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August 2010
The Validity of Police-reported Information on the Injury Severity of Non-fatal Motor Vehicle Traffic Crashes in New Zealand

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A dissertation submitted for the degree of Master of Public Health

at the University of Otago, Dunedin, New Zealand

November 2006
Abstract

Objective
To assess the validity of police-reported information on the severity of injury for non-fatal Motor Vehicle Traffic Crashes (MVTCs).

Methods
Details of MVTCs reported to the police and resulting in non-fatal injury in New Zealand (NZ) from January 2000 to December 2004 were obtained from Land Transport New Zealand (LTNZ). Data about individual’s injuries was matched to New Zealand Health Information Service (NZHIS) hospital discharge data. ICD-10 codes from the hospital data were recorded and a severity score assigned, using a Threat to Life tool, the International Classification of Diseases-based Injury Severity Score (ICISS).

Results
14,869 (51%) records were linked and used in the analysis. Of those crash victims who were recorded by police as having ‘serious’ injuries on the Traffic Crash Report (TCR), only 48% had an injury with a significant threat to life. Of those who were recorded as suffering a ‘minor’ injury on the TCR, 15% had an injury with a significant threat to life. There was variation in the concordance between the injury severity assessment on the TCR and injury severity as measured by ICISS by personal, vehicle and crash variables.

Conclusion
There was marked discordance between the two measures of injury severity. This has implications for interpreting NZ’s road safety statistics, the assessment of road safety programmes and the allocation of funding to target specific road safety problems. These results also raise questions about whether the police assessment of injury severity should be used at all in the surveillance of non-fatal motor vehicle traffic crash-related injury.
Acknowledgements

I would like to thank my supervisors Professor John Langley and Gabrielle Davie for their time and comments during this project. Their supervision was invaluable.

Thank you to Dan for his data matching and all the staff at IPRU for their assistance. Thank you also to Carey Griffiths at NZ Police and Jeremy Byfield at LTNZ for their time and explanations.

I would like to thank Land Transport New Zealand for the funding they provided for this project. I would also like to acknowledge the Australasian Faculty of Public Health Medicine for funding this year of study.

Thank you to Stewart and my family and friends who have been patient and encouraging throughout the duration of this study.
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<th>Description</th>
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<tbody>
<tr>
<td>ACC</td>
<td>Accident Compensation Corporation</td>
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<tr>
<td>AIS</td>
<td>Abbreviated Injury Scale</td>
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<td>APS</td>
<td>Anatomic Profile Score</td>
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<tr>
<td>CAS</td>
<td>Crash Analysis System</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>DHB</td>
<td>District Health Board</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency Department</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>ICD-10</td>
<td>International Statistical Classification of Diseases and Related Health Problems, Tenth Revision</td>
</tr>
<tr>
<td>ICD-10-AM</td>
<td>International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification</td>
</tr>
<tr>
<td>ICE</td>
<td>International Collaborative Effort</td>
</tr>
<tr>
<td>ICISS</td>
<td>International Classification of Diseases-based Severity Score</td>
</tr>
<tr>
<td>IPRU</td>
<td>Injury Prevention Research Unit</td>
</tr>
<tr>
<td>ISS</td>
<td>Injury Severity Score</td>
</tr>
<tr>
<td>LTNZ</td>
<td>Land Transport New Zealand</td>
</tr>
<tr>
<td>MAIS</td>
<td>Maximum Abbreviated Injury Scale</td>
</tr>
<tr>
<td>mAP</td>
<td>Modified Anatomic Profile</td>
</tr>
<tr>
<td>MoT</td>
<td>Ministry of Transport</td>
</tr>
<tr>
<td>MVTC</td>
<td>Motor Vehicle Traffic Crash</td>
</tr>
<tr>
<td>NHI</td>
<td>National Health Index</td>
</tr>
<tr>
<td>NISS</td>
<td>New Injury Severity Score</td>
</tr>
<tr>
<td>NMDS</td>
<td>National Minimum Data Set</td>
</tr>
<tr>
<td>NZHIS</td>
<td>New Zealand Health Information Service</td>
</tr>
<tr>
<td>NZIPS</td>
<td>New Zealand Injury Prevention Strategy</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PI</td>
<td>Pacific Island</td>
</tr>
<tr>
<td>RAMM</td>
<td>Road Maintenance and Management System</td>
</tr>
<tr>
<td>RR</td>
<td>Relative Risk</td>
</tr>
</tbody>
</table>
RTA | Road Traffic Accident
---|---
SAS | Statistical Analysis System
SRR | Survival Risk Ratio
TCR | Traffic Crash Report
UK | United Kingdom
US | United States
Definition of Terms

- **Motor Vehicle Traffic Crash-related Injury:** any injury that occurs as a result of a crash on a public road where the injury is directly attributable to a motor vehicle or its load. This does not include crashes that do not involve a motor vehicle (for example, a crash between a cyclist and a pedestrian), those in which death did not result from injury (for example, a driver that dies from an acute myocardial infarction), or those related to suicide or murder.

- **Police definition of Fatal Injury:** injuries due to MVTCs that result in death within 30 days of the crash.

- **Police definition of Serious Injury:** that which is coded on police reports as ‘serious’. Criteria for a serious injury in police reports are: ‘fractures, concussions, internal injuries, crushing, severe cuts and lacerations, severe general shock necessitating medical treatment and any other injury involving removal to and detention in hospital.’ This includes those who die as a result of their injuries if they die 30 days or more after the crash.

- **Police definition of Minor Injury:** injuries ‘of a minor nature such as sprains and bruises.’

- **International Classification of Diseases–based Injury Severity Score (ICISS):** this is an ICD-10 based injury severity score that allows a ‘probability of survival’ estimate to be calculated directly from a patient’s ICD-10 diagnostic codes.

- **SRR:** The Survival Risk Ratio estimates the chance of survival for a particular ICD diagnosis.

- **Serious Injury by ICISS:** an injury which has an ICISS of 0.941 or less, i.e. a 94.1% or less chance of survival or equivalently, a 5.9% or more chance of death.

- **Minor Injury by ICISS:** an injury which has an ICISS of greater than 0.941.
1. Introduction

1.1 Public Health Significance of Motor Vehicle Crashes

Motor Vehicle Traffic Crashes (MVTCs) are a significant cause of mortality and morbidity in New Zealand. In the 12 months to December 2004, there were 436 deaths, and police reports of 2,460 serious and 11,338 minor injuries resulting from MVTCs. Over the five years 2000-2004 19,831 people were hospitalised for at least one day as a result of an MVTC (Injury Prevention Research Unit 2003). In addition, there were over 42,000 Accident Compensation Corporation (ACC) claims in 2004/5 (Ministry of Transport 2005). ACC estimates that the total social cost\(^1\) of all road crashes each year is $3 billion (Accident Compensation Corporation 2005). These figures do not reflect the personal trauma that can be experienced by individuals and families of those involved, injured or killed in MVTCs.

1.2 Current System of Police Reporting in New Zealand

Any crash on a New Zealand public road resulting in injury is required by law to be reported to a police officer, as stated in Section 22(3) of the Land Transport Act 1998 (Ministry of Transport 1998). The attending police officer completes a Traffic Crash Report (TCR). Part of this TCR involves noting if anyone was injured as a result of the crash. This includes the driver, any passengers, pedestrians and cyclists etc who were involved. Injuries are coded by the police officer as to whether they are ‘minor’, ‘serious’, or ‘fatal’. ‘Serious’ is defined as ‘fractures, concussions, internal injuries, crushing, severe cuts and lacerations, severe general shock necessitating medical treatment and any other injury involving removal to and detention in hospital’ (Land Transport Safety Authority 2004).

There is some data ‘massaging’ by LTNZ after submission of the TCRs. If the text narrative, which is at times quite detailed, describes an injury that appears to be incorrectly coded, adjustments are made. Also, if the mechanism of crash and damage to the vehicle(s) is inconsistent with the injury code, adjustments are made. The data is then entered into the national

\(^1\) Social cost aims to measure the total damage to society. Surveys are conducted to determine how much people would pay to decrease the chances of death, injury, and the pain and suffering associated with crashes. The amount people would be willing to pay, plus the loss of earnings, cost of legal, medical and emergency services and the cost of property damage are all included in the calculation. (Ministry of Transport (2005). Road Safety Progress: a quarterly update of performance measures. Wellington, Ministry of Transport.)
Crash Analysis System (CAS) which is maintained by LTNZ (Byfield J 2006). CAS links data from two primary sources: TCRs and data from the Road Maintenance and Management System (RAMM), which contains information about road categorisation and traffic flows. This information is geospatially mapped. Crash analyses can then be performed based on a number of variables, including location (Land Transport New Zealand).

