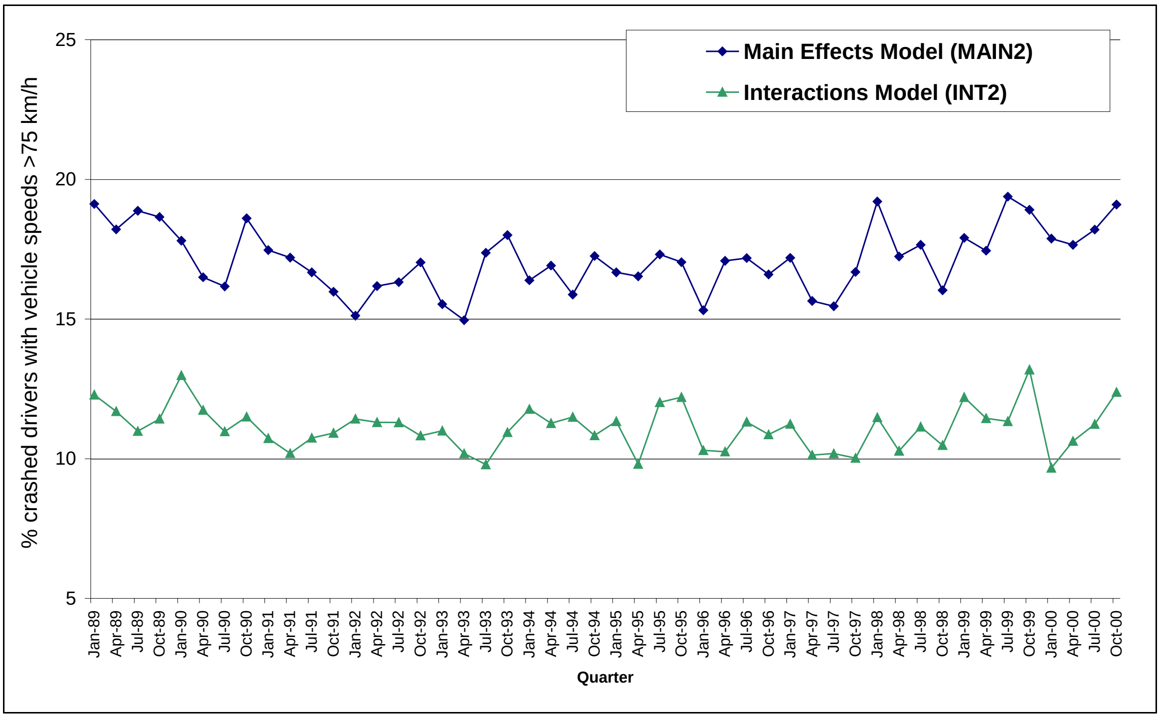
Generally, the percentage of crashed drivers with vehicles speeds exceeding 75 km/h, as estimated from the 'interactions' model, was about 5%-6% lower than that estimated from the 'main effects' model. The 'INT1' proportions fluctuated between 10% and 17% during 1984 – 2000. However, the trends exhibited by both models were similar.

From January 1984 until mid-1988 there has been a downward trend in the proportion of drivers exceeding 75 km/h from 14%-16% to about 10%-12%. Towards the end of 1988 and early 1989 there appears to have been a sharp increase – up to 15% of crashed driver speeds exceeding 75 km/h. Another decrease occurred until 1991, when the proportion of crashed drivers exceeding 75 km/h remained fairly stable, fluctuating around approximately 13% until early 1995. From mid-1995 through to the end of 2000 there has been a steady increase in the proportion of driver speeds exceeding 75 km/h.

6.4.2.2 Models for the period 1989-2000

Figure 4 depicts the proportion of crashed drivers with vehicle speeds exceeding 75 km/h per quarter for the period 1989-2000 based on the second 'main effects' model (MAIN2) and the second 'interactions' model (INT2). These models have used the 'vehicle damage' variable instead of the 'towed' variable to estimate the proportions. Appendix E (Figure E2) depicts the same information as Figure 4 but with 95% confidence limits placed on the estimated proportions.

Figure 4 'MAIN EFFECTS' (MAIN2) & 'INTERACTIONS' (INT2) MODELS: Percentage of crash-involved drivers on Melbourne roads in 60 km/h speed zones with estimated Vehicle Speeds >75 km/h per quarter, 1989 – 2000.



MAIN2 Model

The trends depicted in second ‘main effects’ model, MAIN2, appear to be similar to the trends shown in the first ‘main effects’ model, MAIN1, with the percentage of drivers exceeding 75 km/h fluctuating relatively steadily between 15% and 19% during 1989-2000. From 1989 to the end of 1991, there was a steady decrease from about 19% to 15% in the proportion of drivers with estimated vehicle speeds exceeding 75 km/h. This trend remained relatively consistent from 1992 to end of 1997 fluctuating steadily around 17%. There is a marked increase in 1998, which fluctuates back up to 19% of drivers with estimated vehicle speeds exceeding 75 km/h through to the year 2000.

The drop in the percentage of drivers with vehicle speeds >75km/h during July 1989-July 1990 corresponds with the time when the speed camera program was launched in Victoria (December 1989) together with the TAC speed-related publicity (April 1990).

INT2 Model

The percentage of crashed drivers exceeding 75 km/h fluctuated between approximately 9% and 13% during 1989-2000 for the interaction model (i.e. about 6% smaller than the corresponding MAIN21 percentages). However, the trends during 1989-2000 exhibited by both models were similar. From 1989 to mid-1991, there was a decrease from 12% to 10% in the percentage of crashed drivers with estimated vehicle speeds greater than 75 km/h. This trend remained relatively consistent from 1992 to the end of 1997 fluctuating steadily around 11%. There was an increase beginning in about January 1998, and continuing throughout 1998-2000. The percentage of crashed drivers with vehicles speeds exceeding 75 km/h peaked during October 1999 at over 13%.

6.4.3 Trends in the Proportion of Drivers with vehicle speeds > 90 km/h

The proportion of crashed drivers with vehicle speeds exceeding 90 km/h based on the ‘main effects’ model, MAIN1, and the ‘interactions’ model, INT1, are shown in Figure 5 for the period 1984-2000. Figure 6 gives the corresponding proportions based on the ‘main effects’ model, MAIN2, and the ‘interactions’ model, INT2, for the period 1989-2000. Ninety-five percent confidence limits placed on these proportions are given in Appendix E (Figure E3 and Figure E4).

6.4.3.1 Main Effects Models, MAIN1 & MAIN2

Generally the percentage of crashed drivers with vehicle speeds that exceeded 90 km/h was less than 1% for both ‘main effects’ models MAIN1 and MAIN2 (Figures 5 and 6, respectively). This was reasonable since only crashes in 60 km/h zones were considered, and therefore it was unlikely that there would be a high percentage of drivers with speeds exceeding the speed limit by greater than 30 km/h. This was reflected in Model MAIN1 and in Model MAIN2 where the proportion of drivers exceeding 90 km/h remained relatively constant, only fluctuating by <1%, over all years as shown in Figures 5 and 6.

