

## **How Do Different Definitions of ‘Serious Injury’ Overlap? A Case Study Based On TAC Compensated Traffic Injuries in Victoria (2006-2010)**

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### **Abstract**

Background: The outcomes of road traffic injury can be viewed through a number of lenses, including: threat to life, impairment, pain and suffering, quality of life loss, cost and resource use. While numerous definitions of ‘Serious Injury’ exist based on these aspects, there is no consensus on the most appropriate definition. Aim: To understand how different definitions of ‘Serious Injury’ correlate and overlap. Method: Serious injury was defined in four ways, these being threat to life, impairment, compensation cost, and resource use as indicated by a length of stay of at least 15 days in hospital. The sample consisted of 67,797 road users injured in Victoria in the period 2006 – 2010 inclusive, and who made a claim for compensation to the Transport Accident Commission (TAC). Analysis was performed to investigate the relationship between four definitions of serious injury and an Euler diagram was developed to study the overlap between them. Results: There were significant, but moderate, correlations between all pairs of serious injury measures. In addition, the Euler diagram analysis showed that the cohorts of claimant classified as serious injury by the four different definitions showed only partial overlap, with only 0.6% of claimants classified as ‘serious’ by all four definitions with a far higher proportion classified as serious by one definition of serious injury. Conclusions: The importance of identifying a common, comprehensive definition of serious injury that is robust cannot be underestimated. The analysis presented here suggests a composite measure of serious injury is required.

### **Keywords:**

Serious Injury; Injury Consequences; Threat to Life; Impairment; Transport Accident Commission

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## 1 Introduction

Road trauma afflicts the Victorian community day in, day out, leaving needless deaths and injuries behind. Road traffic injury can be viewed from a number of different perspectives. Injury data can also be defined and measured to fulfill one of a number of purposes from setting road safety strategies (long-term) to managing the operation and resource-distribution of police and ambulance services (short-term).

The assessment of injury severity is somewhat dependent upon the lens through which injury impacts are viewed. For the injured individual, concerns relate to getting back to pre-crash health or achieving independence, remaining employed, fulfilling family roles, and achieving social participation; in short, getting back to the pre-road crash life. Parts of the health care system view injury severity through the lens of threat to life and consequent demand for emergency services. Other parts of the health care system are concerned with rehabilitation and downstream effects of road traffic injury and its ripple effect. Insurers are concerned with fiscal management, and managing premiums and liabilities. Society is collectively concerned with reducing the economic and social impacts of road traffic injury. At the same time, road users demand an efficient road transport system, and as such there is an inherent tension relating to the balance between mobility and safety.

It is widely accepted then that how the impact of road traffic injuries in terms of cost and severity is measured plays a critical role in driving road safety expenditures and resource allocation across the health and transport system. As such, reaching a common definition of serious injury represents a considerable, but essential, challenge to be met.

The gravity of the need to adopt an evidence-based, consistent measure of serious injury, that encompasses important consequences of injury, becomes more evident when the challenges that lack of such definition poses are considered. The lack of such robust definition thwarts efforts to:

- set long-term road safety targets, strategies and policies;
- develop action plans and road safety programs;
- evaluate the effectiveness and efficiency of road safety initiatives;
- monitor improvement/deterioration of road safety outcomes;
- conduct research and analysis to determine causes; and
- allocate a budget to road safety that is commensurate with the magnitude of road traffic injury problem.

The Transport Accident Commission (TAC), established in 1987, a government-owned insurer of third-party personal liability for Victorian road traffic injuries, and receives, on average, 16,000 claims per annum (over 30% hospitalised). The TAC plays an essential role in both the care and rehabilitation of injured road users in Victoria, as well as having a legislative responsibility to improve road safety (Transport Accident Act, 1986). Under the TAC scheme, injured road users have a no-fault entitlement to care, loss-of-earnings replacement and impairment benefits as well as a range of additional entitlements under common law for those seriously injured (e.g., acquired brain injury, spinal cord injury). In the 2011-2012 financial year, the TAC paid over a billion dollars to compensate road traffic injuries in Victoria. Therefore, a better understanding of injury consequences and their correlations and overlap will assist the TAC to more effectively and efficiently fulfill its statutory objectives.

## 2 Aims

The focus of this research project was on understanding potential consequences of road traffic injury and comprehending how a set of currently available and widely used definitions of serious injury correlate and overlap. In doing so, it is anticipated that this will facilitate the development and adoption of a commonly-agreed, consistent and reliable measure (or measures) of serious injury in Victoria. More specifically, it was attempted to

- determine the nature of injury consequences among TAC claimants, and then define ‘serious injury’ on the basis of these consequences; and
- investigate the relationship between defined measures of serious injury by examining their correlations and overlap.

As a means of setting the scene and defining the nature of ‘serious injury’ and its measurement, consideration is given to a number of measurement approaches.

