Australian Government
Department of Infrastructure and Regional Development
Bureau of Infrastructure, Transport and Regional Economics

Developing national road safety indicators for injury

At a glance

- The National Road Safety Strategy 2011–2020 (NRSS) presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent.
- Australia's performance in addressing serious injuries from road crashes is difficult to measure because of the lack of a reliable, nationally consistent, source of non-fatal crash data.
- This information sheet details the current potentially relevant data sources, their limitations, and efforts currently underway to improve data for Australian serious injury reporting.
- While not part of NRSS reporting, the Bureau of Transport, Infrastructure and Regional Economics (BITRE) publishes national data on the number of hospitalised injury cases sourced from the Australian Institute of Health and Welfare (AIHW). This data serves as a broad indicator of likely trends in serious injuries, but does not include any detailed crash information.
- While road deaths have declined steadily, hospital data suggests the number of road traffic injuries has increased. Of those hospitalised, the number of people with high threat to life injuries has also increased.
- There is no national agreed count of 'serious injury' cases for NRSS reporting purposes. The crash data collected by police in the eight different states and territories cannot currently be aggregated to a suitable national injury measure.
- Ideally a national serious injury measure would reflect a range of personal impacts from injury crashes, by including cases above a threshold level of severity but also cases with a threshold level of disability from crashes. Severity scoring systems are used in the health sector to measure threat to life, but have not been shown to be good indicators of the level of disability resulting from injury. Models to predict injury disability outcomes are currently being developed.
- There are clear potential benefits to using hospital data to supplement crash data, and international research supports the data linkage approach. Hospital data offers the opportunity to report national serious injury totals using standardised severity ratings that are based on medical diagnosis, allowing in-depth understanding of medical consequences of particular types of crashes.
- A data linkage study completed in NSW has confirmed that many crash-related injuries, particularly pedal cyclists and motorcyclists, are not reported to police and so do not appear in the crash data.
- Consistent with a priority action in the National Road Safety Action Plan 2015 to 2017, a project has been established to test the strengths and limitations of adopting a data linkage approach at the national level.
- The development of nationally consistent non-fatal crash data is vital to our understanding of the nature and impact of serious injury crashes on the Australian community and will underpin the development of the shared policy response of Australian governments.

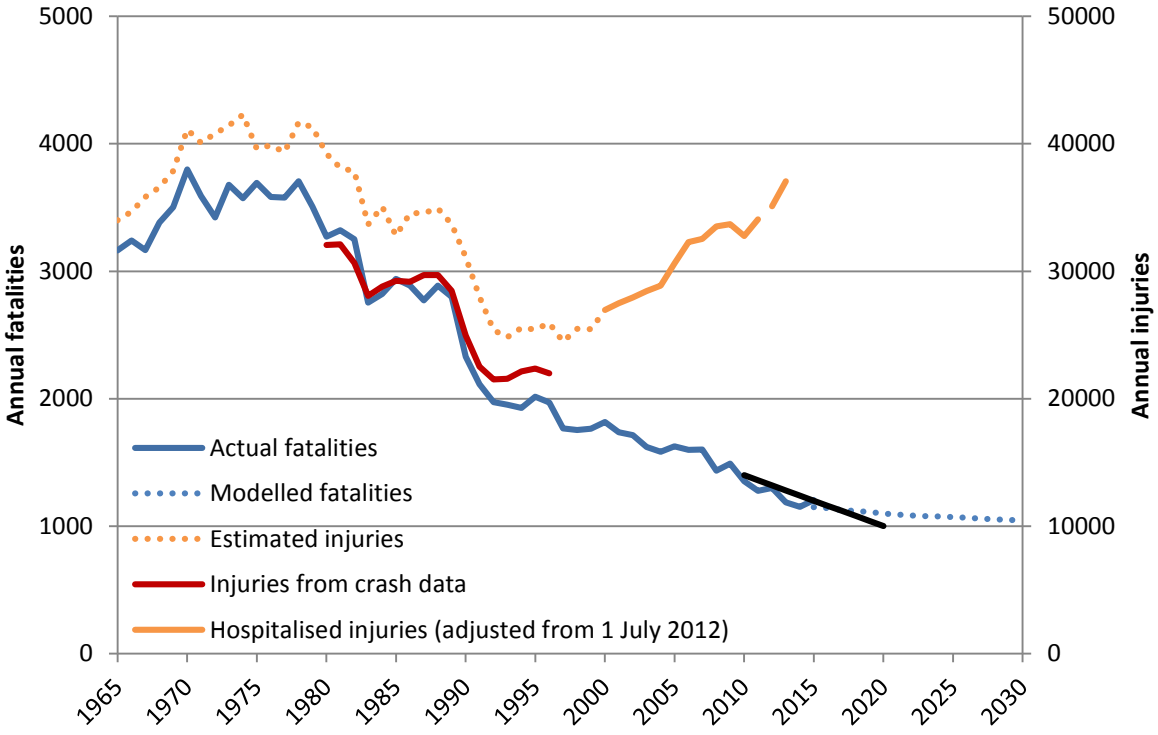
Introduction

The National Road Safety Strategy 2011–2020 (NRSS) sets out the shared commitment of Australian governments to improve road safety and presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent.

Road crash deaths are monitored consistently across jurisdictions and significant progress has been made towards the 30 per cent reduction target. However, Australia does not have systems in place to reliably measure national indicators of serious (non-fatal) injuries that are the result of road crashes.

National data from the AIHW indicates that the number of road traffic hospitalised injury cases has increased significantly since 2000 (Figure 1). The hospitalised injury rate increased from 141.7 per 100,000 people in 2000 to an estimated 160.3 per 100,000 people in 2013 (adjusted for a break in series from 1 July 2012). The latest data for 2013–14 indicates that the number of traffic hospitalised injury cases was 13 per cent higher than the average annual cases for the NRSS baseline period (2008-2010). The number of people with a life threatening injury also increased, with the proportion of high threat to life cases relatively stable at just over 25 per cent of all traffic related hospitalised injury cases.

Figure 1 Australian road fatalities and injuries: historical and modelled, 1965 to 2030



Notes Fatalities and estimated injury series are presented in financial years. Injury series based on crash data prior to 1997 and AIHW hospitalised injury cases from 2000. There is a break in the hospital injury series on 1 July 2012 as a result of a change in the admitted case inclusion criterion in a large jurisdiction that reduced the number of recorded hospitalised injury cases. BITRE has adjusted the injury series to increase hospitalised injuries cases by approximately 2000 in 2012-13 to provide a consistent series.

Source BITRE 2014; updated fatality data (Australian Road Deaths database) and hospitalised injury cases (AIHW unpublished)

A review of the NRSS in 2014 found progress in reducing serious injury numbers was difficult to determine because of the lack of reliable, nationally consistent, non-fatal crash data (Austroads 2015). Addressing this issue has been identified as a priority action (19) in the National Road Safety Action Plan 2015 to 2017 (the Action Plan).

To address Action 19, a research project to test the strengths and limitations of adopting a data linkage approach at the national level has been established through Austroads. If successful this is expected to contribute to the development of national measures of serious injury by linking hospital case data with road crash data consistently across all states and territories, adopting common standards that will enable national aggregation and reporting.

This paper provides information on the issues surrounding the measurement of serious injury from road crashes including:

- current national reporting arrangements;
- current injury data sources;
- linkage of crash and health data;
- injury severity ratings and relationship to impairment and disability outcomes;
- best practice in developing injury safety performance indicators; and
- a summary of options for national injury indicators for NRSS reporting.