The first model MAIN1 showed consistently smaller estimates per quarter than model MAIN2, with the proportion of speeds >90 km/h being approximately 0.2%-0.6% less in magnitude for model MAIN1. The proportions for model MAIN2 were about 1.5-5 times larger than those estimated from model MAIN1. Also, model MAIN2 was more variable then Model 1 but fluctuated steadily around approximately 0.6%.

These findings suggest that the two ‘main effects’ models are **not** consistent estimators of the proportion of crashed drivers with vehicles speeds >90 km/h in crashes, however they do seem to be consistent when estimating the proportion of vehicle speeds exceeding 75 km/h in crashes.

6.4.3.2 Interactions Models, INT1 & INT2

Generally the percentage of crashed drivers with vehicle speeds that exceeded 90 km/h was less than 2% for the first model, INT1, and less than 2.5% for the second model, INT2 (Figures 5 and 6, respectively). For both 'interactions' models, the proportion of crashed drivers exceeding 90 km/h remained relatively constant, only fluctuating by <2%, during the time period as shown in Figures 5 and 6. However, for model INT2 there has been a gradual increase in the proportion of drivers with estimated speeds exceeding 90 km/h from 1995 through to 2000. This increase was also detected in model INT2 from 1995 in the average speeds but not in the proportion of drivers with estimated vehicle speeds exceeding 75 km/h.

Figure 5 ‘MAIN EFFECTS’ (MAIN1) & ‘INTERACTIONS’ (INT1) MODELS: Percentage of crash-involved drivers on Melbourne roads in 60 km/h speed zones with estimated Vehicle Speeds >90 km/h per quarter,1984 – 2000.

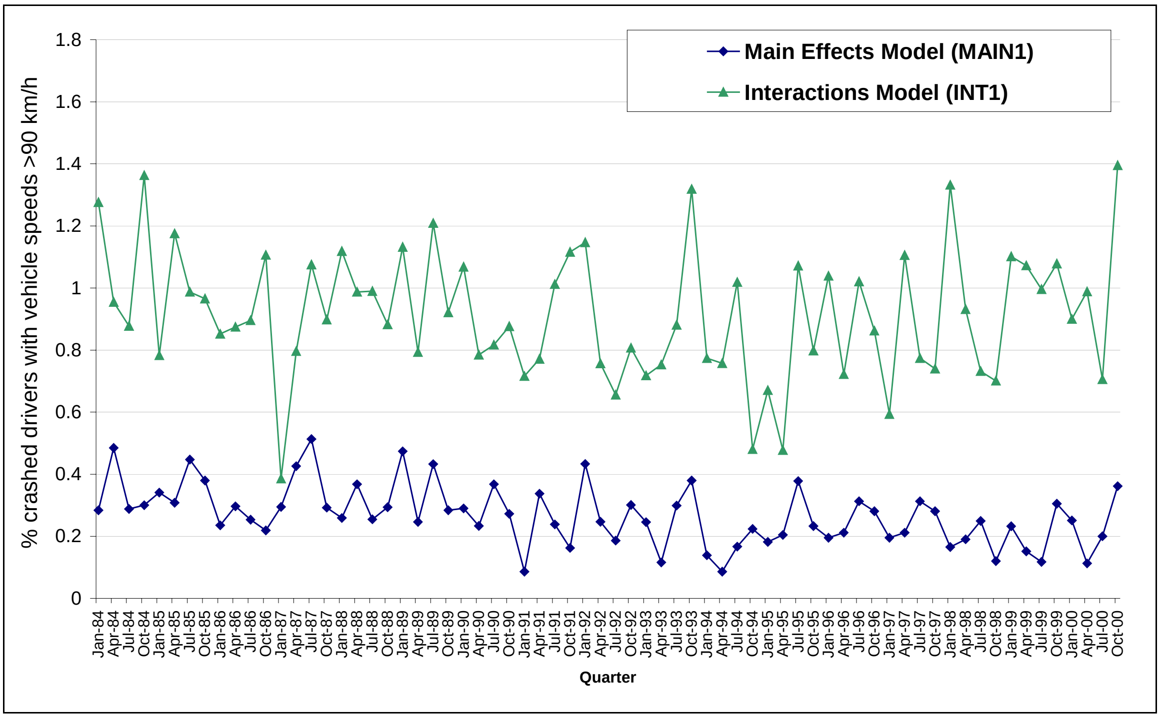
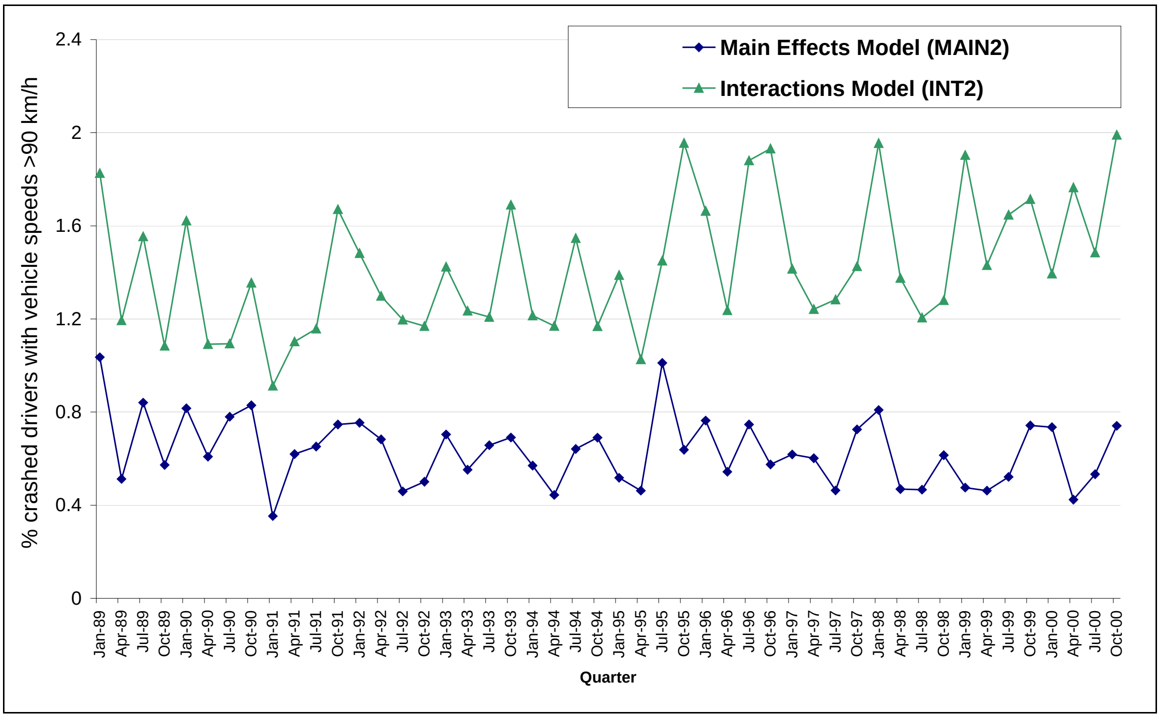


