Measuring the costs of road trauma and its longer term consequences

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Abstract

The aims of this research were to summarise the status of current knowledge about the social and economic dimensions of road trauma and to improve the understanding in Western Australia of its costs and longer term consequences. To address these aims a comprehensive review of the literature in relation to measuring road trauma was undertaken, followed by an assessment of available data sources with information to use in measuring the longer term consequence of road trauma in Western Australia. A number of recommendations were provided in relation to future work in measuring the cost of road trauma and the associated longer term outcomes.

Keywords

Road injuries; cost of injuries; economic factors

Disclaimer

This report is disseminated in the interest of information exchange. The views expressed here are those of the authors and not necessarily those of Curtin University, Monash University or the Pacific Institute of Research and Evaluation.

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

This report presents an overview of the approaches used to cost road trauma, in particular focusing on the nature and extent of long-term consequences and issues to consider in formulating recommendations to undertake future work in this area. The following questions were addressed –

1. What methods have been adopted in studies measuring the costs of road trauma in Australia and elsewhere?

2. How have the longer term consequences of road trauma been incorporated in previous studies?

3. What databases are available in Western Australia with information to incorporate in future work documenting the longer term consequences of road trauma?

4. What issues need to be considered in formulating recommendations for future work on the cost of road trauma and its longer term consequences?

The study consisted of four stages. The first stage was to review the literature on the costs of road trauma. This was followed in the second stage by an assessment of available data sources with information to use in measuring the longer term consequences of road trauma. The third stage of the project drew on the results of the previous stages and raised issues to consider in making recommendations for future work. Following discussions with the Project Advisory Group, the final stage of the study involved formulating recommendations about the directions for future research.

The review of the literature included an overview of Australian studies of the cost of road trauma, a description of key components in costing road trauma and measurement techniques, a discussion of issues in determining the longer term consequences of road trauma, and an international comparison of approaches to measure the costs of road trauma and its longer term consequences. Conceptually, the task of measuring the costs of road trauma is straightforward. It involves multiplying the number of cases of road trauma by the sum of the component costs of road trauma. A consensus exists about the three major components of road trauma costs. The first component is the direct costs of road trauma. These include any additional expenses caused by road crashes such as medical expenses, police and legal costs

and insurance administration. The second component is the indirect tangible costs of road trauma, which include the losses in output attributable to premature death, permanent impairment or temporary absence from work caused by crashes. The third component is the valuation of lost quality of life.

In spite of agreement about the component costs of road trauma, no international consensus exists about methodological approaches to measuring costs and longer term consequences. A comparison of the approaches adopted by the US, the UK, the Netherlands and Australia revealed that costs can be estimated in a number of ways with the various methods not always adopting the same conceptual framework, the same unit of costing, the same cost items or the same methods to measure and value costs. Notable differences in the methodological approaches adopted by the different countries were in regards to the measurement of loss of productivity and lost quality of life.

The review of the literature identified several information gaps in relation to attributing costs to road trauma, with many of these gaps pertaining to measurement of the longer term consequences. Important information gaps were found in respect of the number of road crash casualties with longer term consequences, the duration and severity of these consequences, direct resource use in the longer term attributable to road trauma, the extent to which road injuries were associated with a temporary and permanent reduction in labour market outcomes, and the costs of longer term care needs. Based on the assessment of available data sources, the most promising sources in WA to fill the information gaps were the WA Linked Data and the Insurance Commission of WA's motor vehicle injury claims data base. Data sets from other stakeholder agencies could help address some gaps, but survey information offer the best potential to address others.

In deciding the way forward and formulating recommendations to undertake future work in this area, a number of issues were considered by the Project Advisory Group. These included:

1. What is the main purpose of producing new estimates of the costs of road trauma and its longer term consequences in WA?
2. If costs are to be produced then –
    2.1. What cost perspective should be adopted – a health sector perspective, a government perspective or a societal perspective?
    2.2. What costing unit(s) should be used – the injured person, the crash or both?

2.3. What severity levels should be distinguished in measuring the costs and longer term consequences of road trauma? Broad categories of severity as in the UK and the Netherlands or finer categories as in the US?

2.4. Are all cost components to be included in the cost estimates or only components relevant to the longer term consequences? Alternatively should the focus be to address the information gaps?

2.5. If loss of quality of life is to be included, should this be expressed based on a measurement scale such as a generic quality of life instrument or expressed in monetary terms?

2.6. What method of valuing fatalities should be used? A human capital approach, a hybrid human capital approach or a willingness to pay approach?

2.7. How much primary research should be conducted to address current information gaps such the number of road crash casualties who suffer longer term consequences or the labour market outcomes post-injury?

2.8. Should qualitative research be included examining the costs of road trauma through the experiences of the injured people and their families, friends and colleagues?

In response to the first question about the purpose of producing new estimates of the costs of road trauma and its longer term consequences, any future work conducted in WA to measure these costs should supplement rather than duplicate official estimates of the cost of road crashes produced by the BITRE, and provide data that is useful both to gauge the relative burden of road injury and inform policy formulation and resource allocation. In addition, this work should not duplicate recently commissioned research by the Health Department of WA to provide an overview of the cost of injury in WA.

In response to the other issues raised in regard to future work to measure the costs of road trauma and its longer term consequences, the following recommendations result from consultation with the Project Advisory Group and consideration of the status of current knowledge about the costs of road trauma and data currently available to incorporate in future work.

1. Choice of cost perspective

Each of the perspectives is useful – a health sector perspective, a government perspective and a societal perspective. Given that data required for the health and government perspectives are

more readily available, the initial focus should be to improve our understanding of road injury costs and longer term consequences from these perspectives. In time, the objective should be to work towards extending this work to include the societal perspective.

2. Costing unit

The choice of costing unit depends on the purpose for which the costs are to be used. For example, in assessing risks of poor outcomes from road injury, the injured person is the most useful costing unit. On the other hand, on a broader scale, the crash is more useful as a costing unit in evaluating the benefits of alternative safety interventions. For this reason, both the injured person and the crash are appropriate costing units.

3. Severity levels

A similar argument can be made for severity levels, with both broad categories and finer categories being useful in different contexts. Future research should aim where possible to provide more detailed severity levels of the costs and consequences of road injury, which can be aggregated into broader levels when required.

4. Cost components

Given the availability of the official estimates of the cost of road crashes and limitations in these costs, the initial focus of future research should be directed towards those cost components relevant to the longer term consequences of road injury. It is in this area that the most significant information gaps exist in relation to the real burden of road injury.

5. Measurement of loss of quality of life

Monetary values of the loss of quality of life are more easily communicated to stakeholders, including government agencies involved in shaping policy and allocating resources, industry bodies and community groups. Loss of quality of life following injury, which is has been measured using generic instruments, should be converted to monetary values using people's willing to pay for a QALY.

6. Method of valuing fatalities

The current status of valuing fatalities in Australia is inconsistent across jurisdictions with the official estimates of road crash costs produced by BITRE based on a hybrid human capital approach while the road authorities in New South Wales and WA have changed to using the WTP approach in their economic evaluation of road safety initiatives. Given the recommendation that the initial focus of any new research in WA should be on cost components relevant to longer term consequences, a decision about the most appropriate method of valuing fatalities can be postponed and reconsidered at a later stage.

7. Primary research to address information gaps

More primary research to address current information gaps should be undertaken, with the extent of research dependent on available funding. Information gaps to be prioritised include the number of road crash casualties who suffer longer term consequences by severity level, longer term medical and other direct costs of road injury, labour market outcomes post-injury and the wider impact of road injury on the family of injured people. The catastrophic claims data held by the Insurance Commission of WA potentially provide a valuable source from which to gain a greater insight into the longer term costs and consequences of road injury.

8. Qualitative research

Given other information gaps on the costs and longer term consequences of road injury, qualitative research examining the costs of road trauma through the experiences of the injured people and their families, friends and colleagues should not be identified as a priority area of research at this stage.

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This study is funded by the Office of Road Safety. The authors would like to thank the representatives of stakeholder agencies for providing information about data collected by their agencies on the costs and longer term consequences of road trauma. The authors would also like to thank the members of the Project Advisory Group for their comments on the interim report and for providing valuable input into formulating the recommendations for future work in this area.

1. INTRODUCTION

In 2010, 193 people were killed and 279 people were critically injured on Western Australian roads (WA Police, 2010). In addition, annually almost 3,000 casualties are admitted to hospital and a much larger number of crashes result in less severe injury or property damage only. These road crashes impose a significant health and social burden, with the real costs to individuals, families and the community likely to far exceed the estimated annual costs of approximately $2 billion (Thompson and Hill, 2010).

This report presents an overview of the approaches used to cost road trauma, in particular focusing on the nature and extent of the longer term consequences and issues to consider in formulating recommendations to undertake future work in this area. The following questions were addressed:

1. What methods have been adopted in studies measuring the costs of road trauma in Australia and elsewhere?

2. How have the longer term consequences of road trauma been incorporated in previous studies?

3. What databases are available in Western Australia with information to incorporate in future work documenting the longer term consequences of road trauma?

4. What issues need to be considered in formulating recommendations for future work on the cost of road trauma and its longer term consequences?

The underlying purpose of undertaking this research was to summarise the status of current knowledge about the social and economic dimensions of road trauma and to provide insight into how to improve our understanding of its costs and longer term consequences in Western Australia. Following preparation of an interim report and discussions with the Project Advisory Group, recommendations have been proposed for future work in this area.

