



A framework for costing aviation accidents

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Abstract:

Empirical research on the estimation of productivity losses associated with transport accidents has focused on two methods: willingness-to-pay and human capital. Both of these approaches provide reasonable estimates. However, most recent work has focused on the human capital approach, with some element of the willingness-to-pay concepts adopted. This paper outlines an improved method of estimating the cost of aviation accidents using the human capital approach. The underlying concept of this method is the probability of a person surviving or dying, whether the person is involved in an accident or not. This addresses the question that is often posed by some critics, whether some persons would have died in a relatively short period even had they not had an accident. It also addresses the issue associated with willingness-to-pay approach that some age groups are risk averse. The improved method is then applied to 1996 Australian aviation accidents to estimate productivity losses. To this cost are added other direct expended costs such as aircraft damage, medical costs, insurance administration, court and legal costs, investigation and emergency services cost and even premature funeral costs, to obtain a total picture of the magnitude of the burden on the Australian community.

The views expressed in this paper are those of the authors, and do not necessarily represent those of the Bureau of Transport Economics. The usual caveats apply.

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Introduction

Aviation accidents and indeed all transport accidents resulting in injury or death impact on an individual and the wider community in a number of ways. For example, in Australia the community through the Department of Health and Family Services pays Medicare expenses, and members of the community subscribing to private health cover pay higher health insurance premiums. In addition, medical resources are diverted away from other needs. For the individual, the cost may be out-of-pocket medical expenses such as the gap between pharmaceutical subsidies and actual cost of drugs and between actual medical cost and scheduled cost, and/or loss of earnings from employment. There are also significant costs associated with reduced productivity as a result of a person dying prematurely through an accident or as a result of a person suffering disability. Considered from another angle, the economy benefits from an individual's productivity through increased GNP. Those dependent on the victim suffer the immediate economic hardship from forgone income; the community also suffers through efforts to support the victim or victim's dependants. These eventually result in losses to the nation. All these costs could be avoided in the absence of an accident.

The primary focus of the paper is to outline an enhancement /refinement to the method of estimating the productivity losses associated with aviation accident fatalities and permanent disabilities resulting in permanent loss of employment opportunities. Productivity losses constitute a major cost component when a person dies prematurely. Many research efforts have focused on this area (for example, Bureau of Transport and Communications Economics BTCE 1992, National Highway Traffic Safety Authority NHTSA 1994 and 1996). A basic assumption is that there is the possibility that had the victims not died as a result of an aircraft accident they would have worked at the workplace and or at home and made contributions to the community.

The refined methodology is applied to 1996 Australian civil aviation accidents to derive the cost of productivity losses. To present a complete picture of total losses associated with accident victims, the direct costs expended on victims and property have been estimated and added. These direct costs also represent loss to society. Included in these losses are medical costs, legal costs, emergency services costs (search and rescue), insurance administration costs, property damage, workplace losses, investigation costs and premature funeral costs. These costs could be avoided if an accident or incident did not occur. This notion of avoidable cost is in practice synonymous with opportunity cost. The term is used to denote the costs that could be avoided if a course of action were not followed and the next most appropriate course of action were followed instead. Although it is difficult to maintain that all accidents could be avoided whilst we live in such a chaotic world, we still have the ability to make choices that can have an impact on the extent of the resultant cost of any accident that does occur. To some degree, this notion of avoidable or opportunity cost is subjective, depending on the set of alternatives the decision-maker chooses to consider (Hariton 1984).

The analysis excludes data on any Australian registered aircraft that had an accident in an overseas territory, and military aircraft. We have assumed all victims were permanent Australian residents.

Definitions and data

For the purpose of this analysis the definition of an aviation accident adopted by the International Civil Aviation Organisation (ICAO) is used. An accident is defined as an occurrence associated with the operation of an aircraft, which takes place between the time any person boards the aircraft with the intention of flight until such time as such persons have disembarked, in which a person is fatally or seriously injured and/or the aircraft sustains serious damage or structural failure (ICAO Annex 13).

