

## **An evaluation of road crash injury severity using diagnosis based injury scaling**

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### **Abstract**

In Western Australia, information in Police crash reports currently provides the only measure of injury severity following a road crash. These severity ratings are determined by the attending Police Officer as [1] fatal; [2] hospitalised; [3] minor injury; or [4] non-medical.

This paper makes use of ICD-Based Injury Severity Score (ICISS) methodology to determine the severity of road crash injuries using linked hospital and death records. The severity of an injury is determined by calculating threat to life ratios for patients admitted to Western Australian hospitals from 1988 to 2006.

Certain road user groups appear to be grossly under-reported by Police as requiring hospitalisation, when compared to hospital records. Crashes involving a motorcyclist, pedestrian or bicyclist all appear to have higher numbers of hospital admissions than those reported to Police. Conversely, road crash casualties involving a motor vehicle appear to be over represented by police, indicating that not all crashes classified as requiring hospitalisation by the attending Police Officer actually end up being admitted to hospital.

According to hospital admission records, motor vehicle occupants make up the largest portion of road crash hospital admissions, contributing to approximately 54% of all road crash hospital admissions. Motorcyclists are the second biggest contributor, with 18% of hospital admissions. Pedestrians and other road users each make up 10% of hospital admissions and finally bicyclists contribute to 7%.

Pre-defined severity of injury thresholds were used to determine the seriousness of an injury using hospital admission records. Analysis indicates that serious injuries contribute to approximately 26% of Western Australian hospital admissions by road crash casualties and are growing at a faster rate than non-serious injuries.

This paper reports trends in hospital admissions and injury severity for road crash casualties over the period 1988 – 2006. The severity of an injury is determined using hospital discharge summary information. Comparisons are made with numbers of road crashes reported to Police and for hospital admissions, making use of linked hospital and death records for the period.

### **Keywords**

Serious Injuries; Road Crash Analysis; Injury Severity; Record Linkage

### **Introduction**

Road crashes reported to Western Australian (WA) Police show trends in numbers of hospitalised casualties have been relatively stable over the past ten years. Additional information is required in order to determine if any underlying trends in injury severity exist.

Data collected by the WA Police Department (WAPOL) records the severity of injuries as determined by the attending Police Officer according to the following criteria:

1. Fatality – The person died within 30 days of the crash, due to injuries received in the crash;
2. Hospitalised – the person was admitted to hospital as an inpatient for treatment of injuries sustained in the crash;
3. Minor Injury – the person was injured and may have received medical attention, but was not admitted to hospital as an inpatient;
4. Non Medical - Injuries for which no medical treatment was required.

Further detail regarding the type and severity of injuries to hospitalised casualties is currently not available using Police reported data.

A more robust method of assessing the severity of injuries incurred in a road crash would be to use a method based on assessments by medical staff in hospital. In WA, injury diagnoses for admitted casualties are recorded in hospital notes which are coded in a discharge summary and submitted to the WA Department of Health's Hospital Morbidity Data System (HMDS). For the purpose of this study, hospital records have been restricted to include only those crashes defined as a "traffic accident" by using the External Cause of Injury Code (E code) which are assigned following discharge from hospital using information recorded during the hospital stay (Rosman et al. <sup>1</sup>)

The WA Data Linkage System adds value to these hospital records by routinely connecting all hospital admissions, death records and other information for individuals. Linked hospital and death registration records were utilised in this study, providing an alternative source of information on individual hospital admissions by patients, as well as their subsequent readmissions and the relationship of each visit to a single road crash event.

Injury diagnoses recorded in HMDS are coded according to the International Classification of Diseases 9<sup>th</sup> Revision with Clinical Modification (ICD-9-CM) since 1988. The Australian modification of ICD-10 (ICD-10-AM) was introduced in July 1999 superseding ICD-9-CM.

One method of providing reliable probability of death estimates based on ICD diagnosis codes is ICISS (ICD-based Injury Severity Score). ICISS examines large files of hospital admission records, for which survival status is known, to form an estimate of threat to life. Threat to life is calculated directly from ICD diagnoses codes from the proportion of surviving cases with a particular diagnosis code (Osler et al. <sup>2</sup>). The larger the population analysed the more accurate the calculation of ICISS.

ICISS has an advantage over some other measures as it is a directly derived measure of threat to life (Langley et al. <sup>3</sup>).

