Road Crash Cost Estimation: A Proposal Incorporating a Decade of Conceptual and Empirical Developments

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1 Introduction

In its simplest form, road crash cost is the aggregate value of all types of road crashes. These figures are used in formulating and evaluating policies affecting risks to life and limb due to road crashes. Among other uses, they are also considered important to put in perspective the relatively high costs involved in road crashes.

The Bureau of Transport Economics — now the Bureau of Transport and Regional Economics (BTRE) — last estimated road crash costs in 2000 based on 1996 data. It showed that the total losses to the society and economy due to road crashes was nearly $15 billion a year or $41 million a day in 1996 prices. This comprised about $8.3 billion in human costs, $4.1 billion in vehicle costs and over $2.5 billion in general costs.

The 10 year period since 1996 has seen:

- the implementation of well planned and executed safety programs to mitigate road accident risks;
- the promulgation of an effective ‘safety culture’ that fosters more awareness of the areas of risk and risk avoidance;
- safety oriented developments in road and vehicle technology, a relatively high growth in road use compared to other modes; and
- a significant reduction in road crash deaths and changes in the accident profile.

Although information on the impact of all of the above factors on risk levels of road usage and road crashes is not readily available, the ensuing impact of these changes on the accident profile across the nation, and consequent road crash costs could be fairly significant.

In its 2000 report, the BTRE estimated direct and indirect costs that occur from the time a road accident occurs until the surviving victims return to pre-accident conditions. For the fatalities, the estimates included all costs from accident to the funeral. Considering that life is more than lost labour, the 1996 BTRE study incorporated a non-economic component as a surrogate of the cost of lost quality of life of injured crash victims. However with regard to fatalities, it stated that ‘the value of lost quality of life of relatives and friends of the crash victims has not been estimated’ in the report (BTE 2000:p38).

2 Background and objectives of the paper

After discussing the need to update estimates of the costs of road crashes in Australia, this paper will outline briefly the model used at its last cost estimation and how it addressed the conceptual and empirical issues that were canvassed at the time. It also outlines how the review proposes to build on and add value to the BTRE’s road crash cost estimates of 1996. Towards this end, the authors identified the following priority areas for review under separate sections of the paper. The next section giving reasons for the proposed crash cost review will allude to the reasons for these priorities.

- *Methodology* — review the adequacy of the existing model and methodology, particularly major conceptual and empirical developments since 2000.
- *Value of life and limb* — human costs arising from accident deaths and injuries form a large component of the road crash costs. The Bureau's valuation of life and limb provides a conservative estimate. Has it been seriously challenged by proponents of alternative valuation methods?
- *Losses due to serious injuries* — review main conceptual and empirical developments in the valuation of serious injury accidents — especially in the health sector, and discuss why a more harmonised serious injury grouping is beneficial, both to (a) secure the required incident data as well as (b) to make serious injury valuations more robust and informative.
- *Assumptions* — due to unavailability of data BTRE used assumptions to estimate certain cost components in its 2000 report. This section reviews those assumptions.

3 Some reasons for the crash cost review

Several important changes occurred in the 10 years since BTRE last estimated road crash costs. Australia continued to remain ranked high among OECD countries for road safety (ATSB 2004b). Most notably, the road safety conditions improved and road fatalities decreased. Unfortunately, for every road death, there has been a corresponding increase in injuries requiring hospitalisation (Connelly and Supangan 2006).

Figure 1 shows a significant reduction in road deaths in Australia for all ages and for 17 to 25 year-olds. The number of deaths per 100 000 persons has declined since 1986. The rate of decline for all age groups was steeper in the first 10 years, but the decline in the last 10 years was low. Throughout the 20 years, the deaths of 17 to 25 year olds remained higher than the corresponding figure for all ages. Further analysis of road deaths in conjunction with crash injuries shows that the average age of death has declined from 45.95 years in the first 10 years to 44.34 in the last 10 years. That is, the loss of productive years per fatality has increased in the last decade relative to the previous decade.