An aviation incident is defined as an occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation. It includes violations of controlled airspace or runway incursion. When an aircraft enters controlled airspace without an airways clearance it poses a threat to the air traffic control system and the incident is classified as a violation of controlled airspace. Similarly, if a vehicle, aircraft or person enters the runway flight strip without permission this is classified as a runway incursion incident. This definition implies that no injury or damage to property occurs. Although there may be associated delays and therefore costs, lack of data precluded any estimates being made in this area. However, the costs associated with incident investigation have been included in the analysis. This is an important cost component as it reflects a preventive measure, which has a bearing on accidents.

Data for this analysis have largely been obtained from the Bureau of Air Safety Investigation (BASI). Of particular importance, due to the valuation method being used, is information on the age of fatality victims. This information was not, until very recently, been routinely collected by BASI. However, age information is usually contained in the coroner's records. Where specific age information was not available, descriptions of the victims (such as a young man, middle age, etc.) were used as a basis to estimate age. BASI has now put in place a system whereby the age of fatality victims in future accidents will be collected.

Figure 1 shows that over the past ten years (1987-1996) the number of accidents involving Australian fixed wing aircraft shows no particular trend (upward or downward). The number of fixed wing aircraft accidents has been as low as 171 accidents in 1994 and as high as 219 in 1990. However, comparing hours flown with the rate of accidents over the period may present a different picture. Accidents involving rotary wing aircraft over the same period show a decline in the later years.

In 1996, 247 civil aviation accidents, 4 of which involved regular passenger transport (RPT) with no fatality, were reported by BASI. There were 247 aircraft and 1026 persons involved. Of the victims, 51 were fatalities, 35 suffered serious injuries, and 86 had minor injuries, and 854 persons, about 83 per cent, sustained no injury. Of the 247 aircraft that were involved, 41 were destroyed and 201 sustained substantial damage. Total incidents reported to BASI in 1996 were 3633.

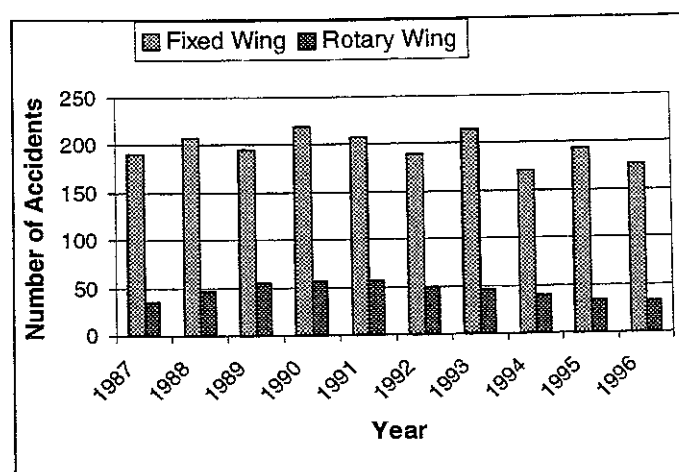


Figure 1 Civil aircraft accidents 1987-1996 (source: BASI)

General approach

Empirical work relating to estimating losses resulting from transport accidents has focused on two main methods: 'willingness-to-pay' and 'human capital' (Schelling 1968; Guria 1990; Cook, Motha et al 1990). The willingness-to-pay method relies on valuing life by determining what individuals actually pay or would be willing to pay to reduce their probability of death. The concept encompasses two components: the value individuals place on safety and health and the cost saved by the rest of society by preventing an injury or death (NHTSA 1992). The values are generally estimated by what economists refer to as 'revealed preference' and 'stated preference'. Revealed preference is observed market behaviour: for example, voluntary purchase of safety devices; higher wages for high-risk jobs; trade-offs between time, money, comfort and safety. Stated preference values are measured through surveys about individuals' willingness to pay for increases in health and safety. For a detailed discussion of this method see BTCE Working Paper 26 (1996).