## 3 Views of road traffic injury

Notwithstanding the different perspectives of road traffic injury presented in Introduction, it is still possible to identify some aspects of injury that underlie all potential definitions of serious injury. Specifically, the severity of a person’s injuries can be assessed in at least six different ways:

- *Threat to Life*: the risk of mortality imposed by an injury sustained in a motor vehicle road crash;
- *Impairment*: a demonstrable anatomical loss or damage (e.g. restricted movement of a joint) or psychological trauma that may or may not culminate in disability;
- *Pain and Suffering*: physical and emotional stress caused from an injury sustained in a motor vehicle road crash;
- *Quality of Life Loss*: the degree to which the consequences of the road crash impact the victim’s enjoyment of the important possibilities of his or her life;
- *Financial Cost*: costs to the community through the treatment, rehabilitation, and compensation of an injury sustained in a motor vehicle road crash, as well as extraneous factors such as legal costs, productivity loss, work-related arrangements, and home and vehicle modifications; and
- *Resource Use*: medical and emergency resources required to cater for an injury sustained in a motor vehicle road crash such as hospital bed/nights, ambulance services and etc.

### 3.1 Threat to life and anatomical measures of injury severity

Threat-to-life measures of injury severity were developed to compare the risk of death across various injured groups for purposes of evaluating their needs for emergency and subsequent care (Baker et al., 1974). The common approach is comparing persons whose injuries, although possibly different, are of the same severity; then the same risk of morbidity and mortality can be assigned to each. Such measures and classification systems report and code injuries sustained as a direct consequence of the road crash. The commonly used threat-to-life measures are:

***Abbreviated Injury Scale (AIS)***: An anatomical injury severity scoring system first introduced in 1971 by the Association for the Advancement of Automotive Medicine (AAAM, 1971) and continuously updated and expanded. The AIS code has two components (1) the injury descriptor which is a unique numerical identifier for each

injury description; and (2) the severity score. The severity score ranges from 1 (minor) to 6 (maximum). AIS severity scores have been assigned to specific types of injuries as determined by consensus among a wide variety of medical specialists to reflect the probability of death as well as other dimensions of severity including hospitalisation, length of stay, treatment cost and complexity, and disability and impairment. AIS severity scores reflect injury severity in an otherwise healthy adult and are seen to have a strong relationship with the probability of survival (Thomas and Elaine, 2008).

**Maximum Abbreviated Injury Scale (MAIS):** AIS codes are defined according to body region (head, face, neck, thorax, abdomen-pelvis, upper extremity, lower extremity, external). Usually, multiple body regions are injured in a road crash and hence it is informative to highlight the highest severity (i.e., most severe) for each body region. The overall MAIS is the severity score for the most severe injury sustained in the road crash, irrespective of body region.

**Injury Severity Score (ISS):** The ISS is based upon the AIS (Baker et al., 1974). To calculate an ISS for an injured person, the body is divided into six ISS body regions. These body regions are: Head or neck (including cervical spine); Face (including the facial skeleton, nose, mouth, eyes and ears); Chest (thoracic spine and diaphragm); Abdomen or pelvic contents (abdominal organs and lumbar spine); Extremities or pelvic girdle (pelvic skeleton); and External. The highest AIS severity code in each of the three most severely injured ISS body regions are squared and added up to calculate an ISS. ISS scores range from 1 to 75 (i.e. AIS scores of 5 for 3 ISS-regions). Any injury coded AIS-6 is automatically assigned an ISS of 75. The ISS is one of the most widely used injury severity indices and is the basis of ‘major trauma’ definitions ( $ISS \geq 12$ ), is seen to have correlation with mortality, length of stay and disability (Bull, 1975), although it not without limitations (i.e., limited to three body regions only, includes a single injury per region; each region weighted equally).

**New Injury Severity Score (NISS):** A modification of the ISS, the New Injury Severity Score (NISS) was developed in 1997 to address the issue of multiple injuries in the same body region (Osler et al, 1997). It is very similar to the ISS except it scores the three most severe AIS scores regardless of their body region location, therefore, multiple injuries within a body region can be accounted for in the calculation of a NISS. The change from ISS to NISS aimed at increasing the predictive value of the index against mortality and simplifying its calculation. Research has demonstrated that it is better able to predict survivors from non-survivors (Osler et al, 1997; Brenneman et al, 1998) and is a more accurate predictor of post injury organ failure than the ISS (Balogh et al 2000) as well as extended hospitalisation and ICU admission following multiple orthopaedic injury (Balogh et al., 2003).

**ICD Based Injury Severity Score (ICISS):** Originally defined in 1996, the ICISS is a score between 0 and 1 and is a method that involves estimating probability of death for each ICD injury diagnosis code using a survival risk ratio (SRR). A given SRR represents the likelihood that a patient will survive a particular injury. Each patient’s final ICISS score (survival probability) is calculated by multiplying the probabilities of surviving each of their injuries individually, in other words, by multiplying all the SRRs for individual injuries.

### 3.2 Impairment

A second element of the injury picture is the physical and psychiatric impairment resulting from road crashes (Mayou et al., 1993; Fitzharris et al., 2007; Fitzharris and Bowman, 2010).

This element is worthy of consideration as it can provide a very different picture to anatomical indices of the impact of injury. In fact, the correlation between threat-to-life measures of severity and long-term outcomes can be poor as not all life-threatening injuries result in permanent impairment (Malm et al., 2008). For example, a ruptured spleen, which is associated with heavy internal bleeding, may not result in any lasting impairment if treated successfully. A spinal cord injury, on the other hand, may leave a person in a wheelchair for life, although the injury as such may not be life-threatening. Therefore, developing an appropriate system for determining the long-term consequences of road injuries is necessary to complement the threat-to-life measures of serious injury. The European Transport Safety Council (ETSC) (2007) highlighted the range of considerations in defining ‘outcomes’ and impairment and noted that a large number of scales have been developed to describe the long-term impacts of injury, some of which are broad-based quality of life and well-being measures while others relate to specific diagnoses.