Current national reporting

The 30 per cent targets for fatalities and serious injury contained in the NRSS are measured against a baseline period of 2008–2010. Progress towards the fatality targets is assessed annually using high level outcomes and a range of safety performance indicators for detailed progress monitoring (see Appendix A, Table 1). Current NRSS reporting of road death and injury trends is based on these definitions:

- A road crash is an unpremeditated event reported to police or other authority resulting in death, injury or property damage; that is attributable to the movement of a road vehicle on a public road.
- A road death or fatality is a person who dies within 30 days of a road crash as a result of injuries received in that crash, excluding deaths from deliberate acts and natural causes.

The BITRE collects jurisdiction crash data annually and produces crash-related fatality NRSS indicators. No NRSS indicators are reported for serious injury because there is no national agreed count of road 'serious injury' cases for NRSS reporting purposes. Development of additional crash-based safety performance indicators and associated data collection arrangements is ongoing.

While it is not part of NRSS reporting, the BITRE (2015) does publish data[1] on the number of and trends in hospitalised injury cases. A hospitalised injury case is a person who is confirmed as admitted to hospital as a result of a road traffic crash, irrespective of the length of stay.[2] The source of this data is the Australian Institute of Health and Welfare.

States and territories use police crash data as the main source of injury data to monitor local injury outcomes and do not measure injury severity based on medical diagnosis or assessed disability outcomes.

Sources of injury data

A range of data sources could be used to develop national serious injury indicators, however, the main sources are police records and jurisdiction crash databases for reported crashes and health systems records (includes hospitals admissions data, emergency department records and trauma registers such as the Australian Trauma Registry). Other sources include ambulance cases transported to hospital and personal injury insurance claims data.

Different sources provide measures of:

1. System utilisation (the number of cases transported to or admitted to hospital), or
2. Injury severity (counts of cases with a minimum length of hospital stay or cases that equal or exceed an injury threshold score, or have at least a minimum probability of death in hospital), or
3. Outcomes of an injury (the number of cases with an assessed level of temporary or permanent disability, or disabling type of injury as recorded on a trauma register).

Each source of injury data is compiled for a different purpose and there are variously issues with timeliness, consistency and completeness. Figure 2 illustrates the relationship between the different data sources and timeliness of data.

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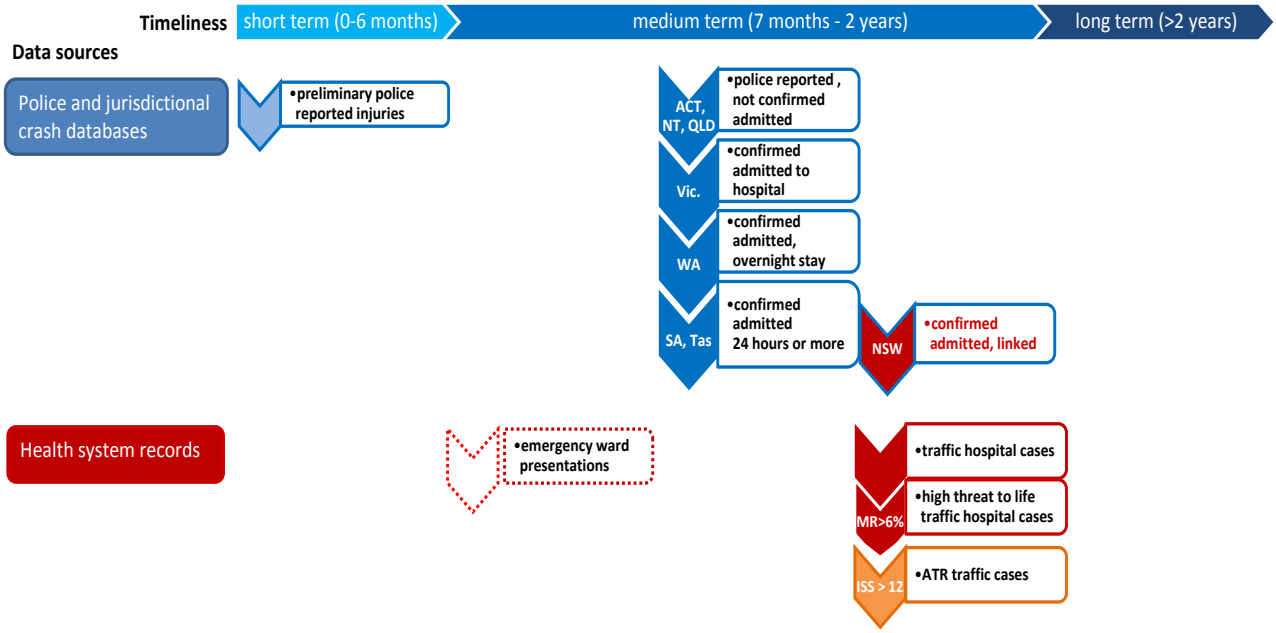
[1] BITRE (2015) provides hospitalised injuries by road user type and age group (Table 1.9), by remoteness area of residence (Table 1.10), by collision counterpart (Table 1.11) and the high threat to life sub-set of hospitalised injury cases (Tables 1.12 and 1.13).

[2] Consequently, a small number of people who die after 30 days will not be counted as either hospitalised injuries or as road fatalities.

A common theme for all data sources is the need to protect individual privacy, and the challenge is to balance this protection against the social need for better information to allow the effective targeting of measures to reduce injury trauma.

Figure 2 Injury data sources and timeliness



Notes MR: mortality risk (ranges from 0 to 100 per cent). ISS: Injury Severity Score (see Box 2). ATR: Australian Trauma Registry.
Source BITRE

Crash data

Police-sourced crash data remains the main source of injury outcomes at the state and territory level. All Australian states and territories record a road death where a person dies within 30 days, however, different injury definitions apply for non-fatal injuries (Table 1).

Table 1 Jurisdiction serious injury definitions

Jurisdiction	*Official 'serious injury' definition*	*Confirms admission*	*Notes*
New South Wales	A person identified in the Police crash report who is matched to a hospital admission record on same day or the day after a crash.	Yes	At a high level "serious injuries" in NSW are considered to be all road-related injuries admitted. Total admissions includes cases which were matched and not matched to police records.
Victoria	Admitted to hospital.	Yes	Includes a small number of cases with unknown admission status.
Queensland	Admitted to hospital for at least 24 hours.	No	Long term goal is matching of police and hospital records.
Western Australia	Admitted to hospital – overnight stay.	Partial	Transitioning to on-line reporting.
South Australia	Admitted to hospital for 24 hours or more.	Yes	No plans to change this definition.
Tasmania	Admitted to hospital for 24 hours or more.	Yes	Police contact hospitals to confirm road users initially classified as a 'serious injury' were admitted to hospital.
Northern Territory	Admitted to hospital.	No	No process in place to confirm admission.
Australian Capital Territory	Admitted to hospital.	No	No process in place to confirm admission.

Source BITRE

There are significant variations in serious injury definitions between jurisdictions. Further, Queensland, the ACT and the Northern Territory do not have processes in place to confirm if a person recorded as hospitalised in a crash is actually admitted to hospital. In these jurisdictions the effective serious injury definition is taken to hospital.

A major limitation of crash data is that it under-reports the number of injury cases, and the level of under-reporting varies significantly by road user type. Even when a crash is reported, injuries may not be recorded by police at the scene or reported by drivers. For a range of reasons, people present later at hospitals or seek treatment from general practitioners (IRTAD 2011).