The number of people killed annually has traditionally been the principle indicator of road safety in New Zealand (Ministry of Transport 2005). Currently, the number of fatal crashes, deaths per 10,000 vehicles, deaths per 100,000 people, total number of hospitalised casualties, casualties hospitalised for more than one day and casualties hospitalised for more than three days are also reported, as well as the number of ‘minor’ and ‘serious’ injuries (Land Transport Safety Authority 2004). Fatal crashes are defined by LTNZ as “...one in which one or more people died as a result of the crash, within 30 days.” (Land Transport Safety Authority 2003). This is consistent with the International Road Traffic and Accident Database definition (International Road Traffic and Accident Database (OECD) 2005).

1.3 Overseas Coding Systems

Systems used in other countries were investigated to ascertain if there are better ways of recording the severity of non-fatal traffic crash injury. Many countries including parts of the United States, Australia and United Kingdom use a similar system to NZ of collecting police-reported information. The definitions of ‘serious injury’ vary slightly between countries, but tend to be in part based on a requirement for medical care or hospital admission. Examples from developed countries are presented below.

1.3.1 Australia

In Australia police collect information on traffic crashes (McDermott FT, Cordner SM et al. 1996), (Treacy PJ, Jones K et al. 2002), (Boufous S and Williamson A 2006) (Meuleners LB, Lee AH et al. 2006). In Western Australia, a Traffic Crash Report is completed that notes if any individuals were killed, admitted to hospital as an inpatient, injured with medical treatment only, injured but not requiring medical treatment, or not injured (Western Australia Police Force 2006).
1.3.2 United Kingdom (UK)
The UK has a similar system to NZ of police attendance at MVTCs. The police officer fills out a comprehensive Road Traffic Accident (RTA) form that includes a field for injury severity. Here ‘serious injury’ is defined as one of the following: “fracture; internal injury; severe cuts; crushing; burns; concussion; shock requiring hospital treatment; detention in hospital as an inpatient; and injuries to casualties who die more than 30 days after the accident from injuries sustained at the accident.” (Cryer PC, Westrup S et al. 2001). This is very similar to the NZ definition of ‘serious’ injury.

In addition to this system, the UK uses occasional intermittent research to increase their understanding of MVTCs. An example of this is the ‘On The Spot Accident Data Collection Study’ which was commissioned to improve road safety and decrease the number of road casualties through better accident research. While this type of research does not give comprehensive yearly data, it can be used to give a snapshot in time about road safety.

1.3.3 United States (US)
In the US all crashes involving a certain degree of property damage or any injury are required to be reported to police. However, time and resource constraints often preclude the collection of detailed information that might be useful in the study of injury prevention. To address this problem, a number of databases have been set up. One of these is the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS). This provides details of a nationally representative sample of all crashes that occur in the United States that involve passenger vehicles damaged enough to require towing. This system contains information obtained from police reports, including their assessments about injury severity and vehicle damage. Additional information relating to injury severity is obtained from hospital and other medical reports and is classified according to the Abbreviated Injury Scale (AIS). In addition to this system, there are also state-based databases of police crash reports. These record a police officers’ assessment of injury severity, however, the definition of ‘serious’ injury differs between states (Farmer CM 2003).

2 The degree of property damage varies between states. Some states assign a minimum monetary value, such as $250 in smaller cities in Texas or $1000 in North Carolina. Others use a functional assessment of vehicle damage such as the need to be towed, as in Pennsylvania and large cities in Texas. In addition, it is possible to request a police report even when these thresholds for severity are not reached (Farmer C 2006). Personal communication.

3 For example, some states use a KABCO code; however they may vary in how they define each of the terms. KABCO is a 5 level scale used to classify injury severity, where fatal injuries are coded as ‘K’, incapacitating injuries are coded as ‘A’, non-incapacitating injuries as ‘B’, possible but not evident injuries as ‘C’ and no injuries as
1.3.4 European Union (EU)
The European Commission maintains a Community Road Accident Database on MVTCs, with data collected from 14 countries in the EU (European Commission 2003). However, there is wide variation in the way in which motor vehicle crash related statistics are collected in the EU, so it is difficult to compare the results from one country to another. While most member states use parameters such as fatal accidents, serious injury accidents and slight injury accidents, the definitions of each of these are inconsistent between countries. The United Nations/World Health Organisation definition of a fatality is a death occurring within 30 days of the crash. However Greece, Portugal and Spain use 24 hours, and France and Italy use six and seven days respectively (MacKay M 2005). There is also significant variation in other data collection practices between countries relating to whether the crash is on a public road or not, if it involves at least one moving vehicle or not, who can report a crash and whether natural deaths and suicides are included or not (MacKay M 2005). A similar pattern can be seen with grading injury severity where that which constitutes a ‘serious’ injury varies between countries. In Finland, a ‘serious’ injury is one resulting in admission to hospital and/or three days off work, in France it is hospital admission of six days or more and in Sweden it is hospital admission or fracture, whether, admitted or not. To complicate matters further, the ‘accident severity’ is often reported. This refers to the number killed per 100 accidents, rather than being an indicator of the severity of individual injuries that were sustained (Lejeune P and Ducassou AM 2003). In addition, of the ten member states that recently joined the EU, most do not have adequate databases recording those who survive MVTCs, regardless of injury severity. In light of this the EU targets relate to MVTC deaths only (MacKay M 2005).

1.3.5 Developing Countries
At the Road Traffic Injuries and Health Equity Conference, an international road traffic injuries conference of 11 developing nations\(^4\), it was identified that data collection and quality are major problems (Nantulya VM, Reich MR et al. 2002). Most countries had data that was collected by police, but was of varying degrees of quality. For example, of the 1345 hospitals in Thailand (both public and private), 22 actively participate in injury surveillance. Nurses with special training perform interviews to obtain details about the crash and relevant clinical information. In 'O'. Other states use their own definitions. Illinois, for example defines possible injury as “complaint of pain or momentary unconsciousness.” Some states use a severity scale, such as in Pennsylvania where injuries are classified into deaths, major injuries, moderate injuries, minor injuries and no injury (Ibid).

\(^4\) The 11 countries represented were Colombia, Ghana, Kenya, Mexico, Mozambique, the People’s Republic of China, South Korea, Thailand, Trinidad and Tobago, Vietnam and Zambia.
addition, police also fill out a standard form for traffic crashes. Part of this form includes an assessment of injury severity (killed, severely injured or mildly injured). However, the information contained in these forms is considered unreliable as the police officers responsible for filling out the forms are not trained specifically for this purpose, and there is variation in recording between police stations. Also, trained officers in highway districts fill out forms regarding crashes from handwritten notes from police officers which further compromises the accuracy of the information (Suriyawongpaisal P and Kanchanasut S 2003).

1.4 Benefits and Deficiencies of the Current New Zealand System

The TCR form is comprehensive and records details about a number of factors that may have influenced the crash. These include variables about the environment, the vehicle and the driver, as well as detailed information on the location. Having a system in which injury-related data is collected as well as other variables relating to the crash is useful, because the injury severity indicator assists in determining priorities for action. For example, a location in which there are ten crashes involving serious injury is more likely to be modified than one in which there are ten crashes with no injuries. However, this severity data is limited in its accuracy.

1.4.1 Data Collection Issues

Some of the reasons for this lack of precision relate to data collection. Police need to be notified that a crash has occurred otherwise they will not know to attend. A number of motor vehicle traffic crashes are not notified to police and consequently do not have a TCR filled out; or are reported to police, but a TCR is not completed. Alsop and Langley found that during 1995, less than two-thirds of victims of MVTCs that were hospitalised had a corresponding TCR (Alsop J and Langley J 2001). They found that reporting rates were higher for crashes involving injuries to drivers than passengers, with car drivers having higher reporting rates than motorcycle drivers. The lower reporting rate for passengers implies that rates for some groups will be biased, such as children aged 0-14 years, as they do not drive. Children in this age group who were involved in crashes were at particular risk of not being reported. This effect remained even when passenger type was controlled for (Alsop J and Langley J 2001). Reporting rates also varied between casualty type, severity of injuries sustained, the number of vehicles involved, the day of the week, month of the year (though no seasonal effect) and geographical area. This shows that not only is the data that is collected incomplete, it is also systematically biased.
This is not only a problem in New Zealand. Giles (Giles MJ 2003) also found that in Australia there is under-reporting of MVTCs. In this study, the police road crash data was made up of a non-random sample of the true population of those involved in road crashes, with the financial cost of police-notified crashes being higher than the cost of crashes that were not notified to police.

