Establishing a Monetary Value for Lives Saved: Issues and Controversies

Peter Abelson

Applied Economics and
Department of Economics, Sydney University

Prepared for Cost-Benefit Conference, Office of Best Practice Regulation, Canberra, November 2007

Abstract

In Australia we spend about one-sixth of GDP to protect life and health in one way or another. This is a substantial diversion of resources away from other goods. Accordingly we would like to know whether this level of expenditure on health and safety is appropriate or whether it is too large or small. To assess such issues, quantitative measures of the value of life and health, and of safety, are needed. However most public agencies in Australia (as in most other countries) have only qualitative views about these values. This paper reviews the relevant key concepts and valuation principles based on what individuals are willing to pay for health and safety. It then describes the major methods of valuation and empirical results for values of life, health and safety. Finally it suggests possible values for saving life and increasing longevity for public policy purposes in Australia and discusses some applications. However there are some unresolved issues for which further analysis would be desirable.

1 Introduction

Most societies devote a large amount of resources to protecting life and health. In Australia the health care sector alone accounts for over 9 per cent of GDP. Safety expenditures in homes and the workplace, on safe products, in transport and in environmental protection account for several more percentage points of GDP. Depending on what is included as relevant expenditure, it would appear that as a nation we spend at least one dollar in six on health and safety. Add expenditure on the police and legal system and the proportion of GDP devoted to health and safety would be still higher.

Government has a major interest in this. Government is directly responsible for about 70 per cent of the health expenditures and for some of the transport expenditures. Government is also responsible for regulating workplace safety, for safe products, and for safety in transport and in the environment. Indeed ensuring the safety of the population and promoting its health are two of the prime functions of government.

But expenditure on health and safety has a cost. Therefore to make rational social choices the benefits of expenditure on health and safety should be compared with the costs, or in other words with the benefits of goods foregone. This comparison depends on the value that we attach to health and safety compared with other goods. The issue is complicated because we often spend money in both the public sphere and in markets to reduce the risk of an adverse event especially the risk of death. This introduces the valuation of probabilities into the equation. We often need estimates not only of the values of longevity and health but also of values of reductions in small risks of death.

Over the last two decades, economists around the world have devoted considerable study to the valuation of life and health and proposed many numbers. However, important issues are unresolved. They include the relationship between the value of life and the value of a life year and how the value of life may vary with age and health status. Also, as we will see, the range of possible values for life and for health states is large.

In Australia there has been relatively little analysis of these issues. Apart from some transport agencies that have developed values of life for investment appraisals, few agencies have developed values for life or health. However, the NSW Roads and Traffic Authority has commissioned a large study by PricewaterhouseCoopers (directed by Professor David Hensher) that is likely to produce recommendations shortly.

Part of the problem is political. Governments may find it hard to declare that life has some finite dollar value. And governments certainly find it hard not to rescue individuals who are known to be at risk of death whatever the expense. However, it should be possible to establish *the value of a statistical life.* Economists define this concept as the amount that society is willing to invest ex-ante to save the life of one person whose identity we do not know in advance.

In this paper the following section reviews the key concepts relating to health and safety and valuation principles. Sections 3 and 4 describe valuation principles and the major methods of valuation. Sections 5 describe empirical results for health and safety. Sections 6 and 7 discuss possible values for life and life years for public policy purposes in Australia and briefly discuss some applications. There is a short concluding section.

2 Key Concepts

A key concept is the value of a statistical life (VSL). By convention this is usually assumed to be the life of a young adult with at least 40 years of life ahead. It is a statistical life because it is not the life of any particular person.

A related reason for talking about the value of a statistical life is that in many cases policies reduce the probability of death. Suppose that a policy or project reduces a small risk of fatality by one in a thousand (by 0.1 per cent). If 1000 individuals are the subject of this policy, on average the policy will save one life. This is important because what we are valuing is the reduction in a small risk for each of 1000 persons. Accordingly empirical studies need to focus on the values that individuals attach to reductions in such risks. The value of VSL will reflect these values.

For many purposes we want to know the value of a year of life because in many cases, especially in health interventions, we can save a small number of years of life rather than 40 years. However, the value of life (VSL) should presumably be related to the value of a life year (VLY).[1] The higher is the value of life, the higher would be the value of a life year, and vice versa.