The Centre for Road Safety (2015) found that the level of injury under-reporting in New South Wales varied by road user category. Under-reporting levels were higher for car passengers than for car drivers, and significantly higher for pedal cyclists and motorcyclists involved in collisions with fixed objects and non-collision crashes.

In Queensland, Watson et al (2015) linked Queensland databases for police reported crash injury cases, hospital admitted patient cases, and emergency department cases. The authors found large variations in the estimated number of and profile of serious road crash injuries according to the definition or measure used, with vulnerable road users becoming more prominent with more precise definitions of serious injury. Table 2 shows how the number of serious injury cases in Queensland police crash records changed with different definitions of serious injury. It does not include hospitalised injury cases that were not reported to police.

By linking crash and hospital records, Watson et al (2015) found 10,649 people recorded by police as being involved in a crash actually attended hospital compared to 6674 cases that were recorded as 'taken to hospital' in police crash reports. That is, 3975 people involved in a crash and recorded as having no injury or non-hospitalised injury subsequently attended a hospital. Applying a severity measure/time in hospital proxy reduces the number of police reported serious injury cases; however, there were still three times as many cases admitted for 24 hours or more than for cases with an Abbreviated Injury Scale rating of 3 or more. The lowest serious injury count (672) was for cases with Abbreviated Injury Scale rating of 3 or more. This represented 6.3 per cent of the total cases treated in hospital emergency wards and/or admitted to hospital (Watson et al 2015). The official road death toll in Queensland in 2009 was 331 (BITRE 2015, Table 1.1).

Table 2 Number of seriously injured persons in police crash records using different definitions of serious injury, Queensland, 2009

Injury definition	*Number of persons in police crash records*
Police definition of 'hospitalised' (taken to hospital)	6,674
Cases where people attended hospital (emergency ward and/or hospital admission)	10,649
Cases where people were admitted hospital > 24 hours	1,879
Abbreviated Injury Scale 3+	672
High threat to life cases with a Survival Risk Ratio < .942	1,041

Source Watson et al 2015

D'Elia and Newstead (2015) conclude that the definition of serious injury within police reported data is not consistent across jurisdictions and may not be accurately operationalised, and that this could lead to misleading estimates of the impact of and cost of crashes.

While crash data in most jurisdictions is timely, it omits a significant number of road injury cases, particularly injuries to pedal cyclists and motorcyclists from collisions with fixed objects and non-collision crashes, and provides limited or no information about individual injury outcomes.

A number of jurisdictions (Queensland, Western Australia and New South Wales) are working towards a long term objective of better local injury data through linking of hospital and crash data. New South Wales recently updated its crash database to include injury status as well as new casualties identified in its data linkage study (Centre for Road Safety 2015).

Health data

Potential sources of health data include hospital admissions, emergency ward cases and trauma registers.

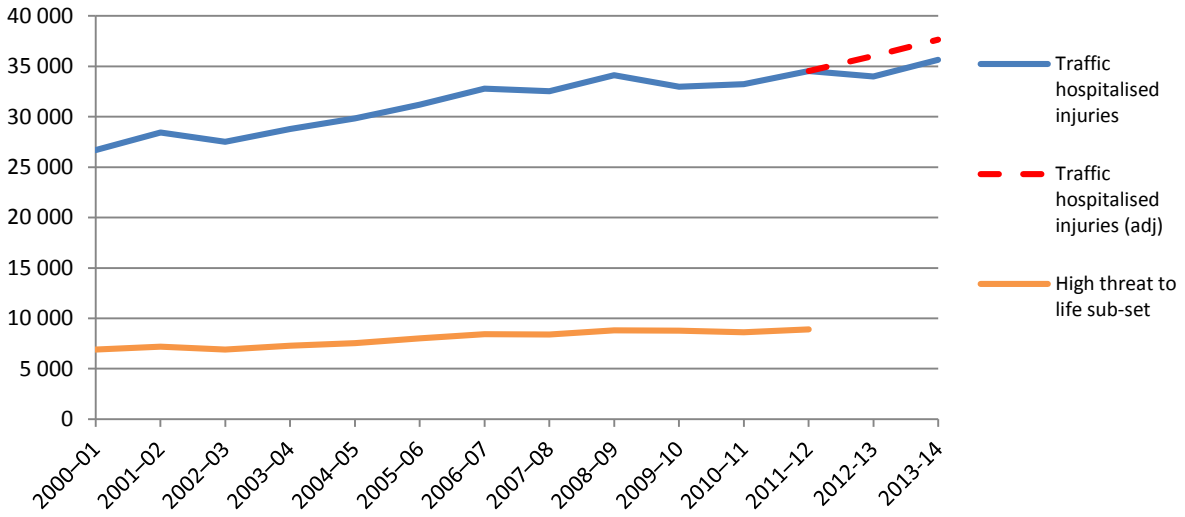
Hospital data

The Australian Institute of Health and Welfare produce data on the estimated number of hospital cases that result from events occurring 'in traffic'.[3] In practice, this is generally assumed to approximate a public road. Data are available for 2000 to 2013-14.

Injury cases admitted to hospital are classified using the Australian modification of the International Classification of Diseases Version 10 (ICD10-AM). High threat to life hospitalised cases are the subset of cases with an International Severity Score of less than 0.942 (Henley and Harrison 2015).

Hospitalised injury data indicates the number of road traffic injuries admitted to hospital in Australia has increased since 2001 (Figure 3). The number of high threat to life cases also increased but the proportion remained relatively stable at just over 25 per cent of all traffic hospitalised injury cases (Figure 3).

Figure 3 Traffic hospitalised injury and high threat to life cases, Australia, 2000-01 to 2013-14



Note A break in hospitalised injury series occurred on 1 July 2012 due to a change in the admitted case inclusion criterion in a large jurisdiction. To account for this the adjusted hospitalised injury series has been increased by approximately 2000 cases in 2012–13 and 2013–14.

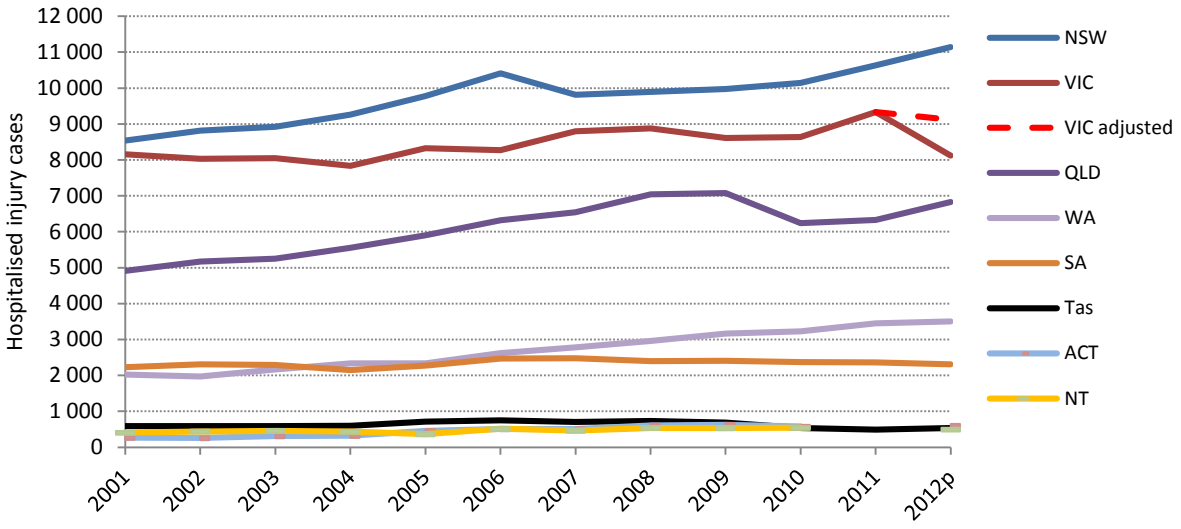
Source AIHW data; National Injury Surveillance Unit estimates for Victoria (unpublished)

Figure 4 shows differences in long term trends in hospitalised injury cases by jurisdiction, with upwards trends in New South Wales, Western Australia, and Queensland.