This paper is about providing refinements to the human capital method in the way it is applied to estimate productivity losses. Notwithstanding the sound economic theory behind the willingness-to-pay concept, the human capital method (at times with some elements of willingness-to-pay concepts included in it) still remains the preferred approach by some practitioners. It must be said though that both approaches have limitations (BTCE 1996).

BTCE (1992) defines the human capital method as an ex-post accounting approach, which focuses on the victim's potential output capacity. In this case the individuals are seen as producers and consumers of a stream of output throughout their lifetime. Individual victims are considered part of total community impact; hence the value of

their decreased production and decreased consumption is included in total cost. The values are measured by extrapolating production and consumption losses to the expected life span of the individual and discounting the values to present time. To this cost are added the direct costs expended in accident-related activities (hospital, legal, insurance etc).

Studies on the cost of transport accidents in Australia (Atkins 1981, Brownbill 1984) generally calculate productivity losses of accident victims by estimating the present value of their assumed future total income, taking account of their age and gender. This involves discounting the income stream to a present value from a predetermined age 65 with an adjustment for future productivity gains. Two key assumptions were that all persons not in the labour force value their leisure at prevailing market wage rates and that all persons age 65+ do not participate in the work force. Other authors have used different age cut-offs in defining the working life period or the potential productive years. Usually the ages between 15 and 70 years are referred to as potentially productive years of life (Gardner and Sanborn 1990). It is also generally assumed that people aged 0 - 14 are not participants in the work force. Any fatality in this age bracket is assigned to age 15. That is, no workplace and household productivity values are assigned until the victims are assumed to have reached age 15. Another approach is the use of years of accumulated ability lost. This method weights the number of deaths by the ages at which they occur, on the assumption that the potential contributions of the victim are greater with greater age and experience (Hahn 1995).

BTCE 1992 introduced some refinements by using the working life table model. The working life tables describe labour force participation and movements into and out of the labour force at each age as well as expectations of years of working and retirement life. These tables were based on Anderson and Ross (1987). The working life tables used 1981 Australian mortality profiles and rates of labour force participation, to yield age and gender specific expectations, in years, of working life and retired life of persons in the labour force. For details and assumptions of working life tables methodology refer to Anderson and Ross (1987), and BTCE (1992).

The 1981 Australian working life table is dated. A reconstruction would require extensive data collection, and derivation of mathematical formulas based on a number of hypotheses and assumptions. However, the same results can be achieved by a simpler and enhanced method, which we describe in the next section. We have not used a working life cut-off age either, because this assumes that there is no working life after the cut-off age. The real life situation, as indicated by ABS Australian 1996 work force participation rates (ABS 1996b), is that working life continues beyond age 65 or 70 (figure 2). For example, people running their own business such as a farm may well continue to work beyond this age. Thus using a working life cut-off age, that is, AB on figure 2, would underestimate productivity losses by excluding the area BC in figure 2. The approach we have adopted assumes a potential working life profile as illustrated by AC in figure 2.

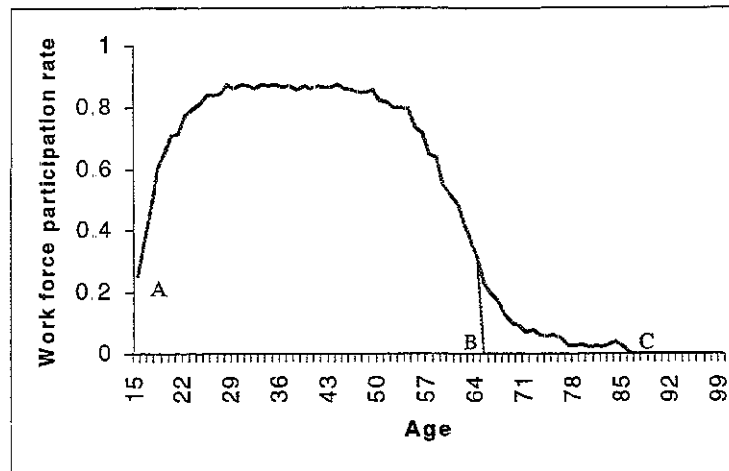


Figure 2 Male working life profile (source: derived from ABS 1996b)