The TAC uses “Degree of Impairment” as the basis of impairment assessment and common law eligibility. The American Medical Association (AMA) Guide to the Evaluation of Permanent Impairment (4<sup>th</sup> Edition) is currently used. An impairment rating percent between 0 (no impairment) and 100 (almost dead) is assigned to the injured person. The assessment must be completed by an independent medical practitioner who has successfully completed the Ministerially-approved training course in the application of the Guide. For the purposes of assessing the degree of psychiatric impairment also, the American Medical Association's Guides could apply to the extent that the overarching principles of the Guides apply. However, psychiatric impairments due to transport road crashes in Victoria are assessed by the TAC using a local guide which is also then modified by the Transport Accident Act 1986.

### **3.3 Pain and suffering**

Pain and suffering denotes the physical and emotional stress caused from an injury, and it includes: aches, temporary and permanent limitations on activity, potential shortening of life, depression or scarring.

Motor vehicle road crashes may result in pain and suffering for the person(s) involved and for those related to them. However, currently, no specific measure of ‘pain and suffering’ has been validated in Victoria, and to the best of our knowledge anywhere else, to capture pain and suffering in the road safety context that can be used to identify serious injury.

### **3.4 Quality of life loss**

There are a number of definitions for ‘quality of life.’ For example, according to the research conducted at the University of Toronto's Quality of Life Research Unit, quality of life is “the degree to which a person enjoys the important possibilities of his or her life”. Their Quality of Life Model is based on the categories “Being”, “Belonging”, and “Becoming”, respectively, who one is, how one is connected to one's environment, and whether one achieves one's personal goals, hopes, and aspirations. The extent of a person's quality of life in the areas of Being, Belonging, and Becoming and their sub-domains is determined by two factors: importance and enjoyment. Thus, quality of life consists of the relative importance or meaning attached to each particular dimension and the extent of the person's enjoyment with respect to each dimension. In this way quality of life is adapted to the lives of all humans, at any time, and from their individual perspectives.

There are a number of quality of life measures, including the Short-Form 12 (SF-12) and the Short-Form 36 (SF-36). SF-36 Health Survey is a brief self-administered questionnaire that generates scores across 8 dimensions of health, namely: vitality; physical functioning; bodily pain; general health perceptions; physical role functioning; emotional role functioning; social

role functioning; and mental health (Hays et al., 1995). SF-36 is a set of generic, coherent, and easily administered quality-of-life measures. These measures are now widely utilized by managed care organizations and by Medicare for routine monitoring and assessment of care outcomes in adult patients.

However, such measures have not yet been adopted in a road safety context to identify serious injury.

### **3.5 Cost**

The economic cost of injury sustained in motor vehicle road crashes is another lens through which injury severity can be measured. For instance, in their report to the Accident Compensation Corporation (ACC) Secretariat for the New Zealand Injury Prevention Strategy, Cryer et al. (2004) recommended that “the injury should be based on events that are associated with significantly increased risk of impairment, disability, functional limitation, or death, decreased quality of life, or *increased cost*.” They, however, did not suggest any measure of serious injury based on the cost of road traffic injuries.

### **3.6 Resource use**

In the road safety context, resource use and management is mainly associated with the deployment, allocation and management of emergency response services, hospital and Emergency Department (ED) treatments and rehabilitation services. The emergency response services, mainly being police and ambulance services, are deemed not to provide a precise and consistent measure of injury severity for long-term strategic purposes. Hospital and ED treatments, on the other hand, are shown to provide a consistent and reliable measure of injury severity for road safety strategy setting (Hoareau et al., 2006). In this research, length of hospital stay is used as the resource use measure.

However, it should be noted that resource use measures, e.g. length of hospital stay or hospital admission, may have low discriminatory power against impairment and threat to life. For example, injuries requiring hospitalisation can range from a mild concussion requiring a day admission to hospital from which the patient will generally make a full recovery in a short time period to major traumatic brain injury that will leave the patient severely disabled and requiring high care for the rest of their life. In addition, resource use measures such as length of stay can be influenced by a variety of extraneous factors unrelated to the severity of the injury such as hospital policy and practices, or socio-demographic factors.

In order to demonstrate how an injury can be viewed through these various lenses, five injury case studies taken from the TAC claims database are discussed in Appendix A.

As stated above, the principal aim of this paper is to examine the relationship between defined measures of serious injury by examining their correlations and overlap. This is presented in the following sections.

## **4 Method**

The TAC claims dataset was consulted and the details of 67,797 injured persons who made a claim during the period 2006 to 2010 formed the basis of the analysis. The data on anatomical injury severity (MAIS), impairment (TAC’s Degree of Impairment), Cost (TAC’s estimated lifetime compensation payout for no-fault benefits) and resource use (length of hospital stay) were collected for all these claims. No data on pain and suffering nor quality of life measures were available.