This paper uses ICISS methodology to estimate the severity of road crash injuries where a casualty has been admitted to a WA hospital, using linked hospital and death records. The study compares trends in reported road crashes and hospitalisations over the period 1988 to 2006.

## Methods

### *Data Sources - WAPOL*

In Western Australia, a road crash is required to be reported to WAPOL using a P72 crash report when at least one of the following occurs:

- Bodily injury occurs during a crash involving a vehicle and it occurs on a road or any place commonly used by the public;
- A crash occurs on a road involving any vehicle where the total value of property damaged to all parties involved exceeds \$1,000 (Note: the monetary value for reporting a crash to WAPOL has increased to \$3,000 from 1/1/08);
- A crash occurs on a road and the owner or representative of any property damaged is not present;
- A 'hit and run' crash has occurred.

The P72 crash report records all details of a road crash including injury severity, crash conditions, nature of crash and more. A P72 crash report is either completed by an attending Police Officer or by a person involved in a road crash.

Police normally attend the scene of a crash if an injury has occurred, there is suspicion of alcohol involvement or traffic flow is impeded. From 1988 to 2006, WAPOL attended an average 84% of crashes where at least one casualty was hospitalised. The remainder of hospitalised road crashes were reported to WAPOL by the driver, rider or cyclist (i.e., self reported) rather than by a Police Officer. Road crashes attended by Police account for 22% of all reported crashes in WA. The practice of self reporting crashes is likely to produce some inconsistencies in data collection, though the majority of self reported crashes

involve either property damage or require attention by a medical practitioner rather than hospitalisation. Hence any inconsistencies arising from self reported crashes are less likely to affect hospitalisation figures reported to WAPOL.

Police reported road crashes in WA were accessed using the Integrated Road Information System (IRIS) which is maintained by Main Roads Western Australia (MRWA). Crashes that occur off-road or in car parks are not included in the IRIS database. Crashes resulting from a medical condition, suicide attempt, or Police chase are also excluded.

#### **Data Sources - Hospital Data**

The Hospital Morbidity Data System (HMDS) is maintained by the Department of Health, WA and consists of all discharge records from both private and public hospitals in Western Australia since 1970. A discharge record for a patient can contain up to 21 diagnosis codes per separation.

WA Road Crashes spanning 1988 to 2006 were analysed using linked HMDS and death records for WA. External cause of injury codes (E code) were used to identify persons admitted to hospital as a consequence of a road crash. Road crash casualties were identified using E code ranges listed in Table 1.

**Table 1:** Road crash hospital admissions as defined using HMDS E codes

<b>ICD Coding System</b>	<b>E code Range</b>	<b>Road User Type</b>
ICD-9-CM	E810 to E819	All road user types
ICD-10-AM	V0(1-6).1(9) V09.2(3,9)	Pedestrian
ICD-10-AM	V1(0-8).3(4,5,9) V19.4(5,6,8,9)	Bicyclist
ICD-10-AM	V2(0-8).3(4,5,9) V29.4(5,6,8,9)	Motorcyclist
ICD-10-AM	V3(0-8).4(5,6,7,9) V39.4(5,6,8,9)	3-Wheeled Motor Vehicle
ICD-10-AM	V4(0-8).4(5,6,7,9) V49.4(5,6,8,9)	Car
ICD-10-AM	V5(0-8).4(5,6,7,9) V59.4(5,6,8,9)	Van or Truck
ICD-10-AM	V6(0-8).4(5,6,7,9) V69.4(5,6,8,9)	Heavy Transport Vehicle
ICD-10-AM	V7(0-8).4(5,6,7,9) V79.4(5,6,8,9)	Bus
ICD-10-AM	V81(2).1 V82.9	Railway train or railway vehicle or streetcar
ICD-10-AM	V8(3-6).0(1,2,3)	Special Vehicles (used on industrial premises, agriculture, special construction, special all-terrain/off-road vehicle)
ICD-10-AM	V87	Unknown mode of transport
ICD-10-AM	V89.2(3,9)	Unspecified vehicle

All road crash casualties resulting in a non-fatal hospital admission were included in the analysis. Hospital admissions did not require an overnight stay. Sequelae of injuries have been excluded for ICD-10-AM, as these relate to the late consequences of an injury, rather than the injury itself (Cryer et al. <sup>4</sup>).

