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Social Cost of Road Crashes

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Abstract

Each year just under 1,800 people die and around 30,000 require hospital treatment after crashes on Australian roads. This is despite the best efforts of government, industry, community groups and road users in promoting road safety and the use of safety equipment. When this loss is considered, in combination with the resultant damage to property and the cost of social infrastructure necessary to deal with road crashes, it is clear that a considerable cost burden is placed on society. Determining the extent of this cost and its components allows a better understanding of the economic benefits of activities to reduce the incidence and severity of road crashes.

This paper provides a discussion of the methodology used in the BTE's latest estimates, which are based on 1996 road crash patterns and will be released later this year. The data used in estimating the number of crashes and people injured are examined, as are two of the major cost elements - lost quality of life and travel delay costs - the estimation of which has benefited from improvements in methodology.

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Introduction

In 1996, 1970 people died and 30 000 received injuries requiring hospital treatment as a result of collisions on Australian roads. This is despite the best efforts of government, industry, and community and road user groups in promoting road safety. When this human loss is considered in combination with resultant property damage and the costs of the social infrastructure necessary to deal with road crashes, it is clear a considerable cost is borne by society.

The costs imposed by road crashes, and the value gained in avoiding crashes, are explicitly and implicitly recognised by the actions of government, industry, community groups and individuals. Governments at all levels promote road safety and this message is enforced through the police service. Motor companies spend money developing safety equipment and structurally testing their vehicles, while road users purchase voluntary safety equipment in cars, including air bags and child restraints, and undertake driver training. These actions all work to lessen the risk of death and injury through road crashes.

Determining the extent of the cost of road crashes and accurately estimating its components allows better decisions to be made about crash prevention and risk minimisation expenditure. It is only through understanding the structure of the costs that a thorough evaluation of the cost effectiveness of programs to reduce the incidence or severity of road crashes can be made. This is important when scarce funds are to be allocated between programs designed to reduce the incidence of specific crash or injury types.

The other use for a value for the cost of road crashes is to illustrate the burden these incidents place on the community as a whole, and on specific groups within the community. For instance, the cost to the medical system, employers, or emergency services can be assessed. Similarly, the extent to which particular sectors benefit from actions to reduce road crashes can be estimated. Understanding the relative burden from road crashes is useful in determining the demand for specific road safety actions and assessing the social returns from road safety expenditure.

The BTE (formerly BTCE) has regularly provided updated estimates of the cost of road crashes (BTCE 1988, 1992, 1996). The most recent estimate placed the total annual value of road crashes in Australia at $6.1 billion in 1993 (BTCE 1996). This paper provides a discussion of the methodology used in the BTE's latest estimates, which are based on 1996 road crash patterns and will be released later this year. The data used in estimating the number of crashes and people injured are examined, as are two of the major cost elements, the estimation of which has benefited from improvements in methodology.

The approach taken to costing

The costs arising from road crashes have been categorised into three groups:

- Human costs – arising from injury to individuals (such as medical costs, productivity losses, declines in quality of life);
- Vehicle costs – due to vehicle damage (such as towage, repair costs and vehicle unavailability); and
- Crash costs – resulting from the crash itself and unable to be tied solely to the people or vehicles involved (such as police and fire services, property damage and lost travel time).

Estimating vehicle and crash costs are relatively straightforward, involving a summation of easily measurable costs. However, in addition to recognising medical costs and productivity losses, the estimation of human costs involves placing a value on the lives lost and the injuries borne by survivors. This is probably the most controversial area of road crash costing and the choice of method will be examined in this paper. Past studies have found that the value placed on life/injury tends to be a substantial component of road crash costs, thereby significantly influencing the final outcome.

Valuing human life

Either of two generic approaches are usually used to value human life.

One is the human capital approach where, in its simplest form, life is valued as the discounted sum of potential output. The human capital approach characterises people, and therefore life, as a labour source and an input to the production process. In practice the discounted value of a victim's future earnings is taken as proxy for the cost of death or permanent injury. Typically a value is not placed on the foregone 'joys of living' for those killed or on the non-financial losses in terms of reduced quality of life for those injured.