Costing framework

In this paper we provide further refinements of the working life model. However, we do not estimate a working life table but use the concept. The basic framework for the estimation process relies on the Australian life expectancy tables published by the Australian Bureau of Statistics (ABS 1996a). We make use of column l_x (number of persons surviving from a birth cohort of 100 000) in the Australian life tables. The underlying concept is the probability of a person surviving or dying. We illustrate this by way of an example. Suppose 6 people had died as a result of an aircraft accident all at the age of 44 in 1996. The victims' fatality situation is hypothetically reversed and a question posed: what are the chances that all 6 at age 44 would have survived to age 45, 46, 47, ..., 99? As the 6 progressively survive to the next age their chance of surviving or dying changes to reflect the specific age they have reached. At a point in time between age 44 and 99 the probability is that all or most of our 6 hypothetical people would have died.

Since the life tables are constructed with actual death rates at year of age, the probability of surviving or dying ratios are in effect weighted to reflect the high-risk age groups. This is an important factor to model into accident cost analysis, as some age groups have associated high risk factors.

After estimating the survival rates (45, 46, ..., 99) of our 6 hypothetical persons we then apply the Australian work force participation rate (at year of age and by gender) to derive the proportion of the survivors that would be in the work force. The mean annual potential earnings (at year of age and by gender) are then applied to each surviving person in the work force. This computation is repeated for each year there is a survivor. Finally, the estimated losses are discounted to present time. Table 1 shows the

spreadsheet computation. This scenario analysis produces productivity losses of \$4 271 535, which is a sub-set of the overall analysis. For the complete analysis this computation is repeated for each age that fatality occurs. The computation formula we have used is:

$$P_x = A_x V_x \left(\frac{l_{x+1}}{l_x} \right)$$

with

$$V_x = W_x E_x$$

where:

P_x is productivity losses for the year the victims would have been age x ,

A_x is the total number, at age x of people who have died in aviation accident who would statistically otherwise have been alive at age x

l_x is the number of people who statistically survive to age x in a birth cohort of 100 000 (ABS life tables 1994-96),

V_x is work force participation rate (E_x) at age X , multiplied by potential earnings (W_x) at age X ,

The result (P_x) for each surviving year is discounted to present time; in this instance the base time is 1996. That is,

$$PV = \sum_{x=i}^{\infty} \frac{P_x}{(1 + rate)^x}$$

where PV is the present value of productivity losses over the relevant period, Rate is the discount rate, and i is age at death from aviation accident

For the valuation in the base year in which the deaths occur, P_x , is halved to reflect the fact that deaths can occur at random throughout the year. This avoids over or under estimation. P_x is computed for each single age (single age is used to distinguish use of data at each year of age, as opposed to data for groups of age eg 15-20 years), and is summed after discounting. Permanently disabled victims, who by the nature of their injuries will never enter the work force, were treated in the same way in terms of estimating potential productivity losses.

Potential earnings from work of accident victims are based on mean weekly earnings by single age and by gender for 1996 (ABS 1996c). Mean earnings best represents the

market replacement wage for future potential labour. The weekly earnings are annualised and factored by 25.4 per cent to take into account labour on-costs (leave loading, superannuation etc.). Finally, a 2 per cent annual growth rate is applied to the earnings stream to take account of real increases in productivity over time.

The work force participation rate was based on single age and by gender (ABS unpublished data). This represents an enhancement in the data set since BTCE (1992) relied on age group data (eg 15 - 19, 20 - 25 etc). The use of work force participation rate at single age and by gender and potential earnings also at single age ensures that the chances of survivors engaging in formal employment and contributing to the nation's wealth are taken into account. Identical computation is carried out to estimate potential losses for the period when the survivors are likely to be unemployed. Housework and other community work are included for this period for a person who was employed.