Serious Injury was then defined based on each of these four elements, these being:

- For the threat to life measure, an MAIS score greater than 2 (MAIS3+) was selected to indicate serious injury. This was chosen in line with the European Union’s recent adoption of a similar measure as an interim indicator of serious injury (the European Commission's High Level Group on Road Safety, 2012).
- For impairment, the TAC’s measure of serious injury as determined in its legislation, i.e. degree of impairment greater than or equal to 30 per cent on a scale of 0 (no impairment) to 100 (almost dead) was used.
- For resource use, a hospital stay of over 14 days where admission was within 7 days from the crash was chosen.
- For cost, an estimated lifetime compensation cost of at least \$52,378 was chosen, because claims exceeding this cost contribute 75% of all TAC liabilities.

Table 1 shows the selected measures and the percentage of the sampled claims that were categorised as ‘Serious Injury’ on the basis of these definitions.

**Table 1**

Representative measures of injury severity and their related percentage of serious injury claims

Aspect	Measure of Injury Severity	Cut-off Point	% of claims classified as serious injury
<b>Threat to Life</b>	Maximum Abbreviated Injury Scale	$\geq 3$	9.2
<b>Impairment</b>	Degree of impairment	$\geq 30\%$	1
<b>Resource Use</b>	TAC claim with an admission to hospital within 7 days from the road crash	$> 14$ days continually admitted	6.1
<b>Cost</b>	Estimated lifetime compensation payout by TAC for no-fault benefits	A cut-off cost (\$52,378) was chosen that 75% of all TAC liabilities cost greater than this	10.4

As can be seen, the percentage of serious-injury claims significantly differs for different measures, indicating that the estimated magnitude of serious injury problem is highly related to the definition adopted.

Four binary (1: serious injury; 0: not serious injury) variables were defined on the bases of the adopted definitions and a set of statistical tests were undertaken to determine the correlation between these variables. The phi coefficients (mean square contingency coefficients) were calculated for each pair of definitions to investigate the significance and magnitude of correlation between them.

Following this preliminary step an Euler diagram was created to investigate the possible logical relations between the sets of ‘Serious Injury’ claims based on the adopted definitions of serious injury. All the claims were classified into “Serious Injury” and “Non-Serious Injury” claims and the overlap between the “Serious Injury” subsets were studied using an Euler diagram.

## 5 Results

Table 3 shows the phi coefficients and their significance. As can be seen, while all the serious injury variables are significantly correlated, pairwise, the magnitude of correlation values are not noticeably high for none of the pairs, indicating no two measures of serious injury are exchangeable.

**Table 2**  
Phi coefficients for each pair of serious injury variables

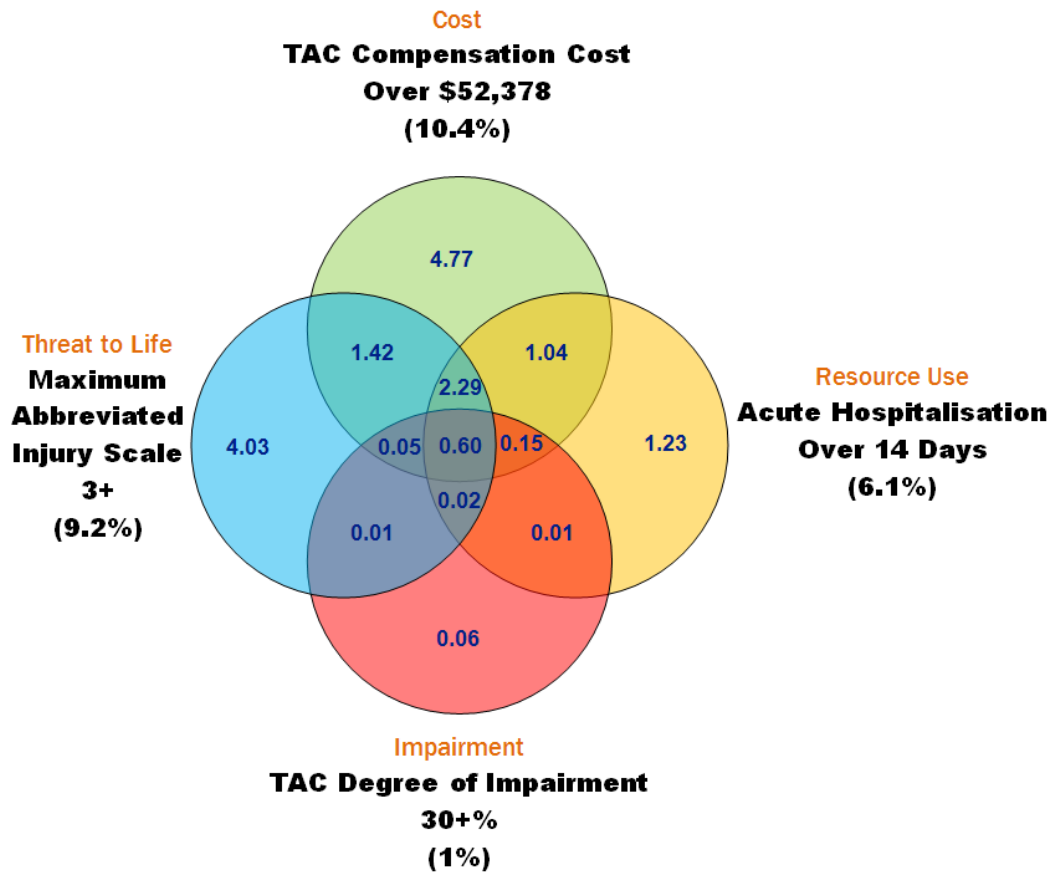
Variables		Phi coefficients	Significance
Threat to Life	Impairment	0.208	< 0.001
Threat to Life	Resource Use	0.451	< 0.001
Threat to Life	Cost	0.385	< 0.001
Impairment	Resource Use	0.304	< 0.001
Impairment	Cost	0.259	< 0.001
Resource Use	Cost	0.471	< 0.001