As observed above, VSL is often taken to be the present value of 40 life years. Most often VLY is taken to be the constant annual sum which, taken over a remaining life span, has a discounted value equal to the estimated VSL. For example, if the VSL for healthy persons with a life expectancy of 40 years is $2.5 million, applying a private time preference discount rate of 3 per cent, the value of a healthy life year would be about $108 000.

$$\$2.5 \text{ million} = \$108{,}000 / 1.03 + \$108{,}000 / 1.03^2 \ldots + \$108{,}000 / 1.03^{40} \qquad (1)$$

This assumes that VLY is constant over each year. This may be a fair assumption but as discussed below VLY may vary over time. Also the result is sensitive to the choice of discount rate. VLY rises with a higher discount rate.

Conversely, estimated VLYs can be used to estimate VSLs that allow for age.

$$VSL(a) = VLY/(1+r) + VLY/(1+r)^2 \ldots + VLY/(1+r)^n \qquad (2)$$

where *a* denotes age, *n* is remaining life expectancy. For example, if estimated VLY is $108 000, the current age is 65 and life expectancy is 80 years, VSL at age 65 would be $1.29 million. This implies that VSL falls steadily with age.

[1] When the value of a life year is derived from the value of a statistical life, it is sometimes described equivalently as the value of a statistical life year.

The value of a life year may also be described as the value of a quality adjusted life year (QALY). In the health economics literature, a QALY is a year of perfect health.

This takes us to the concept of a health state, which is also known as a quality of life (QoL) state. Typically the values of QoLs vary from 1 down to 0. Thus a QALY equals a QoL state with a value of one. On the other hand, a state of death has a value of zero. Accordingly, if someone has a QoL state equal to say 0.5, the value of a life year for that person would equal half that of a person in full health, which would be $54 000 in the above example. Improving the health status of that person from 0.5 to 1.0 would also be valued at $54 000.

Two further points about QoLs should be noted. First, to be consistent with estimated values for VSL and VLY, changes in QoLs should be based on willingness-to-pay values for health states rather than on medically determined estimates of quality of life states. Second, if the valuation methods are consistent, QoLs can be used to weight gains in life years and hence to determine gains in QALYs.

3 Valuation Principles

The traditional method of valuation was the human capital or cost of illness (COI) method. COI is the ex-post sum of various identifiable costs, such as loss of work income and medical expenses, but usually does not account for pain and suffering. The value of health is the increase in the earnings and avoidance of medical expenses of individuals as a result of improved health. The value of life is the discounted present value of output or income.

However, the COI valuation method has several limitations. First, it can hardly apply to fatalities for non-working individuals. Second, it makes no allowance for pain and suffering. Individuals can enjoy relief from pain and suffering and an improved lifestyle without any increase in earnings. Third, it does not reflect the reality of many public policy decisions that are designed to reduce the risk of accidents or injuries rather than to prevent a specific accident or injury. If individuals are risk averse, they may be prepared to pay a premium to reduce risk. Most fundamentally, it is an ex-post value of life based on what is lost after the event of death. For most policy purposes, we want to know what individuals are willing to pay to reduce the possibility of early death.

The alternative willingness to pay (WTP) approach to valuing health is an ex-ante measure of the amount that individuals are willing to pay for various perceived gains. These gains may be a certain improvement in health or the prevention of an impaired health state or a reduction in risk of an adverse event. The ex-ante measure is the appropriate measure for most policy purposes.

Moreover, it is a fundamental premise of welfare economics that public policy decisions should generally reflect the preferences of those who will be affected by them. Thus we want to know what individuals are willing to pay for reduced risk of injury or death. In these cases, it is similar to talking about the value of insurance policies. Importantly, as we have observed, many public policies or projects involve only small changes in risk. The policy issue is then how much *marginal* consumption (or income) are individuals willing to forego in return for this *marginal* increase in safety?

Because we are dealing with WTP to reduce small probabilities of death, VSL is not constrained by the discounted present value of a person's earnings. The proportion of income that an individual is willing to forego may be greater than the proportionate reduction in risk. Suppose for example that an individual has a 99 per cent chance of an income of $100 000 next year and a 1 per cent chance of $0 due to premature death. His expected income is the weighted sum of his expectations, which would be $99 000. However, he may well be willing to pay say $5000 dollars for the certainty (if that were possible) of being alive to earn $100 000 next year. His expected net income after purchase of insurance would then be $95 000.

If 100 individuals with an average income of $100 000 are willing to pay on average amount of $5000 to improve the probability of life for one year by 1 per cent, collectively they would be willing to pay $500 000 to give one person an extra year of life. This is clearly greater than their average income.