The estimated productivity losses are added to the direct costs incurred on or by victims. Readers may refer to BIE (1998, 1992) and Cook, Motha et al (1990), where the methodology for the estimation of the direct expended cost on accident victims is explained. Generally, estimates for the direct costs are based on expenses that have been incurred for or by accident victims. (Because of lack of data, costs that may be associated with airport closures and delays have not been included; although any such costs could be significant). These expenses are obtained from agencies such as the Australian Institute of Health and Welfare (AIHW), Australian Emergency Management Service (EMS), BASI etc. Refer to appendix 1 for definitions of the direct costs. Figure 1 presents the various cost components and their proportions. The estimated productivity losses using this enhanced method compare well with previous BTCE estimates. Table 2 shows the comparison.

Table 1 Productivity Losses for male fatality at Age 44

Age	Probability of surviving out of 100 000	Fatality	Likely to survive	Annual earnings (\$)	Workforce participation rate	Value of productivity lost (\$)	Age	Probability of surviving out of 100 000	Fatality	Likely to survive	Annual earnings (\$)	Employment participation rate	Value of productivity lost (\$)
43	95 478	0	0.0		0.9	0	72	68 510	0	4.3	53 880	0.1	18 596
44	95 281	6	0.0	65 565	0.9	171 557	73	65 971	0	4.2	54 958	0.1	13 699
45	95 071	0	6.0	61 261	0.9	315 043	74	63 296	0	4.0	56 057	0.1	13 406
46	94 845	0	6.0	68 040	0.9	347 044	75	60 484	0	3.8	57 178	0.1	13 067
47	94 600	0	6.0	67 365	0.8	342 713	76	57 532	0	3.6	58 322	0.1	10 565
48	94 334	0	6.0	79 638	0.8	400 225	77	54 436	0	3.4	59 488	0.0	6 118
49	94 044	0	5.9	68 982	0.9	349 282	78	51 195	0	3.2	60 678	0.0	5 868
50	93 726	0	5.9	73 555	0.8	356 854	79	47 821	0	3.0	61 891	0.0	5 591
51	93 378	0	5.9	73 877	0.8	354 041	80	44 332	0	2.8	63 129	0.0	3 525
52	92 996	0	5.9	87 180	0.8	407 408	81	40 752	0	2.6	64 392	0.0	4 957
53	92 576	0	5.8	82 643	0.8	383 980	82	37 118	0	2.3	65 680	0.0	4 606
54	92 113	0	5.8	66 806	0.8	308 459	83	33 467	0	2.1	66 993	0.0	4 236
55	91 601	0	5.8	65 653	0.7	277 213	84	29 847	0	1.9	68 333	0.0	5 137
56	91 035	0	5.7	65 485	0.7	269 539	85	26 303	0	1.7	69 700	0.0	2 309
57	90 407	0	5.7	68 845	0.6	253 978	86	22 885	0	1.4	71 094	0.0	0
58	89 710	0	5.7	79 027	0.6	283 936	87	19 639	0	1.2	NA	0.0	0
59	88 937	0	5.6	64 105	0.5	196 383	88	16 608	0	1.0	NA	0.0	0
60	88 079	0	5.6	72 945	0.5	210 385	89	13 825	0	0.9	NA	0.0	0
61	87 129	0	5.5	114 000*	0.5	302 731	90	11 318	0	0.7	NA	0.0	0
62	86 077	0	5.4	85 899	0.4	192 297	91	9 110	0	0.6	NA	0.0	0
63	84 917	0	5.4	80 812	0.4	158 160	92	7 211	0	0.5	NA	0.0	0
64	83 639	0	5.3	60 489	0.3	101 311	93	5 617	0	0.4	NA	0.0	0
65	82 238	0	5.2	46 906	0.2	55 869	94	4 313	0	0.3	NA	0.0	0
66	80 704	0	5.1	47 844	0.2	48 629	95	3 272	0	0.2	NA	0.0	0
67	79 034	0	5.0	48 801	0.2	41 289	96	2 459	0	0.2	NA	0.0	0
68	77 222	0	4.9	49 777	0.1	31 467	97	1 826	0	0.1	NA	0.0	0
69	75 264	0	4.7	50 773	0.1	24 064	98	1 341	0	0.1	NA	0.0	0
70	73 160	0	4.6	51 788	0.1	21 473	99	973	0	0.1	NA	0.0	0
71	70 907	0	4.5	52 824	0.1	16 511							