In addition, Langley et al (Langley J, Stephenson S et al. 2003) studied the usefulness of traditional indicators of trends in non-fatal MVTCs in NZ. This showed that indicators based on TCRs and number hospitalised were unduly influenced by patterns of data collection. There was an increase in all indicators of injury severity in 2001. This was due to two reasons. One was that the criteria for that which constitutes a hospital admission had changed, resulting in some ED patients being counted as ‘admitted’ where previously they would have been considered ‘outpatients’. Secondly, there was an increase in the number of TCRs being filled out, at least in part because of more enthusiasm in filling out the forms in some police districts (Langley J, Stephenson S et al. 2003).

1.4.2 Problems with the Assessment of Injury

Of those injury crashes for which there is a TCR filled out, the severity of injury that is recorded could be incorrect. Decisions about injury severity are made by police, who are instructed yearly in first-aid, but who are not health professionals. This will influence the degree of accuracy with which the injuries are assessed. There is likely to be some confusion about injury severity with some injuries that initially appear serious being relatively minor, such as bleeding facial wounds, and others that initially appear trivial being serious, such as head injuries. Of those injuries that appear serious, many may not pose a significant threat to life. In addition, assessments of injury severity must be made at the roadside at the time of the crash. Time is a useful aid to diagnosis. Time to observe the victim is not always available to the attending officer, a factor which can limit the accuracy of the information that is recorded. The attending officer also has a number of functions to perform, only one of which is assessing the injury severity of casualties. These factors all potentially limit the accuracy of the information that is recorded.

Additionally, the descriptor of ‘serious’ injury for the TCRs is very broad. For example, any fracture is considered to be a serious injury. While this is true of many fractures, such as a fracture of the femur or a fracture of the base of the skull, it would be misleading to assume all
Fractures are serious in terms of a threat to life, long term disability or cost. Fractures such as those of the digits should not be considered to be equivalent in severity as those in major long bones, vertebrae or the skull. There are 198 ICD-10 codes that describe a type of fracture. Estimated Survival Risk Ratios for these diagnoses range from 0.33 to 1, with 75% between 0.95-1. This does not demonstrate any frequency with which the fractures occur, but shows that the variation in the degree of severity for one diagnosis, fracture, is vast. Therefore, if the police definitions of injury severity are strictly adhered to, the ‘serious’ category on the TCR will include a number of injuries that pose almost no threat to life.

Finally, the definition of ‘serious’ injury includes “...any other injury involving removal to and detention in hospital” (Land Transport Safety Authority 2004). Of people with the same injury, the proportion that are taken to hospital may change over time. It is possible that Emergency Services staff are more likely to recommend medical assessment now than they would have been 20 years ago. If this is the case, by definition we would expect an increase in the number of ‘serious’ injuries as determined by the TCR data, even if the nature and severity of injuries had not changed over this time period.

Minor injury is defined as “injuries of a minor nature such as sprains or bruises.” This is a fairly well-defined category, and should therefore only include injuries that are minor in terms of the International Classification of Diseases-based Severity Score (ICISS) also. However, given the difficulties with roadside assessment of injury severity, it is possible that some injuries at the moderate to severe end of the spectrum will be included in the TCR ‘minor’ category. In addition, it is possible that this category is used by police to describe any injuries that don’t intuitively appear to be serious and therefore are not considered to be severe enough to warrant being recorded in a ‘serious’ category.

1.4.3 Research Investigating the Usefulness of Police-Reported Information
Previous studies have investigated the validity of police-reported information relating to MVTC injury. In the UK, Cryer et al (Cryer PC, Westrup S et al. 2001) examined whether a database linking police Road Traffic Accident reports and hospital data produced less biased information than using RTA reports alone. They used a two-step process of manual and electronic linking of police-recorded and hospital data. Approximately 50% of those involved in road traffic crashes who were admitted to hospital were included in the linked dataset. The proportions of casualties
in the linked database and the hospitals admission data were similar by road user type. However, there was undercounting in the police data for injuries to cyclists (particularly children) and car passengers. They found that using police-reported data alone could be very misleading, and recommended instigating a national dataset linking police road traffic crash data with hospital admission data to obtain more complete information. They also commented that due to the difficulties in assessing injury severity at the roadside, police should not comment on injury severity at all. Rather, injury severity should be based purely on hospital discharge codes. Additionally, they propose that the government should reconsider their safety targets, given they are based on police data which is prone to inaccuracies.

In the US, the National Automotive Sampling System/Crashworthiness Data System is useful. However, there are limitations in the conclusions that can be made about this database. Crashes are sampled by region, rather than state, which could have implications for evaluating the impact of policy change when laws between states differ. Also, less than 5,000 crashes per year are investigated, out of an estimated 6 million (Farmer CM 2003).

Farmer studied the reliability of police-reported injury severity information in the US (Farmer CM 2003). He found that nearly half of the drivers coded as having incapacitating injuries, based on a KABCO scale, were not seriously injured when compared to the MAIS (Maximum AIS) obtained from medical records or patient interview. Furthermore, there was evidence of non-random variation in the police assessment of injury severity. Drivers in daytime crashes were more likely to be miscoded by police for ‘non-incapacitating’ injuries than those involved in crashes during the night. Injury severity was overstated in female drivers significantly more often than in male drivers. Fifty-three percent of female drivers who were thought by police to have incapacitating injuries sustained only minor injuries. In addition, injury severity was overstated by police more frequently for drivers between the ages of 16-64 years than for drivers over the age of 65. There was a tendency for drivers of later model year vehicles to have their injury severity overstated compared to drivers of older cars, however, this was not statistically significant. Overall, police officers were usually able to correctly identify those drivers who were killed or uninjured, but the varying levels of non-fatal injury were frequently misclassified. Farmer concluded that in the US, police coding of the seriousness of injury was too imprecise for many research applications and additional injury data from another source should be used (Farmer CM 2003). This is analogous to Cryer’s assessment of the UK system.
1.5 Economic Factors in Road Crashes

There are important economic reasons for measuring the incidence and impact of MVTC-related injury accurately. Estimates are performed to assess the economic value of various road safety programmes and roading improvements. These estimates factor in the cost of fatalities and the social cost of crashes. The social cost includes the costs associated with injuries sustained in the crash as well as the cost of property damage (Guria J 1999). Recent economic evaluation shows that there is a high incremental benefit/cost ratio of current road safety programmes in NZ, especially for programmes that are aimed at reducing high risk behaviours on the road. This high benefit/cost ratio shows that investment in safety programmes is considerably lower than an optimal level. Therefore, there is economic benefit in increasing investment in road safety programmes (Guria J 1999). This economic equation assumes that the social costs, and therefore injury costs are known entities. If there is poor estimation of the number and severity of injuries on NZ roads, then the benefit/cost ratio could change.

It is especially important to consider the interaction of poor economic measurement of cost and poor assessment of injury severity for at-risk groups. For example, in their analysis of inpatient costs of injury due to MVTCs in NZ, Langley et al found that on average, pedestrians were twice as costly to treat as occupants of motor vehicles. Most of this was due to the fact that their average length of stay was twice as long as that of all other road users (Langley JD, Phillips D et al. 1993). This means that the economic burden of injuries to pedestrians is likely to be underestimated. In addition, if there is a systematic bias in the way in which injuries are reported, there could be significant implications for pedestrians. It is known that pedestrians are less likely to have a TCR filled out, and therefore less likely to have their injuries recorded in official statistics. Pedestrians consequently have the double burden of being undercounted and on average sustaining injuries that are twice as costly. This undercounting of both actual numbers and related costs could affect factors such as resource allocation, the development of health promotion programmes (Langley JD, Phillips D et al. 1993) and influence the benefit/cost ratio of specific programmes aimed at improving pedestrian safety.
1.6 Implications of this Research to Policy

Statistics based on TCR injury severity data are used by the Ministry of Transport (MoT) to monitor motor vehicle crash-related injury over time and are used as a performance measure. It is of great importance that whatever measure is used is a valid indicator that is objective and not prone to influence from changes in either police or emergency services practice or medical management of patients over time. The ‘serious’ injury category includes any injury assessed to be requiring medical treatment. This is a subjective measure, and its use is likely to vary between individuals and over time, and may differ with different patient characteristics, for example, age and sex.