Figure 6 ***'MAIN EFFECTS' (MAIN2) & 'INTERACTIONS' (INT2) MODELS: Percentage of crash-involved drivers on Melbourne roads in 60 km/h speed zones with estimated Vehicle Speeds >90 km/h for years 1989 – 2000.***



6.4.4 Summary of indicator functions

6.4.4.1 'Main Effects' Models

Overall, for the model that used the 'towed' variable as a measure of vehicle damage, MAIN1, the trends in estimated average vehicle speed of crashed drivers paralleled the trends in the proportion of drivers with estimated vehicle speeds exceeding 75 km/h during 1984-2000. This was also true for Model MAIN2 that used the 'vehicle damage' variable instead of the 'towed' variable. For both 'main effects' models, the proportion of drivers with vehicle speeds exceeding 90 km/h did not vary greatly, and remained approximately less then 1% during the time period 1984-2000. However Model MAIN1 showed consistently smaller estimates in the proportion of vehicle speeds exceeding 90 km/h than did Model MAIN2, whilst the trends in the proportion of crashed drivers exceeding 75 km/h as well as the trends in average vehicle speed were similar for both models.

Rogerson et al (1994) found that in response to the introduction of the speed camera program and the launch of the TAC publicity, there was a significant decrease in both the percentage of vehicle speeds exceeding 75 km/h and 90 km/h, in 60 km/h zones from November 1989 to June 1990. This decrease remained through to November 1991. These reductions are apparent in Figures 3 and 4 but are less obvious from Figures 5 and 6, possibly because there are too few observations. Thus the indicator functions that were developed to identify speed in mass crash data have been able to detect some changes in the speed of crashed drivers over time, particularly when considering the proportion of crashed drivers with vehicle speeds exceeding 75km/h.

6.4.4.2 'Interactions' Models

Similar to the 'main effects' model, the trends in average vehicle speed estimated by the first 'interactions' model INT1, paralleled the trends in the proportion of drivers with estimated vehicle speeds exceeding 75 km/h during 1984-2000. For the second 'interactions' model INT2, the trend was very similar. However, the steady increase in average vehicle speed began in 1995 whereas the increase in the proportion of drivers with estimated vehicle speeds exceeding 75 km/h began in 1998. For both models, the proportion of drivers with vehicle speeds exceeding 90 km/h remained approximately less then 2.5% during the time period 1984-2000. However, as with the 'main effects' model, Model INT1 showed consistently *smaller* estimates in the proportion of vehicle speeds exceeding 90 km/h than did Model INT2. For the proportion of crashed drivers exceeding 75 km/h the converse was true with Model INT2 showing the smaller estimates. The trends in average vehicle speed were similar for both 'interactions' models.

6.4.4.3 Comparison of 'Main Effects' and 'Interactions' Models

Average Vehicle Speed

The 'main effects' models and the 'interactions' models showed similar trends in the estimated average vehicle speed of crashed drivers over time. However, the actual estimates of average speed for the 'interactions' models were substantially lower than those estimated by the 'main effects' models. For the 'main effects' models a range of approximately 65 km/h–68 km/h was estimated compared with a range of about 57 km/h-61 km/h for the 'interactions' models.

Proportion of vehicle speeds exceeding 75 km/h & exceeding 90 km/h

When considering the proportion of crashed drivers with estimated vehicle speeds exceeding 75 km/h, the 'main effects' models produced higher estimated proportions than the 'interactions' models. For the 'main effects' models a range of approximately 15%-25% was estimated compared with a range of 9%-17% for the 'interactions' models.

The drop in the percentage of drivers with vehicle speeds >75km/h during July 1989-July 1990 corresponds with the time when the speed camera program was launched in Victoria (December 1989) together with the TAC speed-related publicity (April 1990).

However, for the proportion of crashed drivers with estimated vehicle speeds exceeding 90 km/h, the 'interactions' models gave larger estimates than the 'main effects' models by about 1%.

Overall, both the 'main effects' and 'interactions' models exhibited similar trends during the time periods considered in the study, 1984-2000 and 1989-2000. However, the 'main effects' models produced larger estimates of the average vehicle speed of crashed drivers and the proportion of crashed drivers with vehicle speeds exceeding 75 km/h than did the 'interactions' models. Conversely, lower estimates of the proportion of crashed drivers with vehicle speeds exceeding 90 km/h were produced by the 'main effects' models compared with the 'interactions' models.

7. SUMMARY AND DISCUSSION

During 1999, the Transport Accident Commission suggested that Monash University Accident Research Centre undertake a project to examine the possibility of better defining crashes involving speeding and fatigue based on an analysis of Police-reported mass accident data in Victoria. Such data would enable better tracking of the relative involvement of these problem behaviours in crashes, and better assessment of the effectiveness of countermeasures aimed at each specific behaviour in crashes.

7.1 ADOPTING NSW PROCEDURES FOR VICTORIA

The New South Wales Roads and Traffic Authority (NSW RTA) has had procedures for identifying speeding-related and fatigue-related reported crashes for many years, based on the reporting officer's opinion of the presence of the behaviour and whether the vehicle manoeuvered in a way characteristic of the behaviour. These procedures were reviewed as part of this study to determine if they were applicable to the Victorian context.

The review of the NSW RTA procedures indicated that the identification of speeding-related and fatigue-related crashes was *derived* from Police data, rather than being tested on crash data or being independent of the Police crash reports. It was thus questionable whether these procedures had sufficient scientific basis to warrant directly adopting them for the Victorian Police-reported crash data.

It was therefore recommended that Victoria **should not** adapt the same procedures for use on Victorian Police crash reports because of their insufficient scientific basis, and also because there were too many important differences between Victorian and NSW crash reports.

Because the NSW procedures were determined to be unsuitable, there was a need to investigate whether the identification of speeding-related and fatigue-related crashes directly from mass reported crash data is feasible at all for Victoria. It was therefore proposed to obtain data from recent in-depth crash investigations in which the degree of speeding and/or fatigue was determined objectively. These data would then be matched with Police crash reports for the same crashes, if possible. This would allow for key Police report data and appropriate functions of this information to be identified that discriminates most effectively between whether the crash involves the behaviour (speeding or fatigue, respectively) or not.

7.2 FEASIBILITY OF DISCRIMINATING SPEEDING-RELATED AND FATIGUE-RELATED CRASHES

Two in-depth crash studies, in which the degree of speeding and/or fatigue was thought to have been determined objectively, were identified as being potentially appropriate. One, a study conducted by the New South Wales Roads and Traffic Authority (NSW RTA) was believed to contain crashes where the presence or absence of fatigue had been determined using pre-defined criteria. The other, a study conducted by the NHMRC Road Accident Research Unit, RARU, of the University of Adelaide, determined the free travelling speeds of approximately 150 vehicles involved in crashes.