Source: BTE estimates

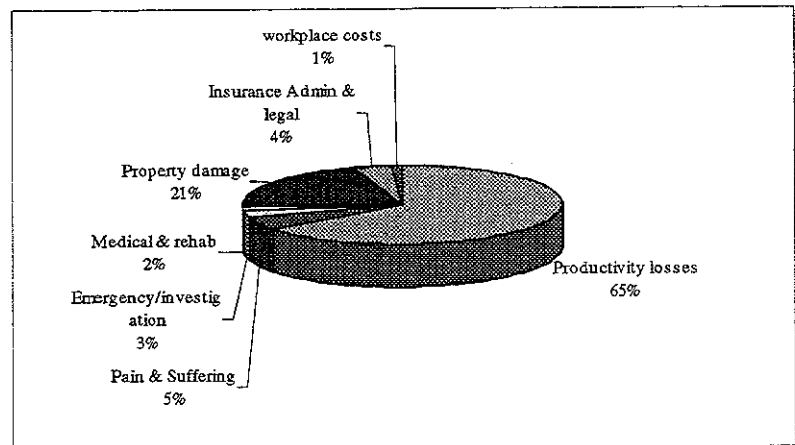
Note: Annual earnings are estimated potential future earnings (not discounted); e.g. the annual earnings for age 86 is the expected earnings by the year 2038 for a person aged 44 (in 1996). Due to rounding of figures in this table calculations from the figures presented here will not yield the same results as shown above.

NA = not applicable. * estimate appears to have an error in the original ABS data.

Table 2 Comparison of values of productivity losses: per fatality—7% discount rate

Year of estimate	Workplace productivity	Household productivity	Total
1988 (BTCE 1992)	349 000	197 000	546 000
1993 (BTCE 1995)	462 213	259 732	721 945
1996 (this paper)	545 561	260 647	806 208

Note: costs are in the year of estimate



Note: Because of rounding, figures do not add up exactly to 100%

Figure 3 Components of 1996 aviation accident costs

Conclusions

In this paper we have shown that, in using the human capital approach to estimate productivity losses of premature deaths and permanent disability, one does not have to go through a complex method of estimating a working life table with its associated assumptions about accessions to and secessions from the work force. Our enhanced method also avoids the limitation associated with using a fixed potential working life span such as 65 or 70 years, as used by some researchers. The methodology we have devised is simple and accurate compared with others discussed in this paper. In addition, life expectancy tables, which are the sources of the base figures for this concept, are regularly updated by the ABS. When comparing the total costs with previous estimates, one should exercise caution for the reasons that additional cost components have been included and others have been re-defined with improved data.

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Appendix 1

Definitions of direct costs

Medical Costs The cost of all medical treatment of victims other than that given during ambulance treatment. This also includes hospital care and paramedical treatment.

Emergency Services The cost of Emergency Management Services (EMS) services to locate, rescue and recover injured and dead persons as a result of aviation accidents. This cost covers helicopter and small plane search and rescue operations.

Rehabilitation and Long Term Care The cost of retraining required to return the victim to the work force, and when not possible the cost of long term care and attention required by the victim.

Losses in Household and Community Production The costs associated with lost productivity in the home and elsewhere in the community. Such losses are relevant to the employed and the unemployed. The market replacement method as opposed to the opportunity cost approach has been used.

Productivity Losses in the Workplace Productivity losses to the workplace for fatalities, serious and minor injuries. The assumption is that had the accident not happened the victim would have worked and made contributions to the community.

Premature Funeral Costs The present discounted value of paying for a funeral in the present instead of at the end of the victim's normal expected life span.