It is recognised that improved data collection will enable better monitoring of progress towards the road safety targets. In the NZ strategic plan for road safety, “Road Safety to 2010”, fatalities, injury crashes and hospitalisations are used as indicators of severity. The goal stated in this publication is to “reduce the number of deaths per year to no more than 300 and hospitalisations to no more than 4500 by 2010.” (Ministry of Transport and National Road Safety Committee 2003) It is possible for the non-fatal targets to be artificially met through reasons other than an actual reduction in the rates of MVTC-related injury. This could influence the evaluation of how effective certain road safety programmes have been, and consequently programmes may be continued or discontinued based on incorrect information. Accurate statistics about injury severity data for MVTCs are required to inform policy and improve injury prevention practice by allowing better allocation of resources to areas of need.
2. Literature Review

2.1 The Need for Valid Indicators

Indicators are used in a variety of settings. A definition of an injury indicator is “…a summary measure which denotes or reflects, directly or indirectly, variations and trends in injuries, or injury-related or injury control-related phenomenon.” (Cryer C 2003) Indicators can be used to monitor injury events for surveillance, priority setting, evaluation and for the international exchange of information (Fingerhut LA 2004). Injury indicators are used in New Zealand and overseas. MVTC data is used by road safety organisations such as the MoT and the Police to monitor trends in injury over time. This information can be used in the process of setting priorities for road safety in terms of targeting risky behaviours and where to undertake roading upgrades.

Indicators can also be used to assess the impact of past and current health promotion programmes aimed at reducing motor vehicle-related injuries. Cryer et al suggest that injury indicators are highly influential and can direct resource allocation into areas of need (Cryer C, Langley JD et al. 2002). In NZ, TCR data on crashes and casualties is used in economic evaluations of road safety programmes (Guria J and Leung J 2004). Therefore getting indicators right is of great importance, as the effectiveness of road safety programmes may be judged and financial resources allocated or withheld based on performance as measured by indicators (Sim F and Mackie P 2002).

2.2 Development of Valid Indicators

When looking at measures of injury severity, a number of indicators can be used. There is a trend in NZ and overseas to use the number of fatalities as an overall indicator of injury. However, it is important not to use fatalities as a proxy measure of serious injury, as the pattern of injury can be different to the pattern of fatalities (Langley JD 1995), (Langley J and Broughton J 2000). Therefore the use of fatality-related data alone will give a misleading picture of serious injury. In addition, the number of fatalities gives no information about the actual burden of non-fatal injury. Much of the fiscal cost of injury results from the hospital treatment, loss of earnings and compensation. Examining only fatal injuries would not demonstrate this. It is therefore important...
to obtain information about both fatalities and non-fatal injury. In recent years, a lot of time has been spent in establishing reliable indicators for non-fatal injury (Fingerhut LA 2004).

While the quest for valid injury indicators might seem to be a relatively simple concept, it is fraught with difficulty. There is still deliberation over the definition of injury, with Injury International Collaborative Effort (ICE) members debating about both the conceptual and operational definitions of injury (Fingerhut LA 2004). An adequate definition is problematic as there is not a scientific basis for the distinction between injury and disease. In the past injuries have been thought of as damage caused by an energy exchange that has been acute in nature. However, damage caused by chronic low-energy exposures, such as carpel tunnel syndrome, pose a problem to this traditional view of injury (Langley J, Stephenson S et al. 2002).

There is currently a push to move away from indicators which use service utilisation as a proxy for seriousness of injury. The weakness of using indicators such as hospital admission and consultation with a medical practitioner is that these are influenced by a number of things other than true injury incidence and severity. However, these continue to be used as indicators, partly because of ease and partly because of lack of a better option. This is particularly true for the assessment of serious injury, as opposed to all injury. Hospital admission is often used as a proxy measure for serious injury for purely pragmatic reasons. Often there is no alternative method to accurately determine severity by anatomical or physiological measures, especially when looking at all injuries (Broughton J and Langley J 2000). Ideally, however, a case definition of injury or serious injury should be based on pathology or a diagnosis, rather than the use of services (Cryer C, Langley JD et al. 2005). Indicators that are service provision based will not remain constant over time as medical practice changes.

In the development of new indicators, some ideals to aim for should be borne in mind. It is important to ensure that indicators reflect the real nature of the problem and validly measure what they are intended to. Indicators should ideally consider anatomical severity of injury, economic costs and disablement (Langley J and Marshall SW 1994). They should also focus on what you would like them to, whether this be all injury, or only injuries at the more severe end of the spectrum (McClure RJ, Peel N et al. 2002).
At the International Collaborative Effort on Injury Statistics Injury Indicators Group meeting in 2001, a consensus was reached as to what criteria should be important when assessing the validity of current injury indicators and for developing new indicators. They developed the following criteria that an ideal indicator would fulfil:

1. Case Definition: this should reflect the occurrence of injury, rather than the use of services.
2. Serious Injury: The indicator should refocus attention on events that are associated with “significantly increased risk of impairment, functional limitation, disability or death, decreased quality of life, or increased cost.”
3. Case Ascertainment: The likelihood of a case being found should be independent of social, economic, and demographic factors, and factors that are influenced by service provision and access; i.e. they should measure the occurrence of injury rather than use of services.
4. Representativeness: The indicator should measure all subpopulations in the target group equally well.
5. Data Availability: It is desirable to be able to use existing data systems or be practical to develop new systems.
6. Indicator Specification: A comprehensive specification of the indicator should be documented, to allow calculation of the indicator to be consistent over time and between places.

From (Cryer C, Langley JD et al. 2005).

Another issue subsequently raised by ICE members is consideration of the accuracy and completeness of the data that is used to derive the indicators (Cryer C, Langley JD et al. 2005). In some instances use of incomplete data sets can be very misleading.

There is ongoing debate about whether to include ‘serious’ and ‘minor’ injury in injury statistics, or whether to just focus on ‘serious’ injury. McClure and colleagues believe that minor injury should be counted as well, as this makes up the vast number of injuries as well as a significant amount of the cost of injury (McClure RJ, Peel N et al. 2002). Cryer and colleagues argue otherwise; they propound that minor injury may be common, but it still makes up far less of the
cost and burden associated with injury, compared to deaths and serious injury (Cryer C, Langley J et al. 2004). They also argue that when the threshold for injury severity is low, the indicator is driven by minor injuries, because of the significantly larger number of minor injuries compared to serious injuries. Additionally, changes in service provision tend to affect the likelihood of admission for those with minor and moderately severe injuries compared to those with serious injuries, (Langley J, Stephenson S et al. 2003) which will affect cost.

2.3 Current Injury Indicators

Current indicators of injury severity used internationally are based on severity measures such as hospital admission, length of stay in hospital, consultation with a medical practitioner, insurance (or ACC) claims and serious long bone fracture. In addition, there are a number of severity scores used in injury research that tend to be based on anatomical injury.

2.3.1 Hospital Admission

The MoT uses hospital admission and hospital stay of one day\(^5\) or greater as an indicator of important injury (Ministry of Transport 2005). A distinction is made between those who were admitted for one day or longer from those who were admitted for less than a day to prevent counting those who were admitted to an Emergency Department, treated and discharged on the same day.\(^6\) While this may seem to be a reasonable proxy for severe injury, there are other factors that also influence whether a patient is admitted to hospital or not. For example, it is known that for children with injuries, admission rates are influenced by age (Walsh SS and Jarvis SN 1992). In NZ, socio-economic status is recognised as being influential in determining access to secondary care (Tobias M and Howden-Chapman P 2000). In addition, while a large portion of injury cost can be related to inpatient treatment costs, this is only one part of the total cost of injury. If one is distributing resources between different areas of health need, using the length of stay can be misleading. Langley et al found that the average cost of an MVTC patient was estimated to be about 1.9 times the average for all admissions. Additionally, MVTC-related injury is about 1.7 times more expensive to treat than other injury, making it an expensive type of injury (Langley JD, Phillips D et al. 1993). In NZ, 16% of injury victims who were treated as

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\(^5\) 'One day' indicates that the patient was in hospital at midnight, rather than being an inpatient for a minimum number of hours.

\(^6\) From 1999 onwards some hospitals have been including those who have been treated in the ED for three hours or longer as having being admitted to hospital. Previously, ED consultations would have been considered outpatient events.
inpatients in a public hospital in 1999 had an AIS of 3 (serious injury) or greater. The vast majority of injuries treated in hospital were AIS 1 (minor) or AIS 2 (moderate) (Langley J 2004). Rosman et al studied measures of injury severity for those admitted to hospital following an MVTC in Australia. While they stated that the length of stay in hospital was closely associated with other measures of injury severity, there were a number of anomalies. Of the casualties who remained in hospital for greater than 30 days, 75% had serious, severe or critical injuries by MAIS (Rosman DL, Knuiman MW et al. 1996). It follows then that 25% of those staying in hospital for a month or longer only had minor to moderate injuries. At a population level, these results show that significant biases can result if using hospital stay as a proxy for injury severity.