The results of the Euler diagram analysis (Figure 1) shed further light on the relationships and overlapping between the adopted definitions of serious injury. The values shown represent the percentage of claims located within each of the intersecting and non-intersecting areas. For example, only 0.6% of the claims were classified as serious injury by all four measures. The relative complement areas (i.e., areas that do not intersect with any other areas) represent those claims that were classified as serious injury by only one serious injury measure.



**Figure 2**

Euler diagram to investigate logical relations between serious injury subsets



Studying the diagram, a few indicative observations can be made:

- No single measure covers all the aspects of serious injury.
- Different measures of serious injury representing different aspects overlap only partially.
- A high proportion of claims are classified as serious injury by only one definition of serious injury.
- The cost-based definition of serious injury includes a marginally larger proportion of clients than does the MAIS 3+ definition of threat-to-life.
- Resource-use-based serious injuries are more likely to be also categorised as serious injury based on the cost measure than other measures.
- Impairment-based serious injuries are more likely to be also categorised as serious injury based on the cost measure than other measures.
- Threat-to-life-based serious injuries are more likely to be also categorised as serious injury based on the cost measure than other measures.

## 6 Discussions and conclusions

The terms serious injury and impairment can mean different things depending on who is the frame of reference, its basis of measurement, and its end use. Regardless, it is argued that the consequence of injury can be captured through six aspects, namely: threat to life, impairment, pain and suffering, quality of life loss, resource use and cost.

The aim here was to examine the overlap between various definitions of serious injury. It was anticipated that the findings would inform the development of an overarching definition of serious injury that could be applied universally in a road safety context. As was shown, while the four definitions of serious injury adopted were significantly correlated, the magnitude of such correlations was not sufficiently high to warrant adopting a single definition of serious injury. This means that it is possible that the overarching, universal definition of serious injury should be based on a combination of different measures of injury severity.

It should be noted that no data was available to this research project to investigate the role of pain and suffering and quality of life loss aspects of injury severity and compare their associated definitions of serious injury with the other definitions adopted in this research. It is anticipated that adding these aspects to the picture may increase the complexity of the issue and better justify the need for adopting a combined measure of serious injury.

Furthermore, it was observed that the magnitude of the serious injury problem in Victoria and its trend over time is highly dependent on the definition of serious injury adopted. Considering the enormous influence of the magnitude and trend of serious injury problem on policy-makers' decisions, it is of great importance to identify the best practice definition of serious injury that best represents serious injury and its consequences in the community.

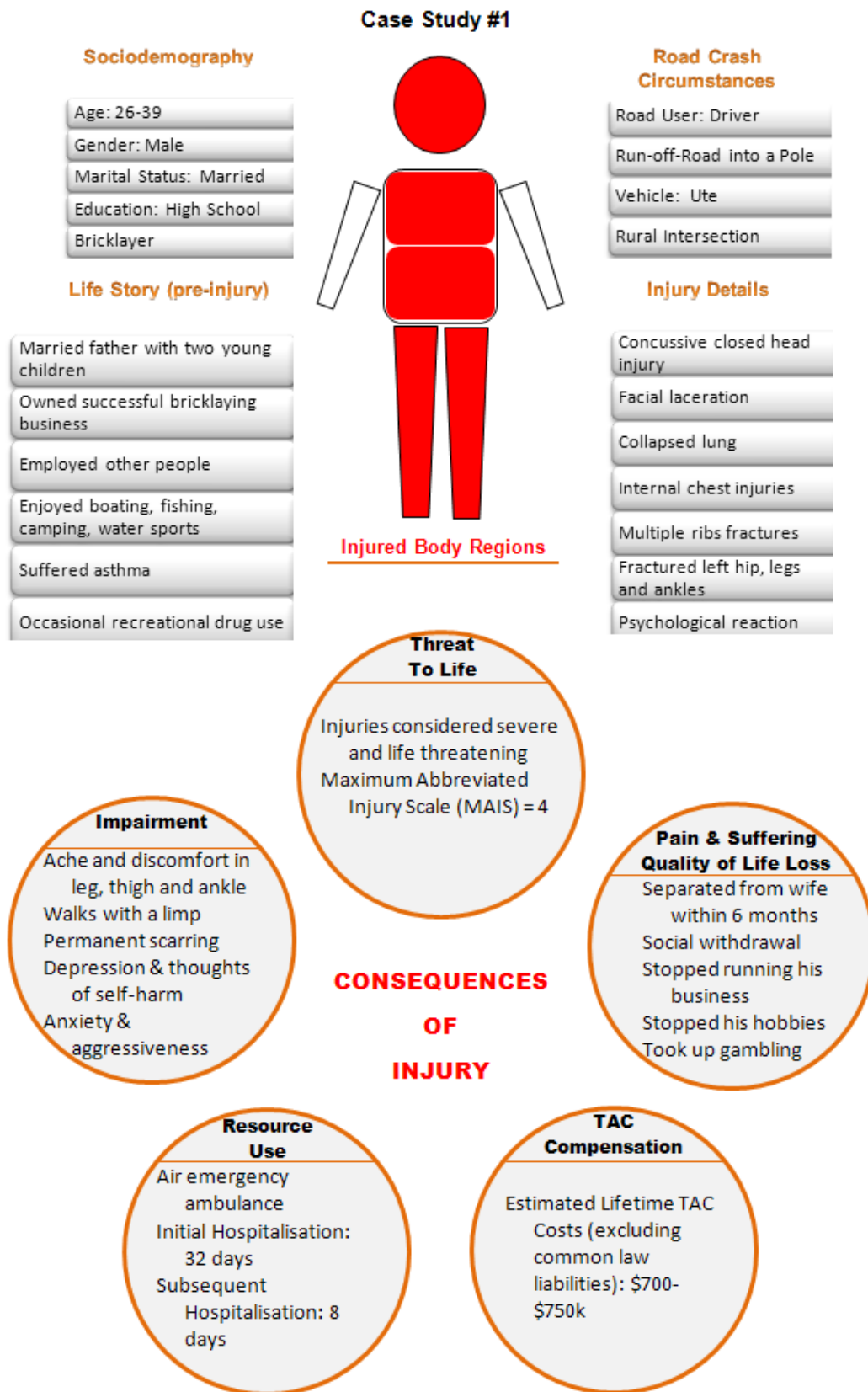
However, there are a few points that should be noted when considering the findings of this research. Firstly, the cost-based definition of serious injury was based on TAC Claim costs and is influenced by payments for hospital admissions and impairment classification. Secondly, degree of impairment is not routinely calculated for all TAC claims, perhaps explaining the very low percent (1%) of injured persons classified as having been seriously injured.