2. METHODOLOGY

The study consisted of four stages. The first stage was to review the literature on the costs of road trauma. This was followed in the second stage by an assessment of available data sources with information to use in measuring the longer term consequences of road trauma. The third stage of the project drew on the results of the previous stages and raised issues to consider in making recommendations for future work. Following discussions with the Project Advisory Group, the final stage of the study involved formulating recommendations about the directions for future research.

In reviewing the literature, the goal was not to undertake a systematic review of all the literature on the costs of road trauma. Rather, the intention was to conduct a comprehensive review to illustrate the scope of available literature and to identify issues and debates regarding methods for costing road trauma, in particular in regard to its longer term costs and consequences. The search framework entailed using relevant search terms to identify articles in the following databases: PubMed, ProQuest and Current Contents. The reference lists of these publications were searched to identify any additional publications, and the websites of government organisations were also accessed to obtain relevant material. Search terms included keywords such as ‘road crash’, ‘road injury’ and ‘road trauma’ in combination with ‘costs’, ‘burden’ and ‘consequences’. To identify available databases that could be used to document the longer term consequences of road trauma, a ‘snowballing’ process was used in which a range of known stakeholders in road safety and disability services were asked to help identify other relevant stakeholders who might have access to relevant data, and in turn these stakeholders were asked the same question (See Appendix 1 for the list of stakeholders and respective agencies).

The remainder of the report is organised as follows. The next section presents the results of the review of the literature including an overview of Australian studies of the cost of road trauma, a description of key components in costing road trauma and measurement techniques, a discussion of issues in determining the longer term consequences of road trauma, and an international comparison of approaches to measure the costs of road trauma and its longer term consequences. Section 4 outlines potential data sources that could be accessed to provide data to document the longer term costs and consequences of road trauma. The final section provides a

summary of key findings and raises issues that were considered by the Project Advisory Group prior to the formulation of recommendations for future work to measure the costs of road trauma and its longer term consequences.

3. REVIEW OF THE LITERATURE

3.1 Overview of Australian studies of the costs of road trauma

Many of the earlier studies measuring the costs of road trauma based their estimates on research conducted by Troy and Butlin into road crashes in the Australian Capital Territory (ACT) (Troy and Butlin, 1971). This was a case study of all collisions occurring in the ACT in the period from May 1965 to April 1966. The study drew on detailed accident reports of police, hospitals, surgeons, panel beaters, insurance companies, courts and employers. The work of Troy and Butlin was generalised for application across Australia by John Paterson Urban Systems (Pty) Ltd on behalf of the Department of Transport, and other government departments subsequently made minor adjustments and updates to the Paterson and Troy and Butlin estimates (John Paterson Urban Systems, 1972, Silcock, 1982).

In the early 1980s, two major studies of road crash costs were conducted, one for Adelaide and the other for the whole of Australia (Somerville and McLean, 1981, Atkins, 1981). Thereafter much of the research into the costs of road crashes has been undertaken by the Bureau of Transport and Communications Economics (Bureau of Transport and Communications Economics, 1992) and the Bureau of Transport Economics (Bureau of Transport Economics, 2000) and Bureau of Infrastructure, Transport and Regional Economics (BITRE) (BITRE, 2009), which succeeded the Bureau of Transport and Communications Economics. The most recent of these studies presents costs for 2006. Other research into the costs of road trauma was undertaken by the Australian Road Research Board (Andreassen, 1992) and the Monash University Accident Research Centre (Hendrie, Watson, Lyle & Fildes, 2007).

Most studies measuring the costs of road crashes estimated these costs by applying unit costs to the corresponding number of incidents (e.g. crashes) to derive the aggregate value of the costs of road crashes. Studies have varied in the base used for calculating unit costs. The Bureau of Transport and Communications Economics (Bureau of Transport and Communications Economics, 1992) and the Bureau of Transport Economics (Bureau of Transport Economics, 2000) presented unit costs by police crash severity level, distinguishing four categories of crash severity: fatal, serious, minor and property damage. The Bureau of Transport and Communication Economics adopted the crash as the costing unit, with crashes classified by the

highest degree of injury severity of the casualties involved, while the Bureau of Transport Economics produced costs on both a per crash and per injured person basis. The more recent estimates of the cost of road crashes produced by BITRE also distinguished four categories of crash severity, but these categories were not the police severity levels but instead were fatal, hospitalised injury, non-hospitalised injury and property damage only (BITRE, 2009).

Other studies have produced unit cost estimates by injury severity level. For example, the Bureau of Transport and Communication Economics (1992) calculated national estimates for 1985 of the per crash costs of road trauma for each injury severity level of the Abbreviated Injury Scale (AIS), while Somerville and McLean (1981) produced estimates of per crash costs for crashes investigated in the Adelaide In-Depth Study by selected intervals of the Injury Severity Score (ISS). The AIS is a threat-to-life scale that classifies injuries by body region on a 6-point severity scale ranging from minor to unsurvivable (Association for the Advancement of Automotive Medicine, 1990). The study produced by the Bureau of Transport and Communication Economics did not present unit cost estimates by body region, only by injury severity level. The ISS is a measure of overall injury severity, which is determined by scoring each injury with the AIS, then adding together the squares of the highest AIS rating for each of the three most severely injured body regions (Baker et al., 1974). Hendrie et al (2007) produced more detailed unit cost estimates by both body region and injury severity level of the Abbreviated Injury Scale (AIS). The primary costing unit was the injured person, but unit costs were also produced by type of injury (e.g. AIS severity level 4 head injury).

A third approach to producing unit cost estimates has been to calculate these on the basis of crash type. Andreassen (1992) produced per crash costs for Australia for a range of frequently occurring crash types. Crashes were classified as single vehicle or multi-vehicle, and standardised costs were calculated for nine single vehicle and 10 multi-vehicle crash types.

3.2 Costing road trauma

3.2.1 Incidence data

The first step in producing an estimate of the costs of road trauma is to determine which cases are to be considered for the period under study (e.g. one year). This

requires a decision regarding the base or unit of costing (e.g. the crash, the injured person, etc.) and the severity groups into which cases can usefully be classified (e.g. fatal, serious and slight). A variety of data sources is generally needed, as no single direct data collection is available covering incidents of all severity levels. Available sources include police data, hospital administrative datasets, death data, injury surveillance systems and national health surveys.

3.2.2 Cost perspective

The perspective of a costing study is the point of view from which the costs are assessed (Drummond, Sculpher, Torrance & Stoddart, 2006). The choice of perspective depends on the research question and how the costs will be used. The most comprehensive perspective is the societal one, which incorporates all costs including those borne by the individual, the government and all relevant societal costs. Other common perspectives include the health sector, in which case only costs related to health care use are included, and a governmental perspective including all costs to government.

3.2.3 Cost categories

Costs of road crashes and their outcomes can be grouped into human costs (arising from the injury to a person), vehicle costs (arising from damage to a vehicle) and general costs (not directly dependent on level of damage to vehicles or injury of person) (Table 3.1) (Bureau of Transport Economics, 2000). A further distinction can be made between direct costs which require actual payments by individuals or institutions and indirect costs which refer to lost resources and opportunities resulting from road crashes (Butchart et al., 2008).

In the human cost category, given the importance of documenting the costs of medical treatment for injuries arising from road crashes, direct costs can be further divided into medical and non-medical costs. Direct medical costs include those relating to hospital treatment, outpatient visits, ambulance or other transport to hospital, medical and allied health care, drugs and laboratory tests, counseling and long term care. Direct non-medical costs include those associated with policing, correctional services and legal services. Indirect costs comprise both tangible costs such as reduced productivity and the amount of work time lost as a result of road

crashes and intangible costs such as reduced quality of life including pain, grief and suffering (Butchart et al., 2008).

In the vehicle repair and general cost categories, all costs with the exception of travel delays are direct costs including vehicle repairs and towing, non-vehicle property damage, police and emergency services and insurance administration.

Table 3.1 Categories of road crash costs

Category	Type of cost		Component	Costing unit
Human costs	Direct	Medical	Hospital inpatient Hospital outpatient Transport/ambulance Medical and allied health care Drugs/laboratory tests Counselling Long term care	Crash severity level, injury severity level, type of injury, crash type
		Non-medical	Criminal prosecution Correctional services Legal services Coroner	
	Indirect	Tangible	Loss of productivity (earnings and time)	
		Intangible	Health-related quality of life	
Vehicle costs	Direct		Repairs Towing	
General costs	Direct		Non-vehicle property damage Police and emergency services Vehicle insurance administration	
	Indirect		Travel delays	

3.2.4 Which cost components to include?

Two factors determine the components to include in measuring the costs of road trauma: the costing unit and the perspective. In general, if the unit of costing is the crash, then all cost categories – human costs, vehicle costs and general costs – tend to be included in calculating costs. Alternatively, if the unit of costing is the injured person, then only human costs directly related to the injured person are included. Given the unit of costing, the perspective then guides which cost components are included. For example, if the unit of costing is the injured person and the perspective

is societal, then all costs components in the human category are included. If the perspective is the health sector, then only medical costs are included.