2.3.2 ACC Claims
ACC claims are one of the performance indicators used by the MoT (Ministry of Transport 2005). The total number of claims relating to MVTCs can be divided into treatment only claims and compensation or rehabilitation claims (entitlement claims). Entitlement claims show part of the financial burden of injury and give an indication of long-term disability resulting from injury, if it impacts on ability to work. However, those who were not earning prior to their injury, such as children and full time parents are less likely to be eligible for an entitlement claim as one of the primary reasons for doing so (loss of earnings) is not available to them.

2.3.3 Serious Long Bone Fracture
Serious Long Bone Fracture is defined as “those cases admitted to hospital with a primary diagnosis of fracture of the femur, or fracture of other long bones of the upper and lower limbs (i.e., radius, ulna, humerus, tibia, fibula) for which some operative procedure of the bones (excluding the hand or foot) was carried out.” This was proposed by Cryer and colleagues as an interim measure for assessing serious injury trends in the situation of blunt trauma injury, at a time when there was no direct measure of anatomical severity that was suitable for use with large databases. However, they acknowledged that serious long bone fracture does not represent all serious injury and that the trend in injury incidence for serious long bone fracture might not be the same as the trends in incidence for other serious injuries, for example head injuries (Cryer PC, Jarvis SN et al. 2000).

2.3.4 Injury Severity Scales
There are a number of severity scales that use either physiologic measures or anatomical injury. Physiological-based scores grade injury severity using measurable physiologic variables such as
heart rate, blood pressure and neurological state (Reilly JJ, Chin B et al. 2004). These are rarely used in population-based studies. Anatomical injury severity scales, such as the AIS, assign a severity score based on anatomical injury. Both these types of measures require either a diagnosis code (e.g., ICD-9) or a consultation with a health professional.

2.3.4.1 Abbreviated Injury Scales (AIS)
This method assigns a severity score of 1-6 to six body regions. This has an anatomical base, and looks at the most severe injury in each of the six body regions. AIS 1 reflects a minor injury, AIS 6 is usually fatal. An AIS score of 3 or greater is considered to be serious. There are three different functions of the AIS: the Injury Severity Score (ISS), the New Injury Severity Score (NISS) and the Anatomic Profile Score (APS).

The ISS is calculated by using the sum of the squares of the three highest AIS scores, from three separate body regions. However, if a patient has an AIS score of 6 they are automatically given an ISS of 75. The ISS scores range from 0-75. The NISS was developed to allow for multiple injuries in the same body region to be included in the calculation. The NISS is the sum of the squares of the three highest AIS measures, regardless of body region. The APS gives a score that is a weighted sum of the scores derived from the AIS, within specified body regions.

While it is beneficial to have an anatomical rather than service based indicator of injury severity, the AIS has some drawbacks. It can be costly therefore not practical in many instances, with the average traumatic incident taking between 10 to 20 minutes to code (Meredith JW, Evans G et al. 2002). While the variants ISS and NISS initially looked promising, neither predict long-term disability in survivors well (McClure RJ, Peel N et al. 2002).

2.4 Proposed Coding System

2.4.1 International Classification of Diseases-based Severity Score
For this study, the International Classification of Diseases-based Injury Severity Score (ICISS) will be used. This is an injury severity score that gives a probability of survival score, accounting for multiple injuries. The ICISS is calculated directly from ICD-10 codes. For each diagnosis code, a Survival Risk Ratio (SRR) has been computed. The SRR is calculated from a sample population, and is the proportion of cases with that injury diagnosis who did not die. The ICISS is the product of the SRRs for each individual:
ICISS = SRR(diagnosis A) \times SRR(diagnosis B) \times SRR(diagnosis C) etc.

The ICISS therefore represents the chance of survival, for that particular combination of diagnoses. The SRRs were developed based upon the survival of a number of cases with each diagnosis in NZ from 1 July 1999 to 31 December 2001 (Stephenson SC, Langley JD et al. 2002). Those who died at the scene of their injury are not included, and as survival was determined by a patient's state at discharge, those who died later at home were counted as survivors.

One of the benefits of using the ICISS is that it is consistent between different crash and road user types, making it a useful measure with which to compare injuries sustained by different mechanisms. It is also desirable because it does not involve a subjective value judgement about injury severity. As the ICISS is based on ICD-10 codes rather than service utilisation, it does not change with changing patterns of service provision.

2.4.2 Comparison of the ICISS to other Severity Scores

The use of the ICISS as a measure of injury severity based on the ICD-10 discharge codes has been assessed and it has been found to be a useful tool (Stephenson SC, Langley JD et al. 2002), (Stephenson S, Henley G et al. 2004) (Rutledge R, Osler T et al. 1998). Osler et al found that the ICISS outperformed the ISS. Part of this improvement was because it assessed the patient's worst injuries (as opposed to the AIS) and part was due to better modelling that enables all injuries to contribute to the final score (Osler T, Rutledge R et al. 1996). Meredith et al found the ICISS among the best in terms of discrimination\(^7\) of the ISS, NISS and APS (Meredith JW, Evans G et al. 2002). Hannan et al also compared the abilities of several injury severity measures. As well as the ICISS, they looked at the Injury Severity Score (ISS), the New Injury Severity Score (NISS), the Modified Anatomic Profile (mAP) and the Anatomical Profile Score (APS). They found that of the eight measures assessed, the ICISS was significantly better in terms of discrimination, and somewhat better in terms of calibration.\(^8\) Additionally, the ICISS appeared to be a better measure of injury severity regardless of whether physiological and demographic variables were also available to predict mortality (Hannan EL, Hicks Waller C et al. 2005).

\(^7\) 'Discrimination' refers to the ability of the measure to distinguish between patients who die in hospital and those who were discharged alive.

\(^8\) 'Calibration' refers to the model's ability to predict survival for various levels of patient risk.
2.4.3 Threshold for ‘Serious’ Injury
An ICISS of \( \leq 0.941 \) will be used in this research to indicate a serious injury. An ICISS of 0.941 means that the case had a 94.1% chance of survival, therefore 5.9% likelihood of death, given the injuries sustained. The threshold of 0.941 has been used previously to indicate serious injury in the New Zealand Injury Prevention Strategy (NZIPS) (Cryer C, Langley J et al. 2004). This threshold is intended to capture all injuries of a serious nature, but only include those injuries with a high likelihood of admission to hospital. The cut-off means that diagnoses such as fractured neck of femur, intracranial injury (excluding concussion) and injuries of nerves and spinal cord at the neck level are included as serious, among others. Those suffering from injuries of this severity are very likely to be admitted to hospital, and this is unlikely to change over time despite changing medical practice. Cryer et al found that a cut-off that included less serious injury had some drawbacks. These included a mix of more heterogeneous diagnoses, some of which were able to be treated as outpatients. This is undesirable, as including diagnoses that can be treated as outpatients means that the indicator can be subject to change with changes in hospital service provision and other extraneous factors (Cryer C, Langley JD et al. 2006). Therefore, the 0.941 cut off will be used again for this study.

2.4.4 Strengths of using the ICISS Measure
An advantage of using ICISS as a measure of severity is that one has the ability to calculate severity based on multiple injuries and not be constrained by only using the most severely injured body region, as is required with the AIS. Aharonson-Daniel et al found that using multiple injuries to assess morbidity with the AIS was more useful than a ‘primary’ injury diagnosis (Aharonson-Daniel L, Giveon A et al. 2005). Although, Kilgo et al found the ICISS was a better predictor of survival if just the lowest score was used (Kilgo PO, Osler TM et al. 2003). Another advantage of the ICISS is that it can easily be calculated based on ICD-10 codes, which are routinely collected. Further, it does not require any mapping programmes or manual steps to calculate the ICISS.

2.4.5 Limitations of the ICISS Measure

2.4.5.1 The Calculation of Survival Risk Ratios
While the ICISS is superior to other injury severity scores, it does have some drawbacks. The ICISS is highly dependent on the quality of ICD-10 coding (Stephenson SC, Langley JD et al. 2002). Also, a patient with multiple injuries may experience a very different outcome to one who has only one injury. ICISS recognises this. However, somebody with coexistent chronic illness
may also experience a very different outcome from a previously health person, despite receiving the same injuries (Reilly JJ, Chin B et al. 2004). This is an area which is currently under investigation.