Hospital re-admissions were not included in the analysis to follow. Instead, all admissions related to a single injury event (i.e., road crash) were grouped and the hospital admission with the lowest ICISS (i.e. the lowest probability of survival) was retained and used in the analysis to follow.

### ***Calculation of Survival Risk Ratios:***

Linked hospital admission records were extracted from the Western Australian (WA) Hospital Morbidity Data System (HMDS) for the period 1 January 1988 to 31 December 2006. Deaths registered in WA between 1 January 1988 and 31 December 2006 was also linked to HMDS and used to determine the survivability of a patient post discharge from hospital.

ICISS methodology is utilised in this study to calculate the severity of an injury which is derived for each ICD injury diagnosis code. Hospital admissions are selected with a principal diagnosis in range 800 to 999 for ICD-9-CM or in range S00 to T89 for ICD-10-AM. Survival Risk Ratios (SRR) are calculated for each diagnosis code as a ratio of the number of cases with a given diagnosis code who survived. Each case is then assigned an ICISS, which is the product of SRR for all injury diagnoses (Langley et al. <sup>3</sup>). All injury diagnoses are included in the calculation of a patient's SRR if they fall within the specified ranges listed above. For example, if a patient has five valid diagnosis codes in addition to a principal diagnosis, then all six diagnoses will contribute to the calculation of SRR, not just the principal diagnosis is used. A given SRR represents the likelihood that a patient will survive those injuries. Each patient's ICISS score is the product of the probabilities of surviving each of their injuries (Stephenson et al. <sup>5</sup>). ICISS may be calculated using a single SRR (as in the case of a single injury) or it may be calculated using multiple SRR (as in the case of multiple injuries) (Osler, Rutledge et al. <sup>2</sup>).

If no SRR exists for a certain diagnosis code, then the SRR for that diagnosis code is assumed to be equal to one.

Only one hospital admission was included for an individual injury event per patient. All re-admissions for the same injury event were excluded. Re-admissions were identified as occurring within 90 days of discharge and had similar external cause of injury. This methodology reduced over counting of road crash hospital admissions.

Records where a hospital stay ended in death were included in the analysis regardless of the length of stay. A hospital admission was classified as "Dead" if one of the following events occurred:

1. HMDS mode of separation field is coded as "Deceased";
2. Death occurs within 60 days of hospital discharge whereby the patient died from the original injury (as recorded in HMDS and linked Death record).

Pre-defined severity of injury thresholds have been utilised in this study to identify serious and non-serious injuries. The severity of injury thresholds evaluated by Langley et al. <sup>3</sup> and Cryer et al. <sup>6</sup> ensure that only those injuries representing a significant threat to life are included (i.e., serious injuries). The severity of injury thresholds were estimated by comparing injuries that normally require hospital admission against those typically categorised as minor. Analysis by Langley et al. <sup>3</sup> reported that low thresholds of severity are heavily weighted towards trends in minor injury. This is due to vast numbers of minor injuries requiring hospital admission. The severity thresholds used throughout this study have been chosen to capture injuries with a very high probability of admission, thus minimising bias in ascertainment (Cryer et al. <sup>4</sup>). High severity of injury thresholds allow for a high probability of hospitalisation per injury incidence which is minimally influenced by changes in service delivery, treatment methods and the like (Cryer et al. <sup>6</sup>).

Serious injuries were identified by Langley et al.<sup>3</sup> as those hospital admissions (for ICD-9-CM) with ICISS values less than 0.96. A severity of injury threshold of ICISS < 0.96 was used to identify serious injuries for ICD-9-CM and represents approximately 14% of hospital admissions for the period January 1988 to June 1999.