7.2.1 Fatigue-related crashes

The NSW RTA in-depth crash investigation was designed to examine the relationships between vehicle defects and road safety, and as such, the data gathered was essentially based on vehicle information such as vehicle controls, suspension, steering, tyres and chassis. Behavioural causal factors such as fatigue were not identified.

On this basis the NSW RTA data was deemed unsuitable for the identification of fatigue-related crashes. Consequently, the study's objective to identify fatigue in Victoria's mass crash database of Police records was not feasible at this stage. The feasibility of adopting the methodological approach illustrated in this study for the identification of speed-related crashes, should be revisited in the future if and when a suitable in-depth study in which the identification of fatigue is objectively determined has been completed.

7.2.2 Speed-related crashes

The second study, conducted by RARU, examined the effect of free travelling speed on the risk of involvement in a casualty crash in a 60 km/h urban speed limit setting in Adelaide. Accident reconstruction techniques were used to determine free-travelling speeds of crashed vehicles. It was deemed feasible to use the data from this study, matched with South Australia Police crash reports, to develop a procedure to identify speed in Victoria mass crash data.

The matching process of the South Australia Police crash data with the RARU case study data resulted in a database of 149 crashed vehicles for analysis.

7.3 DEVELOPMENT OF MODELS AND INDICATOR FUNCTIONS TO IDENTIFY SPEED IN MASS CRASH DATA

A statistical modelling analysis of the South Australia matched crash database identified a number of factors associated with driver speed, i.e.:

- male drivers;
- drivers aged 25 years or less;
- fatal crashes;
- extensively damaged vehicles;
- morning crashes;
- crashes in which the driver was performing a manoeuvre other than going straight ahead.

The statistical methodology used was General Linear Modelling (GLM). Two types of models were developed; one that included only main effects and assumed no interactions between factors, and a second model that allowed for interactions and modelled them explicitly.

The significant factors that were obtained from the 'main effects' and 'interactions' GLM models (listed above), were used to develop indicator functions that estimated the travelling speed of a vehicle prior to a crash. These indicator functions were then applied to Victorian Police-reported mass crash data to identify speed-related crashes for the period 1984-2000.

To apply the South Australia findings to the Victoria crash data, both data sets had to be compatible. For this to occur, certain conditions had to be selected from the Victoria data set to match the conditions inherent in the South Australia in-depth-crash study. These were selecting only:

- crashes that occurred on roads in 60 km/h speed zones;
- day-time Crashes (i.e. between 08:00 – 20:00);
- crashes in urban areas as defined by the Local Government Area (i.e. areas in the Melbourne Statistical division);
- drivers;
- passenger car or passenger car-derivatives (i.e., car, station wagon, taxis, utilities, panel vans).

One of the significant factors in identifying speed, 'vehicle damage' was not available for the years 1984-1988 in the Victoria crash data. A related variable 'towed' indicating whether or not the vehicle had been towed after a crash was used as a substitute for the 'vehicle damage' variable. Because of this, two types of indicator functions were developed:

- one covering the full data period, 1984-2000, and using the 'towed' variable to estimate vehicle damage,
- the other covering the period 1989-2000 in which the 'vehicle damage' variable was readily available.

The following speed measurements were estimated:

- average vehicle speeds of crashed drivers per quarter for the periods January 1984–December 2000 and January 1989-December 2000;

- the proportion of crashed drivers with estimated vehicle speeds >75 km/h per quarter for January 1984-December 2000 and January 1989-December 2000;

- the proportion of crashed drivers with estimated vehicle speeds >90 km/h per quarter for January 1984-December 2000 and January 1989-December 2000.

The aim was to see if there had been any changes over time in average vehicle speeds of crashed drivers or in the proportion of drivers exceeding the speed limit in metropolitan (urban) areas on 60 km/h roads for crashes that occurred during daytime hours.

Initially the Victorian speed camera program occurred primarily in urban areas during low alcohol times of the week. These times of the week mainly correspond with daytime hours. Hence, trends in speed outcomes could then be compared to the Victorian speed enforcement programs to determine whether there had been a change in average speed or in the proportion of crashed drivers exceeding the speed limit as a response to these initiatives.

7.4 MAIN FINDINGS

7.4.1 Average vehicle speeds

The indicator functions that were based on the models that used the 'vehicle damage' variable and the 'towed' variable exhibited fairly similar trends in average vehicle speed over the time period 1989 - 2000. This was the case for both the ‘main effects’ and the ‘interactions’ models. This suggests that the variable ‘towed’ is a good estimate of ‘vehicle damage’ when determining the average vehicle speed of crashed drivers.

The ‘main effects’ models and the ‘interactions’ models showed similar trends in the estimated average vehicle speed of crashed drivers during 1984-2000 and 1989-2000. However, the actual estimates of average speed for the ‘interactions’ models were approximately 7 km/h lower than those estimated by the ‘main effects’ models. For the ‘main effects’ models a range of approximately 65 km/h–68 km/h was estimated compared with a range of about 57 km/h-61 km/h for the ‘interactions’ models.

A previous MUARC study (Rogerson et al, 1994) found that after the introduction of the speed camera program and the launch of TAC mass media speed-related publicity, there had been little change in average speeds in a 60 km/h zones during November 1989 to June 1990. This current study supports this result in the way that average vehicle speeds over time did not vary greatly, ranging from 65 km/h to 68 km/h (‘main effects’ models) or 57 km/h to 61 km/h (‘interactions’ models). However, there was a definite decline in average speed from July 1989 to July 1991.

7.4.2 Proportion of vehicle speeds exceeding 75 km/h and 90 km/h

When considering the proportion of crashed drivers with estimated vehicle speeds exceeding 75 km/h, the ‘main effects’ models produced higher estimated proportions than the ‘interactions’ models. For the ‘main effects’ models a range of approximately 15%-25% was estimated compared with a range of 9%-17% for the ‘interactions’ models. However, for the proportion of crashed drivers with estimated vehicle speeds exceeding 90 km/h, the ‘interactions’ models gave larger estimates than the ‘main effects’ models by about 1%.

The ‘main effects’ model that included the ‘towed’ variable showed consistently smaller estimates per quarter in the proportion of crashed drivers with vehicle speeds >90 km/h than the corresponding model that used the ‘vehicle damage’ variable. The proportion of speeds >90 km/h was approximately 0.2%-0.6% less in magnitude for the first model. Also, the latter model was more variable than the former model but fluctuated steadily around approximately 0.6%.

Thus the models that used the ‘vehicle damage’ variable and the ‘towed’ variable were not consistent estimators of the proportion of crashed drivers with vehicles speeds >90 km/h. However they do seem to be consistent when estimating the proportion of vehicle speeds exceeding 75 km/h in crashes.