The Centre for Road Safety (2015, p.56) found that in New South Wales that 'total serious injuries'—defined as all hospitalised cases—due to road crashes increased by 12 per cent over the nine year period from 2005 to 2013. Over this period the number of hospital cases that could be matched to a police record increased by 4 per cent and the number of unmatched cases increased by 27 per cent. The overall linkage (matching) rate for the period was 62 per cent (Centre for Road Safety 2015, p.14).

[3] Hospital separations records are used to estimate the number of hospitalised injury cases (for example, by excluding transfers between hospitals).

Figure 4 Traffic hospitalised injury by jurisdiction, 2001 to 2012p



Note The Victorian series been increased by 1000 cases in CY2012 to adjust for the break in the Victorian series on 1 July 2012.
Source AIHW hospitalised injury series; National Injury Surveillance Unit estimates for Victoria (unpublished)

A major limitation of hospital data alone is the lack of information about the crash. This can be overcome by linking police and hospital databases on a jurisdiction-by-jurisdiction basis, or prospectively at the national level (see *Linking police and health data sources* on page 13).

A number of issues also need to be addressed for national reporting purposes:

1. *Consistency over time and across jurisdictions*. Changes in hospital admission and clinical practices over time can make it difficult to distinguish trends in hospitalised injury cases.[4] This can be mitigated by using a standardised injury severity scoring system and severity threshold in the definition of serious injury, for example, by limiting to cases that meet the criteria for high threat to life or a Maximum Abbreviated Injury Scale score of three or more. Henley and Harrison (2009) note that high threat to life injury counts are less susceptible to changes in admission practice over time and may also provide more accurate comparisons between jurisdictions.
2. *Timeliness*. Hospital data takes significantly longer to produce than crash data. Currently, national hospitalised injury data are available approximately 16 months after the end of the financial year.[5] A national linkage process would be expected to add to this timeframe; however, once procedures were established, the actual linkage process could be streamlined.

Despite these challenges, there are clear benefits to using hospital data to supplement police data (IRTAD 2011). In particular, hospital admission data captures many injuries due to road crashes that are not reported to police and, unlike crash data, it should be feasible to report national totals for injury that are based on medical diagnosis and standardised International Classification of Diseases based ratings.

Emergency department records

IRTAD (2011) suggests that, in addition to hospital records, emergency department records data—although less developed—have the potential to provide a more complete picture of traffic related injury.

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4 Henley and Harrison (2015) note there is potential for variation over time in admission practice, especially for lower severity cases and changes over time in the coding of external causes. There may also be jurisdictional differences in admission practice.

5 Hospital injury data is available 21 months after the end of the calendar year. Jurisdiction breakdowns take an extra 3–12 months due to the need to obtain permissions from health departments.

Australian crash and health data linkage studies in New South Wales (Centre for Road Safety 2015) and Queensland (Watson et al 2015) included hospital emergency department databases.

According to Watson et al (2015), a major limitation in Queensland is that full ICD10-AM injury coding is not carried out for emergency ward cases. Experience to date suggests that external cause coding and diagnosis coding of emergency department cases across Australia varies significantly in quality and method, with many unstructured systems that use non-systematic descriptions. Consequently, hospital Emergency Department data is not currently a suitable source for NRSS serious injury monitoring.

The Australian Trauma Registry

The Australian Trauma Registry (ATR) collates data from 27 designated trauma centres across Australia, for injury cases with an Injury Severity Score greater than 12.

The inaugural ATR report reported data for 2010 to 2012. Transport (including off-road transport) accounted about half of new cases on the ATR between 2010 and 2012, however, the number of road transport cases that would be relevant to NRSS monitoring was 36 per cent of new cases (Alfred Health 2014, p.25). Reported data was incomplete for several trauma centres in the base period and did not include an unknown number of cases treated outside the major trauma network. The inaugural report provided very limited information on traffic cases and did not report data that identified jurisdictions (Alfred Health 2014).

As with hospital data, the ATR appears to provide little information about the crash. Any linkage of the ATR with crash data would require a national process to obtain ethics approvals in all jurisdictions.

By design the ATR captures only very severely injured people. It excludes more than 90 per cent of people hospitalised due to traffic crashes and approximately three-quarters of high threat to life injury cases (Table 3). Further analysis of patterns and types of injury above and below the Injury Severity Score 12+ would be needed to understand what the ATR is measuring in terms of road crash injury severity and disability outcomes.

Table 3 Comparison of ATR, hospital and high threat to life cases

Definition	*Number of cases*	*Proportion of hospital cases*	*Notes*
Admitted to hospital	34,550	100.0	2011-12 AIHW hospital series
High threat to life hospital	9,919	25.8	2011-12 AIHW hospital series
Australian Trauma Registry	2,438	7.1	Average annual new road transport cases 2010-2012

The ATR is not a suitable source for NRSS monitoring due to its focus on very severe injury. However, it has the potential to be a useful supplementary source to crash and hospital data on the most severe cases of road injury (particularly if crash data linking could be undertaken).

Personal injury claims data

Another source of injury data is data related to personal injury claims for motor vehicle accidents. Personal injury claims systems vary by jurisdiction.

From 1 July 2016 all jurisdictions have no-fault insurance schemes as agreed in the 2013 intergovernmental agreement for the National Disability Insurance Scheme (NDIS) launch. These schemes provide different degrees of cover from lifetime care and support ranging from catastrophic injuries (New South Wales) to all severities (Victoria). The Productivity Commission (2011) defines catastrophic injures as those resulting in substantial and permanent disability—mainly major acquired brain injuries, spinal cord injuries, burns and multiple amputations—and for which, in most instances, people need lifelong support and, particularly in the

initial post-injury phase, have intensive clinical needs and require post treatment supports, early interventions and rehabilitation services.

In Victoria the Transport Accident Commission (TAC) is the government insurer of third party personal liability. It receives on average 16,000 claims per annum (over 30 per cent hospitalised). Injured road users have a non-fault entitlement to care, loss of earnings replacement and impairment benefits, as well as a range of entitlements under common law for those with injuries such as acquired brain injury or spinal injury. Degree of impairment is the basis of impairment assessment and common law eligibility, with a person assigned an impairment rating between zero (no impairment) and 100 (almost dead) (Alavi et al 2013).

Alavi et al (2013) compared four alternate measures of severity in Victoria: MAIS3+, impairment, resource use (hospital stay>14 days); and cost (estimated lifetime compensation cost of at least $52,378). They found significant, but moderate, correlations between the definitions, but only 0.6 per cent of claimants were classified as "serious" by all four definitions.

D'Ely and Newstead (2015) linked Victorian injury claims data and police crash data, and showed that different measures resulted in different 'trends' in the measured injuries series.