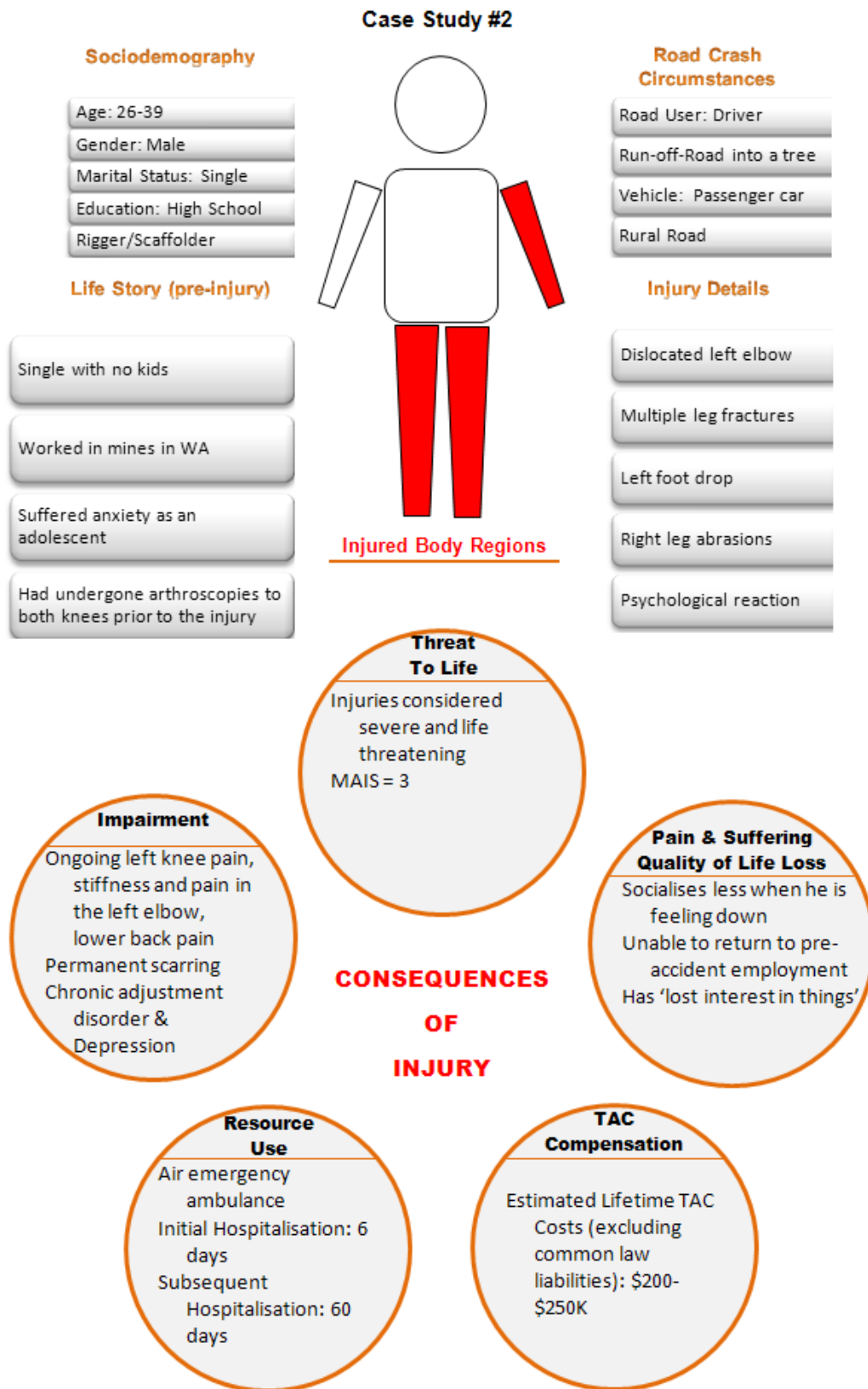
In conclusion, the findings of this research shed some light on the interactions between various measures of serious injury and how fully combined measures of serious injury can cover the whole serious injury problem. It is recognised that the formulation of an integrated definition of serious injury is a substantial challenge. Certainly, the case studies presented in the Appendix highlight the complexity of assessing injury severity, impairment and disability. Nonetheless, this work represents the first step in understanding how a common definition of serious injury can be conceptualised and highlights a number of factors deserving further consideration.