Rogerson et al (1994) found that in response to the introduction of the speed camera program and the launch of the TAC publicity, there was a significant decrease in both the percentage of vehicle speeds exceeding 75 km/h and 90 km/h, in 60 km/h zones from November 1989 to June 1990. This decrease remained through to November 1991. These reductions were also apparent when the speed measure considered in this current study was the proportion of crashed drivers with speeds exceeding 75 km/h, but were less obvious for the corresponding proportions exceeding 90 km/h, possibly because there were too few observations. Thus the indicator functions that were developed to identify speed in mass crash data have been able to detect some changes in the speed of crashed drivers over time, particularly when considering the proportion of crashed drivers with vehicle speeds exceeding 75km/h.

Overall, both the ‘main effects’ and ‘interactions’ models exhibited similar trends during the time periods considered in the study, 1984-2000 and 1989-2000. However, the 'main effects' models produced larger estimates of the average vehicle speed of crashed drivers and the proportion of crashed drivers with vehicle speeds exceeding 75 km/h than did the ‘interactions’ models. Conversely, lower estimates of the proportion of crashed drivers with vehicle speeds exceeding 90 km/h were produced by the ‘main effects’ models compared with the ‘interactions’ models.

7.5 USEFULNESS OF THE INDICATOR FUNCTION

The indicator functions developed as part of this study can be used:

- to estimate the pre-crash travelling speeds of vehicles crashing on Melbourne roads in 60 km/h speed zones;
- as monitoring tools to assess and/or monitor changes in the average vehicle speed of crashed drivers as well as the proportion of crashed drivers exceeding the speed limit at various levels over a specified time period;
- to assess the impact of new speed enforcement programs or new publicity and education campaigns targeted at speeding drivers - this could be achieved by monitoring any changes that occurred in these speed measures during the times when these new speed initiatives were implemented.

7.6 LIMITATIONS OF STUDY

The indicator functions of speed that were developed are only applicable for crashes that occurred on Melbourne roads in 60 km/h speed zones, predominantly during day time hours. These constraints were placed on the analysis because it was necessary to match the Victorian crash data with the criteria used in the RARU in-depth study. The RARU study examined the effect of free travelling speeds on the risk of casualty crash involvement in 60 km/h urban speed limit setting in Adelaide.

All crashed vehicles that met the above criteria were selected from the VicRoads crash database, not just those with assumed free travelling speeds. Thus stationary vehicles involved in a crash could also potentially have been selected. A refinement of the indicator function would be to exclude vehicles that were stationary at a crash, if possible, and re-estimate the speed of drivers prior to a crash.

8. RECOMMENDATIONS

It is clear that the planned procedures for this study – particularly obtaining the relevant data to allow the identification of fatigue-related crashes – were not as simple and straightforward as anticipated. It is suggested that the plan to identify fatigue-related crashes (and the expansion of speed-related crashes) be re-examined.

To develop higher quality procedures for defining/indicating the presence of key behaviours in crashes, it may be necessary for MUARC to undertake special investigations of behaviours which were the precursors or precipitators of an adequate sample of crashes or at least to add such behavioural investigations to MUARC's existing crash studies. The data would be matched with Police accident reports and the correlation of the existing data with the presence of the behaviour examined. It may be necessary to recommend that additional data be collected by the Police to more accurately identify whether certain safety-related behaviours are likely to have been present in the crash.

It is also recommended that the indicator functions of speed developed as part of this study be refined to exclude crashed vehicles that may have been stationary at the time of impact.

9. REFERENCES

Australian Transport Safety Bureau (2000). *Community Attitudes to Road Safety*, Road Safety Research Report CR197, Philip Mitchell-Taverner.

Australian Transport Safety Bureau (2002). *Fatigue-related crashes: An analysis of fatigue-related crashes on Australian roads using an operational definition of fatigue.* Road Safety Research Report CR197, Kim Dobbie.

Bittner, R., Smrcka, P., Vysoky, P., Hana, K., Pousek, L., Schreib, P. (2000). *Detecting of Fatigue States of a Car Driver*, First International Symposium on Medical Data Analysis, Springer-Verlag, Berlin Heidelberg, pp. 260-273.

Cody, R. P. & Smith, J.K. (1997). *"Applied Statistics and the SAS® Programming Language"*, 4th Edition, Prentice-Hall, New Jersey, U.S.A.

Data Analysis Australia (2000). *Analysis of Road Crash Statistics, 1900-1999*, Road Safety Council.

Fatigue Expert Group (2001). *Options for regulatory Approach in Drivers of Heavy Vehicles in Australia and New Zealand.* World wide web site: http://www.atsb/gov.au/pdf/cr202.pdf.

Fildes, B.N. & Lee, S.J. (1993), *"The Speed Review: Road Environment, Behaviour, Speed Limits, Enforcement and Crashes"*. CR 127 Federal Office of Road Safety, Canberra.

Fildes, B.N., Rumbold, G. & Leening, A. (1991), *"Speed Behaviour and Drivers' Attitudes to Speeding"*. Report No 16, Monash University Accident Research Centre, Melbourne.

Harrison, W.A., Fitzgerald, E.S., Pronk, N.J. & Fildes, B. (1998). *"An Investigation of Characteristics Associated with Driving Speed"*. Report No. 140, Monash University Accident Research Centre, Melbourne.

Haworth, N. (1998). *Fatigue and Fatigue Research: The Australian Experience*, Proceedings of the 7th Biennial Australasian Traffic Education Conference: Speed, Alcohol, Fatigue Effects. February, Brisbane.

Haworth, N.L. & Heffernan, C.J. (1989), *"Information for development of an educational program to reduce fatigue-related truck accidents"* Report No. 4, Monash University Accident Research Centre, Melbourne.

Haworth, N.L., Heffernan, C.J. & Horne, E.J. (1989), *"Fatigue in truck accidents"* Report No. 3, Monash University Accident Research Centre, Melbourne.

Haworth, N.L, Triggs, T.J. & Grey, E.M. (1988). *"Driver fatigue: Concepts, measurement and crash countermeasures"*, CR 72, Federal Office of Road Safety, Canberra.

Holgate, J., Harkness, D. & Vertsonis, H. (1999). "New South Wales Crashed Vehicle Study", *Proceedings of the Research, Policing and Education Road Safety Conference, Canberra, 28-30 November.*

Horne J.A., Reyner, L.A. (1995). "Sleep Related Vehicle Accidents", *British Medical Journal, Vol. 310, pp. 565-567.*

Horne J.A. Reyner, L.A. (1999) "Vehicle Accidents related to sleep: A review", *Occupational and Environmental Medicine, Vol. 56, No. 5, pp. 289-294.*

Kloeden, C.N., Ponte, G. & McLean A.J. (2001). *"Travelling Speed and the Risk of Crash Involvement on Rural Roads"*. CR 204, Australian Transport Safety Bureau, Canberra.

Kloeden, C.N., McLean, A.J., Moore, V. M. & Ponte, G. (1997a). *"Travelling speed and the risk of crash involvement: Volume 1 – Findings"*, CR 172, Federal Office of Road Safety, Canberra.

Kloeden, C.N., McLean, A.J., Moore, V. M. & Ponte, G. (1997b). *"Travelling speed and the risk of crash involvement: Volume 2 – Case and Reconstruction Details"*, CR 172, Federal Office of Road Safety, Canberra.