3.2.5 Measuring and valuing costs

Valuing direct costs requires tracking how much of each resource is used and attaching a unit cost to each of these resources. Conceptually this task is simple, with much information available from published official sources, administrative databases or elsewhere. For example, in WA the number of road crash casualties admitted to hospital for treatment can be obtained from the hospital morbidity system and readmissions for injuries sustained can be identified using the WA linked data, which is maintained by the Data Linkage Branch at the Department of Health WA (Department of Health WA). Unit costs of each hospital admission based on diagnostic related groups (DRGs), a patient classification system which provides a clinically meaningful way of relating the types of patients treated in a hospital to the resources required to treat the patient, is available from the National Hospital Cost Data Collection (NHCDC) (Department of Health and Ageing, 2011). This latter is a collection of national public and private sector cost weights for each of the DRGs recorded in the Australian Refined Diagnosis Related Groups (AR-DRG) Classification System.

However, not all cost components have such readily available data relating to resource utilisation and unit costs. For some cost components, data are available but not in the public domain so special arrangements must be made with the appropriate data custodians to access these data. Vehicle repair costs is an example of such a case, with insurance claims the traditional source of these data but insurers not always willing to make these data available for reasons of commercial sensitivity.

Other cost components, particularly those associated with the longer term outcomes of road trauma, are more difficult to measure and value. For some components, these difficulties arise from not having information systems that track patients in the post-acute phase of injury, rehabilitation and recovery. For others, the difficulties are more complex and relate to conceptual and measurement issues and the lack of consensus surrounding valuation methods.

3.3 Issues in determining the longer term consequences of road trauma

A complex array of issues of concern emerge in relation to attributing costs to road trauma (Risbey, De Silva & Tong, 2007), with many of these issues particularly relevant to efforts to identify the longer term outcomes.

3.3.1 Incomplete and inaccurate reporting

In WA, the availability of linked police crash reports, hospital records and death records in the WA Linked Data provides a reliable source of road crash surveillance data for analysis. The hospital discharge records and death data provide details about the incidence of more severe injuries, while the police crash reports provide complementary details about road crash casualties with less severe injuries not requiring hospitalisation. Not captured are road crash casualties sustaining minor injuries not reported to the police.

However, in regards to the longer term outcomes of road trauma, population-based incidence data are not available recording those road crash casualties suffering longer term impacts of their injuries. Some data are available if the injuries sustained require ongoing hospital treatment, but very little is known about the outcomes and needs of cases discharged from hospital and reliant on community care and support.

3.3.2 Longer term direct costs

Calculating direct medical and related costs in the acute stages following road injury is mostly straightforward with data available about resource use and unit costs. However, very limited empirical data are available on the longer term direct medical and related costs, and the measurement of components costs such as rehabilitation, aids and appliances and home and vehicle modifications.

3.3.3 Longer term indirect costs and outcomes

Injuries cause a number of longer term post-incident costs as a result of the physical and other impairments and disabilities they cause (BITRE, 2009). The main tangible costs are the paid and unpaid productivity losses and costs incurred by replacing injured people who do not return to work or in the re-training required to enable them return to work. In addition to these costs, injuries give rise to intangible costs through pain and suffering and lost quality of life.

Productivity losses

Loss of income is the primary cost associated with the loss of productivity. Income includes earnings (wages or salary) to individuals and their families and revenue to employers. Loss of value from household and community production (i.e., unpaid work) is also incurred by individuals and their families as a result of injury; while 'friction costs' are incurred by employers in replacing injured workers such as the costs associated with hiring and training temporary or permanent staff replacements (Department of Labour, 2004).

The most common approach to calculating workplace and household losses and workplace disruption losses is to classify road crash casualties based on the severity of the impacts of the injury and then to estimate the losses associated with post-injury consequences. For example, in the most recent estimates of the cost of road crashes in Australia, BITRE used the following categories of post-injury consequences as the bases to estimate workplace and household losses –

- Withdraw from the workplace due to permanent incapacity
- Return to work to perform duties at a reduced capacity
- Return to full duties after a temporary absence
- Return to full duties after a few days absence. (BITRE, 2009)

Loss of productivity was then estimated based on the age and gender of people sustaining road injuries, the extent to which work capacity was reduced, estimates of employment and participation levels of people with disabilities, estimates of the duration of workplace disruption, and age- and gender-specific average weekly earnings (BITRE, 2009).

Less common are studies that actually investigate the extent to which road injuries are associated with a reduction in disposable income and employment. One such study undertaken by the Danish Institute of Local Government Studies compared differences in labour market outcomes between injured persons and matched controls. The data were taken from a random 10% sample of the adult population of Denmark for the years 1981 to 2000 and the overall result was that road injuries were associated with significant differences in the labour force outcomes between injured persons and matched controls (European Transport Safety Council, 2007). Another study conducted in Spain examined return to work outcomes for people with road

injuries road and reported on the percentage who are forced to take different periods of sick leave from work, those who never go back to work, those who need to be retrained to a different type of work, and those who have moderate disabilities but may be able to work reduced hours (European Transport Safety Council, 2007).

Loss of quality of life

A large number of road users involved in crashes recover from their injuries but some never recover fully and suffer from some kind of permanent disability. One problem in determining the loss of quality of life following a road crash is that the longer term impact of injury cannot be observed at the time of the crash and in many cases may not be established for a fairly long time after the incident. A second problem is that loss of quality of life does not necessarily correspond closely to the severity of injury. For example a potentially life-threatening injury such as a ruptured spleen, which is associated with heavy internal bleeding, will not result in any lasting impairment if treated successfully. On the other hand, a spinal cord injury may not be life threatening but can result in a person being in a wheelchair for life. And an injury such as whiplash, which gets the lowest score in the Abbreviated Injury Scale (AIS 1), can be associated with considerable pain and discomfort and is one of the most costly conditions from the perspective of insurance companies. There is also the question of how to account for psychosocial conditions such as post-traumatic stress disorder (European Transport Safety Council, 2007).

One approach to measuring the loss of quality of life post-injury is to use one of many measurement scales that have been developed over the years. A distinction can be made between universal outcome scales, which measure the impact of injury or illness across multiple dimensions of health such as physical, psychological and social wellbeing, and those that measure outcomes in relation to a specific type of injury.

One universal outcome scale developed specifically for road injury is the Functional Capacity Index (FCI). It was developed by the National Highway and Traffic Safety Administration (NHTSA) in the US as a measure to map AIS injury descriptions into scores reflecting the expected levels of reduced functional capacity at one year after injury (MacKenzie, Damiano, Miller, Luchter, 1994; Mackenzie, 1996). These predicted FCI scores are referred to as $pFCI_{12}$. The $pFCI_{12}$ predicts functional

capacity across 10 domains (eating, excretory function, sexual function, ambulation, bending and lifting, hand and arm movement, visual function, auditory function, speech, and cognitive function) and assigns a value between 0 (no loss of function) and 1 (complete loss of function) to each domain to indicate the predicted reduction in function resulting from a specific injury (National Highway Traffic Safety Administration 2002). For each domain, discrete levels of function were described. An expert panel predicted the expected level of function at one year post injury in each of the ten domains for every injury listed in the 1990 Abbreviated Injury Scale3. A relative value for each domain and each level of function was derived from a convenience sample representing a cross section of society, and an algorithm based on multi-attribute utility theory was developed for combining these values into an overall FCI value for each injury The overall FCI scores reflecting whole body functional capacity scores range from 0 to 100 (Mackenzie, 1996). Following a validation study showing there were many injury patterns where the measured FCI outcomes did not agree with the predicted outcome, revised pFCI12 scores were calculated but are yet to be validated (Expert Group on Injury Severity Measurement, 2004; Polinder et al., 2010).

A variety of generic quality of life instruments have been developed measuring health-related quality of life across different conditions. In addition to being generic rather than specific to road injury, these instruments extend beyond measuring functional outcomes as in the FCI and are derived from a comprehensive model of health incorporating physical, psychological and social dimensions of health (Spicer, Miller, Hendrie & Blincoe, 2011). Quality of life is described by means of a profile of scores across these multiple dimensions. These scores together with utility or preference weights reflecting the value of social preferences and perceived relative importance of each dimension are used to yield a value between 0 and 1 to score a person's health, where 0 equals death and 1 equals perfect health. Some instruments also allow health states that are perceived to be worse than death to be scored less than 0. In a systematic review of studies measuring health-related quality of life of general injury populations, a commonly used generic health-related quality of life instruments was the EuroQoL or EQ-5D (Polinder et al., 2010). The EQ-5D is a preference-based instrument that simplifies health into five domains: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each domain is given a score from 1 to 3, so the health profile would read 11111 for the best scores in all

domains and 33333 for the worst. The EQ-5D thus has 243 possible health profiles, plus two additional profiles representing unconscious and death thus offering a total of 245 health states, all of which have been assigned a utility value between 0 and 1 by general population surveys (Kind, 1996). Other widely used quality of life instruments include the Health Utilities Index (Drummond et al., 2006), numerous utility-scored versions of the Short-Form 12 (SF-12, (Ware et al., 2002), (Sengupta et al., 2004), the SF-6d (Brazier et al., 2002), the WHOQOL BREF (Skevington et al., 2004), and the Assessment of Quality of Life (AQoL) (Richardson, Peacock, Iezzi, Day & Hawthorne 2007).

Total loss of quality of life following road injury can be quantified using a standardised utility-based measure called a quality-adjusted life year (QALY). A QALY is a health outcome measure valued at 1 for a year in perfect health and at 0 if someone is dead. The QALY measure includes health-related work loss also, but some analysts choose to value the wage-related loss separately and explicitly. Losses in health related quality of life are calculated based on two factors: the loss in health-related quality of life and the number of life years over which the loss is sustained. For example, the average quality of life loss to a hospital-admitted concussion without skull fracture is 0.764 in the first year post-injury, 0.226 in years 2 to 5, and 0.068 thereafter (Miller et al., 1995). A person age 40 in Australia has an expected remaining lifespan of approximately 40 years. So without discounting future losses (a techniques used by economists to account for time preferences), the QALYs lost to a concussion at age 40 would be equal to 4.048 (0.764 + 0.226 * 4 + 0.068 * 35).