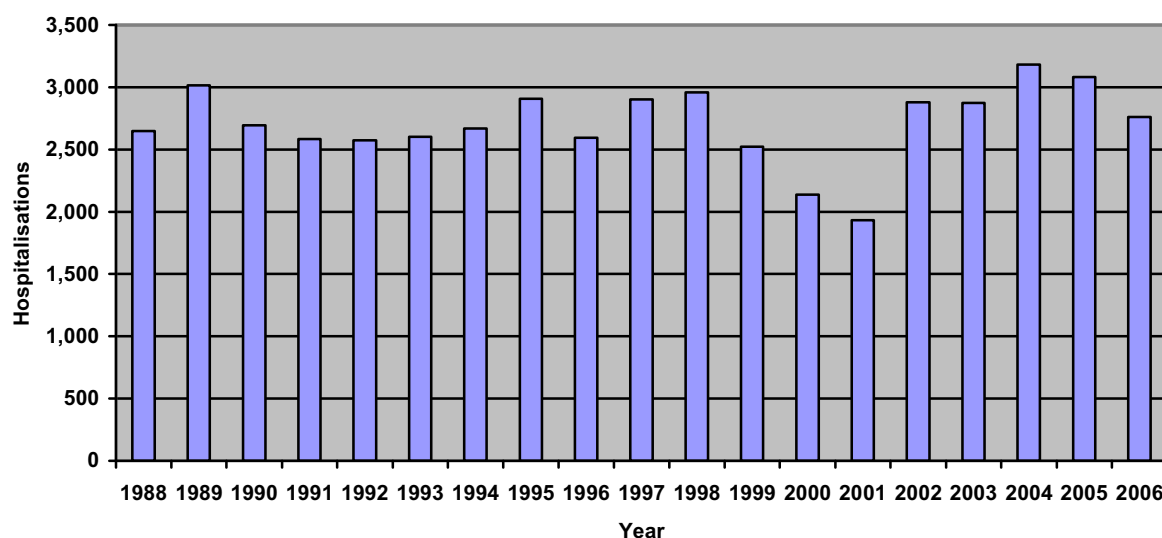
Serious non-fatal injuries requiring hospital admission (for ICD-10AM) were defined by Cryer et al. <sup>6</sup> using a severity of injury threshold less than or equal to 0.941. Those cases with an ICISS score greater than 0.941 are considered to be non-serious. An ICISS score of less than or equal to 0.941 is equivalent to selecting patients whose injuries give a survival probability of 94.1% or a probability of death of at

least 5.9%. A severity of injury threshold of  $ICISS \leq 0.941$  (for ICD-10-AM) represents 10% of hospital admissions over the period July 1999 to December 2006.

## Results

### *Trends in Road Crashes Reported to WA Police*

Road crash casualties that require hospitalisation are reported to WAPOL and recorded in the Main Roads/IRIS database. Figure 1 displays the number of road crash hospitalisations in WA over the period 1988 to 2006 as reported to WAPOL.



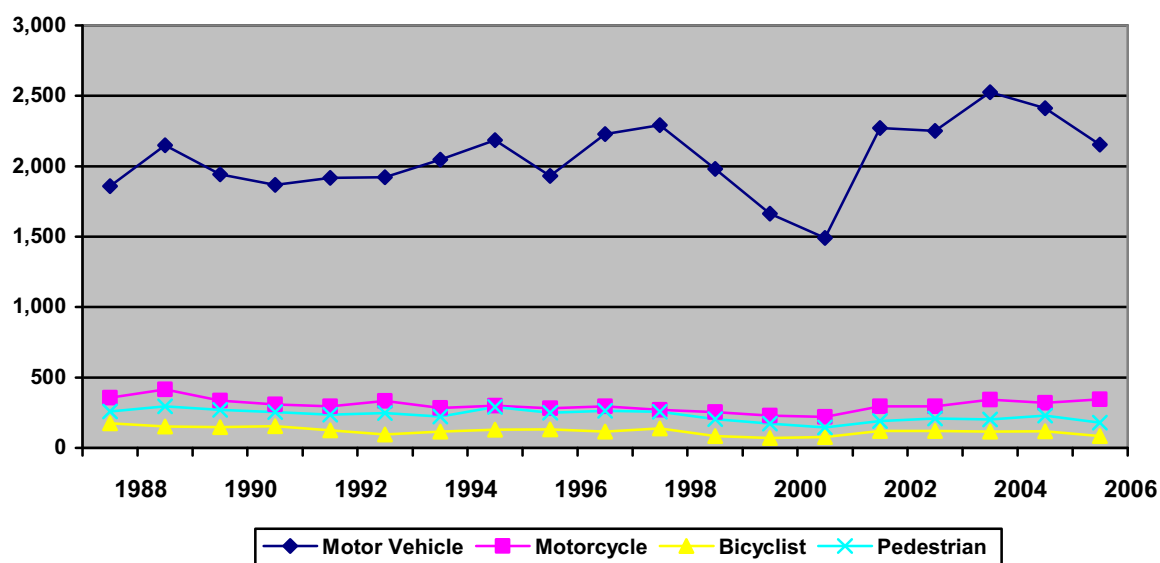
**Figure 1:** Hospitalised road crashes reported to WAPOL (Main Roads/IRIS data). WA road crash hospitalised casualties 1988 to 2006