There are some limitations of the ICISS that relate to the way in which the Survival Risk Ratios were derived. SRRs are based on hospital discharge codes. This means that to have been included in the calculation a patient needed to have been admitted to a hospital. Therefore, those who died at the scene of the crash were not included in the dataset used to calculate the SRRs. Of those who were admitted to hospital, the true survival outcome was not always known, as in the case of those who died at home after discharge. These cases would have been counted as survivors. In NZ it is estimated that at least 60% of injury deaths would be included in one of these two groups. This could overestimate the survival probabilities (Cryer C, Langley JD et al 2006). There are plans to account for the impact of these missing deaths in SRRs.

The SRRs are a better estimate of the true chance of death when a large database has been used for their calculation. In New Zealand, because of our small population we do not have estimates for survival that are as good as countries that have a larger population, such as Australia (Stephenson S, Henley G et al. 2004). However, it is important for the SRRs used to be taken from the same population as the study population. It is also important for the SRRs to be updated as improvements in medical care improve case fatality rates (Stephenson SC, Langley JD et al. 2002).

Another limitation of the SRRs is that patients included in the calculation might have multiple injuries. Therefore, their survival or death will be counted for each of the ICD-10 diagnoses, regardless of the relative importance of each injury to the survival outcome of that patient.

2.4.5.2 Performance of ICISS for Very Severe Injuries
Stephenson et al found that the ICISS appeared to underestimate mortality for patients with an ICISS less than 0.6. This may be because the ICISS method assumes that the SRRs are independent, which for some diagnoses they are not (Stephenson S, Henley G et al. 2004). However, for the purposes of this study, where the ICISS will be used in a dichotomous manner with the cut-off at 0.941, this is immaterial.
2.4.5.3 Future Improvements to the ICISS

There are currently plans to address some of the limitations of the ICISS. Work to develop valid indicators that reflect injury that is important with regard to factors other than mortality or threat-to-life needs to be performed (Cryer C 2005). It is possible that there will be measures developed that will reflect the probability of disablement, average loss of quality of life, or average cost for each ICD-10 diagnosis. This would give a better picture of the true cost of injury (Cryer C, Langley JD et al. 2002). The development of a complementary measure of threat-of-disability is needed (Cryer C, Langley JD et al. 2006). This should take into account disability that involves little or no threat to life, such as the loss of function of hands, digits or eyes (Cryer C 2005).
3. Aims and Hypotheses

The aims of this study are to assess the validity of police-reported information on the severity of non-fatal motor vehicle traffic crashes.

Specifically:

1. To determine the validity of the police-reported information about the severity of injury in non-fatal MVTCs.

2. To determine if the validity varies by the following factors:

   - **Gender**
     Farmer found that injury severity was overstated for females more frequently than for males in the US. We hypothesise that the same will be true in NZ.

   - **Age**
     We hypothesise that injury severity will be more difficult to assess at the extremes of age, in particular with injury severity being underestimated in older people.

   - **Ethnicity**
     We predict that injury severity will be more difficult to assess in those who are not fluent in English. Therefore, there might be some variation in validity between ethnic groups, where this acts as an indicator of fluency in the English language.

   - **Nature of injuries**
     By their nature, some injuries are more difficult to detect than others. Injuries which are not visible to the naked eye, such as internal injuries, may be more difficult to detect than those which are clearly visible, such as bleeding abrasions. We hypothesise that injuries which are not clearly visible will be less likely to be detected, and those that are easy to see will have their injury severity overstated.

   - **If alcohol is suspected**
     While it is generally recognised that consumption of alcohol increases the chance of injury through impaired judgement and psychomotor performance, there is a common misconception that following a crash, alcohol protects against injury. Laboratory studies of animals have shown that this is not the case, with poor tolerance to injury if intoxicated (Malt SH and Baue AE 1971). Waller et al examined the influence of alcohol in road...
traffic crash victims. After controlling for a number of confounding factors\(^9\), they found that a driver who had consumed alcohol is more likely to die or suffer serious injury compared with a driver who had not been drinking (Waller PF, Stewart JR et al. 1986). We hypothesise that the validity of the assessment of injury severity will be worse when alcohol has been thought to be involved, particularly in the case of severe injury being more likely to be overlooked.

- **Type of road user**
  A previous investigation by Langley et al (Langley J and Marshall SW 1994) has shown that some road user groups are at particular risk for serious injury, such as motorcyclists and pedestrians. We wish to ascertain if the seriousness of these injuries is recognised at the roadside or not.

- **Degree of vehicle damage**
  There is a direct relationship between energy transfer and injuries sustained, and vehicle damage is often used as a proxy assessment of injury severity. However, conclusions based upon the vehicle’s maximum deformation alone should be avoided. These do not take into account other variables, such as the stiffness of the vehicle and the principle direction of the force (Stefanopoulos N, Vagianos C et al. 2003). We predict that the severity of injuries will be overestimated in vehicles that have marked damage.

- **Vehicle year**
  Farmer found that in the US there was a trend towards drivers of later model cars being misclassified more frequently than drivers of earlier model cars (Farmer CM 2003). We will investigate the data to see if this is true in NZ also.

- **Accident severity**
  We predict that for crashes in which one or more parties is severely or fatally injured, the injury severity assessment of less injured parties will be influenced. Severe and fatal crashes will force police to triage, and could lead to the less severely injured in the crash being overlooked, although they might still have a significant injury.

- **Time of day**
  In the US, Farmer found that police-reported injury severity was overstated for drivers in day time crashes more frequently than for night time drivers. We hypothesise that the validity of injury severity assessment will be better for TCR ‘serious’ injuries at night, as

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\(^9\) Confounding factors that were controlled for were driver age, seat belt use, vehicle deformation, vehicle speed and vehicle weight.
injury severity will tend to be overstated less. However, we predict that during night time hours, when it is dark and therefore more difficult to see, some serious injuries will have a tendency to be overlooked.

- **Police district**
  Studies both in NZ and overseas have found that there is variation in the accuracy of data between geographical regions (Farmer CM 2003) (Alsop J and Langley J 2001). This will be examined.
4. Background to Methodology

There are a number of issues in the study design that need to be considered. These relate to the process of linking databases and sources of confounding that might arise in the police assessment of injury severity.

4.1 Linking Databases

Database linkage is a useful way to combine information from two different sources to gain additional information about an event, as in the case of MVTCs. However, there are intrinsic problems with linking databases. They can result in a substantial loss of information (Cryer PC, Westrup S et al. 2001). Linkages might not be made as not all cases are reported to the police, and therefore will not have a TCR filled out. Additionally, errors in the details of cases in either database can result in failure to link information for that case (Cryer PC, Westrup S et al. 2001). The information gained after the linkage is only as good as the quality of data that is entered. Marshall et al note that the success of linking databases can be highly dependent on the specificity of the personal identifiers that are routinely captured by each database (Marshall SW, Langley JD et al. 1993). In the situation of using the date of the crash as an identifier, if the number of crashes on a given day is high, there is more opportunity for confusion between cases, meaning accuracy of other details becomes more important (Rosman DL 1996). Furthermore, biases and idiosyncrasies that are associated with each database need to be assessed and borne in mind at all stages (Marshall SW, Langley JD et al. 1993).

Previous studies that have used a process of linking two databases have had similar results. Cryer et al used a manual method of data linkage to link hospital admission data with police road traffic crash data. They estimated that 50% of cases involved in a road traffic crash that were admitted to hospital were included in their database (Cryer PC, Westrup S et al. 2001). However, they found that there were no significant differences between those who were able to have records linked and those who were not. Their linked non-fatal serious injury data was a reasonable estimate of the relative magnitude of the problem for each age, gender and road user group, although police tended to underestimate the magnitude of the problem of injury relating to cyclists (Cryer PC, Westrup S et al. 2001). Similarly, Rosman appeared to achieve a 54% success rate in an initial process using the Generalised Iterative Record Linkage System (GIRLS), to
match police casualty and hospital records (Rosman DL 1996). Low linkage rates have been attributed to failure of road users to report MVTCs to the police, accuracy of the linking variables, the organisation of the police records and failure to identify road traffic crashes on hospital systems (Cryer PC, Westrup S et al. 2001).

4.2 Factors Associated with a Higher Level of Injury Severity

Singleton et al (Singleton M, Qin H et al. 2004) studied factors that were associated with higher levels of injury severity in occupants of motor vehicles that were severely damaged in crashes. They examined occupant, crash and vehicle information for cases in Kentucky who were involved in an MVTC where the vehicle suffered either ‘severe damage’\textsuperscript{10} or ‘very severe damage’\textsuperscript{11}. A number of factors were associated with an increased likelihood of a higher level of injury severity when involved in a crash where the vehicle was severely damaged. Occupant factors included increasing age, females, no use of a seat belt or restraint, ejection from the vehicle and drivers who were suspected of being under the influence of alcohol or drugs. Vehicle factors that were related to an increased chance of severe injury were vehicle rollover (compared to no rollover) and the vehicle catching on fire. Head-on collisions, collisions with a fixed object and a maximum speed limit posting of 89km/hr or greater were also risk factors for a greater severity of injury. It is not clear why gender differences exist; however, some theories have been postulated. It may be due to physiological gender differences, or possibly because on average females are shorter and therefore have to sit closer to the steering wheel and airbag (Singleton M, Qin H et al. 2004).