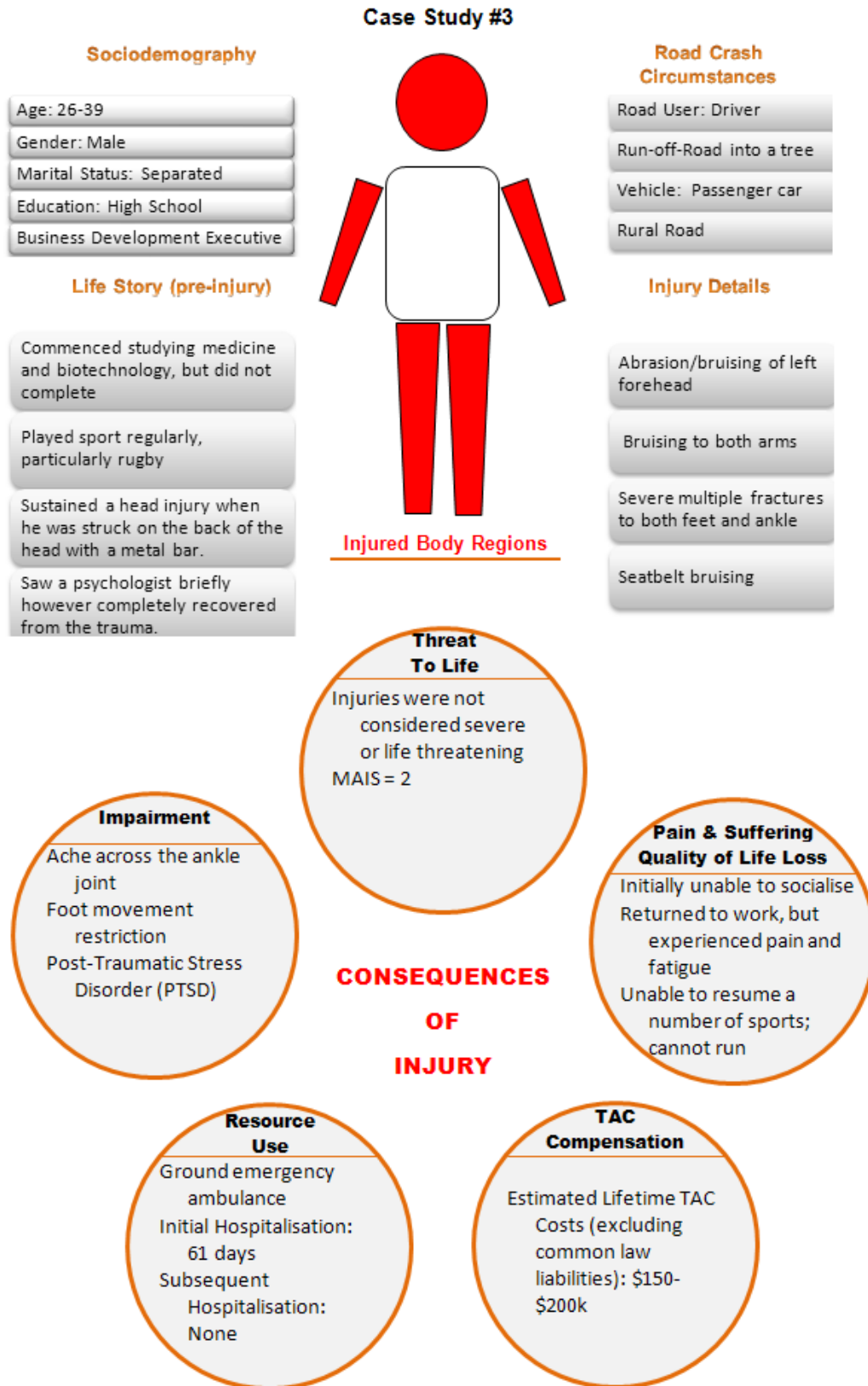
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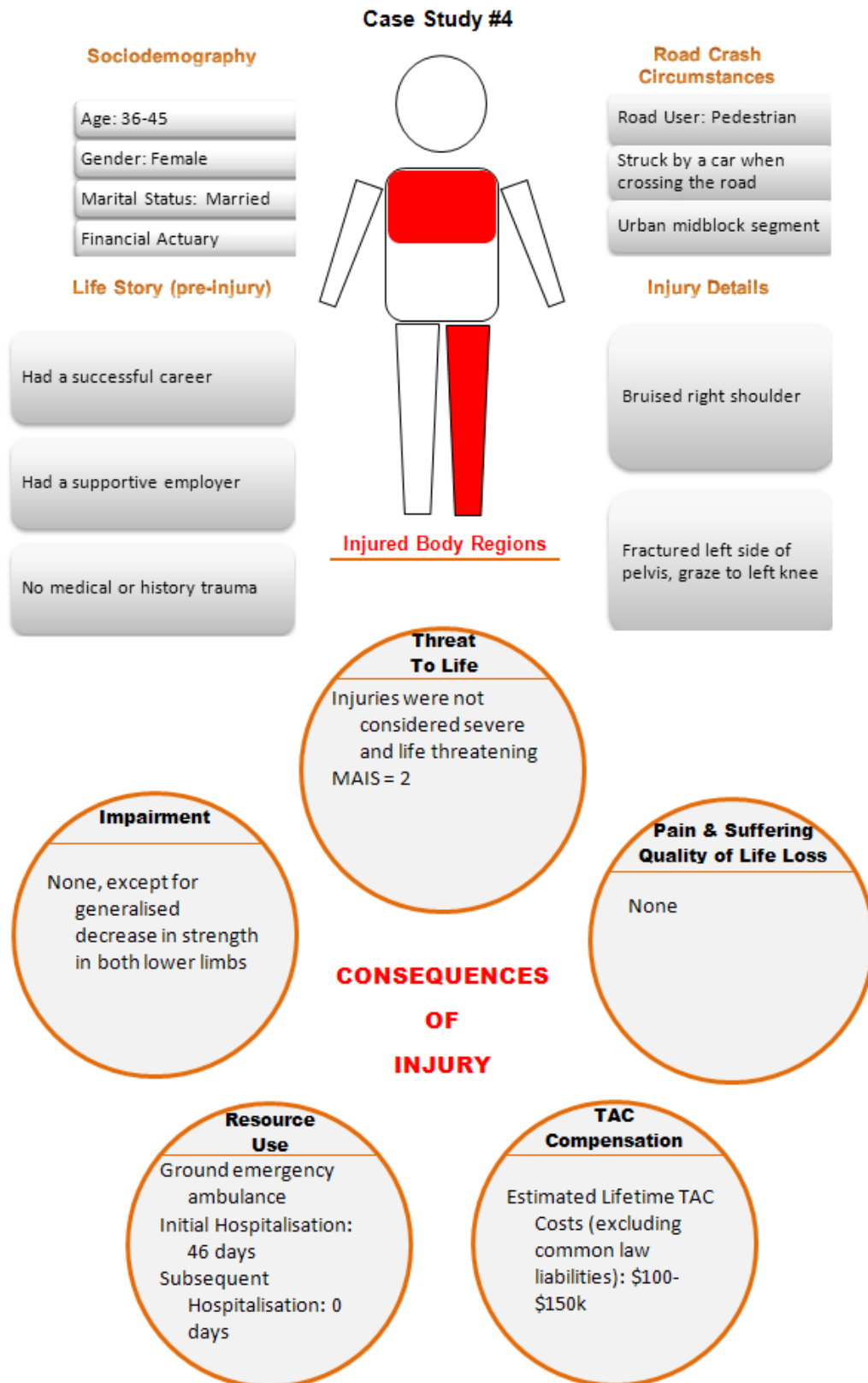
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## Appendix A: Injury case studies