A 53% drop in hospitalisations occurred for Main Roads/IRIS data over the three year period of 1999 to 2001. One possible reason for the drop in reported hospitalisations could be linked to a change on the P72 crash report that took place in 2001. The current P72 crash report defines an injury requiring hospitalisation as a road crash casualty where a patient has been admitted to hospital as an “inpatient”. In 2001, a change to the P72 crash report defined a casualty requiring hospitalisation as one where hospital treatment was required or administered. Both definitions should capture only those casualties actually admitted to hospital but the omission of the term “inpatient” in the 2001 crash report may have caused some confusion for road users. If this had been the case, the number of hospitalised casualties would be expected to increase as visits to the Emergency Department may have been included. Hence, it is unlikely the change in the terminology on the P72 crash report would cause the sudden drop in reported hospitalisations. Additionally, in 2002 MRWA performed an audit on the crash report files held by WAPOL against those entered in to the Main Roads/IRIS database. No significant differences were identified in the audit. Ultimately, no real explanation for the drop in hospitalisations can be identified for the period 1999 to 2001.

Apart from a drop in the number of hospitalisations reported to WAPOL between 1999 and 2001, there does not appear to have been a significant shift in hospitalised road crash casualties over the 19 year period. In fact, the overall change in hospitalised casualties from 1988 to 2006 was only 4%. As stated earlier, road crashes in WA are either attended by a Police Officer or self reported to WAPOL with no strict set of criteria used to determine the severity of an injury.

Figure 2 displays road crash hospitalised casualties grouped by road user type for the entire period as recorded in the Main Roads/IRIS database. The drop in road crash hospitalisations displayed in Figure 1 has been reciprocated across all road user types. Hospitalisations resulting from a motor vehicle crash accounted for an average 76% of road crash hospitalisations. Hospitalisations by motorcyclists made up

the next largest proportion accounting for approximately 11% of hospitalised casualties. Pedestrians and bicyclists closely followed, accounting for 8% and 4% of hospitalisations, respectively.



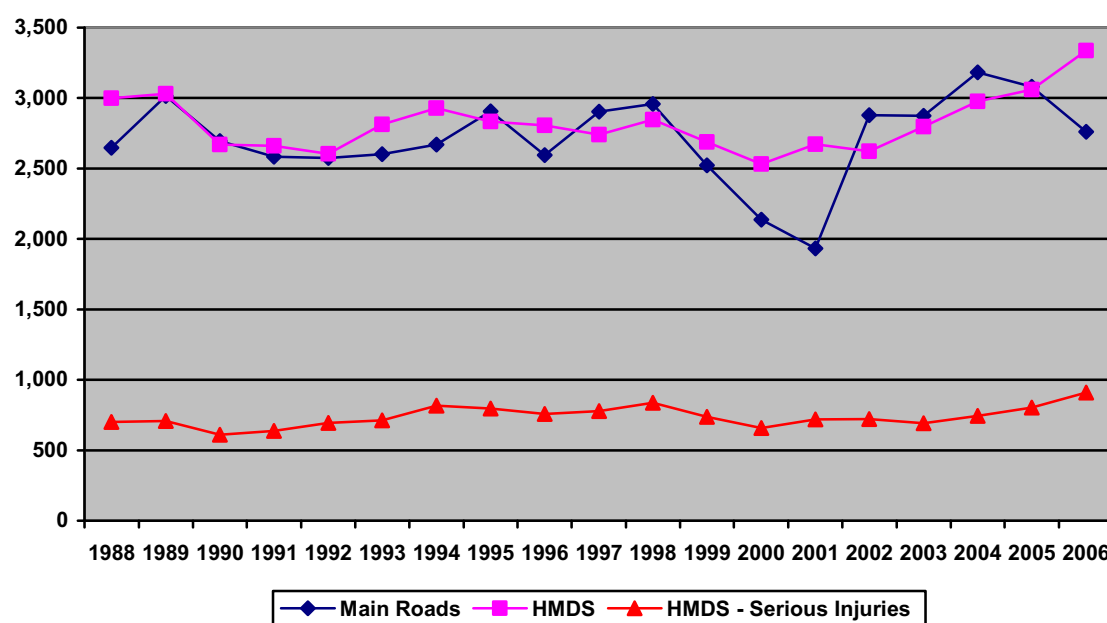
**Figure 2:** Hospitalised casualties reported to WAPOL by road user type (Main Roads/IRIS). WA road crash hospitalised casualties 1988 to 2006

### *Hospital admission records*

For this study, serious injuries have been classified according to pre-defined severity of injury thresholds for ICISS. A hospitalised injury is classified as serious according to the following severity of injury thresholds:

- ICD-9-CM : ICISS < 0.96;
- ICD-10-AM: ICISS  $\leq$  0.941.