Second is the willingness to pay approach, which uses welfare economics' principles to base the value of life upon amounts that individuals are prepared to pay to reduce the risk to life or to accept in compensation for such risk. It uses people's preferences (either stated or revealed) to reflect the value of intangible elements such as the quality of life and the joy of living. The human capital approach has difficulty costing these elements and as a result willingness to pay estimates of the value of life are generally higher.

An extended human capital method is used in this estimation of crash costs. Improvements have been made which still maintain the social cost focus of the methodology. It has been extended to value non-paid work – services to the family and community – which will be lost in the case of death or injury. Perhaps, most importantly, estimates of the value of the lost quality of life are also made. How this particular refinement was made is discussed in detail later in the paper

The decision to use this approach was made to ensure this work had a basis for comparison with previous BTCE studies in this area and also with work carried out last year in estimating the cost of civil aviation accidents. The results also provide an up to date benchmark to compare the results of any willingness to pay outcomes derived in the future

How many collisions?

Determining how many road crashes occurred is basic to an estimation of crash costs. Four sources of data were used:

- Federal Office of Road Safety (FORS) – collects data on fatal and serious road crashes.
- Police – Federal, State and Territory police collect information on attended and reported crashes
- Australian Institute of Health and Welfare – collects volume and cost details of the medical outcomes of road crashes.
- Insurance companies/State accident authorities – hold information on the number and value of claims made in respect to road crashes.

Obviously, these data overlap considerably, for example, the data collected by FORS (1998) is a subset of police data Similarly, many crashes for which insurance claims are made will have also been reported to police This is useful in cross checking of data coverage but also means that care must be taken to avoid double counting.

Additionally, some people or vehicles involved in crashes will not be caught in the data due to a number of factors. These factors include non-insured vehicles, decisions not to make a claim despite insurance being held, lack of registration of cause of injury in the case of medical data, failure to report crashes to police and variations in reporting requirements among states.

As a result, estimating the number of vehicles damaged and people injured in road crashes requires some assumptions to be made. At the lower injury and lower vehicle damage end of the scale more assumptions are required in estimating the proportion of the whole population represented by captured data. The estimates may greatly vary as assumptions are changed, and therefore conservative assumptions, and hence conservative estimates, have been used. In 1996, the number of fatalities totalled 1970 and the number of seriously injured amounted to 21 989. The estimated numbers of road crashes, and vehicles involved in these crashes, in Australia in 1996 are shown in table 1.

Table 1: Road crashes and vehicles involved, 1996 (source: BTE estimates using FORS (1998), Police and insurance company data.)

Level of crash	Crashes	Vehicles
Fatal	1 768	2 681
Serious	17 512	28 124
Total	707 500	1 132 000

Note: The full study differentiates between motorbikes, cars, truck and buses in recognition of the different costs when these vehicles are involved in crashes.

Some areas of improved estimation

Over time improved data collection has contributed to better estimates of road crash costs. Access to more detailed and up-to-date data has increased the rigour of several of the cost components. Improved methodology has also contributed to better estimates. The two cost components discussed below, travel delays and quality of life, have benefited by both these improvements. The full listing of cost components and their values is presented towards the end of the paper.

Travel delays

Motor vehicle crashes can result in travel delays to other motorists through slowing or a blocking of traffic either directly or indirectly through the actions of emergency services. Such delays impose costs as the time lost queuing in traffic has a productive value. The BTE work has improved previous estimates of the cost of travel delays (BTCE 1992, Andreassen 1992) by developing updated estimates of average delay times and average number of vehicles affected by fatal and serious crashes based on measured Australian traffic flows. Earlier studies tended to rely on delay time estimates from Faigin (1976) which are based on United States traffic flows from the early 1970s

The value of time lost

Transport analysts routinely place values on travel time saved and lost for use in policy formulation and decisions concerning investment in capital roadworks (Hensher, Battellino and Daniels 1994, Walters 1994, Bradley and Rohr 1995, Miller 1996, and

Wigan et al (1998) Miller (1996) and Hensher et al (1994) pointed out that as crash-related delays are unexpected and travellers are generally prepared to pay a premium to avoid the unplanned delay, time lost is worth more than time saved. Hensher et al (1994) derives the values of 44 to 68 percent of the wage rate for travel time lost and 35 to 41 percent for travel time saved.