Rather than using QALYs to measure loss of health-related quality of life, some analysts use the disability experienced by a person to measure a gain in disability-adjusted life years. Disability weights are the equivalent of 1 minus the utility weights measuring health-related quality of life. Both the World Bank and World Health Organization at times have incorporated age or income weighting in their calculations of DALYs (Murray, 1996), but this practice seems to be falling out of favor.

In addition to universal outcome scales measuring loss of quality of life, organ-related measures are also available. For example, a frequently-used outcome measure following head injury is the Glasgow Outcome Scale (GOS). This scale assesses

survival, social integration and level of care for daily living using 5 exclusive levels. The Extended GOS, or GOS-E, has extended the scale to an 8-level score. The Disability Rating Scale (DRS) also scores the outcome following head injury, but on a 30-point scale (Rappaport et al, 1982). Other examples of assessment tools following head injury are the European Brain Injury Questionnaire, Quality of Life after Brain Injury and Rivermead post-concussion questionnaire.

Monetary values of loss of quality of life

Rather than using a measurement scale to express loss of quality of life following road injury, an alternative approach is to measure loss in monetary terms. This can be done using a few approaches including –

(i) *Court awards and settlements* – Courts make decisions about the appropriate compensation for a given loss of quality of life. Alternatively out-of-court settlements can be reached in which the plaintiff accepts an agreed payment rather than following through with litigation procedures. Court awards for loss of quality of life can be argued to be representative of the value that society places on loss of quality of life, especially if these values are based on jury decisions (Hendrie et al., 2007).

(ii) *Compensation awards* – In most Australian states and territories, compensation for loss of quality of life following road injury is controlled by legislation. All motor vehicles are required to be insured against causing injury and death in road crashes. Governments carry the political responsibility for the size of the premium and the compensation paid out for injury. Since the amount paid for this compensation is determined by Australian state and territory parliaments, the magnitude of compensation payments by injury type can be interpreted as a reflection of the corresponding value of loss of quality of life assigned by the electorate and the wider society from which they come (Hendrie et al., 2007).

(iii) *Monetising QALYs* – Two basic approaches have been used to attach a monetary value to the loss of QALYs (Krupnick, 2004). The first compares the cost per QALY of treatments funded within a fixed health care budget, such as expenditure by the Australian government on pharmaceuticals approved for listing on the Pharmaceutical Benefits Schedule. The cost per QALY gain of the last treatment funded yields a potential monetary value for a QALY (Karapanou and Visscher,

2010), in that it places a ceiling on treatments accepted as cost-effective. The second approach involves estimating people's willingness to pay for a QALY gain. One way to achieve this is by directly eliciting people's willingness to pay for marginal gains in QALYs (EuroVaQ, 2010). The alternative way is to value a QALY by utilising existing willingness to pay values of statistical life (see next section) and apportioning a value to a QALY on the assumption that the value of a QALY does not depend on a person's age (i.e., that the loss of six months of quality of life is valued the same at age 18 and age 88) or vary with the type of risk involved (e.g., cancer versus heart attack) (Miller and Hendrie, In press). These approaches to placing monetary values on QALYs have been criticised as not theoretically sound, in part because individuals cannot be expected to have a constant value of statistical life year (Krupnick, 2004).

Qualitative measures

While measurement scales attempt to capture loss of quality of life, and several methods are used to monetise this loss, all consequences of road traffic injuries are difficult if not impossible to measure using quantitative metrics. An alternative approach is to document intangible costs using qualitative methods that give voice to people affected by road injuries or the relatives of people who died as a result of road traffic injuries (Perez-Nunez et al., In press).

A number of overseas studies have attempted to gain a better understanding of all the consequences of road injuries by examining the 'costs' through the experiences of the affected person, their family and friends, and carers. Common findings have been that the consequences ripple out impacting not just the injured person but family and friends also; costs continue to compound long after the injury and are not compensated in many cases; relatives are forced to restructure their daily activities in order to care for an injured person with implications in terms of lost income or the reduction of leisure time; and suffering of grief, increased psychological problems and loss of quality of life for relatives even in the longer term and in certain cases permanently (Perez-Nunez, Peicastre-Vilafuerte, Hijar, Avita-Burgos & Celis, In press; Blincoe et al., 2002; Cleiren, Grad, Zavasnik & Diekstra, 1996; Merlevede et al., 2004; European Transport Safety Council, 2007)

A recent study commissioned by the Insurance Commission of Western Australia adopted a qualitative framework to seek to explore the cost and accessibility of care for people with catastrophic injury in Western Australia following settlement of their injury claims (Bulsara et al., 2010). The context for the study was the issue of a no-fault long-term care scheme for people catastrophically injured in motor vehicle crashes or otherwise, which has been on the national agenda for some years. Data were collected from injured persons, carers, health professionals and service providers. Key areas that were explored included models and cost of care including utilisation of paid carers, decision making around model of care arrangements, regional issues, use of aids and appliances including home modifications, reliance on unpaid (family) carers, case management utilisation and perceived care needs versus actual level of care. The study identified a number of major issues around the short and longer term effects of catastrophic injury and access to care including lack of services and support, insufficient information and advice, social and emotional costs borne by injured people and their family, and regional areas being particularly disadvantaged in terms of access to care and services.

3.3.4 Valuing a fatality

The two most common approaches to quantifying the value of a road fatality are: (i) the human capital/production loss model and (ii) the willingness to pay (WTP)/comprehensive models.

Historically, most countries including Australia have used the human capital approach to value road fatalities. This approach calculates the various identifiable costs associated with a road fatality, such as loss of work income, medical and related expenses, property damage costs and general costs such as travel delays, insurance administration, and police and emergency services. The value of a fatality is then measured as the sum of the discounted present value of these various costs (Abelson, 2008). To account for the quality of life loss associated with death or injury in a road crash, BITRE also incorporates a notional value of pain, suffering and grief associated with a road fatality into the costs of a fatality. This approach is thus concerned with the effects of road fatalities and injuries on output and income, and focuses on the value of lives and quality of lives ex-post (after the event) (Hendrie, 2010).

The alternative WTP approach to valuing road safety is based on capturing and valuing the amount of money that individuals are willing to pay for reducing the risk of premature death while performing a certain risky activity such as travelling in a motor vehicle. Rather than deriving an ex-post value of the costs associated with a road crash, it sets out to capture the ex-ante (before the event) value individuals place on safety in terms of avoiding the fatality (PricewaterhouseCoopers and the Hensher Group, 2008).

Both approaches have advantages and disadvantages. The main advantage of the human capital approach is that it is relatively simple to calculate and use (Austroads, 2009). Its main disadvantage is that it is theoretically flawed from the economist's standpoint since the appropriate measure for policy purposes is individuals' preferences for reductions in the risk of premature death or injury (Henscher et al., 2009). The main advantage of the WTP approach is that it is a theoretically sound measure of the value of risk reduction as it is based on society's willingness to pay for the benefit of risk reduction. The main disadvantage of the WTP approach relates to difficulties in obtaining reliable estimates of the willingness to pay for risk reduction and the wide range in empirical estimates derived from various studies (Miller, 2007). New South Wales and WA are the only jurisdictions in Australia to have adopted the WTP approach for use in their economic evaluation of road safety initiatives

3.4 International comparison of approaches to measuring the costs of road injury and its longer term consequences

There is no international consensus about how to estimate road crash costs and its longer term consequences. The least controversial item is the direct cost of crashes including medical costs, non-medical costs (e.g. criminal prosecutions), vehicle costs (e.g. repairs and towing) and general costs (e.g. police and emergency services). The most controversial is indirect cost, in particular loss of productivity and health-related quality of life (Elvik, 2000). Earlier studies in the 1950s and 1960s calculated indirect human cost using the human capital or lost production approach without including a value for loss of quality of life. In the period from the 1970s until the late 1980s, a number of countries added an arbitrary value entitled 'pain, grief and suffering' to the value of lost production as a means of capturing the lost quality of life as a consequence of a road crash (Elvik, 1995). Following criticism by several

economists that the human capital approach was inconsistent with theoretical principles that the value of risk reduction should be based on society's willingness to pay for the benefit of risk reduction (Mishan, 1971; Schelling, 1968), a number of countries from the late 1980s onwards changed the basis of their official economic valuation of road crashes from the human capital approach to the willingness to pay approach (Elvik, 1995).

In order to illustrate the different approaches taken in valuing the cost of road trauma, a brief description of included cost items and valuation methods is presented for selected countries. The countries covered are the US, UK and Netherlands. Also discussed is the approach adopted in BITRE's official road crash cost estimates for Australia.

3.4.1 United States

The most recent official estimates of the cost of road crashes produced by the National Highway Traffic Safety Administration (NHTSA) provide good coverage of items across the human, vehicle and general cost categories, and detailed estimates of average crash costs (

Table 3.2) (National Highway Traffic Safety Administration 2002). The conceptual framework for calculating costs was the human capital approach, with estimates generated by adding the value of decreased production to direct costs and other indirect costs (National Highway Traffic Safety Administration 2002).