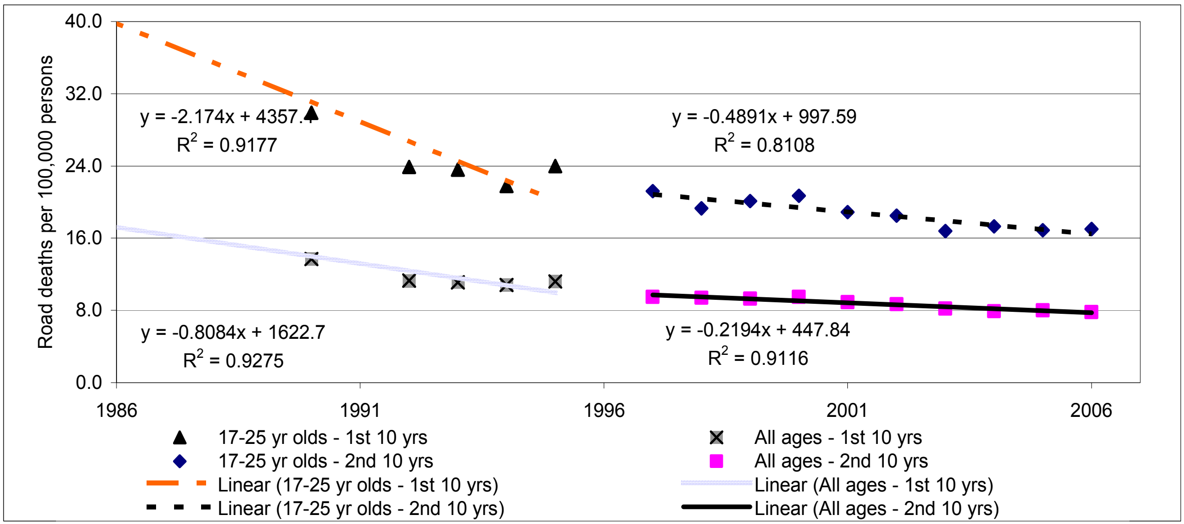

Figure 1 Comparison of road deaths of 17-25 year olds with deaths at different ages

Further analysis of the data also showed changes in percentage composition of the accident mix. For example, compared to the first 10 years in which there were 1.83 serious injuries per death, the corresponding number increased to 1.93 in the last 10 years.

These observations suggest that compared to the 10 years ending in 1996, the 10 years that elapsed not only showed changes in the composition of the accident mix, but also an increase in the years of lost productivity as the average age of a fatality declined and life expectancy increased.

Apart from distinct changes in the accident profiles between the two decades noted above, the last decade also contributed more to the debate/controversy over the use of human capital, willingness to pay and other methods in the valuation of accident costs, prompting some government and non-government organisations to re-evaluate their methods of valuing human costs.

Advances in vehicle and road technology aimed at reducing accident risks improved in the last decade. In that period, the affordability of people to own technologically better vehicles improved and governments accounted for better road technology in infrastructure investments.

The impact of these changes no doubt would have had a significant effect on the unit costs per accident casualty and the road crash costs as a whole. Because of many complexities involved, the nature and magnitude of these effects on unit costs cannot be easily predicted. Nevertheless, on the basis of the changes in the economy, tax structure and the prices that impinge on medical, emergency, legal and insurance costs alone, there is reason to update the 1996 accident cost estimates.

Furthermore, several government bodies with policy making responsibilities inclusive of administrators of the nation's key infrastructure programs, such as *Austlink,* required comprehensive and updated crash cost figures.

4 BTRE crash cost model — 1996

In the 2000 report, a simple empirical model was presented, involving aggregation of relevant costs to estimate road crash costs for Australia — similar to that used in countries such as Canada, Germany, Norway, Portugal, Japan and Austria.

In its cost estimation, the BTRE used 10 human cost elements, 3 vehicle cost elements and 5 general cost elements. Some cost elements are common to all four types of accidents (eg. vehicle costs). Each cost element has a unit cost. Equation 1 shows how the unit cost of each element was combined with the number of accidents of a particular type to determine the total cost for a particular accident in a given year. The equation illustrates the estimation of total crash costs for any one of the 6 states and the 2 territories in Australia (jurisdictions).

$$C_{acc} = \sum_{i=1}^{8} C_f N_{fi} + C_g N_{gi} + C_h N_{hi} + C_d N_{di} \qquad (1)$$

where

C_{acc} = total accident cost per year (dollars/year)
C_f = unit cost of a fatal accident per crash (dollars)

N_{fi} = number of fatal crashes in jurisdiction *i*
C_g = unit cost of a serious injury crash (dollars)
N_{gi} = number of serious injury crashes in jurisdiction *i*
C_h = unit cost of a minor injury crash (dollars)
N_{hi} = number of minor injury crashes in jurisdiction *i*
C_d = unit cost of a property damage crash (dollars)
N_{di} = number of property damage crashes in jurisdiction *i.*

In Equation 1, the unit cost of a fatal accident per crash (C_f) was estimated by discounting pre-tax earnings during the average number of years of life lost due to an accident. Values were added to this to account for (a) the loss of household and community labour and (b) for the loss of quality of life.

The unit cost of serious injury crashes (C_g) was estimated by discounting the pre-tax earnings during the average number of years of disability due to an accident. Values were added to this to account for (a) the loss of household and community labour and (b) the loss of quality of life. To estimate crash costs using this model, the costs due to a specific type of crash were first divided into three components, as shown in Table 1. Next, costs were further sub-divided into a number of cost elements. To estimate the total crash cost for a jurisdiction or a road type, the average unit cost of each cost element was applied to the number of accidents in the jurisdiction or the particular road type.