For comparison, Figure 3 charts hospital admissions using HMDS and Main Roads/IRIS. Serious injuries are also displayed using pre-defined severity of injury thresholds. Serious injuries have been increasing at a faster rate than non-serious injuries since 1988. The average year on year growth rate for serious and non-serious injuries is 1.8% and 0.5%, respectively. Since 1988, serious injuries have increased by 30% compared to 6% for non-serious injuries. Hospital admissions on the whole have increased by 11% with an average year on year growth rate of 0.7%. Serious injuries only contribute to a quarter (26%) of hospital admissions but are increasing at a greater rate than hospital admissions overall.



**Figure 3:** Comparison of hospitalised casualties using WAPOL reports (Main Roads/IRIS) and hospital admission records (HMDS). WA road crash hospitalised casualties 1988 to 2006

It can be seen that annual road crash hospitalisations as recorded by Main Roads/IRIS and HMDS differ substantially.

The drop in hospitalisations reported by Main Roads/IRIS for 1999 to 2001 shown in Figure 1 is not evident in HMDS (see Figure 3). Instead, HMDS shows hospital admissions with steady growth from 2000 onwards.

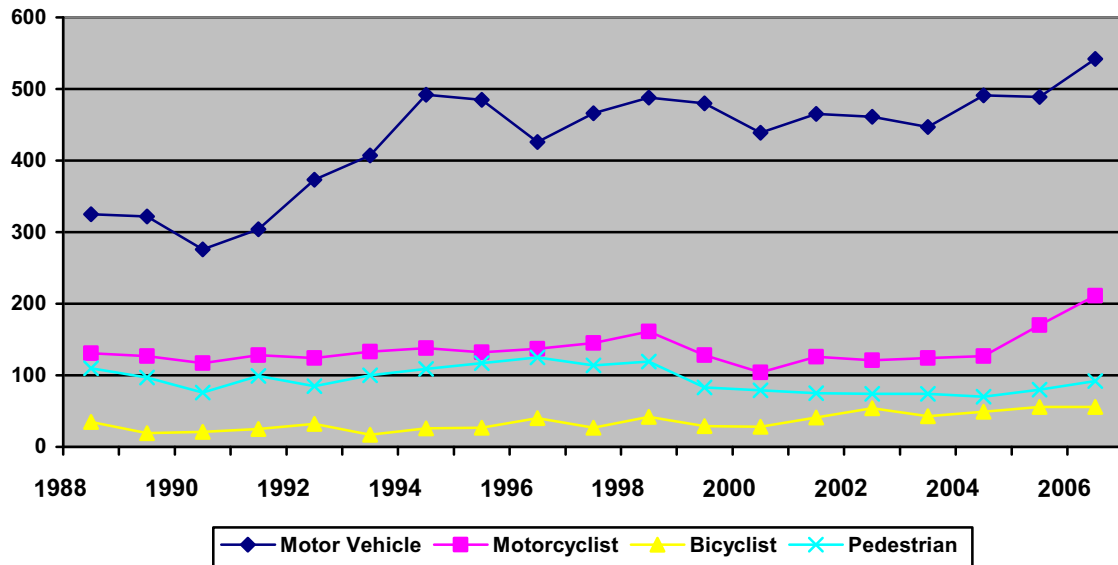
There are small differences in the road user types defined by HMDS and Main Roads/IRIS. For consistency, in this analysis HMDS data has been re-grouped to more closely align with those definitions used by Main Roads/IRIS. Some differences in the classification of road user types still exist, but the differences are considered to be only minimal.