As the police crash reporting data in the US does not accurately capture injury incidence and severity, adjustments were made to police data to improve its accuracy. These adjustments used data from the National Health Interview Survey and the tri-level National Accident Sampling System. The resultant output file comprised an improved record of all road crash casualties with injuries coded based on Maximum Abbreviated Injury Scores (MAIS) (National Highway Traffic Safety Administration 2002).

The next step was estimating average crash casualty costs by maximum AIS, body part, and whether the casualty suffered a fracture/dislocation. These average costs were generated for forty-one body part descriptors based on body region, system/organ, lesion and aspect of each injury. Burns were classified as a separate category due to the lack of location information for such injuries. A societal perspective that included costs to all parties was adopted (National Highway Traffic Safety Administration 2002).

Medically related costs were computed in the acute phase from several sources including the National Hospital Discharge Survey for hospital-admitted casualties, the National Health Interview Survey for non-hospitalised casualties and the Civilian Health and Medical Program of the Uniformed Services. Subsequent costs in the medium and longer term were calculated from National Medical Expenditure Survey and the National Council on Compensation Council data. For spinal cord injuries and burn injury, first year and annual costs were calculated based on special studies.

Loss of market (paid) productivity was calculated based on MAIS, with a distinction made between permanent partial or total disability, temporary disability and fatalities. Probabilities of permanent disability were obtained from the National Council on Compensation Insurance data, and unit costs were calculated by multiplying the probability times the net present value of lifetime work loss. Injured people were assumed to lose housework on 90 percent of the days they lose wage

work. For children, it was assumed an adult caregiver would lose work for each day that the child would have been unable to work if employed. Based on data from selected roads, travel delay time was modelled by road type (e.g., expressway, arterial) and rural-urban location. Delay was valued at 60% of the wage rate.

Other direct costs including legal and insurance administration costs per crash casualty were derived from medical and work loss costs. Legal costs were modelled based on survey data about frequency of lawsuits and associated legal fees. Insurance administrative costs were computed from insurance industry data on the ratio of administrative costs to claims payments. Insurance industry data also provided property damage estimates.

Table 3.2 Cost categories in the US crash cost estimates

Direct medical human costs	
Medical	Includes ambulance travel, emergency room and inpatient costs, follow up visits, physical therapy, rehabilitation, prescriptions, prosthetic devices and home modifications
Direct non-medical human costs	
Vocational rehabilitation	Cost of job or career retraining required as a result of disability caused by motor vehicle injuries
Workplace costs	Costs of workplace disruption that is due to the loss or absence of an employee. Includes the cost of retraining new employees, overtime required to accomplish work of the injured employee, and the administrative costs of processing personnel changes
Insurance administration	Administrative costs associated with processing insurance claims resulting from motor vehicle crashes and defense attorney costs
Legal costs	Legal fees and court cases associated with civil litigation resulting from traffic crashes
Indirect tangible human costs	
Market productivity	Present discounted value of the lost wages and benefits over the casualties' remaining life span
Household productivity	The present value of lost productive household activity valued at the market price for hiring a person to accomplish the same tasks
Indirect intangible human costs	
Excluded from official estimates but included in calculations of comprehensive costs	
Direct vehicle costs	
See below with property damage	
Direct general costs	
Emergency services	Police and fire and rescue services
Property damage	Value of vehicles, cargo, roadways and other items damaged in traffic crashes
Indirect general costs	
Travel delays	Value of travel time delay for persons who are not involved in traffic rashes but who are delayed in the resulting traffic congestion from these crashes

Source: (National Highway Traffic Safety Administration 2002)

While NHTSA's official estimates of the cost of road crashes exclude loss of quality of life, an appendix in the report publishing costs presents estimates of comprehensive costs, which include a value for lost quality of life. These costs come from physician estimates of the functional losses over time by injury diagnosis, measured on the Injury Impairment Scale (III). III data were converted to quality-adjusted life year (QALY) loss estimates based on a systematic review of QALY

scorings. To value a QALY, the study started from a systematic review of willingness to pay values for a statistical life. It subtracted lifetime wage and household work loss to get the present value of a lifetime of QALYs. Dividing that value by the number of QALYs lost yielded a cost per QALY. This procedure requires the questionable assumption that the value of a QALY is constant over the lifespan.

3.4.2 Netherlands

The approach to measuring road crash costs in many European countries, including the Netherlands, is based on recommendations from a review conducted by the European Commission (Table 3.3) (Blaeij, Koetse, Tseng, Rietveld & Verhoef, 2004). In the Netherlands, research into the cost of crashes is periodically carried out by the Institute for Road Safety Research (SWOV) and the Centre for Transport and Navigation (DVS), previously the Transport Research Centre (AVV) (Institute for Road Safety Research, 2009). While earlier crash cost estimates were calculated using the human capital approach with a component added for 'pain, grief and suffering' (McMahon & Dahdah, n.d.), more recent estimates have been based on willingness to pay (Institute for Road Safety Research, 2009).

Compared with the US, a less detailed account of costing methods was available for the Netherlands in the published literature in English, especially in regards to measuring longer term outcomes. In the most recent estimates, incidence data were estimated based on the 'real' number of crashes and casualties by making adjustments to the police data to include crashes and casualties that were not registered. Two units of costing were used: crashes and casualties. For casualties, three categories of severity were recognised: fatal, inpatient and emergency department presentation. An additional two categories, light injury and property damage, were added when crashes were the unit of costing (Institute for Road Safety Research, 2009).

Various sources were relied on to measure medical costs, including data from Statistics Netherlands and the National Medical Register. No information was provided on how longer term medical costs were estimated, although rehabilitation, nursing home care and adaptations for people with disabilities were included. For the other direct costs, Statistics Netherlands and insurance data were among the data

used in deriving costs. Production losses for paid work were calculated as the present value of loss of earnings, with no allowance made for unpaid work such as domestic or voluntary work. Loss of quality of life was calculated based on the results of a survey into the amount people are willing to pay for a certain reduction in crash rate, which was used to determine the so-called 'value of a statistical life' (VOSL). The VOSL was corrected for the consumption loss of fatalities because these costs were already included in production loss. Loss of quality of life for serious injury casualties was estimated at 10 percent of the equivalent amount for a fatality (Institute for Road Safety Research, 2009).

Table 3.3 Cost categories in the Netherlands' crash cost estimates

Direct medical human costs	
Medical	Includes hospital costs, rehabilitation, medicines and adaptations for people with disabilities
Direct non-medical human costs	
Vocational rehabilitation	-
Workplace costs	-
Insurance administration	]Settlement costs include expenses incurred by organisations such as the fire brigade, police, law courts and insurers
Legal costs	]See above with settlement costs
Indirect tangible human costs	
Market productivity	Present discounted value of the lost wages and benefits over the casualties' remaining life span
Household productivity	-
Indirect intangible human costs	
Loss of quality of life	Amount people are willing to pay to avoid this loss of quality of life less the economic value of the consumption loss (latter included in production loss)
Direct vehicle costs	
See below with property damage	
Direct general costs	
Emergency services	See above with settlement costs
Property damage	Value of damage to vehicles, freight, roads and fixed roadside objects
Indirect general costs	
Travel delays	Value of travel time delay for traffic jams

Source: (Institute for Road Safety Research, 2009)

3.4.3 United Kingdom

Estimates of road crash costs in the UK are produced by the UK Department of Transport (Table 3.4). Although police-reported figures are widely recognised as being an incomplete count of crashes and casualties, incidence data on crashes and casualties were drawn only from police records (Keep and Rutherford, 2011). Costs were presented for both casualties and crashes, and three levels of severity identified: fatal, serious injury and slight injury (Department for Transport, 2011).

The UK was one of the first countries to adopt a willingness to pay approach, with the adjustment to valuing loss of quality of life of fatalities and non-fatal casualties made in 1988 and 1993 respectively (O'Reilly et al., 1994, Department for Transport, 2011). Medical costs associated with road trauma were based on the UK's Department of Health data for usage of services, but an explanation on the derivation of longer term medical and related costs was not provided. For other direct costs, the cost of damage to vehicles and property was derived from a survey of claims data from a major insurance company, police costs were derived from interviews with police officers, and insurance administration costs estimated from data from insurance companies. Loss of productivity was calculated as the present value of expected loss of earnings plus any non-wage payments (national insurance contributions, etc.) paid by the employer (Asian Development Bank). Loss of household productivity was not included in the cost estimates.

Table 3.4 Cost categories in the UK crash cost estimates

Direct medical human costs	
Medical	Includes ambulance, emergency department, hospital in-patient, blood transfusion services, district nurse services, cost of medical appliances and social security services
Direct non-medical human costs	
Vocational rehabilitation	-
Workplace costs	-
Insurance administration	Administrative costs
Legal costs	-
Indirect tangible human costs	
Market productivity	Present value of the expected loss of earnings plus non-wage payments made by employers
Household productivity	-
Indirect intangible human costs	
Loss of quality of life	Willingness to pay to avoid pain, grief and suffering to the casualty, relatives and friends as well as intrinsic loss of enjoyment of life in the case of fatalities
Direct vehicle costs	
See below with property damage	
Direct general costs	
Emergency services	Police costs
Property damage	Cost of damage to vehicles and property and costs relating to the loss of use of the damaged vehicles and hire of a replacement vehicle
Indirect general costs	
Travel delays	-

Source: (Department for Transport, 2011)

3.4.4 Australia

Official estimates of the cost of road crashes in Australia are published approximately every 10 years by the agency within the federal government department responsible for transport. Currently, this is BITRE, with the most recent estimate for 2006 (BITRE, 2009). As in previous estimates (Bureau of Transport Economics, 2000; Bureau of Transport and Communications Economics; 1992, Bureau of Transport and Communications Economics, 1988), the approach taken in measuring road crash costs was a hybrid human capital approach, in which a notional

value for the quality of life lost in the event of premature death was added to lost production and other costs. Two units of costing were adopted: crashes and casualties. For crashes, four categories of severity were identified: fatal, hospitalised injury, non-hospitalised injury and property damage only. In the case of casualties, five categories were recognised: fatal, profound impairment, severe impairment, moderate impairment and mild impairment (Table 3.5).