The ranges of values calculated by Hensher et al indicate that different road users value time differently. Miller (1996) suggested a time lost value of 55 percent of the wage rate for passengers and 75 percent for drivers (whom he assumed to be working). The Hensher et al estimates are adopted in this study primarily because the values are derived in Australia and are therefore more appropriate than, say, Miller's US figures. For time lost by freight traffic, the figures from Wigan et al (1998) have been used. Table 1 shows these values and average vehicle occupancy rate, as well as number of pallets per truck (a pallet as used here is equivalent to one tonne of load).

One further consideration when valuing time lost is the determination of whether every minute is valued equally by every traveller. Small (1982) demonstrated one minute lost or saved could be valued minimally or very highly, depending on the trip length. Time is typically worth less on longer journeys. Similarly, the amount of time lost affects its value – the first minute lost may be of a lower value than the 30th minute lost. This raises the question of whether there is a pattern in the valuation of time in certain circumstances or for particular people. Miller (1996) did not find any consistent patterns. Thomas and Thompson (1970), Lee and Dalvi (1969), Horowitz (1978, 1980) and Hensher (1976) all found patterns, albeit different, in the value of time saved. Although the value of time lost varies with both the amount and the situation, the uncertain nature of this relationship, and its applicability to time lost, has meant that this study does not attempt to model any of the possible scenarios. Instead constant values, as shown in table 1, are used for all time lost.

Table 2: Valuing time (source: Hensher et al (1994), Wigan et al (1998) and BTE)

Vehicle type	Value of time lost		Occupancy rate	Pallets per truck	Value per vehicle ($/hour)
	$/hr/occupant	$/hr/pallet			
Car	9.00	na	1.62	na	14.58
Bus	8.38	na	18	na	151.00
Articulated truck	na	0.66		16	11.00
Rigid truck	na	1.40		12	14.00
Other	9.00	na	1.62	na	14.58

Note: The car value used is an average of the various car travel classes as used in Hensher et al (1994). The time value for bus passenger is an average of 'social trip' and 'other trip' from Hensher et al (1994). 'Other' covers motorbikes.

Framework for estimating travel time lost/saved

The length of any crash-related delay to other motorists, hence the cost, depends on three factors:

- Level of blockage of the road (in turn dependent on the type of crash, severity of injuries, and the road type);
- Traffic flows (determined by the time of day and the type of road); and
- Clearance time (dependent on the type of crash, severity of injuries, and emergency services response time).

The type of road is an important determinant of the length of travel delay expected from a particular crash. Different roads experience greatly differing volume and composition of traffic flows – as, for example, the differences between a suburban street and a major inter-city highway. Another factor that is an important influence on traffic flows is the existence of alternate routes.

The deterministic queuing model in Mannering and Kilareski (1998) is used to estimate the duration of crash delays and the number of vehicles affected by the delay in the case of a typical crash. This estimate is then used to calculate the value of the delay. The concept of queuing is based on assumptions concerning vehicle arrival and departure characteristics at a point of reference such as a crash site; queue discipline (for example, first-in-first-out); and the number of available departure channels. The model assumes uniform deterministic arrival and departure, with one departure channel. It offers the advantages of being simple, lending itself to an intuitive mathematical solution (see Appendix 1), and also represents heavily congested traffic conditions well.

A graphical example highlights how the estimation is made (Figure 1). A crash occurs at time zero and blocks the carriageway. Emergency services arrive 20 minutes after the crash, and after 10 minutes one channel is opened for traffic. The traffic flow in this restricted condition is down to 30 percent of the flow prior to the crash. An hour after the crash, the wreckage is completely cleared from the road to allow traffic to depart at the practical capacity flow level (3500 vehicles per hour). At point C the freeway flow normalises. The delay to all vehicles affected by the crash is equal to the shaded area between the arrival and departure curves (triangular and trapezoidal areas).