The approach to injury compensation takes a different approach to hospital data in the assessment of severity (for example, the use of impairment assessment). A number of studies suggest this approach would result in substantially different total counts of injuries and trends to alternative measures of serious injury. While all jurisdictions now have no-fault injury insurance schemes, most schemes limit coverage to catastrophic cases.

Best practice in measuring serious injury

Measuring trauma from injuries is more complex than monitoring fatalities for a range of reasons:

- There are no international definitions of serious injuries. IRTAD states that "Internationally harmonized and accepted definitions of (serious) injuries are not yet available. This means that it is not possible to compare the wider safety record of countries as long as data definitions and data collection procedures differ." (IRTAD 2011, p.3)
- Both crash and health data are needed and these sit in different datasets, collected by police and health systems in eight different jurisdictions.
- Jurisdictions' crash casualty data cannot be aggregated to national measures due to different injury definitions and validation of injury outcomes.
- Under-reporting of crashes to police means that crash data systematically under-states the total number of injuries due to traffic crashes, notably injuries to pedal cyclists and motorcyclists from collisions with stationary objects and non-collision crashes such as falls. Under-reporting of serious casualties is a widely recognised problem, and many countries are working hard to eliminate this (IRTAD 2011, p.3).
- Hospital data is available nationally and captures many injuries not reported to police, however, it provides little information about the crash. Its usefulness as a series is limited by changes over time in reporting definitions and clinical practice, as well as uncertainty as to the accuracy of traffic classifications of injury.

The World Health Organisation's Global Status of Disease Report on Road Safety (2009) concluded that two main actions were required to improve the quality of data on fatal and non-fatal road traffic injuries:

1. Encourage the use of the 30-day definition of a road traffic death and standardise terminology for classifying the severity of non-fatal injuries; and
2. Improve data linkages between police, transport and health services to address under-reporting.

IRTAD (2011) stated its members already used the 30 day definition for a fatality but are far from a clear definition of what is meant by a serious injury. The key challenges are:

1. How to allow for under-reporting to make the best possible estimates of serious injuries, possibly by linking data from police and hospital sources.
2. How to define "serious" injuries. Important factors in this choice include comparability with other countries and the use of a medically based diagnosis to determine a standardised injury scoring.

In 2011 an IRTAD special report made recommendations on ways to develop better estimates of the real number of road traffic casualties (Box 1). A key finding was that it is increasingly common to link police crash and hospital admission databases to overcome the limitations of both databases, thereby improving road safety research to support road safety policies.

Box 1 International best practice in measuring non-fatal road injury

A special report by the IRTAD Working Group on Linking Police and Hospital Data identified and assessed methodologies for linking different sources of accident data in order to develop better estimates of the number of road traffic casualties, and reviewed the choice of a medically based definition of a 'serious injury'. The objective was to identify a definition of serious injury suitable for monitoring trends within countries, and trends between countries. The report includes a survey of IRTAD members and literature reviews of recent research work on linking hospital and police data.

A selected summary of key findings and recommendations include:

- A complete picture of casualty totals from road crashes is needed to fully assess the consequences of road crashes and monitor progress. Injury information should complement fatal crashes information, and should become more important for international comparisons.
- Police data should remain the main source for road crash statistics. However, because of underreporting problems and possible bias (for example, differing rates of reporting by vehicle type), police data should be complemented by hospital data. In-depth understanding of medical consequences of particular types of crashes can be gained if police and hospital data are linked.
- There are clear benefits to using data on those admitted to hospital following a road traffic crash to supplement police data but it is not easy to control quality and completeness of data collected for medical and hospital administration purposes. There may also be ethical concerns in releasing medical information. Some issues will be less significant for more serious casualties.
- Data from hospital emergency departments on people admitted to the emergency room only, although less developed, may be available in some countries and should be monitored regularly and researched to determine if they might shed more light on road casualties.
- Other data sources used for road safety throughout the world cannot replace police or hospital data. They have a limited value on their own in developing preventative measures to improve road safety but can be used to build a more balanced and comprehensive picture, enrich the main data sources, and as a quality check.
- There are no commonly agreed definitions on injury severity across IRTAD countries, and criteria in police records and official statistics to classify crash severity vary from country to country. The assessment of the severity of injuries should preferably be done by medical professionals, not by the police officer at the scene of the crash.
- Medical staff should be trained to systematically classify traffic injuries using the International Classification of Diseases and to assess severities with indices such as the Abbreviated Injury Scale or Maximum Abbreviated Injury Scale. This information without personal information should be available for statistical, policymaking and research purposes.
- Due to limitations of the individual databases, it has become increasingly common to link data from different sources to improve road safety research. Where two or more injury sources exist such as police and hospital admissions data, it is possible to estimate the number of injuries missed by both sources and hence estimate the total number of cases of interest.
- Having an internationally agreed definition of "serious" injuries will help the safety research community to better understand the consequences of road crashes and to monitor progress. While length of stay in hospital is most often used in IRTAD countries, its drawbacks include that it does not necessarily reflect the severity of injuries and is not appropriate for international comparisons given diversity of admissions practices.
- Given existing knowledge and practice, it is recommended that a 'seriously injured road casualty' be defined as a person with injuries assessed at having a score of three or more on the Maximum Abbreviated Injury Scale.

Source IRTAD 2011

The challenge: develop and agree national measures of injury

In terms of international best practice, the IRTAD (2011) findings and recommendations have a number of important implications for developing an Australian serious injury reporting system:

- An effective national injury monitoring system requires a standardised measure of serious injury based on a medical diagnosis and a well understood severity threshold (to allow jurisdictions' data to be combined into national counts and facilitate monitoring of national injury trends over time);
- International Classification of Diseases coding should be used to assess hospital injury severities with scoring indices that can be mapped to the Maximum Abbreviated Injury Scale (to ensure consistency in coding across hospitals and jurisdictions, and to facilitate international comparisons);
- Linking can overcome some limitations of police and hospital databases (to give an understanding of outcomes for particular types of crashes);
- Injury reporting should be expanded to report all hospitalised injuries (to provide a more complete picture of road injury);
- Injury data and reporting systems need to be careful designed and streamlined (to provide timely de-identified data and safety performance indicators that are useful for policymaking and research).

The critical steps required for a national injury monitoring system are:

- Agreeing a measure for a reportable serious injury that includes a medical injury threshold and is consistent with international efforts to improve road related injury reporting.
- Deciding whether unreported injuries that meet the agreed definition of a serious injury should be included in national counts.
- Establishing systems to regularly undertake linking of crash and health data sources to maximise the value of both datasets to policy makers and safety researchers.

National agreement on a definitions

A key underpinning for injury monitoring and reporting system for the NRSS will be national agreement on the definition of a 'serious injury'. This is important because the term 'serious injury' is used in road safety to describe an injury resulting in an important personal and social impact, whereas in health it has a range of defined technical meanings that include threat to life; mortality; energy dissipated/absorbed; tissue damage; hospitalisation and intensive care needs; length of hospital stay; treatment cost/complexity; temporary and permanent disability; permanent impairment and quality of life (Harrison 2015).

While a national source of hospitalised injury data is available from the AIHW, hospitalised injuries vary widely in severity and injury classification tools have been developed in the health sector to assign standardised severity ratings and risks of mortality based on International Classification of Diseases classifications (Box 2).