However, caution must be used when comparing data for 1999 with other years as two different HMDS coding systems were utilised over the 19 year period, namely ICD-9-CM and ICD-10-AM. For the purpose of this paper, 1999 has been treated as two independent time segments; pre and post July. If a patient was admitted to hospital in the first half of 1999 (under ICD-9-CM) and then readmitted within 90 days post July 1999 (under ICD-10-AM) for the same injury event (i.e., road crash), then these two hospital admissions will not be treated as the same injury episode (as is the case in other years), rather, they will be treated as two separate injury events. Over counting of hospital admissions may occur for 1999, though it is only likely to be a marginal increase.

In Figure 4, HMDS hospital admissions classified as serious are displayed according to the road user type determined by the External Cause of Injury code (E code). Approximately 26% of road crash hospital admissions are categorised as a serious injury. Pedestrians have the highest rate of serious injury with 32% serious and 68% non-serious, though pedestrians account for only 13% of serious injuries overall. Motor vehicles have the second highest incidence of serious injuries at 28%, followed by motorcycles at 26%, bicycles at 22% and other road user type at 15%.

In the case of HMDS, a higher proportion of injuries to pedestrian and motor vehicle road users are classified as serious. That is, on average, pedestrians contribute to 13% of serious injuries whereas they only contribute to 9% of non-serious injuries. Motor vehicles contribute to, on average, 58% of serious injuries and 53% of non-serious. Alternatively, pedal cyclists make up for on average 7% of non-serious

injuries compared to 5% of serious injuries. Injuries by motorcyclists are distributed equally among serious and non-serious injuries (cf. 18%).



**Figure 4:** Serious injuries by road user type for non-fatal hospitalisations (HMDS). WA road crash hospitalised casualties 1988 to 2006

#### *Hospitalisations for motor vehicle occupants*

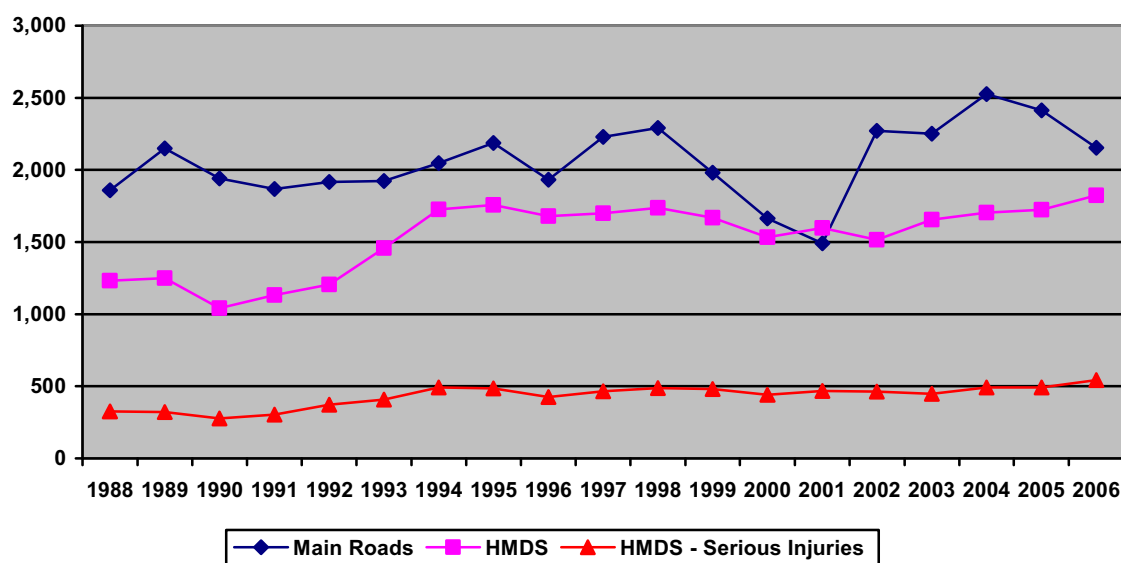
Motor vehicle hospitalisations are predominantly higher for Main Roads/IRIS data compared to HMDS. This is likely to be a direct result of HMDS excluding patients who are presented to the Emergency Department but are not admitted to hospital. A patient must be admitted to hospital in order to be included in HMDS.