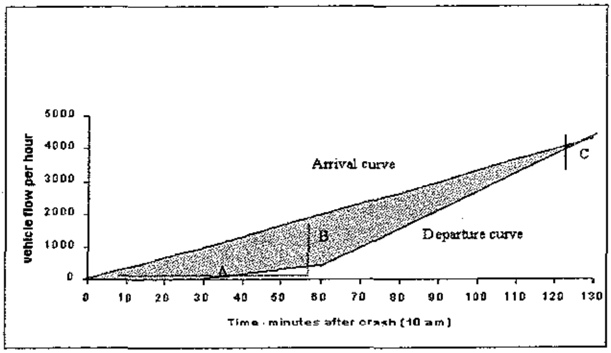

Figure 1 Traffic queuing model (source: Mannering and Kilareski 1998)

Data and assumptions

The key data required are emergency services response time, average time to clear the crash site and average traffic flow per hour.

Average figures from VicRoads' incident response time (1996) and RTA traffic counts (1998) have been used. By using observed traffic composition data from NSW Roads and Traffic Authority (RTA) traffic counts we are able to proportion the vehicles affected into cars, trucks, buses and others. The specific values for time were then applied to the number of crashes in each vehicle class and the average vehicle delay. The summation of the results provides the total cost of time lost as a result of 1996 motor vehicle crashes.

To estimate the value of time lost associated with crashes that occurred in 1996 a number of simplifying assumptions have been made in regard to the crashes believed to cause significant delays. These assumptions were used in interrogating the FORS fatal and serious crash database.

Traffic flow: In order to maintain a manageable computation to estimate delay for each road in the crash database, three 'traffic flow scenarios' based on local government areas are used. This approach was used to assign traffic flows per hour that are reasonably representative of each group. Table 3 shows the flows used for each group

Table 3: Traffic flow and composition (source: BTE estimate and RTA (1998))

Traffic Zone	Traffic flow/hr	Proportion in traffic %			
		Cars	Buses	Artic. trucks	Rigid trucks
Sydney & Melbourne	1358	87	1	2	10
Other capital	679	87	1	2	10
Highway/rural (over 70kph)	240	78	0.8	16	5

It is recognised that the 'Highways' scenario probably contains the most diverse set of roads. While the traffic flow selected is more representative of major interstate highways than many of the single lane rural connector roads also in the over 70 kph speed zone category, this is believed to be appropriate as the majority of crashes occur on the higher flow roads.

Speed: The traffic flow scenarios presented above contain an implicit assumption concerning speed. Crashes that occurred in 60 kph or less zones have been excluded. The assumption is that 60 kph zones are generally in built up areas with light traffic flows and many alternative routes, should one route be blocked or slowed. Resultant costs from diversion have not been estimated.

Time of crash: For urban crashes it has been assumed that delays would be caused to traffic only between the hours of 6am to 8pm when traffic is heavier. For crashes occurring on highways the time period has been expanded to between 5am and 10pm.

Crashes: Single vehicle crashes have been excluded from the highway scenario. These are believed to generally occur off the carriageway and so cause little, if any, blockage. In the urban scenarios, single vehicle crashes have been included only where the crash resulted in a fatality or a severe injury. Multiple vehicle crashes with fatalities or serious injuries have been included as causing significant traffic delays in all three scenarios. Fatalities and serious injuries involving pedestrians and cyclists have also been included in the scenarios.

Results

Using the above criteria it was found only 8 percent of the fatal and serious crashes were considered to cause significant traffic delays that impose costs. The estimated costs from time lost to road users as a result of these motor vehicle crashes amounted to $1.8 billion. This is considerably higher than the estimate of $220 million in BTCE

(1998), even when inflation over the eleven year period is taken into account. This earlier estimate only valued travel delays during rush hour periods in urban areas.