While injury classification tools provide injury severity categories of (or ratings equivalent to) 'serious' and 'severe', these tools were designed to capture only one aspect of injury severity: the short term probability of surviving an injury, or immediate threat to life. Their ability to predict other aspects of severity, such as impairment, or temporary or permanent disability, have not been demonstrated (Box 3).[6]

Given there are currently no national data sources that can provide timely data on disability outcomes, a monitoring system to measure progress against the NRSS injury target could focus initially on measuring the number of road related cases of injury that are a serious and immediate threat to life. The choice of measure for serious injury is critical as it will influence not just the total count but also the observed trends. A key challenge for policy makers will be to make an informed decision on what minimum severity criteria should define a serious injury for NRSS reporting. Models to predict injury disability outcomes are currently being developed and mortality based severity measures of serious injury could be supplemented by measures (predictions) of the number new disability cases that result from road related injury.

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[6] Impairment is an objective construct defined as a loss, loss of use, or derangement of any body part, organ system or organ function, whereas disability is evaluated by non-medical means and is defined as an alteration of an individual's capacity to meet personal, social or occupational demands because of an impairment (Reddan 2007, p.24). ABS (2004) defines a disability as any limitation, restriction or impairment, which has lasted, or is likely to last, for at least six months and restricts everyday activities.

Box 2 Definition of injury classification indices

International Classification of Diseases (ICD)

The International Classification of Diseases and related Health Problems is published by the World Health Organisation and provides codes to classify diseases as well as signs, symptoms and external causes of injury or disease.

Every health condition can be assigned to a unique category and given a code, of up to six characters. In addition to enabling the storage and retrieval of diagnostic information for clinical, epidemiological and quality purposes, these records also provide the basis for the compilation of national mortality and morbidity statistics by World Health Organisation Member States. The International Classification of Diseases is currently in its tenth edition (ICD10), although the ninth edition is still widely used (ICD9).

Injury cases admitted to hospital in Australian are classified using the Australian modification of the International Classification of Diseases Version 10 (ICD10-AM). Causes of accidents are classified and traffic injuries have a specific code in the section "external cause" as well as codes to describe the injury.

Abbreviated Injury Scale (AIS)

The Abbreviated Injury Scale—published by the Association for the Advancement of Automotive Medicine—was developed for crash investigation purposes to provide a simple numerical method for ranking and comparing injuries by severity, and to standardise the terminology used to describe injuries.

It is an internationally agreed tool to describe the severity of injury for each of nine regions of the body: 1 Minor, 2 Moderate, 3 Serious, 4 Severe, 5 Critical, 6 Unsurvivable. Body regions are 1 Head, 2 Face, 3 Neck, 4 Thorax, 5 Abdomen, 6 Spine, 7 Upper Extremity, 8 Lower Extremity, 9 External and other.

The AIS uses ICD injury classifications to assign standardised severity ratings, however, it does not reflect the combined effects of multiple injuries.

It is possible to convert ICD9 or ICD10 codes into Abbreviated Injury Scale scores.

Maximum Abbreviated Injury Scale (MAIS)

The Maximum Abbreviated Injury Scale is the maximum of the Abbreviated Injury Scale scores for each region of the body. It is used to assess the overall severity of the various injuries.

Injury Severity Score (ISS) and International Classification Injury Severity Score (ICISS)

The Injury Severity Score was developed to predict mortality. It is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned an Abbreviated Injury Scale allocated to one of six body regions (Head, Face, Chest, Abdomen, Extremities including Pelvis, External). Only the highest AIS score in each region is used. The three most severely injured regions have their Abbreviated Injury Scale score squared and summed to produce the Injury Severity Score.

The Injury Severity Score can be derived from ICD codes and this is known as the International Classification Injury Severity Score (ICISS).

High-threat-to-life or life-threatening injuries are defined as the sub-set of hospitalised cases with an ICD10-AM based Injury Severity Score of less than 0.941 (that is, a predicted mortality risk of 6 per cent or more) (Henley and Harrison 2015).

New Injury Severity Score (NISS)

The New Injury Severity Score is the simple sum of squares of the three most severe Abbreviated Injury Scale injuries, regardless of body region.

Trauma Mortality Prediction Model (TMPM)

The Trauma Mortality Prediction Model is a recent mortality based approach that can be based on AIS-coded data or ICD-coded dated (published results only for ICD9). In initial testing TMPM outperformed ISS, NISS, MAIS and ICISS in predicting mortality (Harrison 2015).

Source adapted from IRTAD 2011, p.26; Henley and Harrison 2015; Harrison 2015

Box 3 Health measures for 'serious injury'

IRTAD (2011) recommended a 'seriously injured road casualty' be defined as a person having a Maximum Abbreviated Injury Scale score of three or more (MAIS3+).

In Australia this would mean additional complexity in sourcing health data as all hospitalised cases are ICD-coded and only trauma service cases are AIS-coded.

Mapping from ICD-10-AM to the Abbreviated Injury Scale can be done but available maps are not well validated and ICD-10-AM limits what can be done. While these maps might become satisfactory for threat-to-life purposes, they would appear to offer no advantages (other than comparability to MAIS3+) over the ICD10-AM based Injury Severity Score (ICISS) or—possibly in future—an ICD-10-AM based Trauma Mortality Prediction Model (TMPM).

In terms of severity, Abbreviated Injury Scale-based measures (NISS, MAIS3+ and perhaps AIS-based TMPM) and International Classification of Diseases-based measures (ICISS and perhaps ICD-10-AM based TMPM) provide a satisfactory basis for measuring severity in terms of threat to life.

In terms of measuring other aspects of severity, notably disability, neither Abbreviated Injury Scale-based measures nor ICISS-based measures have been well demonstrated.

Disability often follows injury that rates low in terms of the Abbreviated Injury Scale (AIS 1 and AIS 2) which are not cared for by specialised trauma services and their case data are not usually coded to AIS.

Evidence is emerging that disability outcomes can be measured in groups of patients followed for at least a year and be used to predict how injury diagnoses soon after injury relate to problems later. Victoria is at the forefront of this research with its unique program of following up all survivors of severe trauma and many survivors of admitted orthopaedic injury at 6, 12 and 24 months.

Follow up of patients has shown that injury diagnosis, with other factors (notably age), can be used to predict disability at a later time. All hospitalised cases are ICD-coded, and the weights developed by following up patients can be applied to grouped injury case data to predict severity *in terms of disability*.

Source adapted from Harrison 2015

Linking police and health data sources

Linkage is used to identify records within different data sources that refer to the same person using data such as name, address, sex, date of birth and/or age; and event dates (such as the dates of a crash and of a hospital admission). The process can use a unique personal identifier (deterministic) or computer software to identify possible matched pairs (probabilistic, with a weight assigned to indicate the likelihood that a match is correct).[7] Linking is not an exact process; the proportion of matching records and confidence level depend on the methodology and will depend on the:

- *Available data*. Both the type of recorded data (for example, age or date of birth) and completeness of personal information fields in unit crash and hospital data (for example, age is often not captured in crash data). Data may also be randomised to protect privacy (for example, health data custodians may randomise hospital admission dates to reduce the likelihood of re-identifying individuals).
- *Case inclusion criteria*. Inclusion criteria include the time after crash event (for example, one day or one week). The criteria chosen influence both the total proportion of matching records and reliability (that is, the level of false positive and false negative matches).

Privacy provisions limit access to data identifying individuals in health and transport sectors at both the jurisdiction and at the national level (Chapter 6 of the Australian Privacy Principles and Guidelines).[8] It is well

[7] IRTAD stated that the deterministic method is preferred if a unique personal identifier is available, otherwise the probabilistic method is a good alternative (2011, p.10).