Incidence of the number of people injured in road crashes was drawn from several sources, including official fatality estimates, national data on hospital admissions due to road injury, and estimates of the ratio of hospital admissions to other levels of injury severity. Longer term outcomes of people with injuries were estimated in a two-stage process. The number of people with impairments was estimated using claims data from the Transport Accident Commission of Victoria, data on the length of hospitalisation from the Australian Institute of Health and Welfare, and published disability weights. Impairment relates to the functional outcomes of injuries and is generally measured by the medical profession on a scale from zero to 100. Disability was then considered as a sequential outcome of impairment and defined as any limitation, restriction or impairment likely to last, for at least six months and restrict everyday activities. The number of people with disabilities following impairment due to road injury was estimated from surveys of disability, ageing and carers conducted by the Australian Bureau of Statistics and information on disability on discharge collected in a study of road trauma patients admitted to 10 hospitals in Victoria in the late 1980s. The number of reported crashes and vehicles involved in crashes was calculated from the Bureau's national road crash database, and estimates of the number of unreported crashes was estimated using vehicle numbers involved in crashes, crash rates from reported crashes and vehicle kilometres traveled (BITRE, 2009).

Medical and other related costs were calculated separately for medical costs, hospital costs and paramedical costs. The latter were estimated using claims data provided by the Transport Accident Commission of Victoria, but sources of unit cost data for medical and hospital costs were not clearly spelt out. Ambulance costs were estimated based on information from the different jurisdictions and emergency services costs from estimates produced by the Steering Committee for the Review of Government Service Provision (BITRE, 2009).

Disability-related costs included the cost of providing care for people who suffer disability, the cost of disability services and a range of one-off and recurrent costs. The cost of providing care was based on assumptions about a weekly care cycle for people with profound, severe and moderate limitations, with people with mild limitations assumed not to require care. The cost of disability services was estimated using the annual average level of government support for people with disabilities. Methods for calculating one-off and recurrent costs items were not clearly explained (BITRE, 2009).

Other direct non-medical costs included in the derivation of road crash costs and the sources were –

- Recruitment and retraining costs estimated from data from the Australian Bureau of Statistics' Disability, Ageing and Carers survey, the Transport Accident Commission of Victoria and the Office of Workplace Development.
- Insurance administration costs estimated from data provided by the Transport Accident Commission of Victoria.
- Legal costs estimated from data provided by the Motor Accidents Authority, Transport Accident Commission of Victoria and PricewaterhouseCoopers Actuarial Pty Ltd (BITRE, 2009).

The other direct non-medical cost, workplace disruption costs, and loss of workplace and household productivity were calculated based on injury-specific post-injury consequences, workforce participation rates for people with disabilities, duration of short-term and long-term workplace and household output loss, workforce participation rates and weekly wage rates. Sources of data included the Australian Bureau of Statistics, the Australian Safety and Compensation Council, and previous studies of road crash costs (BITRE, 2009). Specific methods used to derive these costs were not consistently outlined and the robustness of the evidence supporting some assumptions is unclear. For example, the short-term output loss for each person suffering an injury-related disability was assumed as 25 work days, an estimate used in earlier studies of the cost of road crashes but never well justified (Bureau of Transport Economics, 2000).

Loss of quality of life was quantified using the personal injury awards ascribed by the Transport Accident Commission of Victoria as a proxy for individual pain and suffering, loss of amenities of life and loss of enjoyment of life. The maximum amount payable was $371 380, with average amounts payable to individuals estimated by considering the body region affected by an injury and its severity, the level of impairment, the level of disability caused by the impairment, and the age and gender of casualties. The number of casualties affected by injury, how severely they were affected by injury, how severely they were affected and the resulting level of impairment and disability was estimated from data from the Transport Accident Commission of Victoria, the Australian Institute of Health and Welfare's estimates of serious injury due to land transport accidents, and the Australia Bureau of Statistics' survey of disability, ageing and carers (BITRE, 2009).

Vehicle damage costs were estimated from insurance information, the NSW Roads and Traffic Authority and industry sources. A range of government and non-government sources were used to estimate direct general costs, and indirect general costs were modeled based on assumptions relating to value of time and vehicle mix, traffic flow, crash severity , response time and so on (BITRE, 2009).

Table 3.5 Cost categories in the Australian crash cost estimates

Direct medical human costs	
Medical	Includes ambulance, medical, hospital inpatient and paramedical costs
Direct non-medical human costs	
Disability-related costs	Costs of providing care for people with a disability including carers, specialist accommodation, therapy and specialist services, day programs, aids and equipment, and home modifications
Recruitment and retraining costs	Recruitment costs to replace casualties with profound limitations and the costs of re-training people with severe limitations to take on alternate duties
Workplace costs	Costs borne by employers including output foregone and costs associated with hiring temporary employees
Insurance administration	Administrative costs associated with processing insurance claims resulting from motor vehicle crashes
Legal costs	Legal fees and court cases associated with civil litigation resulting from traffic crashes
Indirect tangible human costs	
Market productivity	Present discounted value of the lost wages and benefits over the casualties' remaining life span
Household productivity	Present value of lost productive household activity
Indirect intangible human costs	
Personal injury awards ascribed by the Transport Accident Commission of Victoria as a proxy for individual pain and suffering	
Direct vehicle costs	
Vehicle damage	Vehicle repair costs, towing costs and the cost of vehicle unavailability
Direct general costs	
Emergency services	Police and fire department response costs
Vehicle insurance claims	Costs of administering the motor vehicle property damage insurance system
Property damage	Cost of repairing street furniture
Additional vehicle operating costs	Additional vehicle operating costs from extra time spent in congested traffic caused by road crashes
Indirect general costs	
Travel delays	Value of travel time losses
Health costs of additional local air pollution	Imputed additional health costs resulting from additional exhaust emissions from delay caused by a road crash

Source: (BITRE, 2009)

3.4.5 Summary of findings

The overview of approaches adopted by the four countries illustrates that the costs of road trauma can be estimated in a number of ways. Various methods of estimation do not always adopt the same conceptual framework, the same unit of costing, the same cost items or the same methods to measure and value costs. However, a number of features are common to the approaches adopted by the four countries. All countries use a societal perspective incorporating all costs including those borne by the individual, the government and society. Costs are measured across three categories, namely human costs, vehicle costs and general costs; and costs are presented for two units of costing, a per casualty and per crash basis.

Important points of difference in the approaches used by the countries were the extent to which adjustments were made for incomplete and inaccurate reporting, categories of injured person or crash used to measure and report costs, the scope of longer term costs covered, and the use of a human capital, hybrid human capital or willingness to pay approach.

Of the countries assessed, the estimates of the cost of road crashes in the US produced by NHTSA provide the most complete analysis of costs, with data drawn from a range of valuable data systems. The main strength of the US estimates of the cost of road crashes are the availability of estimates for more than 40 categories of injury, the breadth of the cost items included, use of actual acute medical care costs for individual diagnoses rather than a broad average cost per hospital day, availability of data on long-term medical costs and work outcomes, and inclusion of both human capital and comprehensive costs. Its limitations are the age of the data on long-term outcomes, the use of average cost factors by diagnosis (e.g., the ratio of physician fees to hospital payments) rather than patient-level data for most medical treatment, the modest validation of the III estimates by diagnosis, and the linearity assumption underlying the QALY valuation.

4. IDENTIFICATION OF DATA SOURCES OF LONGER TERM COSTS AND CONSEQUENCES

In addition to reviewing the literature on the costs of road trauma and its longer term, a second objective of this study was to identify potential data sources to use in documenting the longer term consequences of road trauma. Interviews were conducted with representatives from the following stakeholder agencies –

- Insurance Commission of Western Australia (ICWA)
- Subacute Care Team, Health Department Western Australia
- Home and Community Care Services, Health Department Western Australia
- Paediatric Rehabilitation Department, Princess Margaret Hospital
- Department of Medical Engineering and Physics, Royal Perth Hospital
- Rehabilitation in the Home, Royal Perth Hospital
- Trauma Services, Royal Perth Hospital
- Physiotherapy Department, Royal Perth Hospital – Shenton Park
- Occupational Therapy Department, Royal Perth Hospital – Shenton Perth
- ParaQuad WA
- Services for Younger People, Brightwater Care Group
- Silver Chain
- Headwest

Representatives were questioned in regard to any data their agencies had available that could be used in measuring the longer term costs of road trauma (Table 4.1). Contact was made with three additional agencies - the Disability Services Commission, the State Head Injury Unit and Royal Perth Hospital's Hospital in the Home Service - but efforts to interview representatives from these agencies were unsuccessful. A representative of the State Head Injury Unit did provide a written response to attempts to make contact. This response indicated that the agency may have data relevant to the area but changes to its data collection systems to make them more compatible with the Department of Health WA's data collection protocols had made it more difficult to retrieve and interpret these data.