Table 1 Costs considered by BTRE in 1996 by road accident type

Cost components and cost elements		Fatal accident	Serious injury accident	Minor injury accident	Property damage only accident
	Human cost component				
1	Medical/ambulance/rehabilitation	✓	✓	✓	
2	Long-term care		✓		
3	Labour in the workplace	✓	✓		
4	Labour in the household	✓	✓		
5	Quality of life		✓		
6	Legal		✓	✓	✓
7	Correctional services		✓		
8	Workplace disruption	✓	✓	✓	✓
9	Funeral	✓			
10	Coroner	✓			
	Vehicle cost component				
11	Repairs	✓	✓	✓	✓
12	Unavailability of vehicles	✓	✓	✓	✓
13	Towing	✓	✓	✓	✓
	General cost component				
14	Travel delays	✓	✓	✓	✓
15	Insurance administration	✓	✓	✓	✓
16	Police	✓	✓	✓	✓
17	Non-vehicle property damage	✓	✓	✓	✓
18	Fire and emergency services	✓	✓	✓	✓

5 Review of the Bureau's model

Table 2 shows relative sizes of the three main crash cost components and a detailed comparison of the size of the output-based human costs with the total costs: long term care, labour in the workplace and labour in the household. The human cost components amounted to about 56 per cent of the total crash cost. The three output-based human costs (shown in italics in Table 2) amounted to over 33 per cent of the total crash cost.

This comparison identifies the important cost elements for comprehensive research and analysis in the proposed crash cost review. Cost components that contribute less than 5 per cent to human costs require the least research and analytical effort.

Table 2 Comparison of road crash costs with particular reference to human costs

Costs	Cost ($ million)	Human costs as a per cent of total human cost	Road crash costs	Comparison of cost components
Human costs				
Long-term care	*1 990*	*23.7%*	*1,990*	*13.3%*
Labour in the workplace	*1 625*	*19.4%*	*1,625*	*10.8%*
Labour in the household	*1 493*	*17.8%*	*1,493*	*10.0%*
Quality of life	1 769	21.1%	1,769	11.8%
Legal and Insurance Admin costs	813	9.7%	813	5.4%
Medical and other associated costs	361	4.3%	361	2.4%
Correctional services	17	0.2%	17	0.1%
Workplace disruption	313	3.7%	313	2.1%
Funeral	3	0.0%	3	0.0%
Coroner	1	0.0%	1	0.0%
Total human costs	**8,385**	**100.0%**		**56.0%**
Total vehicle costs			**4,110**	**27.4%**
Total general costs			**2,485**	**16.6%**
Total of all crash costs			**14,980**	**100.0%**

Source BTRE estimates based on BTE (2000)

5.1 Review of the human cost component

The output-based human cost components are estimated by adding the discounted value (present value) of lost productivity due to death or injury. Equation 2 summarises the parameters considered by the Bureau to estimate the present value of lost output (BTE 1998, BTE, 2000, BTRE 2006). As a number of parameters in this equation vary both in time and space, the present values estimated were based on the arithmetic mean or the moving average of relevant parameters.

$$L = f(F, r, W, \phi, R, A, S) \qquad (2)$$

where

L = present value of lost output
r = discount rate
F = average number of fatal accidents
W = average annual income
ϕ = average employment rate
R = average retirement age had the victims survived
A = average age at which the victims that were killed
S = gender of the victims

As a majority of the output drivers (see Equation 2) require the estimation of averages, it is advisable to use expected values rather than arithmetic means[1] (DFA, 2006) to avoid errors in the present value estimates. BTRE (2006) demonstrated that the total cost of $2.17 million attributable to a fatality would fall by 15 per cent to a value of $1.9 million if the average age of a fatality rises from 35 to 42 years. Although the averages may not vary so dramatically, the degree of estimation error could be significant because, the parameters in Equation 2 are averages. The expected values would enable BTRE to estimate averages with respect to the likely probability of occurrence of a certain type of accident. For example, the probability of a 17-25 year old becoming a road fatality is higher than of an older person. The expected value approach also enables to capture significant changes in probabilities due to changes in accident risk. Accident risk reduces with improvements in vehicle and roadway design, traffic enforcement, and other factors.

Commenting on methodological details, particularly the human capital approach, Giles (2003) proposed some refinements to the adjustment of value of labour, 'one such refinement relates to inaccuracies of human capital (foregone earnings) estimation based solely on age and gender', as in BTE (2000). Giles (2003) quoted literature to support the argument that many of the characteristics that have a strong influence on earnings outcomes 'also impact on the incidences and cost of road crashes …' suggesting that 'estimates of the cost of road crashes that ignore these characteristics will be biased' (Giles 2003:p106). Therefore, research will also be carried out to explore the inclusion of additional parameters like occupation, level of educational attainment etc in Equation 2. Recent studies also show that the cost of road crashes is influenced by whether a person is indigenous or not (Berry, Nearmy and Harrison 2007).

Although hospital in-patients databases may have patient occupation as a variable 'educational attainment is not a variable collected routinely in Police road crash reports' Giles (2003:p106). It is envisaged that research will be required to arrive at meaningful estimates of occupation, educational attainment etc, through matching of accident information kept by different organisations, as well as overcoming discrepancies arising from underreporting and overlaps of information.