Figure 5 displays motor vehicle hospitalisations for Main Roads/IRIS and HMDS. Interestingly, the dip that exists for Main Roads/IRIS hospitalisations from 1999 to 2001 is not apparent in HMDS. In fact, in 2001 HMDS actually recorded more road crash hospital admissions where a motor vehicle was involved than Main Roads/IRIS, with 1,491 hospitalisations reported in Main Roads/IRIS and 1,593 hospital admissions recorded in HMDS. From 2002 onwards, a positive trend in HMDS hospital admissions is evident with an average year on year growth of 5%. An average year on year growth of -1% is recorded for Main Roads/IRIS data from 2002 onwards. Since 1988, motor vehicle hospitalisations have been growing steadily at 2% per annum compared to 3% per annum for HMDS.

Non-serious motor vehicle injuries have been growing an average 2% per annum compared to 3% per annum for serious injuries. Hence, hospital admissions for serious injuries are growing at a faster rate than non-serious for motor vehicle crashes.

Main Roads/IRIS data shows a decrease for motor vehicle hospitalisations for 2005 and 2006 of -4% and -11%, respectively, compared to 1% and 6% for HMDS. HMDS has motor vehicle hospital admissions on the rise since 2004 whereas Main Roads/IRIS has hospitalisations on the decline.





**Figure 5:** Hospitalisations by motor vehicle occupants using WAPOL reports (Main Roads/IRIS) and hospital admission records (HMDS). WA road crash hospitalised casualties 1988 to 2006.

## Discussion

A robust measure of serious injury is required by road safety strategists and policy analysts in order to understand the impact of interventions. Killed and Seriously Injured (KSI) measures, rather than fatalities alone have been discussed for some time.

This paper has demonstrated how ICISS methodology can be utilised to estimate the severity of hospitalised road crash casualties by making use of information stored in the discharge summary of a hospitalised patient. ICISS methodology is retrospective in its approach, making use of large datasets to evaluate threat to life.

A mapping technique devised by MacKenzie, Steinwachs, and Shankar<sup>7</sup> had previously been used for determining injury severity by making use of ICDMAP software to convert ICD-9-CM diagnosis codes to Abbreviated Injury Scale (AIS) codes. Serious injuries are identified by  $AIS \geq 3$ . ICDMAP software was made obsolete with the introduction of ICD-10-AM in mid 1999. ICISS is one methodology of evaluating injury severity and is derived directly from hospital admission data which is not dependent upon a particular version of ICD.

ICISS scores were calculated using WA hospital admission data (HMDS) for road crash casualties. The time period covered included admissions to WA hospitals from 1988 to 2006 and contained both ICD-9-CM and ICD-10-AM coding systems. Survival Risk Ratios (SRR) were calculated using admissions with a principal diagnosis between 800 to 999 for ICD-9-CM and S00 to T89 for ICD-10-AM. Up to 21 diagnosis codes could be included per admission; all contributing to the calculation of SRR. The HMDS records were internally linked to combine records of transfers and re-admissions. Linked death records were also utilised, to determine those patients who died as a result of their injuries, following discharge from hospital.

All non-fatal hospital admissions with a diagnosis code in range 800 to 999 (for ICD-9-CM) and S00 to T89 (for ICD-10-AM) were included in the calculation of ICISS for WA road crashes. ICISS was evaluated by multiplying all SRR values associated with a patient's hospital stay. ICISS scores were calculated for all non-fatal hospital admissions where at least one diagnosis code fell in the above ranges, not just the principal diagnosis.

Pre-defined severity thresholds were used to categorise the seriousness of an injury. Langley et al.<sup>3</sup> and Cryer et al.<sup>6</sup> identified severity of injury thresholds of ICISS < 0.96 for ICD-9-CM and ICISS ≤ 0.941 for ICD-10-CM. High severity of injury thresholds have been utilised allowing for a high probability of hospitalisation per injury incidence, ultimately excluding hospital admissions with minor injuries.

### Further Work

Differences in the data recorded by Police and WA hospitals need to be further investigated. By linking individual crash reports with other data sources such as hospital admissions and data collected by the Insurance Commission of WA (ICWA) we will be able to identify the overlap between crashes reported to WA Police and those admitted to hospital. We will then be able to confirm whether the level of disparity seen in previous work by Rosman et al ( Rosman and Knuiman<sup>8</sup>, Rosman<sup>9</sup>) showing a linkage rate from hospital to Police of 64% and 51.6% has been sustained.

In addition, we will be able to use Injury Severity Scores (ISS) stored in the ICWA dataset to compare with ICISS in estimating injury severity. It should be noted however that although not all road crashes reported to WAPOL are included in the ICWA database, we expect there to be a reasonable subset to have been reported.

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