Based on the interviews with representatives from the stakeholder agencies, potential data that might be incorporated into measures of the costs and longer term consequences of road trauma are discussed under four themes: identification of road

crash casualties by severity level, longer term medical and related costs, workplace costs and loss of paid productivity, and longer term care needs.

4.1 Cases with longer term consequences

While BITRE drew its road crash casualty statistics from several sources to take account of the under-reporting of non-fatal injuries in police casualty records, these sources were not linked and several assumptions were required to estimate how many people were injured in road crashes and the severity of injuries (BITRE, 2009). A similar issue arose in regards to estimating the number of casualties with adverse outcomes following road injury.

The WA Linked Data with its set of core and satellite linkages provides a valuable resource for identifying the number of people injured in road crashes, the severity of injury and the number of casualties with adverse outcomes following road injury. Linking core population health datasets including hospital discharge records, mortality data and emergency department presentations with police casualty records and the claims records of the Insurance Commission of WA would provide a means to

(i) address the under-reporting problem in the police crash data and any misclassification of injury severity and (ii) obtain a more complete understanding of the recovery pathway of casualties who sustain injuries with longer term adverse outcomes. Previous work linking police, hospital and death records of road crash casualties has been shown to provide accurate outcome information for casualties in crashes reported to the police, with measures of injury severity derived from the medical diagnoses in the hospital morbidity system a useful measure of adverse outcomes (Rosman, 2001, Rosman and Knuiman, 1994).

Table 4.1 Stakeholder agencies and relevant datasets

Organisation	Role	Data
Insurance Commission of Western Australia	Manages motor vehicle personal insurance scheme	Individual-based electronic data on claims paid for hospital, medical and rehabilitation payment; an allowance toward lost capacity to earn an income; future treatment expenses; an allowance for pain and suffering and inconvenience of injury; travelling expenses; and an allowance for any homecare services.
Sub-acute Care Data Collection, Health Department Western Australia	Manages subacute care data including national reporting of data	Sub-acute data including ambulatory care and community based services.
Home and Community Care Services, Health Department Western Australia	Provides basic support services to older people, people with a disability and their carers to assist them to continue living independently at home	Individual-based electronic data collected in Minimum Data Set including demographics and services provided. No diagnosis field.
Paediatric Rehabilitation Department, Princess Margaret Hospital	Provides care for severely injured children particularly those with acquired brain injury and spinal injury	No additional data to what is captured in the hospital morbidity data.
Department of Medical Engineering and Physics, Royal Perth Hospital	Provides clinical interventions and aids and appliances to patients with a need for these services	Individual-based electronic data, part pre-coded and part text, of all interventions including clinical interventions and aids and appliances. Database has recently changed and the data migration resulted in some scrambling of data.
Rehabilitation in the Home, Royal Perth Hospital	Provides short to medium term, hospital-substitution allied health therapy to assist in the hospital to home transition and prevention of readmission to hospital	Individual-based services captured electronically in the Allied Health Services data base maintained by the Health Department of WA.

Table 4.1 (Continued). Stakeholder agencies and relevant datasets

Organisation	Role	Data
Trauma Services, Royal Perth Hospital	Provides emergency trauma and critical care for injured patients and maintains the RPH trauma registry	Individual-based electronic records on hospital trauma services but no additional data on longer term outcomes.
Physiotherapy Department, Royal Perth Hospital – Shenton Park Hospital	Provides inpatient and outpatient physiotherapy services	Individual-based services captured electronically in the Allied Health Services data base maintained by the Health Department of WA
Occupational Therapy Department, Royal Perth Hospital – Shenton Park Hospital	Provides inpatient and outpatient occupational therapy services	Individual-based services captured electronically in the Allied Health Services data base maintained by the Health Department of WA
ParaQuad WA	Provides support services to people with spinal injury or disease and related conditions	No additional data to that captured in the medical records from the spinal unit at Shenton Park, RPH.
Services for Younger People, Brightwater Care Group	Provides residential, rehabilitation, transitional care and respite accommodation for younger people with acquired neurological disabilities, between the ages of 18 and 65	Individual-based electronic records for the past 12 to 18 months care needs, where clients come from and where they go. Hard copies in medical record files for 20 years prior to this.
Silver Chain	Provides a range of services, including home care, palliative care, emergency care, family health care and other care services	Individual-based electronic records of services provided.
Headwest	Provides a specialist advocacy service for people living with an acquired brain injury, their families and carers	Individual-based electronic database but reporting does not allow easy searching although some data could be extracted. Note Headwest does not itself provide services but provides support to investigate issues and provide useful contacts and links to other services and facilitating solutions.

4.2 Longer term medical and related costs

In addition to offering an information-rich data source to identify cases with longer term outcomes, the WA Linked Data, including core and satellite datasets, provides the opportunity to gain an understanding of the longer term medical and related costs on an individual casualty-level basis. While previous studies of the cost of road crashes in Australia have attempted to include longer term medical and related costs including disability-related cost and the cost of carers, these cost estimates have been produced using a range of assumptions and were based on using average cost factors for groups of injured casualties categorised by injury severity (BITRE, 2009). In the US, longer term medical and other related costs produced by NHTSA in its estimates of road crash costs adopted a similar approach based on average cost factors (National Highway Traffic Safety Administration 2002).

Using core data sets from the WA Linked Data, the acute stage treatment pathway of road crash casualties could be tracked from the emergency department presentation to an index hospital admission. Readmissions for the same crash event could be identified by using algorithms based on the unique medical record number and selected other variables including date of admission, days elapsed since index admission, external cause, and so on. In New Zealand, readmissions have been readily identified from electronic hospital discharge data using an algorithm based on unique person identifier, the date of injury and dates of admission and discharge (Davie et al., 2011). For compensable road injury cases, linking core population health datasets with ICWA's claims dataset would avoid the need to rely on algorithms to identify readmissions since the claims data includes payments for each hospital admission relating to an index hospital admission. ICWA's claims dataset also includes resource utilisation and payment for ambulatory medical and allied health services, home care, long term care, home and vehicle modifications, and aids and appliances (Insurance Commission of Western Australia), which together with the emergency department and hospital morbidity data from the WA Linked Data would capture a more comprehensive post-injury treatment pathway for people requiring medical treatment following a road crash. A limitation of relying on ICWA's data to identify longer term utilisation and costs of medical and related resources is that claims cannot be made for ongoing medical treatment for injury not providing some sustained improvement in a client's medical condition. To the extent claimants seek medical treatment not resulting in an improvement in their condition,

using personal injury claims to measure longer term medical costs would result in costs being underestimated.

Additional potentially useful datasets identified in the stakeholder interviews included the Allied Health Services (AHS) database, the Health Care and Related Information System Client Management System (HCARe) and The Open Patient Administration System (TOPAS). The AHS database is maintained by the Health Department WA and records metropolitan occasions of service by allied health professionals. Similar data is collected for country areas in the Health Care and Related Information System Client Management System (HCARe). In addition, as a patient administration system, TOPAS records all inpatient episodes of care and outpatient appointments. An important limitation of the AHS and HCARe datasets is that reporting is based on time use of health professionals rather than relating to a service event or occasion of service. A second limitation is the current lack of standardisation, with different health professionals within the same department not necessarily adopting the same different reporting practices and differences also likely to exist in reporting standards between departments and institutions. The TOPAS data for non-admitted patients also has limitations in regards to providing valid and accurate data on individual-based resource utilisation, with problems existing with missing data and standardised reporting practices. With the introduction of a new web-based patient administration system, webPAS, to replace the TOPAS infrastructure and the implementation of activity based funding from July 2013, it is expected that clinical documentation of service events will improve.

4.3 Workplace disruption costs and loss of productivity

Workplace disruption costs borne by employers include output foregone and costs associated with hiring temporary or new employees, and loss of productivity includes loss of workplace and household output. Of these component costs, data are currently only available for estimating the loss of workplace productivity. As part of the compulsory third party insurance scheme in WA, casualties with compensable road injuries are eligible to claim for past and future loss of earnings capacity (Insurance Commission of Western Australia). Past economic loss of earnings capacity is calculated on a net basis taking into account gross weekly earnings less tax payable multiplied by the period of unfitness that is medically supported. This payment for past economic loss is based on maximum earnings of three times average weekly

earnings at the time of the award. Future economic loss of earnings capacity is assessed taking into account what the future holds for the injured claimant and what the future would have had they not been injured. Compensation for future loss of earnings capacity is classed as an item of General Damages, which covers pain and suffering, loss of amenities of life, loss of enjoyment of life, curtailment of expectation of life and bodily or mental harm. A deductible applies to overall general damages such that no payment is made for claims below a threshold of $17,000, with the deductible beginning to decrease at $53,000 and no deductible applying after $68,000. The maximum payment for general damages is currently $350,000. While restrictions on payments in the form of deductibles and a maximum payment ceiling impacts on its accuracy as a valid measure of loss of workplace productivity, ICWA's claims data provide the best available data on this particular cost item. More accurate estimates of workplace productivity would require primary research investigating return to work following road injury and the extent to which injuries are associated with a temporary and permanent reduction in labour market outcomes.

4.4 Longer term care needs

Previous Australia studies on the costs of road crashes and injury have measured longer term care needs based on either average cost factors for groups of injured casualties by levels of disability (BITRE, 2009) or the payment to claimants by third party motor vehicle injury insurers (Hendrie et al., 2007).