[8] The Australian Privacy Principles are contained in schedule 1 of the *Privacy Act 1988* (Privacy Act) and outline how most Australian and Norfolk Island Government agencies, all private sector and not-for-profit organisations with an annual turnover of more than $3 million, all private health service providers, and some small businesses must handle, use and manage personal information (see https://www.oaic.gov.au/privacy-law/privacy-act/australian-privacy-principles).

recognised by ethics committees and data custodians and in the Australian Privacy Principles that some purposes require the use of personal information, but that many such purposes can be served by the use of de-identified data linkage methods with minimal or no disclosure of personal information.

In order to link hospital and crash databases, it is necessary to obtain approvals from ethics committees and permissions from data custodians. This process is time consuming and costly, and in some jurisdictions there may be additional requirements (for example, specific legislation can prohibit sharing of identifying data).

While linking can be done at a jurisdiction level, jurisdictions would need to use consistent matching criteria so injury data could be aggregated into national totals. It may also be difficult for all jurisdictions to fund the on-going process to provide routine injury data needed for NRSS reporting.

While several Australian jurisdictions are exploring[9,10] systems to link police and health data, only New South Wales has integrated linked casualties into its crash data reporting system (see Appendix B).

The Centre for Road Safety (2015) reports that approximately 60 per cent of people hospitalised in New South Wales as a result of road crashes between 2008 and 2013 were matched to a police crash record. While the proportion of matching records was high amongst drivers (86 per cent), pedestrians (69 per cent) and passengers (60 per cent), rates were considerably lower among motorcyclists (49 per cent) and pedal cyclists (22 per cent). However, the majority of cases involving a collision with a light vehicle were matched for both motorcyclists (85 per cent) and pedal cyclists (70 per cent), with lower rates for crashes involving collisions with a fixed object, non-collision or unspecified crash types (see Box 4 below).

At the national level, an Austroads pilot project commenced in November 2015 to provide proof of concept for a national system for linking crash and hospital admissions data to provide timely and reliable national source of data on the number, severity and pattern of non-fatal serious injury.[11] This pilot project:

- Aims to obtain the ethics approvals necessary to undertake national linkage of hospital and crash databases for Australian states and territories for past and future years.
- Where permissions are obtained, use health systems to link data for the most recent data year available while protecting privacy and using consistent national case-inclusion criteria.
- Make de-identified data for the matched year available for reporting and research purposes.
- Report on the best practice method and key data characteristics (for example, the overlap between the sources, degree of concordance of on-road crash with in-traffic hospital cases, and characteristics of unmatched hospital cases).

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9 These include Western Australia, Victoria and Queensland (Watson et al 2015). Delia and Newstead 2014 describes a process in Victoria that linked police reported crash records with TACV claims data containing high level injury outcome information. BITRE notes that other jurisdictions have faults based injury claims systems which means this method could not produce national measures.

10 The Parliament of Victoria Road Safety Committee (2014) has recommended that a working group be established in Victoria to investigate implementation of an independent data linking entity, and be comprised of: The Transport Accident Commission, VicRoads and Victoria Police; The Department of Health; The Victorian State Trauma Outcomes Registry and Monitoring Group and the Victorian State Trauma Committee; and Victorian Health Records and Privacy Commissioners.

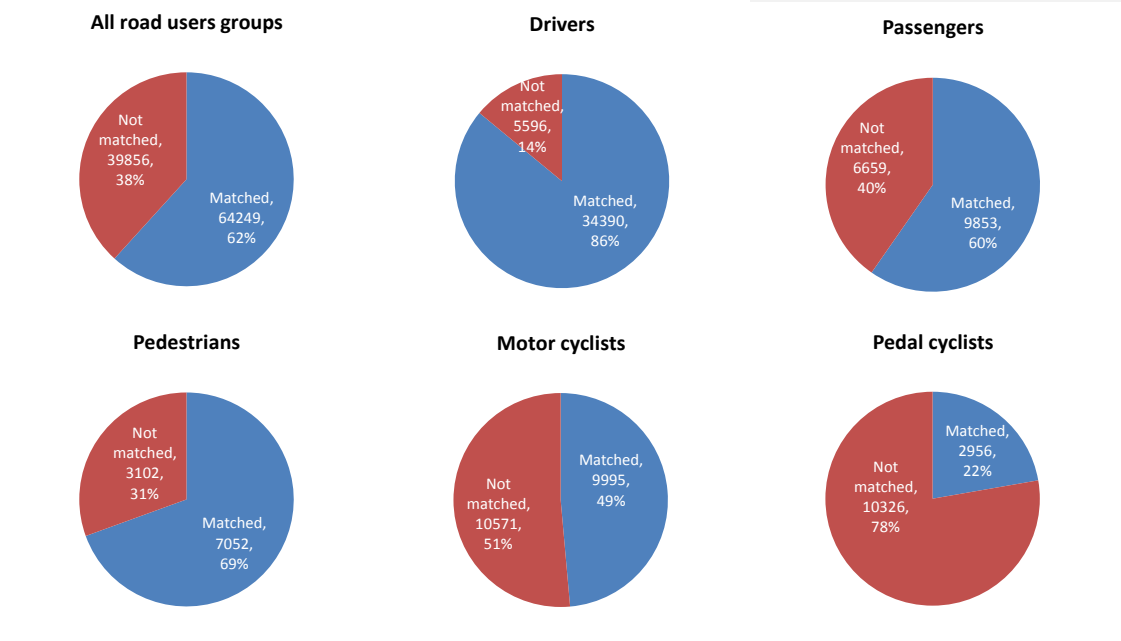
11 Subject to the successful completion of the pilot project, a second stage would be to produce a historical series of matched National data for an agreed number of calendar years. A third stage would be to develop an on-going process to produce timely annual updates and reporting including summary NRSS non-fatal serious injury indicators.

Box 4 Key findings of the New South Wales linkage study

Over 104,000 people were seriously injured (all hospitalised injuries) on public roads in New South Wales over the nine year period 2005 to 2013.

Almost 40 per cent of all hospitalised injuries were not matched to a police crash record. While the proportion of serious injuries matching to police reports was high among drivers, pedestrians and passengers, the rate was considerably lower among motorcyclists and pedal cyclists.

NSW serious injuries by road user type (all hospitalised injuries), 2008 to 2013



Total serious injuries have increased by 12 per cent over the nine year period. Serious injuries *matched* to a police report increased by 4 per cent. This can be largely attributed to increases in metropolitan crashes; unclassified and lower order classified roads; roads with a posted speed limit of 50 km/hour and 80 km/hour; and rear enders and manoeuvring crashes.

Serious injuries *not matched* to a police report increased by 27 per cent.

The rise in total serious injuries can be largely attributed to an increase among:

- Motorcyclists (up 39 per cent from 1,860 in 2005 to 2,588 in 2013)
    - The increase in total motorcyclist serious injuries was driven by increases in matched (up 44 per cent) and unmatched motorcyclist serious injuries (up 35 per cent).
    - Those involved in collisions with a fixed object (up 71 per cent), non-collision crashes (up 59 per cent) and collisions with a car/pickup/van (up 40 per cent).
- Pedal cyclists (up 35 per cent from 1,333 in 2005 to 1,800 in 2013)
    - The increase in total pedal cyclist serious injuries was mainly driven by a 44 per cent increase in unmatched pedal cyclist serious injuries.
    - Those involved in non-collisions [*unmatched*] (up by 197 per cent).
- Drivers (up 11 per cent from 4,381 in 2005 to 4,856 in 2013)
    - Those involved in collisions with another car, pickup truck or van (up by 17 per cent).