Medical Cost Prior to Death Any medical costs incurred where the outcome was death.

Pain and Suffering Pain and suffering is taken to include the pain and distress endured by the people directly involved in aviation accidents.

Property Loss and Damage Damage to aviation vehicles and any property on the ground as a result of an air accident.

Insurance Administration Costs The underwriting expenses related to claims made as a result of aviation accidents.

Legal Costs Legal costs incurred when a settlement to an aviation accident is contested.

Airport Closure/Delay Costs Any costs incurred due to the disruption caused to other flights or aircraft activity as a result of an air accident.

References

- ABS 1996a *Deaths—Australia* catalogue 3302.0 Canberra: Australia
- ABS 1996b Australian workforce participation rate unpublished data
- ABS 1996c Australian workforce earnings unpublished data
- Anderson, M and Ross, B 1987 *Labour force projections and tables of working life: A preliminary investigation*, Paper presented at the 16th Conference of Economists held at the Holiday Inn, Surfers Paradise
- Atkins, A S 1981 *The Economic and Social Cost of Road Accidents in Australia: With Preliminary Cost Estimates for 1978* CR 21 Melbourne: Centre for Environmental Studies, University of Melbourne
- BASI 1996 *Aviation Safety Indicators December 1996* Canberra: BASI
- BASI 1997 *Quarterly Safety Deficiency Report QSDR 4/97 1997* Canberra: BASI
- Brownbill, A 1984 *The Cost of Aircraft Accidents in Australia: With Preliminary Estimates for 1980* Canberra: BASI
- BICE 1988 *Cost of Road Accidents in Australia* Occasional Paper 91 Canberra: AGPS
- BTCE 1992 *Social Cost of Transport Accidents* BTCE Report 79 Canberra: AGPS
- BTCE 1994 *Cost of Aviation Accidents in Australia* BTCE Information Sheet 5 Canberra: BTCE
- BTCE 1996 *Valuing Transport Safety in Australia* BTCE Working Paper 26 Canberra: BTCE
- BTE 1998 *Cost of Civil Aviation Accidents and Incidents* BTE Report 99 Canberra: BTE (in preparation)
- Cook, M J Motha J et al 1990 Cost of aviation accident in Australia pp 593-610 of *Papers of the 15th Australasian Transport Research Forum 15 (2)* Sydney: ATRF
- Gardner, J W Sanborn, J S (1990) Years of potential life lost: what does it measure? *Epidemiology* 1990 (1), 322-329
- Guria, J C 1990 Estimating of social costs of traffic accidents and injuries in New Zealand, pp 579-592 of *Papers of the 15th Australasian Transport Research Forum 15 (2)* Sydney: ATRF
- Hahn, R A (1995) Years of accumulated ability lost (YAAL): A new measure for public health *Technology: Journal of the Franklin Institute* 1995 (332A), 101-103
- Hariton, G. 1984, *Railway Costing: A Review*, Canadian Transport Commission, Ottawa

ICAO 1994 *Aircraft Accident and Incident Investigation, International Standards and Recommended Practices Annex 13 to the Convention on International Civil Aviation, Eighth Edition*, July 1994, Montreal: International Civil Aviation Organisation

Internet Various web sites and home pages notably US Department of Health and Human Services CDC

Miller, T R 1989 *Narrowing the Plausible Range Around the Value of Life* Washington, DC: Urban Institute

Miller, T R and Guria, J 1991 *The Value of Statistical Life in New Zealand* Wellington: Land Transport Division, Ministry of Transport

Miller, T R Luchter, S and Brinkman, C P 1989 Crash costs and safety investment *Accident Analysis and Prevention* 21 (4), 303-315

NHTSA (1992) *The Economic Cost of Motor Vehicle Crashes* US Department of Transport

NHTSA (1996) *The Economic Cost of Motor Vehicle Crashes* US Department of Transport

Schelling, Thomas (1968) The life you save may be your own, In *Problems in Public Expenditure Analysis* Washington, DC: The Brookings Institution