Maycock, G. (1996). "Sleepiness and driving: the experience of U.K Drivers", *Accident Analysis and Prevention, Vol. 29, No. 4, pp. 453-462.*

New Zealand Land Transport Authority (1998) *Factsheet 24, Fatigue and Driver Alertness*. World Wide Web site: http://www.ltsa.govt.nz/factsheets/24.html

NSWRTA (2001a) *Road Traffic Accidents in NSW 2000; Road Traffic Accidents in NSW – 2000: Statistical Statement: Year Ended 31 December 2000.*

NSWRTA (2001b) *Driver Fatigue: Problem Definition and Countermeasures Summary*, Road Traffic Authority.

Pack, A. I., Pack, A. M., Rodgman, E., Cucchiara, A., Dinges, D.F., Schwab, C. W. (1995). "Characteristics of Crashes Attributed to the Driver having fallen asleep", *Accident Analysis and Prevention, Vol. 27, No. 6, pp. 769-775.*

Portans, I. (1988). *The potential value of speed cameras.* Report No. SR/88/2, Road Traffic Authority, Victoria.

Rogerson, P., Newstead, S., Cameron, M. (1994), "Evaluation of the Speed Camera Program in Victoria: 1990 – 1991" Report No. 54, Monash University Accident Research Centre, Melbourne.

Sagberg, F. (1999), "Road Accidents caused by drivers falling asleep", *Accident Analysis and Prevention, Vol. 31, pg. 639-649.*

Silcock, D., Smith, K., Knox, D. & Beuret, K. (1999). *"What Limits Speed? Factors That Affect How Fast We Drive"*, AA Foundation for Road Safety Research, Basingstoke. (original not cited).

Summala, H., Mikkola, T. (1994). "Fatal Accidents among Car and Truck Drivers: Effects of Fatigue, Age, and Alcohol Consumption", *Human Factors, Vol. 36, No. 2, pp. 315-326.*

Taylor, M.C., Lynam, D.A. & Baruya, A. (2000). *"The Effects of Drivers' Speed on the Frequency of Road Accidents"*, Transport Research Laboratories TRL Report 421, Berkshire, United Kingdom.

Thiffault, P., Bergeron, J. (2002). "Monotony of Road Environment and driver fatigue: a simulator study", *Accident Analysis and Prevention, Vol. 848 1-11.*

Webster, D.C. & Wells, P. A. (2000). *"The Characteristics of Speeders"*, TRL Report 440, Transport Research Laboratories, Berkshire, United Kingdom.

Williamson, A., Feyer, A.M., Friswell, R. & Finlay-Brown, S. (2000). *"Development of Measures on Fatigue: Using an Alcohol Comparison to Validate the Effects of Fatigue on Performance"*, Report CR 189, Australian Transport Safety Bureau (ATSB), Canberra.

Wundersitz, L. N., Baldock, M. R. J., McColl, R. A. & Allsopp, J. (2001). "Rural Speed Situation Analysis". *Proceedings of the National Speed and Road Safety Conference, 23-24 August 200*1, Adelaide.

APPENDIX A

Case vehicle selection criteria:

The criteria used in the selection of case vehicles in the RARU *Travelling Speed and the Risk of Crash Involvement* study, are listed below.

RARU used the following criteria for the selection of case vehicles:

- Crash was in the Adelaide metropolitan area
- Crash occurred on a road that had in a 60 km/h speed limit
- Case vehicle was a passenger car or passenger car derivative (e.g., station wagon or derivative)
- At least one person was transported from the crash scene by ambulance
- Case vehicle had a free travelling speed prior to the crash
- Case vehicle was not executing an illegal manoeuvre prior to the start of the crash sequence
- Case vehicle driver did not suffer from a medical condition that caused the crash
- Case vehicle driver had a zero blood alcohol concentration (BAC)
- Sufficient information was available to carry out a computer-aided crash reconstruction
- Case vehicle did not roll over
- Crash did not occur while it was raining

APPENDIX B

FREQUENCIES OF VARIABLES IN MATCHED CRASH DATABASE

Sex of driver		
	Frequency	Percent
Male	98	65.8
Female	51	34.2
Total	149	100

Number of units involved *		
	Frequency	**Percent**
2	123	82.6
3	19	12.8
4	4	2.7
5	3	2
Total	149	100

* Unit can be a pedestrian or fixed object.

Travelling speed category		
km/h	**Frequency**	**Percent**
30 – 49	5	3.4
50 – 59	35	23.5
60 – 69	63	42.3
70 – 79	24	16.1
80 – 89	12	8.1
90 – 109	7	4.7
110 - 150	3	2
Total	149	100

Number of occupants		
	Frequency	**Percent**
1	92	61.7
2	42	28.2
3	11	7.4
4	1	0.7
5	3	2
Total	149	100

Number of serious injuries in the crash		
	Frequency	**Percent**
0	103	69.1
1	29	19.5
2	12	8.1
3	2	1.3
4	3	2
Total	149	100

Severity of crash		
	Frequency	Percent
PDO	1	0.7
Injury	138	92.6
Fatal	8	5.4
Total	147	98.7
Unknown	2	1.3
Total	149	100

No. of casualties in unit		
	Frequency	Percent
0	53	35.6
1	73	49
2	15	10.1
3	5	3.4
4	3	2
Total	149	100

Crash type		
	Frequency	Percent
Rear end	10	6.7
Hit fixed object	13	8.7
Side swipe	7	4.7
Right angle	46	30.9
Head on	8	5.4
Hit pedestrian	10	6.7
Right turn	51	34.2
Hit parked vehicle	4	2.7
Total	149	100

Damage category		
	Frequency	Percent
$100 to $999	7	4.7
$1000 to $5000	22	14.8
$5001 to $10000	70	47
$10001 to $15000	25	16.8
$15001 to $20000	11	7.4
$20001 to $30000	4	2.7
$30001 to $40000	3	2
Unknown	7	4.7
Total	149	100

Apparent driver error		
	Frequency	Percent
Dangerous Driving	1	0.7
Disobey - Traffic Lights	2	1.3
Excessive Speed	3	2
Fail to Keep Left	2	1.3
Fail to Stand	2	1.3
Follow Too Closely	1	0.7
Inattention	21	14.1
No Errors	117	78.5
Total	149	100

Number of casualties		
	Frequency	Percent
1	79	53
2	54	36.2
3	8	5.4
4	5	3.4
5	2	1.3
6	1	0.7
Total	149	100

Age group		
≤ 25 years	46	30.9
26 – 59 years	82	55
≥ 60 years	21	14.1
	149	100

No. of casualties in unit		
	Frequency	Percent
0	54	36.2
1	71	47.7
2	16	10.7
3	5	3.4
4	3	2
Total	149	100

Number of occupants in unit		
	Frequency	**Percent**
0	1	0.7
1	91	61.1
2	42	28.2
3	11	7.4
4	1	0.7
5	3	2
Total	149	100

APPENDIX C

Reclassification of variable 'vehicle movement' from the VicRoads definitions for classifying accidents (DCA).