5.2 Aggregation across important cost drivers

Accident costs are often estimated by applying unit costs to the corresponding number of accidents. Unit costs are derived by aggregating across important cost drivers, like ages at which road crash deaths occur, accident severity, income and socio-demographic groups (Equation 2 shows some cost drivers). Such aggregation masks the influence of important variations and underlying trends associated with the data of a given cost driver while introducing aggregation bias (Preston 1999). A good example is the tendency in the past to aggregate all different types of serious injuries, irrespective of their variability in economic consequences irrespective of the level of severity. Similarly, to estimate the loss of future earnings of a deceased victim and costs to the family, it is common practice to aggregate costs irrespective of the age group to which the deceased person belongs, their years of productive life left, for those in that age group etc (Figure 2). BTRE is aware of these anomalies and has adopted some measures, such as single parameter-based weighted averaging to rectify these anomalies (BTE 2000:pp26, 27, 47 and 49). The proposed review would explore where it may be appropriate and feasible to adopt weighted averaging based on multiple parameters and probabilities (e.g. probability of road crash death associated with age groups etc).

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[1] The expected value of a set of observations differs from its arithmetic mean. The latter is calculated by adding all observations and dividing by the number of observations — "whereas the former is derived using the probability distribution" (Traub, 1994:p7) of those observations.

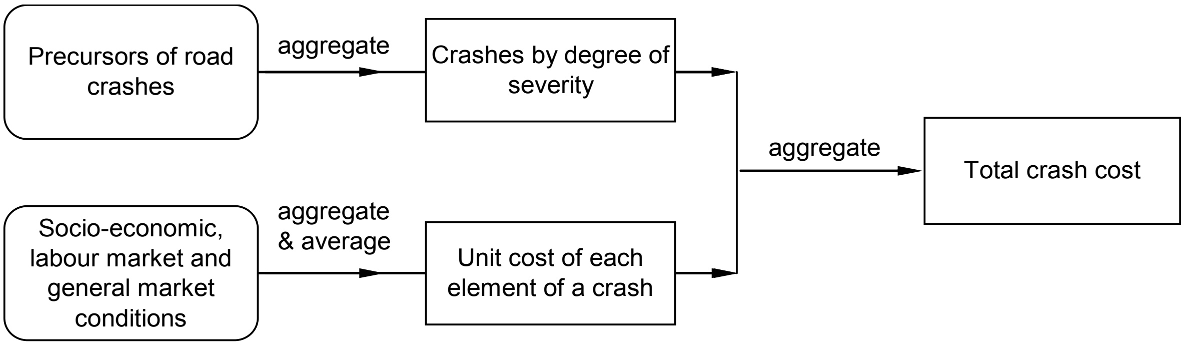

Figure 2 Derivation of total costs based on aggregate cost function

5.3 Other limitations

There are a number of conceptual and empirical limitations inherent in generic forms of human capital approaches to value life. In its use of this approach in 1996, BTRE took on board measures to address most of these limitations. Nevertheless, BTRE's choice of valuation method, and how it was carried out, still continue to attract criticism from some practitioners (Abelson 2003, Giles 2003). These limitations include:

- the failure to reflect main reasons for investment in safety — that is, to avert risk of death or injury — or the fact that individuals may be more averse to certain types of causes of death/injury than others;
- Ignores the loss of 'joy of life', while values assigned for pain, grief and suffering are often arbitrary;
- values some lives higher than others due to labour market imperfections, such as wage discrimination and there is a tendency to undervalue the very young and the old;
- overestimates cost in an economy with less than full employment (but see ;
- embodies uncertainties about life expectancy and earnings, age of entry and retirement; and
- the choice of discount rate as this is a parameter that significantly impacts on the estimation of value of labour.

6 BTRE approach to valuing human life

A road death is any person who is killed outright or dies within 30 days as a result of a road crash. There are many methods to estimate the cost to the society of a road death. Ideally, the method used should generate values that could be used in policy decisions to improve vehicle and road safety and ultimately save lives. Figure 3 summarises the available valuation methods.