Lost quality of life (non-economic costs of road crashes)

From an individual standpoint, non-economic costs (pain and suffering, loss of amenities of life, loss of expectation of life and disfigurement) can be the most devastating result of a road crash. The refinement of the basic human capital approach through the inclusion of such an intangible cost element brings it closer to the willingness to pay method without losing its strong real world accounting basis. The social belief that life is more than just a stream of income also necessitates some attempt to value lost quality of life. It is therefore a valuable refinement to include non-economic loss estimates to reflect the full range of costs borne by society

Pain and suffering is relatively easily recognisable, but understanding what quality of life encompasses is more difficult. For those who are left with a disability following a road crash, the lost quality of life comprises all the things they were able to do prior to the crash but are unable to do after the crash. Permanent disability can remove the opportunity of achieving even minor goals in life that others take for granted.

Loss of quality of life for fatalities is simultaneously both easy and difficult to conceptualise. It is easy because lost quality of life can be seen as a scale, with a healthy person at one end. This scale covers a range of progressively more debilitating injuries, with death as the logical point marking the other end of the scale. Loss of quality of life is difficult to understand because a dead person does not feel or comprehend the loss. This report does place a value on the loss of this intangible component of life by fatalities, as numerous willingness-to-pay studies have demonstrated that people will pay at a level well above the value of lost production to avoid dying

Quality of life is also a difficult concept to quantify. Economists have developed many different ways of measuring loss of quality of life. Such measurements include Quality-Adjusted Life Years (QALYs); Disability-Adjusted Life Years (DALYs); jury verdicts and willingness-to-pay estimates. Work is also being carried out on cross-validating estimates using different approaches. For example Miller (1996) describes work which has been done on cross-validating jury verdict estimates and QALY estimates. One of the simplest estimations for loss of quality of life according to Miller (1996) is to subtract productivity loss estimates with some adjustments for transfer payments and tax from a willingness-to-pay estimate. This, he contends, will give a value for the loss of quality of life (including pain and suffering).

In the absence of a willingness-to-pay estimate specific to Australia, and also without age data from which QALYs or DALYs can be ascertained, the use of non-economic payments is the best guide to the value of the quality of life foregone. This approach assumes that such payments accurately reflect the true losses experienced by the victims and that these experiences can be converted into adequate monetary compensation. This is very much an intangible concept, but the method detailed below is an attempt to estimate such values. Non-economic payments have a clear advantage in that they are 'real' costs arising from crashes being borne by society.

Two sets of non-economic payments data have been used. All Australian states require motor vehicles to be insured against causing injury and death in road crashes, usually referred to as compulsory third party insurance. These schemes are typically administered by a government agency. In most states, government control of compensation extends to legislated upper limits on payments. There may also be a lower threshold This means that the maximum level of compensation is decided by state parliaments; courts only decide the relative amounts given for lesser injuries. In most states, cases that go to court are decided by judge alone

Data from the Victorian Traffic Accident Commission (which administers the Victorian third party insurance scheme), concerning both the no-fault and common law parts of that State's scheme, was used. The data shows the spread of payments across different levels of impairment from road crashes. The inherent problems in using such information have been recognised, and these have been addressed to the maximum extent possible.

The major arguments against such data are their perceived inconsistency and unreasonableness. Consistency amongst third party insurance schemes is ensured in some states by requiring the payment to be proportional to a numerical 'degree of impairment'. This principle is used together with data from Victoria based on an objective medical scale of impairment, so the amounts are predictable

Reasonableness is a more difficult question. Viscusi (1988) disputes that there is any compelling justification for the use of any specific impairment schedule. However the amounts awarded for compensation are ultimately determined by state parliaments, and so are a reflection of the value placed on quality of life by the electorate, and the society they come from. Compensation awards are determined by the size of the premium government is prepared to impose on vehicle owners. Excessive premiums, in the perception of vehicle owners, is an important political issue for state governments, as is any perceived inadequacy of compensation. This places pressure on governments to balance the two. Currently no insurance scheme is subsidised.