The VicRoads Definition for classifying vehicles classified vehicle movement on the basis of the type of movement, the DCA type, and which vehicle was performing the movement.

DCA was recoded into a binary outcome to signify whether the vehicle was moving straight ahead or performing another type of manoeuvre. These outcome codes were:

1 = Straight Ahead or 0 = Other Manoeuvre, and are shown in the following Table.

dca	vehicle	outcome
100	1	1
	2	na
101	1	1
	2	na
102	1	1
	2	na
103	1	1
	2	na
104	1	1
	2	na
105	1	1
	2	na
106	1	0
	2	na
107	1	0
	2	na
108	1	1
	2	na
109	1	0
	2	na
110	1	1
	2	1
111	1	1
	2	0
112	1	1
	2	0
113	1	0
	2	1
114	1	0
	2	0

dca	vehicle	outcome
115	1	0
	2	0
116	1	0
	2	1
117	1	0
	2	0
118	1	0
	2	0
119	1	0
	2	0
120	1	1
	2	1
121	1	0
	2	1
122	1	1
	2	0
123	1	0
	2	0
124	1	0
	2	0
125	1	0
	2	0
129	1	0
	2	0
130	1	1
	2	1
131	1	1
	2	0
132	1	1
	2	0

dca	vehicle	outcome
133	1	1
	2	1
134	1	0
	2	1
135	1	0
	2	1
136	1	0
	2	0
137	1	0
	2	0
139	1	0
	2	0
140	1	0
	2	1
141	1	0
	2	0
142	1	0
	2	1
143	1	0
	2	1
144	1	0
	2	0
145	1	0
	2	0
146	1	0
	2	0
147	1	0
	2	1
148	1	0
	2	1

dca	vehicle	outcome
149	1	0
	2	0
150	1	0
	2	1
151	1	0
	2	0
152	1	0
	2	0
153	1	0
	2	1
154	1	0
	2	1
159	1	0
	2	0
160	1	1
	2	0
161	1	1
	2	0
162	1	1
	2	0
163	1	1
	2	0
164	1	1
	2	0
165	1	1
	2	0
166	1	1
	2	0
167	1	0
	2	0
169	1	0
	2	0
170	1	0
	2	0
171	1	0
	2	0

dca	vehicle	outcome
172	1	0
	2	0
173	1	0
	2	0
174	1	0
	2	0
175	1	1
	2	0
179	1	0
	2	0
180	1	0
	2	0
181	1	0
	2	0
182	1	0
	2	0
183	1	0
	2	0
184	1	0
	2	0
189	1	0
	2	0
190	1	0
	2	0
191	1	0
	2	0
192	1	0
	2	0
193	1	0
	2	0
194	1	0
	2	0
198	1	0
	2	0
199	1	0
	2	0

APPENDIX D

Estimation of the 'towed' variable

The variable 'vehicle damage' was not available in the 1984 – 1988 Victoria Police-reported crash data. Thus another related variable was used in its place. This variable was 'towed' which represented whether a vehicle had been towed or not. The coefficient for this variable was estimated using a weighting of the coefficients from the variable 'vehicle damage' as follows.

From the South Australia in-depth crash study data, each level from 'vehicle damage' was represented by the following proportions:

Extensive:	0.181		
Major – towed:	0.302		
Moderate – towed:	<u>0.356</u>	=	83.9%
Minor:	0.161		

The 'minor' category was excluded as this is the reference group. Therefore each of the remaining levels were represented by the following proportions:

Extensive:	0.181 * 83.9%	=	21.6%
Major – towed:	0.302 * 83.9%	=	36.0%
Moderate – towed:	0.356 * 83.9%	=	42.4%.

Thus using the above weightings multiplied by the original coefficients, a single weighted coefficient was obtained to represent the variable 'towed', i.e. $\beta_{towed} = \Sigma w_i \beta_i$.

Extensive:	21.6% * 14.3584	=	3.1014		
Major – towed:	36.0% * 9.2434	=	3.3276		
Moderate – towed:	42.4% * 8.9233	=	<u>3.7835</u>	=	10.2125

Therefore, if the vehicle was 'towed', it received a weighting of 10.2125.

APPENDIX E

Percentage of crash-involved drivers (with 95% confidence limits) on Melbourne roads in 60 km/h speed zones with estimated vehicle speeds:

- ➢ 75 km/h
- ➢ 90 km/h

Figure E1. 'MAIN EFFECTS' (MAIN1) & 'INTERACTIONS' (INT1) MODELS: Percentage of crash-involved drivers (with 95% confidence limits) on Melbourne roads in 60 km/h speed zones with estimated vehicle speeds <u>> 75 km/h,</u> 1984-2000

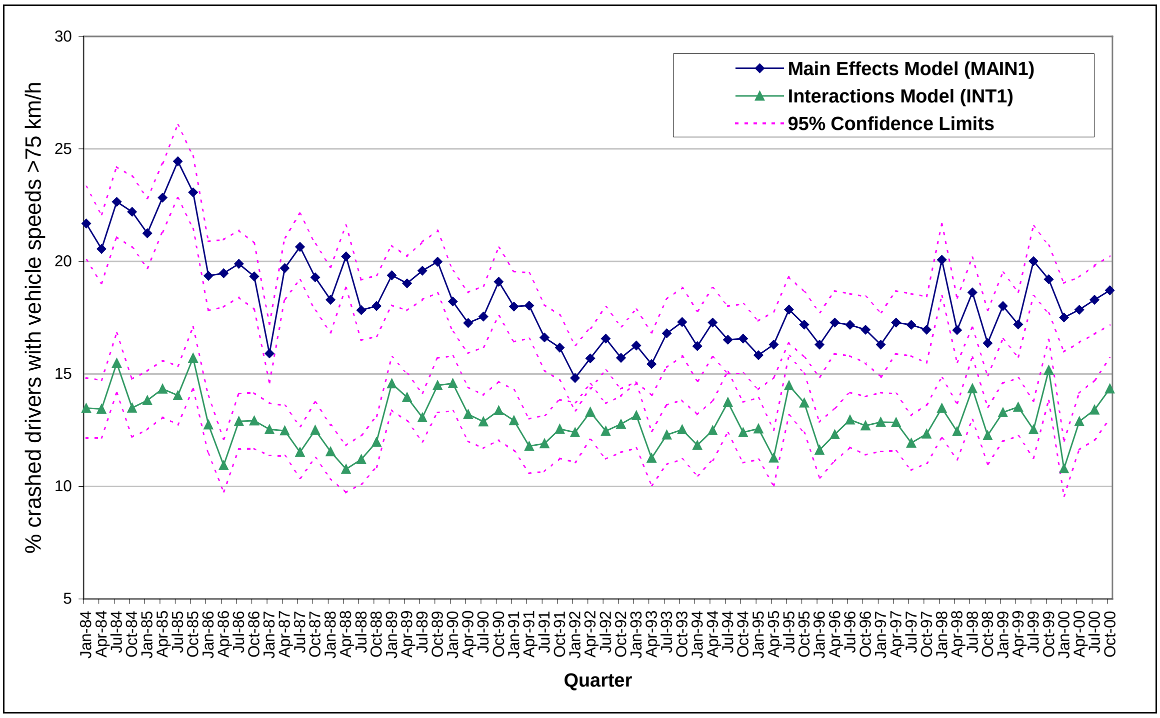


Figure E2. 'MAIN EFFECTS' (MAIN2) & 'INTERACTIONS' (INT2) MODELS: Percentage of crash-involved drivers (with 95% confidence limits) on Melbourne roads in 60 km/h speed zones with estimated vehicle speeds <u>> 75 km/h</u>, 1989-2000