Source Centre for Road Safety 2015

Developing a national injury monitoring system

While some jurisdictions are taking steps to improve their systems for collecting non-fatal injury data—notably through linking of hospital and crash databases—there is a need for national collaboration on linking to produce a reliable, consistent and timely series of national injury data. This will require development of best-practice approaches and case-inclusion standards for matching, as well as agreement from all jurisdictions on a standardised definition of a severe injury for NRSS reporting purposes that is based on medical diagnosis and includes a threshold for severity.

Getting the right systems in place will be an incremental endeavour. The aim of the Austroads pilot project (see *Linking police and health data sources*, page 13)—which has a timeframe of 24 months—is to obtain the ethics approvals needed to provide a national source of injury data for past and future years through national matching and linkage of hospital, deaths and crash data.

Subject to successful completion of the pilot, Austroads approval will be sought for separate projects to:

- Produce a historical series of matched national data for an agreed number of calendar years.
- Develop an on-going matching to produce timely annual updates. A key requirement will be formalising data handling arrangements between the parties.

While regular and timely production of matched national data should provide the data needed for reporting aggregate indicators (for example, the total number of defined injury cases and the number of traffic crashes resulting in at least one defined injury) it still needs to be determined if all of the NRSS performance indicators currently reported for fatalities (Appendix A) will also be reportable for serious injury.

Key criteria for a national monitoring system include quality, national consistency and timeliness. Mitchell et al (2009; cited in Watson 2014, p.15) suggest that data for injury monitoring systems be assessed using quality criteria (completeness, sensitivity, specificity, representativeness), operational criteria (purpose and objective; case definition; and uniform classification systems) and practical criteria such as usefulness.

While the Austroads pilot project will shed light on the suitability of matched data for NRSS reporting, it is possible to make a number of observations on completeness and usefulness.

IRTAD (2011) recommends including all hospitalised injuries meeting the chosen injury criteria to provide a more complete picture. Including all traffic cases from hospital data helps overcome limitations of crash reporting—notably, under-reporting of motorcyclist and pedal cyclist injuries. NSW has defined serious injury as all hospitalised cases, not just cases matched with police reports (Centre for Road Safety 2015).

Where a hospital injury record cannot be matched to a crash record, only limited contextual data will be available to help inform preventative action and it will not be possible to include unmatched cases in some disaggregated injury indicators. For example, hospital data does not have data about the location of the crash and it may not be possible to include unmatched cases in injury indicators for metropolitan, regional and remote roads.

Even when matching hospital and crash records are identified, what is possible in terms of safety research and NRSS reporting will depend on the permissions obtained from data custodians in specific jurisdictions.

In order for the linked crash-hospital dataset to be useful, it will need to contribute in a timely way to identifying potential areas for preventive action by: (a) identifying new and/or emerging injury mechanisms; (b) monitoring injury trends over time; and (c) describing key characteristics of the injured population.

Appendix A NRSS fatal crash-related indicators for 2008–2010, the baseline average, and 2014

	2008	2009	2010	3 year average [a]	2014
TOTAL DEATHS	1437	1488	1352	1426	1155
TOTAL FATAL CRASHES	1315	1344	1232	1297	1055
SAFE ROADS					
1. Number of deaths from head-on crashes	251	287	279	272	219
2. Number of deaths from single-vehicle crashes	682	698	584	655	503
3. Number of deaths from intersection crashes	337	282	285	301	234
4. Number of deaths from crashes occurring on:					
– metropolitan roads	542	516	435	498	376
– regional roads	754	820	760	778	644
– remote roads	128	140	147	138	129
– uncoded to a national region	13	11	11	12	7
SAFE SPEEDS - no crash related indicators					
SAFE VEHICLES - no crash related indicators					
SAFE PEOPLE					
- RESPONSIBLE ROAD USE					
6. Number of young driver and motorcycle rider deaths	237	215	215	222	150
6.1 Number of deaths from crashes involving a young driver or motorcycle rider	502	470	434	469	330
7. Number of older driver and motorcycle rider deaths	121	113	107	114	136
7.1 Number of deaths from crashes involving an older driver or motorcycle rider	214	205	202	207	223
8. Number of motorcyclist deaths	246	225	230	234	191
9. Number of pedal cyclist deaths	28	31	38	32	44
10. Number of pedestrian deaths	191	195	172	186	150
11. Number of deaths from crashes involving a heavy vehicle	270	246	240	252	223
- IRRESPONSIBLE ROAD USE					
12. Number of drivers and motorcycle riders killed who had a blood alcohol concentration (BAC) above the legal limit[b]	149	155	126	143	78
12.1 Number of deaths from crashes involving a driver or motorcycle rider who had a blood alcohol concentration (BAC) above the legal limit[b]	222	223	171	205	126
13. Number of deaths from crashes involving an unlicensed driver or motorcycle rider[c]	165	135	128	143	96
14. Number of vehicle occupants killed who were not wearing a restraint (where restraint use is known)	231	241	176	216	162

na not applicable. nc not calculated.
a. To the nearest whole number.
b. Excludes Victoria as BAC data was unavailable and Western Australia as licencing data needed to determine the applicable BAC legal limit was unavailable.
c. Excludes Western Australia as licencing data was unavailable.
Source Jurisdictional crash data and BITRE analysis (http://roadsafety.gov.au/performance/spis.aspx)

Appendix B NSW data linkage process

The New South Wales Centre for Road Safety has implemented a routine quarterly linkage (including historic data from 2005) which includes the following state data collections –

- Ministry of Health data collections: Admitted Patient Data Collection and Emergency Department Data Collection.
- Mortality Data Collection from the Register of Births, Deaths and Marriages.
- Centre for Road Safety CrashLink crash reporting database: road crash records derived from Police reports.

Record linkage brings together information that relates to the same individual, place or event from different data sources. In this way it is possible to identify casualties from road traffic crashes and their chronological sequence of health events.

The linkage of person records between the data collections is conducted by the Centre for Health Record Linkage (CHeReL). In bringing together these records, the CHeReL uses strict privacy preserving protocols which ensure the security of the data and confidentiality of the individuals and their related records. This process includes -

- Custodians of the data collections to be linked provide the CHeReL with an encrypted source record number and demographic details for each record in their dataset. Note that clinical data is not provided to the CHeReL.
- The CHeReL links these records using probabilistic matching of the personal identifying information (e.g. name, address, date of birth, gender) to match records between different datasets, and assigns a Project Person Number for records that belong to the same person. The CHeReL Project Person Number and the associated source record numbers form the CHeReL Master Linkage Key. The Master Linkage Key provides a 'pointer' to records for a person in different datasets. The CHeReL sends each data custodian a list of Project Person Numbers and the associated encrypted source record numbers for their database.

The respective data custodians provide input files which include Project Person Numbers and approved variables.

The Centre for Road Safety project team load the files into a database and match all records from different datasets for a person using the Project Person Number.

The data linkage process also requires a ‘crash date’ to match records; an agreed approach is to link a hospital record to a crash record if the personal identifying information is probabilistically matched, and the hospital admission was on the same day or next day after the crash. This avoids linking a hospital record to an unrelated crash. However, this can result in missed links.

Approved Centre for Road Safety researchers are then able to analyse the de-identified analytical views of matched and unmatched data. This process ensures that:

- CHeReL staff performing the linkage use demographic variables but do not have access to the clinical information about individuals;
- Data custodians only have access to data within their data collections; and
- Researchers receive data which contains no identifying variables, or variables which provide a link back to the CHeReL Master Linkage Key.

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