### Case Study #5

#### Sociodemography

Age: 50-60  
Gender: Male  
Marital Status: Single  
Education: High School  
Transport Driver

#### Life Story (pre-injury)

Painter and decorator by trade

Worked as taxi driver and  
barman

Never married and no children

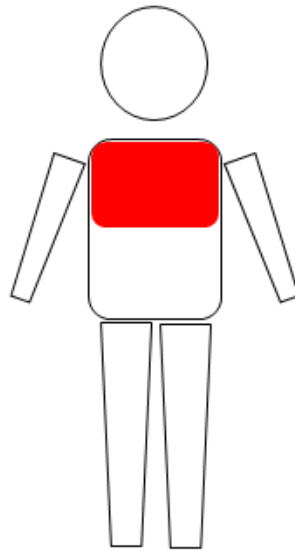
Enjoyed gardening, snooker and  
ten-pin bowling

#### Road Crash Circumstances

Road User: Driver  
Intersection road crash  
due to give-way failure  
Regional small town

#### Injury Details

Soft tissue injury (SIT)  
to neck and both  
shoulders



#### Injured Body Regions

#### Threat To Life

Injuries were not  
considered severe  
and life threatening  
MAIS = 1

#### Impairment

Walking, sitting and  
standing restrictions  
of 30 minutes at a  
time due to ongoing  
neck and back pain  
and numbness  
down the thighs

#### Pain & Suffering Quality of Life Loss

None

### CONSEQUENCES OF INJURY

#### Resource Use

Ground emergency  
ambulance  
Initial Hospitalisation: 1  
day  
Subsequent  
Hospitalisation:  
None

#### TAC Compensation

Estimated Lifetime TAC  
Costs (excluding  
common law  
liabilities): \$450-  
\$500k