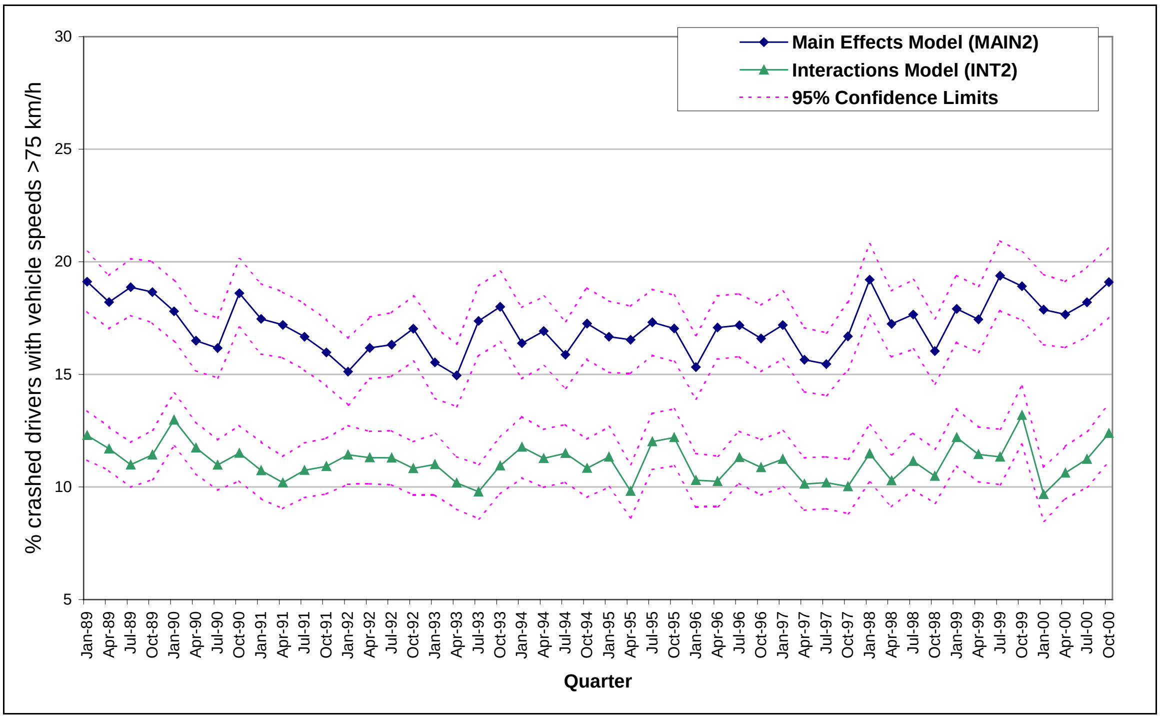


Figure E3. 'MAIN EFFECTS' (MAIN1) & 'INTERACTIONS' (INT1) MODELS: Percentage of crash-involved drivers (with 95% confidence limits) on Melbourne roads in 60 km/h speed zones with estimated vehicle speeds <u>> 90 km/h</u>, 1984-2000

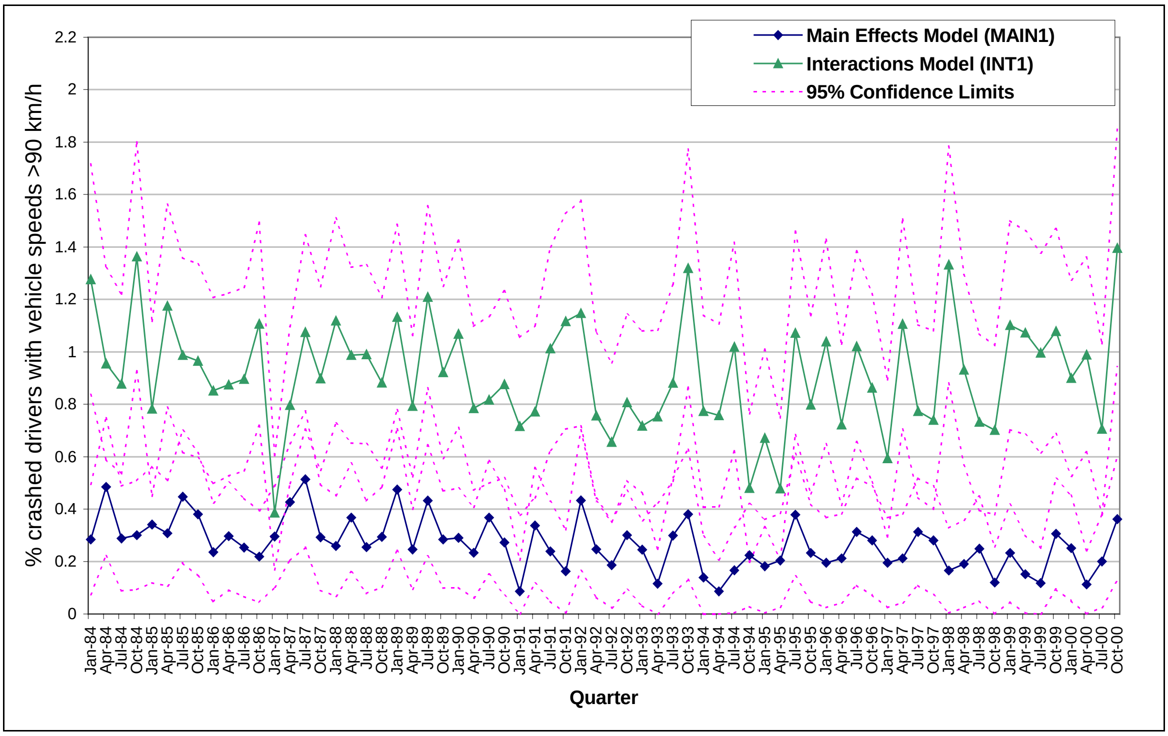


Figure E4. 'MAIN EFFECTS' (MAIN2) & 'INTERACTIONS' (INT2) MODELS: Percentage of crash-involved drivers (with 95% confidence limits) on Melbourne roads in 60 km/h speed zones with estimated vehicle speeds <u>> 90 km/h</u>, 1989-2000