Additional potentially relevant datasets identified in the stakeholder interviews included the Home and Community Care (HACC) Minimum Data Set (MDS) and those maintained by other agencies providing long term care and support. All HACC-funded agencies providing support services to their clients are required to complete the HACC MDS and report to the National Data Repository maintained by the Department of Health and Ageing (Western Australian Department of Health, 2009). Support services provided by HACC include allied health (home and centre); assessment; centre-based day care; client care coordination; counselling support, information and advocacy; domestic assistance; formal linen service; home maintenance; home modification; meals (home and centre); nursing care (home and centre); other food services; personal care; provision of goods and equipment; respite care (for carer); social support and transport. In addition to utilisation of support services, data are also collected on the characteristics of care recipients (e.g. sex, age,

indigenous status, functional status items), the circumstances of care recipients (e.g., where they live, whether they have a carer), the characteristics of carers (e.g. age, sex, indigenous status) and information about the service episode (e.g. source of referral, date of entry, date of last update). No data are collected relating to diagnoses. A strength of the HACC MDS is that recording of service types and utilisation is standardised based on the National MDS Guidelines and the MDS WA User Guide (Western Australian Department of Health, 2009). A problem though is in accurately attributing service utilisation to a road crash casualty other than by linking these data to the hospital morbidity and/or police crash data and analysing use before and after the crash event.

As a HACC service provider the Silver Chain contributes data to the HACC MDS on long term care provided to people assessed to be in need. In addition, Silver Chain receives government funding to provide a hospital in the home service for eligible patients and individual-based data on service utilisation are available. Other agencies interviewed that provide long term support to people with disabilities, such as the Brightwater Care Group and Headwest, have administrative databases but the scope of coverage of the data and the search capacities of their databases limit the usefulness of these data for measuring long term care needs and costs.

For people with spinal cord injury, guidelines have been developed for use in the Lifetime Care and Support Scheme and the Compulsory Third Party Insurance Scheme in New South Wales relating to their long term care needs (Motor Accidents Authority of NSW, 2002). The level of care is for a 'typical' person with a spinal cord injury who lives independently in the community in an appropriately modified environment. The level of support required is provided by level of neurological deficit and whether the injury is complete or incomplete. For each category (e.g. complete C1-3, complete C4, etc.) a range of hours is given for various tasks, which could be valued by attaching a shadow price to the time periods specified (Drummond et al., 2006). A Care and Needs Scale (CANS) has also been developed with the support of the Motor Accidents Authority of New South Wales to capture the support needs experienced by people with traumatic brain injury (Tate, 2011). The CANS identifies five levels of needs that underpin seven support levels. However, unlike the guidelines for people with spinal cord injury, no time is

allocated to the care and support needs, which makes the resource less useful for valuing the longer term care needs of people with traumatic brain injury.

5. SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS FOR FUTURE WORK

Accurate data about the incidence and costs of road trauma are essential to research and policy analysis, and are also needed for planning and managing road safety at a population level. The aim of this study was to (i) present an overview of the approaches and methods used to cost road trauma, in particular focusing on the nature and extent of its longer term consequences, and (ii) provide recommendations for future work in this area.

Conceptually, the task of measuring the costs of road trauma is straightforward. It involves multiplying the number of cases of road trauma by the sum of the component costs of road trauma. A consensus exists about the three major components of road trauma costs. The first component is the direct costs of road trauma. These include any additional expenses caused by road crashes. The second component is the indirect tangible costs of road trauma, which include the losses in output attributable to premature death, permanent impairment or temporary absence from work caused by crashes. The third component is the valuation of lost quality of life (Elvik, 2000).

In spite of agreement about the major components of road trauma costs, different methodological approaches and information gaps complicate the process of determining the magnitude and costs of road trauma. Different methodological approaches apply primarily to measuring loss of productivity and lost quality of life, while the main information gaps are in respect of the number of road crash casualties with longer term consequences, the duration and severity of these consequences, direct resource use in the longer term attributable to road trauma, the extent to which road injuries are associated with a temporary and permanent reduction in labour market outcomes, and the cost of longer term care needs. In the main, the most promising sources to use to address the information gaps are the WA Linked Data and the Insurance Commission of WA's motor vehicle injury claims data base. Data sets from other stakeholder agencies could help address some gaps, but survey information may offer the best potential to address others.

In deciding the way forward and formulating recommendations to undertake future work in this area, a number of issues were considered by the Project Advisory Group. These included –

1. What is the main purpose of producing new estimates of the costs of road trauma and its longer term consequences in WA?
2. If costs are to be produced then –

2.1. What cost perspective should be adopted – a health sector perspective, a government perspective or a societal perspective?

2.2. What costing unit(s) should be used – the injured person, the crash or both?

2.3. What severity levels should be distinguished in measuring the costs and longer term consequences of road trauma? Broad categories of severity as in the UK and the Netherlands or finer categories as in the US?

2.4. Are all cost components to be included in the cost estimates or only components relevant to the longer term consequences? Alternatively should the focus be to address the information gaps?

2.5. If loss of quality of life is to be included, should this be expressed based on a measurement scale such as a generic quality of life instrument or expressed in monetary terms?

2.6. What method of valuing fatalities should be used? A human capital approach, a hybrid human capital approach or a willingness to pay approach?

2.7. How much primary research should be conducted to address current information gaps?

2.8. Should qualitative research be included examining the costs of road trauma through the experiences of the injured people and their families, friends and colleagues?

In response to the first question about the purpose of producing new estimates of the costs of road trauma and its longer term consequences, any future work conducted in WA to measure these costs should supplement rather than duplicate official estimates of the cost of road crashes produced by the BITRE, and provide data that is useful both to gauge the relative burden of road injury and inform policy formulation and resource allocation. In addition, this work should not duplicate recently commissioned research by the Health Department of WA to provide an overview of the cost of injury in WA.

In response to the other issues raised in regard to future work to measure the costs of road trauma and its longer term consequences, the following recommendations result from consultation with the Project Advisory Group and consideration of the status of current knowledge about the costs of road trauma and data currently available to incorporate in future work.

1. Choice of cost perspective

Each of the perspectives is useful – a health sector perspective, a government perspective and a societal perspective. Given that data required for the health and government perspectives are more readily available, the initial focus should be to improve our understanding of road injury costs and longer term consequences from these perspectives. In time, the objective should be to work towards extending this work to include the societal perspective.

2. Costing unit

The choice of costing unit depends on the purpose for which the costs are to be used. For example, in assessing risks of poor outcomes from road injury, the injured person is the most useful costing unit. On the other hand, on a broader scale, the crash is more useful as a costing unit in evaluating the benefits of alternative safety interventions. For this reason, both the injured person and the crash are appropriate costing units.

3. Severity levels

A similar argument can be made for severity levels, with both broad categories and finer categories being useful in different contexts. Future research should aim where possible to provide more detailed severity levels of the costs and consequences of road injury, which can be aggregated into broader levels when required.

4. Cost components

Given the availability of the official estimates of the cost of road crashes and limitations in these costs, the initial focus of future research should be directed towards those cost components relevant to the longer term consequences of road injury. It is in this area that the most significant information gaps exist in relation to the real burden of road injury.

5. Measurement of loss of quality of life

Monetary values of the loss of quality of life are more easily communicated to stakeholders, including government agencies involved in shaping policy and allocating resources, industry bodies and community groups. Loss of quality of life following injury, which has been measured using generic instruments, should be converted to monetary values using people's willing to pay for a QALY.

6. Method of valuing fatalities

The current status of valuing fatalities in Australia is inconsistent across jurisdictions with the official estimates of road crash costs produced by BITRE based on a hybrid human capital approach while the road authorities in New South Wales and WA have changed to using the WTP approach in their economic evaluation of road safety initiatives. Given the recommendation that the initial focus of any new research in WA should be on cost components relevant to longer term consequences, a decision about the most appropriate method of valuing fatalities can be postponed and reconsidered at a later stage.

7. Primary research to address information gaps

More primary research to address current information gaps should be undertaken, with the extent of research dependent on available funding. Information gaps to be prioritised include the number of road crash casualties who suffer longer term consequences by severity level, longer term medical and other direct costs of road injury, labour market outcomes post-injury and the wider impact of road injury on the family of injured people. The catastrophic claims data held by the Insurance Commission of WA potentially provide a valuable source from which to gain a greater insight into the longer term costs and consequences of road injury.

8. Qualitative research

Given other information gaps on the costs and longer term consequences of road injury, qualitative research examining the costs of road trauma through the experiences of the injured people and their families, friends and colleagues should not be identified as a priority area of research at this stage.

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APPENDIX 1. LIST OF REPRESENTATIVES INTERVIEWED FROM STAKEHOLDER AGENCIES

Representative	Organisation
Janet Wagland	Brightwater Care Group - Services for Younger People
Leanne Brensell	Headwest
Paula Gevers	Health Department WA - Home and Community Care Services
Janine Alan	Health Department WA - Subacute Care Team
Neil Morphett	Insurance Commission of Western Australia (ICWA)
Nigel Glass	ParaQuad WA
Tracey Dawson	Princess Margaret Hospital - Paediatric Rehabilitation Department
Trevor Jones Rob Bingham	Royal Perth Hospital - Department of Medical Engineering and Physics
Julie Brayshaw	Royal Perth Hospital - Occupational Therapy Department
Sue Kent	Royal Perth Hospital - Physiotherapy Department
Rochelle Hoggan Ros Jones	Royal Perth Hospital - Rehabilitation in the Home
Maxine Burrell	Royal Perth Hospital – Trauma Services
Gill Lewin	Silver Chain