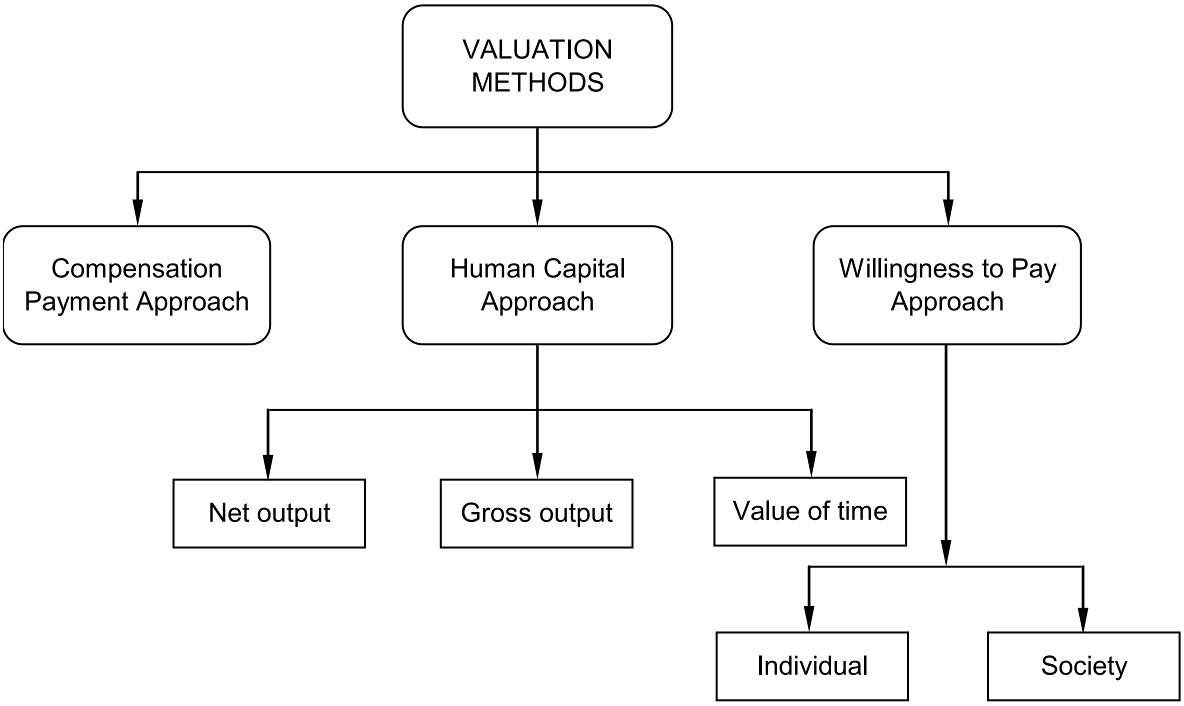

Figure 3 Alternative methods used for valuing human lives lost in accidents

The remainder of this section briefly describes the core methods used in the transport sector *viz* willingness to pay (WTP) approach and the human capital approach followed by an account of the proposed BTRE method.

6.1 Willingness to pay

From a conceptual view point, a road user's willingness to pay (WTP) to minimise and/or eliminate potential risk of death, injuries, or property damage due to an accident is regarded as the theoretically superior concept for use in conventional cost-benefit analyses (Mishan, 1971). Provided the correct survey techniques are used to elicit respondent views, it has the added advantage of fully reflecting the way people value their own lives and that of others. The proponents claim that this method enables the allocation of scarce capital more efficiently while contributing to the maximisation of social welfare.

Eliciting preferences of individuals, as in the case of willingness to pay, is difficult (see for instance Motha, 1990, Parish, 1991). Despite advances in sampling and surveying techniques for use in social sciences, obtaining reliable estimates representative of the relevant road-user population prior to the occurrence of an incident or an accident has proven to be particularly difficult. It is also likely that the values elicited may be high if people state values without being required actually to pay. There is also the related problem of reconciling a wide range of values from different willingness to pay studies.

Out of the individual and social WTP approaches (Richardson, 1999), the individual willingness to pay approach is not suitable for making public infrastructure investment decisions. The reasons are noted below with reference to social WTP.

Social WTP is considered suitable for the purpose because it enables public investment decisions to recognise (a) outcomes (eg. reducing risks of death and threats to quality of life), (b) process (eg. achieving equity and social justice) and (c) context (eg. air traveller *vs.* road user) — the three dimensions of social value to the wider community (Richardson, 1999).

WTP is based on the conceptual premise that people correctly perceive the risks associated with a given behaviour (Zerbe, 1998) — which may not be always true. Nevertheless, economists such as Mishan are of the opinion that it is better to measure the theoretically correct concept imperfectly than the wrong concept (Mishan 1971).

6.2 Human capital approach

The human capital approach (HCA) measures an individual's value to society in terms of his or her production potential, reflected in earnings. Accordingly, the value of a lost life (due to premature death) is the discounted stream of future earnings of that individual.

Of the many variations of the human capital approach, transport sectors — both in Australia and overseas — have used the gross output approach to value human life. HCA entails measuring the output that a person produces over the productive life (Giles, 2003). The loss of this output due to an accident is equated to the cost to society of the loss of a person's capacity to contribute productively. Ex-post evaluation methods (such as this) are often criticised because they do not allow for an individual's aversion to risks of death or being exposed to pain and suffering at a future time (Abelson 2003). On the other hand, the human capital approach gains support from arguments put forward by researchers, who believe that under the WTP approach, the individuals may state a value that they are not willing to pay in practice.

6.3 Practical implications of the two approaches

Viscusi (2000) noted that the value of life estimates based on willingness to pay for risk reductions increased human capital estimates by a factor as high as ten.

Does assigning lower value to human life and limb — such as through HCA, result in less spending on road safety and accident risk mitigation programs? Does the method adopted by BTRE in 1996 implicitly places less value on the elderly and the young (see for instance*.* Cohen, Miller and Rossman 1994)?

Both Viscusi (2000) and the BTRE (BTE 2000:p38) have observed that 'the adoption of a willingness to pay value of life would have a substantial effect on the estimated cost of road crashes in Australia'. Giles (2003:p106) noted that the willingness to pay value of road crashes has two further effects:

- "altering the funding priorities of road crashes; and
- encouraging the adoption of vehicle safety features and road engineering projects that are hitherto marginally rejected on CBA (cost-benefit analysis) grounds (Vulcan 1990)".