\textsuperscript{10} ‘Severe damage’ is defined in the Kentucky Uniform Police Traffic Collision Reporting Manual as “… a vehicle which must be towed and is totally damaged. This includes vehicles which could be driven but would be further damaged by doing so.”

\textsuperscript{11} This is defined as “…damage to the entire vehicle with no possibility of repair” or extreme damage due to water immersion, fire, explosion, and so on (Singleton M, Qin H, et al. (2004). "Factors Associated with Higher Levels of Injury Severity in Occupants of Motor Vehicles that were Severely Damaged in Traffic Crashes in Kentucky, 2000-2001." Traffic Injury Prevention 5: 144-150.
5. Methods

5.1 Overview

This study used information from NZ police Traffic Crash Reports and hospital discharge data. The two datasets were matched by person and the combined information used to examine the validity of the police assessment of injury severity, based on the hospital discharge codes. These record a single or multiple discharge codes for each event. This study examined matched cases only.

5.2 Crashes Resulting in Inpatient Treatment

Hospital discharge data was obtained from the National Minimum Data Set (NMDS) through the New Zealand Health Information Service (NZHIS). The Injury Prevention Research Unit (IPRU) has ethical approval to obtain and use this data for a number of projects including this one. The NMDS collects information on all publicly funded hospital discharges for inpatients and day patients, and some privately funded events. All records must have a valid NHI (National Health Index) number (New Zealand Health Information Service).

The NMDS dataset was restricted to:
- Discharges from January 2000 to December 2004
- Publicly funded health events
- First admissions only. Readmissions for the same injury were excluded
- Motor vehicle traffic crashes only
- Discharges with a principle diagnosis code of injury. This included all ICD-10 ‘S’ codes and ‘T’ codes T00 – T79

That which constitutes an admission varies between hospitals in New Zealand. In some hospitals, attending the Emergency Department for three hours or greater constitutes an admission. Therefore, there are discharge codes for a number of people who would not have been admitted for a whole day, or even overnight.
The motor vehicle traffic crashes were selected using the ICD-10 external cause codes. ICD-10-AM codes that relate to motor vehicle crashes involving at least one moving vehicle on a public road are: V02-V04 (with a 4th digit in the range .1-.9), V09 (.2), V12-V14 (.3-.9), V19 (.4-.6), V20-V28 (.3-.9), V29-V79 (.4-.9), V80 (.3-.5), V81-V82 (.1), V83-V86 (.0-.3), V87 (.0-.8) or V89 (.2).

5.3 Injury Crashes Resulting in a Traffic Crash Report

The Traffic Crash Report data was obtained from Land Transport NZ (LTNZ). It is a subset of the routinely collected data which makes up the Crash Analysis System.

The Traffic Crash Report dataset was limited to:
- Crashes between January 2000 and December 2004
- Those in which an injury or death occurred

5.4 Linkage

The two data sets were then linked by the IPRU data manager using the computer programme Automatch (MatchWare Technologies Inc 1996). This programme uses probabilistic record linking (Jaro MA 1989).

67,728 TCR records and 30,025 NZHIS records were included in the linkage. Of these, 15,204 (50.6%) of the NZHIS records linked.

To check the validity of the linkage process, two steps were performed.

5.4.1 Step I: To verify the predicted 50% linkage rate

A sample of 200 NZHIS records was selected randomly. This number was chosen as assuming a 50% linkage rate, the 95% confidence interval would be (43%, 57%). Considering the time required to manually link 200 records, a confidence interval width of 14% was considered acceptable.

The NZHIS dataset was used to select the records, as if all crashes were reported to police and resulted in a TCR being filed with LTNZ, as is the ideal, there would be a TCR for each of the
people with an NZHIS record. However, we would expect the TCR dataset to contain a substantial number of records for people whose injuries did not require hospitalisation, for example those who attended an emergency department and were treated and discharged immediately, or those who received first aid at the site of the crash. There would not be a corresponding NZHIS record for these cases.

This subset of 200 was manually compared to the 67,728 TCRs. The variables used in the matching process were gender, surname, first name (initials), age calculated from date of birth (age as stated by person to police officer) and date of injury (date of crash) from the NZHIS and TCR datasets respectively. For those who were drivers, the date of birth was usually recorded on the TCR. However, only the age was recorded for passengers or other casualties. These are the same variables as used in the Automatch process; with the exception that for the Automatch process the Soundex code was also used. Soundex is a computer programme that assigns a code to names based on what they sound like. Therefore, names that sound the same are assigned the same code, regardless of how they are spelt. This in part reduces the problems caused by inaccurate spelling of names in the database, where one or both records contain a spelling error. In the matching process, Soundex was used to block groups of records prior to being matched.

In the manual checking process, disagreement of one variable was allowed if all other variables were consistent. This disagreement was allowed only if the inconsistent variable appeared to be as a result of inaccurate data entry (for example, one digit in one of the ‘date’ fields incorrect), or due to different spelling of the surname. Differences in the surname were accepted where the first letter of the surname was the same and the sound of the name was not significantly different between the two records. A variation of one year was accepted for the age, as in the NZHIS data these were calculated from the date of birth, and on the TCR they were recorded in whole years. Differences in the recording of gender were not allowed.

Of the 200 NZHIS records, 102 were able to be manually matched to TCR records, at a rate of 51.0%.

5.4.2 Step II: Verification of the quality of the matched data

The 102 records that were able to be manually linked were then compared to the records linked by the Automatch programme.
We expected approximately 50% of the initial sample of 200 would be able to be linked manually, based upon the linkage rate by Automatch and based upon previous data linking studies that have found a similar number. This would give approximately 100 records for Step II of the process. Assuming that 90% of the linked records were matched to the same TCR records by Automatch and the manual process, the 95% confidence interval would be (82%, 95%). This confidence interval width was considered acceptable for this purpose.

5.5 Manipulation of the Matched Dataset

A unique identifier was assigned to each case to enable names to be deleted from the data set after the matching process was completed. This enabled the conservation of anonymity for individuals in the database from all except the data manager and the investigator checking the validity of Automatch.

The linked data was then converted to a form that could be read by the computer programme Intercooled Stata Version 9.1 (StataCorp 2005). Stata was the computer software programme that was used for all the analysis of the data. Before the linkage of the NZHIS and TCR datasets, all the variables that were not required for the matching process were removed. After linkage, the additional details from each data set were re-entered into the database and subsequently variables that were not relevant to the research questions were excluded.

To determine any remaining individuals whose injuries resulted in death who had not already been excluded, admissions resulting in a discharge code of “discharged dead” were searched for. For these individuals, the number of days between the day of the crash and the date of death were calculated. Those who died within 30 days as a result of their injuries were excluded, to remain consistent with the police definition of ‘fatal injury’. Those whose injuries resulted in death after 30 days of the crash should, by the police definition, be classed as ‘serious’. Those who had a TCR code of ‘fatal’ were also excluded.

The discharge variable on the NZHIS data also included a category “discharged for organ donation”. The assumption was made that those who were “discharged for organ donation” died as a result of their injuries sustained in the crash within 30 days of the event. These were all coded by the police as being fatal crashes. However, their second admission did not show up in
our dataset. We believe this is because the IPRU only receives data with an external cause code indicating injury. If someone was transferred for organ donation, the original event leading to this (the injury) may not be recorded.

All cases with a principle ICD-10-AM ‘S’ or ‘T’ diagnosis from NZHIS were included. In the ICD 10-AM coding system, injuries coded ‘S’ usually relate to injuries for single body regions, whereas ‘T’ relates to injuries to multiple or unspecified body regions or consequences of injuries. There are a number of accepted definitions of injury, including all discharges with a principle ‘S’ or ‘T’ diagnosis or all discharges with an ‘S’ code or ‘T00-T79’. It was decided that all ‘T’ codes would be included to reflect the burden of injury caused by MVTC. In our dataset, none of those with ‘T’ codes had codes of T80-T97, which describe diagnoses related to complications of surgical and medical care. Therefore all were due to injury, or acute events directly attributable to the injury (for example, early wound infection or compartment syndrome).