In developing an estimate of lost quality of life, those compensated under the no-fault part of the Victorian scheme, but not under common law, were assigned the legislated compensation for their degree of impairment. Those compensated under common law were not assigned the actual amounts paid to them, because these are often discounted to reflect the contribution of the victim to the crash. For the purposes of estimating the value of lost quality of life, this was inappropriate, as being partially responsible does not diminish the losses suffered due to the injury. Instead, it was assumed that the payment was proportional to the degree of impairment above 10 percent, up to the maximum payment of $319,030 (equal to the average cap for 1995-96 and 1996-97). Impairment of less than 10 percent was assumed to have a negligible impact on the quality of life. This gives a value about 50 percent higher than the total actually paid by the TAC in 1996. From this it was possible to extrapolate for the whole of Australia on the basis of the level of serious injuries in each State and Territory.

For fatalities, compensation equivalent to that allocated to 100 per cent impairment cases was applied. This was done to place a lower bound value of the intangible component of life which those who die have lost. It is a lower bound, as it equates death with permanent incapacity.

The estimated value of lost quality of life was $319 030 for each fatality and $19 874 per serious injury. The estimated total cost of lost quality of life due to road crashes in 1996 was $1.066 billion, comprising $629 million for fatalities and $437 million for those seriously injured.

The estimate for the loss of quality of life is considered a lower bound, partially because it does not include the pain and suffering of friends and relatives. It is acknowledged that economists using willingness-to-pay methods in other countries have calculated much higher figures. The different theoretical basis of these two approaches means that although ostensibly trying to provide a value of life, they are doing so by measuring different proxies, and as such cannot be expected to provide identical results. Compensation awards and payments form a conservative estimate for the human cost of road crashes, but the large contribution of human costs to the total means that even a doubtful estimate is important in giving perspective on where the true non-economic costs of crashes lie.

Conclusions

The two cost elements discussed are some of those that have benefited from increased focus in the upcoming BTE study. More broadly, the findings regarding the social costs of road crashes are important for two reasons. Firstly, they provide invaluable information to be used in the assessment of road projects. But from a theoretical perspective, it develops an expanded human capital approach to the value of life, which can be compared with any future calculations of willingness to pay values for life.

Appendix A: Mathematical approach to valuing travel delays from road crashes

Equations *a* to *d* to allow computation of the total traffic delays arising from crashes Knowledge of the traffic composition (table 2) and the vehicle delay cost data (table 1) allows a cost to be placed on this delay.

The total number of vehicles affected in the period between the initial crash and the complete dissipation of the queue, is

(a)

$$Q_f = (\mu_r * t_r) + (\mu * (t_n - t_c))$$

where: Q_f is the total number of vehicles delayed by the crash; μ is full capacity departure flow rate per minute; μ_r is restricted departure flow rate per minute; and t is time in minutes after the crash (r= restricted flow allowed; c= crash cleared; n= normal flow resumed).

t_n is unknown, however, the queue dissipates at the point when departing vehicles are equivalent to those arriving, that is

(b)

$$\lambda * t_n = (\mu_r * t_{30}) + (\mu * (t_n - t_{60}))$$

$$Q_f = \lambda * t_n$$

where: λ is observed normal traffic flow per minute.
The delay to all vehicles affected by the crash is equal to the shaded area (figure 1) between arrival and departure curves. This can be expressed as:

(c)

$$D_t = 0.5(t_r * \lambda * t_r) + 0.5(\lambda * t_r) + (\mu_r * t_c)(t_c - t_r) - 0.5(t_c - t_r) * (\mu_r * t_c) +$$

$$0.5(\lambda * t_r) - (\mu_r * t_c) * (t_n - t_c)$$

where: D is the delay time in traffic queue, with subscript denoting total (t) delay.
From this the average delay per vehicle can be determined

(d)

$$Dv = D_t / (\lambda * t_n)$$

where: D is the delay time in traffic queue, with subscript denoting average (v) delay.

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