BTE (1998:p44) has also noted that "the adoption of WTP values in themselves will not guarantee significant change' in road safety – i.e. spending more money may not necessarily help!" Rather it could "make a certain case for action (*and in specific fear areas*); more safety regulation and control, greater enforcement of traffic regulations and higher vehicle standards".

In response to criticisms of the human capital approach, some practitioners have explored means to combine HCA and WTP to develop hybrid methods for use in CBA and the like. For example, Landefeld and Seskin (1982:p555) claimed that estimates of human life 'based on the human capital approach--reformulated using a willingness-to-pay criterion — produce the only clear, consistent, and objective values for use in cost-benefit analyses of policies affecting risks to life'. Their reformulation involved adjustment of HCA using risk to life. Other forms of hybridisations have been tried. The BTRE used such a hybrid approach (BTE 2000). However, the BTRE's value of statistical life using the hybrid approach is still well below most willingness to pay values.

6.4 Proposed BTRE approach for 2007 review

BTRE recently reviewed literature published in the last ten years on competing accident costing methodologies, especially of the cost of human lives lost in accidents (BTRE, 2007). The findings of the literature survey, a staff seminar and consultations, affirmed the use of a suitably tailored version of the human capital approach to value life. A similar approach was adopted in BTRE's 1996 road crash cost estimates.

BTRE's estimates of road crash costs in 1996 used the human capital approach to value life, supplemented by a cost element to compensate for pain, grief and suffering, components of intrinsic value in a human life. The highest value of this component was assigned to 100 per cent impairment/incapacity and was scaled down as the impairment decreased. For "fatalities, the compensation amount allocated to 100 per cent impairment case was assigned. This was done to place a lower bound on the intangible component of life, which those who die have lost' (BTE 2000:p38). This in other words, 'equates death with permanent incapacity' (BTE 2000:p38). As for the relatives and friends of the deceased, the 1996 BTRE estimates did not add a cost component to capture their 'lost quality of life' (p38, BTE 2000). In the 2007 BTRE review of road crash costs, it proposes to rectify this lapse.

Giles (2003:p105) posed the question 'if the ex post methodology continues to be used in the estimation of road crash costs, are there some refinements that can improve its credibility?' She suggested that 'if human capital approach is used in the absence of ex ante measures, then the derivation of human capital (foregone earnings) measures needs to comprehend factors such as age and gender, educational attainment, labour force experience and sector of employment, which are currently ignored' Giles (2003:p 95). In the 2007 review, BTRE will explore possibilities of adjusting the present value of lost output (see Equation 2) using some or all of the socio-demographic factors suggested by Giles (2003) and other relevant factors. The 1996 BTRE estimates considered age and gender in its estimates (see BTE 2000:p25).

6.5 Method of quantifying pain grief and suffering

Allowing for pain, grief and suffering or the 'loss of quality of life' purport to address the criticism that under the human capital approach, the social cost of injury is limited only to the loss of employment and hospital costs. In 1996, the BTRE estimates showed that it was the second highest road crash cost component and amounted to about $1.8 billion. Because of its significant importance, detailed conceptual and empirical research is warranted to minimise estimation errors of this component.

As pain, grief and suffering is a non-market cost, it needs to be estimated using informed judgement and expert opinion. It can also be directly elicited using the willingness to pay approach by asking the respondents to "consider themselves either as potential victims of a road accident or as relatives of potential victims and to state their willingness to pay to reduce the likelihood of such an accident" (Christe and Soguel, 1996:p277).

In the 1996 BTRE estimates, a conservative estimate of the pain, grief and suffering/quality of life was made. It estimated the costs based on an objective medical scale of impairment similar to that used by the Transport Accident Commission (TAC 2007). Accordingly, it added a dollar amount to each severity type of crash proportional to the degree of impairment. A death for instance was equated to 100 per cent impairment/incapacity, irrespective of whether the victim contributed to the crash or not (page 37, BTE 2000). The values that BTRE estimated are in Table 3.

Table 3 BTRE estimates of the quality of life and the levels of impairment by accident severity, 1996

	Death	Serious Injury	Minor Injury
Level of impairment considered by BTRE	100%	11%	5%
Value of Quality of life lost ($)	319 030	34 228	1 584
Number of victims	1 968	22 000	213 322
Total Quality of life lost ($m)	628	753	338

Notes: The figures in the table are based on BTE (2000). All dollar values are in 1996 prices.

Avraham (2006) quantified pain grief and suffering of a crash victim by assigning age-adjusted multipliers to the victim's medical costs (not other economic costs). This approach assumes that the medical cost is a proxy of victim's level of impairment. Most past work on pain and suffering were deficient in the method used for (a) quantifying non-economic costs and (b) measuring the degree of pain and suffering (Parliament of New South Wales 2002).