The overall aim of this study is to examine how closely our current indicators reflect the true severity of morbidity caused by MVTCs. We believe that inclusion of all injury-related conditions directly attributable to injuries sustained in the crash is therefore warranted.

A separate file containing clinical codes for the linked discharge events was constructed and Survival Risk Ratios assigned for each of the ICD10-AM codes for each individual. These SRRs were estimated from 1999-2001 NZ hospital discharge data. The Survival Risk Ratio gives the likelihood of survival for each ICD-10 diagnosis. The product of all of the SRRs for each separate discharge event was calculated; this is the ICISS Score.

5.6 Variables Analysed

5.6.1 NMDS Variables

Variables from the NMDS dataset that were analysed were gender, age, ethnicity and nature of injury.

Age

Age-based data was also grouped as follows:

- 0-14 years
- 15-24 years
- 25-44 years
These age groups were chosen to reflect different life stages and physiological changes at various ages.

**Ethnicity**
Ethnicity was collapsed into broader categories also. Groups were:
- NZ European
- Māori
- Pacific Island
- Asian (includes South East Asian, Chinese, Indian)
- Other (includes Middle Eastern, Latin American, African and Other European)
- Not Stated (NS)

For the logistic regression, these were further grouped into NZ European, Māori and Other.

For the main analysis of ethnicity, the codes recorded in the NZHIS data were used. This was because this data was more complete than the ethnicity data on the TCRs. In the NZHIS dataset, the ethnic group was recorded for 14,380 cases, with 489 (3%) unknown. The TCRs had an entry for ethnic group for only 7,873 cases (53%) with 180 of these being ‘other or unknown’. The NZHIS dataset had a number of ethnicity variables, so the prioritised ethnic group variable was used. This is consistent with the way in which ethnicity data is commonly analysed in New Zealand. See Appendix for the NZHIS decision making process for the prioritisation of ethnic group.

Ethnicity was also examined by the ethnic group as recorded on the TCR. This was done as we were interested in the police assessment of ethnicity, which in some cases may be different to the individual’s self-reported ethnic group. If there is any variation in validity in the police assessment of injury severity, this is more likely to vary depending on the officers’ impression of ethnicity, which may be different to the self-reported ethnic group of the individual. The number of conclusions that could be made on the basis of this data was limited, due to the large proportion of cases where ethnicity was not recorded. Ethnicity data has only been recorded on the TCRs from June 2001, with an apparent phase in period over the remainder of 2001. The
proportion of records in our dataset with complete ethnicity details has increased each year since then.

*Nature of Injury*

ICD-10 diagnostic codes were grouped into the following diagnostic categories:

- fracture
- intracranial
- organ damage
- dislocation, sprain, strain
- nerve damage
- blood vessel damage
- muscle, tendon damage
- crushing
- superficial injury
- open wound
- traumatic amputation
- other and unspecified
- adverse events/complications/sequelae
- foreign body entering natural orifice
- burns and corrosions
- poisoning
- effects of other external causes

These diagnostic categories were then combined to the following groups:

- fracture
- intracranial
- organ damage
- soft tissue injury
- superficial injury and open wound
- other

These groupings enabled meaningful analysis with adequate numbers in each group to allow for comparisons between groups.
5.6.2 TCR Variables

Variables from the TCR dataset that were analysed were accident severity, casualty type, whether alcohol was suspected, time of day, vehicle year, degree of vehicle damage and police district.

Alcohol Suspected

Whether alcohol was suspected or not was based upon the police impression of whether the injured person was thought to have been drinking alcohol, or if the breath screen was positive. Other variables recorded whether there was an evidential breath test result, or a blood test result. The latter two were not examined, as we were wanting to assess if the impression of alcohol present influences assessment of injury severity. Additionally, the blood test results are often filled in some hours to days after the crash. The result from this would therefore not influence the judgement of injury severity at the scene of the crash.

Most of the entries regarding alcohol were for drivers. However, information was given for some passengers also. Information for both drivers and passengers was used, as we wanted to elicit if the impression of the presence of alcohol in an individual changes the validity of the assessment of injury severity.

Casualty Type

Casualty type refers to the type of vehicle the casualty was using. The casualty categories were grouped as follows:

- Small Passenger Vehicles (cars, taxis, four wheel drives, vans/utes)
- Heavy Vehicles (buses, school buses, trucks)
- Motor Cycles (motor and power cycles)
- Other (wheeled pedestrians, equestrian riders, skateboarders and other)
- Cyclists
- Pedestrians

For the multivariate model these groups were condensed into motorised (small passenger vehicles, heavy vehicles and motor cycles) and non-motorised (cyclists, pedestrians and other) to enable meaningful analysis.

Vehicle Damage

Vehicle damage is a variable based on the police officer’s assessment of the damage to the vehicle that the case was involved in. The possible options for this are minor, nil, extensive,
overturned or caught fire. These were looked at in the three groups: nil/minor, extensive/caught fire and overturned.

*Vehicle Year*

The vehicle year was recorded for all vehicles. These were grouped together to enable meaningful analysis.

*Accident Severity*

Accident Severity is a crash-related, rather than individual-based, variable. It refers to the most severe injury sustained by anyone involved in the crash that the case was injured in. For example, in a two car crash, if one person was killed, three people seriously injured and one person received minor injuries, all the passengers of both vehicles would be classed as being involved in a fatal crash.

*Time of Day*

The time of day was recorded for all crashes in hours and minutes. The 24 hours of one day were divided into daytime, 5:00am to 10:59pm, and night time, 11:00pm to 4:59am. The hypothesis was that the severity of injury would be more difficult to assess overnight when there is a lack of light. The hours were chosen to ensure that during the ‘night’ period, it would always be dark, taking into account the changes in daylight hours that occur seasonally, with daylight savings and with the variation between north and south.

*Police District*

The police district was recorded for most cases. The twelve police districts that cover NZ are Northland, North Shore/Waitakere, Auckland, Counties/Manukau, Waikato, Bay of Plenty, Eastern, Central, Wellington, Tasman, Canterbury and Southern.

**5.7 Analysis**

New variables were created based upon the injury severity as recorded on the TCR and the ICISS injury severity which was calculated from hospital discharge data. As the TCR dataset had been limited to injury events only, all cases in the dataset had either a ‘severe’ or ‘minor’ injury code on the TCR. This was then compared to the ICISS that had been calculated for each case. The ICISS severity score was considered the gold standard severity score. An ICISS of \( \leq 0.941 \) was used to indicate serious injury (Cryer C, Langley J et al. 2004). If the ICISS was \( \leq 0.941 \), the injuries were considered serious in terms of a threat to life, here after referred to as ‘ICISS
serious'. If the ICISS was >0.941, the injuries were considered minor in terms of a threat to life, and will be referred to as ‘ICISS minor’. Each TCR therefore, had a TCR injury severity score and an ICISS severity score. Analysis was performed separately for those classified as ‘serious’ and those classified as ‘minor’ by the TCR. For each group, it was recorded whether the police assessment of injury severity was concordant or discordant (Table 1).

<table>
<thead>
<tr>
<th>ICISS Minor (&gt;.941)</th>
<th>TCR ‘Minor’</th>
<th>TCR ‘Serious’</th>
</tr>
</thead>
<tbody>
<tr>
<td>concordant</td>
<td>discordant</td>
<td></td>
</tr>
<tr>
<td>ICISS Serious (&lt;=.941)</td>
<td>discordant</td>
<td>concordant</td>
</tr>
</tbody>
</table>

Table 1 Possible outcomes from analysis

This was undertaken for all cases overall. Then separate analyses were performed looking at each variable independently, to examine which factors influence the validity of the police injury severity assessment. Demographic details examined were age, gender and ethnicity. Other variables that were examined were the nature of the injury, accident severity, casualty type, degree of vehicle damage, whether alcohol was suspected, time of day and police district.

Results are described separately for TCR ‘serious’ and TCR ‘minor’ injuries. The percentage of cases that were coded in a discordant manner is commented on. Confidence Intervals for the percent of cases that were discordant with the ICISS measure of severity are presented. Relative risks were calculated so that the validity of the severity assessment within each category could be compared.

For each variable a reference category was chosen, based upon norms and which group it was thought would be most likely to have the most accurate assessment of injury severity. Male was chosen as the reference gender category, due to previous research showing that police overstated injury severity in females. The age group 25-44 years was chosen as it was hypothesised that injury severity would become more difficult to predict at the extremes of age. NZ European was chosen as the reference ethnic group, as we have hypothesised that it would be more difficult to accurately assess injury severity if the casualty does not speak English well. For Accident Severity, ‘fatal’ was used as the reference group. This is because by definition, someone suffering