This paper proposes to use BTRE's 1996 methodology to quantify pain, grief and suffering in the 2007 review as well, but with improvements. The methodology will be improved by (a) adopting a wider classification of serious injury accidents than in the 1996 estimates and (b) gaining a detailed knowledge of impairment using health literature, medical data and details of grief counselling. 'Value transfer' methods will be explored to meet any knowledge gaps. These methods are claimed to have the potential to 'reduce cost of arduous and time-consuming studies and obtain information with less research effort' Tervonen (1999:p3). It implies that these methods would enable to adopt overseas information on willingness to pay to avoid pain, grief and suffering and loss of quality of life to the Australian context.

7 Valuing losses due to serious injuries

If an individual is permanently incapacitated, it is assumed that he or she would be inhibited from living as full a life as if they were fully able because of chronic pain, for example, or the immobility/absence of a limb. Various studies, particularly in the health field, have developed quality of life indexes to rate such injuries or disabilities. Adopting a similar approach, BTE (2000:p32) treated 'quality of life effects of death as equivalent to the most extreme injury, because the losses suffered by the victim are similar'. On this basis, BTE (2000) estimated a value of $7.15 billion for serious injuries (in 1996 prices). This is about half the overall road crash cost for that year. The 'real extent of road crash injuries, and hence the cost to the community, may be greater than is believed' (ACRS 2004: p1).

Abelson (2003) and the Department for Health and Ageing criticised BTE (2000) approach and reasoning, arguing that those killed in road accidents no longer have any quality of life to assess. Indeed, as noted in BTRE (2006), 'common law rules hold that personal claims for damages are extinguished with the death of a person'; by extension, personal costs accrued to those killed in road crashes are redundant and need not be calculated.

However, by excluding the cost component for the value of quality of life, the cost of a fatality may be valued less than a serious injury, since ongoing medical costs are likely to be high for a serious injury (NHTSA 2002); this contradicts some views that death is the most significant cost in road accidents. Hence, this raises a 'moral issue'. BTRE continues to use court awards for the most severe injuries as a proxy for loss of quality of life due to a fatality (BTRE 2006).

The literature reviewed by BTRE noted an approach that has the potential to overcome most of the criticisms of the present approach. It is based on valuation of medical costs associated with the treatment of injury according to body region. This approach stems from two notable studies undertaken by Zaloshnja et al (2003) — who studied injury by body part in the United States and Hendrie, Lyle and Fildes (2005), who replicated the method in an Australian context using cost data from NSW.

A key advantage of the Hendrie et al (2005) approach is the ease of tracing unit costs to either the body region or the severity of the primary injury. Hendrie et al (2005) showed how the method could be extended to value injury costs to victims suffering multiple-injuries.

Their cost estimates showed that the cost of a head injury — excluding fatalities — was approximately double the cost of any other injury. Cost of spinal injury per incident was highest and was valued at almost $2 million per incident because of the ongoing medical and personal care needs — especially if the person lived after the accident. This cost was much higher than the value assigned to a fatality.

The generalisation of the findings of Hendrie et al (2005) may need to be carried out cautiously, especially because they were not based on a representative sample of cases. Nevertheless the method has considerable value as it establishes conceptual and empirical foundations useful in BTRE modelling work to separate serious injury road accidents by their unit costs, thus avoiding masking of serious injury cost differentials, as in most past accident cost valuations, as well as avoiding undervaluation of serious injury accident costs.

The method by Hendrie et al (2005) has a specific safety focus. It is envisaged that obtaining necessary data for its national applicability is relative easy. Therefore the method has the potential for detailed valuation of serious injuries.

However, a comprehensive and reliable database on serious road crash injuries is not available. This is an important issue that needs to be addressed, especially with reference to the work of Hendrie et al (2005) as it would otherwise affect the cost estimates of this review.

8 Reducing reliance on assumptions

The 1996 BTRE estimates were affected due to unavailability of data on certain key parameters — particularly the data for estimating significant costs such as human costs. Several of the conceptual and empirical assumptions that were made to overcome data deficiencies can be relaxed now as (a) data have become available in the last decade for estimation of some of the key parameters, (b) research methods have advanced (eg hedonic econometric analysis) enabling the implicit derivation of parameters — some of which (that are discussed below) in the past relied on assumptions and (c) econometric techniques have been developed to refine data as well as to overcome data deficiencies stemming from under-reporting as well as inconsistencies in data recording across different jurisdictions.

Road crash statistics — due to gaps in crash statistics kept by the police, the 1996 analysis used data from insurance companies and scaled these upwards to obtain an estimate of crashes for the jurisdiction under consideration. For this purpose, BTRE used the percentage of registered vehicles insured by the relevant companies in that jurisdiction. This data were then adjusted using statistics on total vehicle-kilometres driven in each jurisdiction.

The 1996 estimates also assumed that the number of people injured due to motor vehicle crashes is a function of the size of population.

To address anomalies arising from assumptions on crash cost data, the 2007 review expects to take advantage of improvements to data recording and statistical cross-validation techniques that developed in the last decade.

Productivity losses of serious injury victims — due to the unavailability of adjustment techniques and research in the area, the 1996 estimates assumed that those with serious injuries rejoin the workforce at their previous capacity after a time of absence equivalent to the average length of stay in hospital. This is an important cost element and errors leading to this assumption may be addressed by using recent work carried out in the health economics area (*c. f.* Connelly and Supangan 2006; Hendrie, Lyle and Fildes 2005; Guria et al 2003). The underestimation of serious injury costs alluded to by some observers (NHTSA 2002) could be a result of this assumption.

Legal costs — in the estimation of costs per fatality and serious injuries, the 1996 estimates assumed that fatal injuries account for $23.6 million of legal costs ($12 000 per fatality), serious injuries for $465.0 million ($21 147 each) and minor injuries for $269.7 million ($1 264 each). The Bureau acknowledged that these assumptions could result in underestimation of the costs per fatality and serious injury. This is a further area where work is planned to minimise under-estimation of human costs.

Other assumptions — a number of other assumptions that should be assessed and 'reality-checked' are listed below.

- the loss of hours of unpaid work carried out by crash victims outside their workplace should be valued at the same level of earnings per hour as at formal workforce;

- impairments of less than 10 per cent, including injuries have a negligible impact on the quality of life; and

- although the age of a victim is important when it comes to determining the amount of time spent recovering from an injury, and hence the level of ancillary medical services consumed, the 1996 BTRE estimates used a blanket average age in the calculation.

The 1996 BTRE estimates also use of a number of proxies. There is no harm in using proxies — but only if the proxies used bear a significant relationship to the parameters that they represent. For example, the use a victim's future earnings as a proxy for the cost of premature death or injury in the 1996 BTRE estimates can hardly be challenged as it is founded on the concept of human capital approach to valuing life.

9 Additional cost components

Transport Canada in its recent estimate of accident costs included cost components to cover the costs associated with replacing a deceased person at workplace (recruitment, training etc), extra pollution created due to road crashes etc (Transport Canada 2007).

The proposed 2007 BTRE review will explore important cost components and elements hitherto not included in crash cost estimates. These include externality costs, accident costs involving road users/vehicles and other transport modes such as rail. Relevant costs will be included after judging the importance of such cost elements according to their contribution to overall costs and the availability of data to estimate those.

10 Concluding observations

Associating explicit costs to road accidents is important — especially to put in perspective high costs involved in improving safety of roads and other programs, such as those aimed at educating motorists to use roads safely as well as to prevent under investment in road safety (World Bank 2005). Therefore efforts to derive road crash costs are not merely academic.

This paper reviewed a number of conceptual and empirical developments in the last 10 years. Of particular interest was the changing trend in the composition of the accident mix, associated increases in the years of lost productivity due to road accident deaths of young people and the slow trend in the decline of serious injury accidents.

The contribution of economists to reverse these trends rests largely in their ability to provide the road sector with detailed, up-to-date and meaningful cost estimates and other related information to influence policies aimed at saving lives and improve the nation's road safety. Therefore, the challenge for the authors was to rigorously review the BTRE road crash cost estimates of 1996, elicit gaps and identify priority areas with a view to address the current and emerging road safety issues and explore how best to make a valid contribution. Towards this end, the paper identified and discussed the following priority areas, noting where possible the direction of research that BTRE would engage in this regard.

- Add value to human capital approach used in the 1996 BTRE crash cost estimations to value human life by using additional socio-demographic and other factors to adjust the present value of lost output. The 1996 BTRE estimates used only two factors — age and gender (as discussed in Section 5 Sub-section 5.1).

- Reduce aggregation of data on cost drivers such as age of accident deaths. The objective of this is to avoid masking of important differentials in cost variability that is associated with data. This is discussed in Section 5 sub-section 5.2.

- Provide estimates of pain, grief and suffering taking advantage of more up-to-date data and methodological and empirical developments in valuing pain grief and suffering (as outlined in Section 6 Sub-section 6.5).

- Provide a workable breakdown of unit costs of serious injury accidents and avoid masking of cost differentials associated with the treatment of, and caring for victims who have met with accidents of varying levels of injury and the consequent undervaluation of serious injury accident costs as discussed in Section 7.

- Add a cost component to capture the 'lost quality of life' of relatives and friends of deceased road crash victims. This is to augment the 1996 estimates of road crash costs that did not account for the welfare of relatives and friends of deceased victims (as noted in section 6 Sub-section 6.4).

- Take advantage of conceptual and empirical developments in the last decade in the road accident estimation methodologies, data refinement techniques etc and reduce the reliance on assumptions (as discussed in Section 8).

- Take on board cost components and cost elements that are hitherto not included in Bureau's accident cost estimates — especially in its 1996 road crash cost estimates (as noted in Section 9).

Given the large differences in the accident rates between urban and rural areas (ATSB 2004a, Berry, Nearmy and Harrison 2007), some observers are of the opinion that the costs of injury accidents should be estimated separately for urban and rural roads — but such an effort is beyond the scope of a national review such as this. What the review hopes to do is to provide sufficient information and guidance to help others to be able to do this.

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