Most studies of the value of life are based on these kinds of marginal trade-offs between income (or expenditure) and changes in the risk of death. If a number of individuals are willing to pay an average of $\$X$ to reduce the probability of death by Y per cent (where Y is expressed as a value between 0 and 1), the value of life is given by X/Y.

Note that $\$X$ is here an average of the willingness to pay values of different individuals. If, as is likely, these willingness-to-pay values vary over the population, some groups may have higher values of life than others. This would imply that there is no unique VSL or VLY over the population. Arguably economic evaluations should allow for different VSLs. However, as discussed in section 6, countries and agencies within countries commonly adopt an average VSL and VLY.

Finally it may again be observed that these estimated values reflect what individuals are willing to pay for reduced risks of death. These are sometimes described as efficiency values. If society so wishes, it may replace these individual values with socially determined higher or lower values that reflect different ethical views.

4 Methods of Valuation

Willingness to pay values for life are derived in three main ways: from wage-risk studies, studies of consumer purchases, and stated preference (SP) surveys.

In wage-risk studies, workers are assumed to be willing to give up income for improved workplace safety or to require (accept) income for taking on more risk. To disentangle the wage–risk trade-off from other factors that affect wages, it is necessary to employ statistical models that control for differences in worker productivity as well as the quality component of the job.

The wage-risk equation is typically of the following kind:

$$w_i = \alpha + \beta_1 H_i + \beta_2 X_i + \gamma_1 \pi f_i + \gamma_2 \pi n f_i + \gamma_3 WC_i + \varepsilon_i \tag{3}$$

where w is the wage rate of worker i, α is a constant term, H is a vector of personal characteristic variables for worker i (such as age and level of education), X is a vector of job characteristics variable for worker i, πf_i and $\pi n f_i$ are the probabilities of a fatal or non-fatal injury, WC is workers compensation for an injury, and ε_i is an error term reflecting unmeasured factors. The coefficients show the effects of a change in the independent variable on the wage rate. In this case, γ_1 shows the change in wage rate associated with an increased risk of a fatality. This may be viewed as a willingness to pay for safety by accepting a lower wage rate or as a willingness to accept a higher risk in return for wage compensation. Of course, WTP values should be after-tax values, whereas wage-risk studies tend to pick up gross wage rates.

The wage-risk method presumes that workers are similar except in the measured characteristics, they understand risk differentials which are often small, and that workers in safe occupations have similar safety preferences to those workers who are willing to take on risks. It also presumes that the model distinguishes between the premiums for fatal and non-fatal accidents and that the results are not statistical artefacts of the way in which the model is specified (Miller, 2000). Researchers have tested various linear, log-linear and semi-logarithmic functional forms of the wage risk equation and the results have been quite sensitive to the specification. These strong assumptions have led some analysts to question the results (Dorman and Hagstrom, 1998). Jones-Lee and Loomes (2004) express concern that wage-risk studies are seriously constrained by weak perceptions of risk by economic agents.

Studies of consumer behaviour infer values of life from trade-offs between mortality risk and money. Here economists are estimating a hedonic price equation rather than a hedonic wage equation. The price trade-offs involve seatbelt use, cigarette smoking, home smoke detectors, automobile safety bicycle helmets and housing price responses to hazardous waste site risks.

For example Blomquist (1991) and Blomquist et al. (1996) estimate the value of risk reduction implied by the use of safety belts, child restraint systems, and motorcycle helmets. In order to estimate the true WTP values for risk reduction, these studies have to make adjustments for individuals' under or over perception of the true risks as well as estimates of time values. In this case there is a presumption that consumer of safer products would have similar safety preferences to consumers of less safe products.

Andersson (2005) analysed the price premiums that Swedish consumers were willing to pay for safer motor vehicles and estimated that the value of a statistical life (VSL) was between US$1.0 million and 1.5 million in 1998 prices, which he noted was a significantly lower than the value that had been inferred from several other American and Swedish studies of motor vehicle purchases.

Stated preference (SP) methods derive estimates of WTP values from individual responses to survey questions. In **contingent valuation (CV)** surveys, individuals are asked what they are willing to pay for a defined health benefit or for a reduction in risk.

For example, Hultkrantze et al. (2006) conducted a CV study in Sweden to elicit WTP for safety enhancement. In this case the outcome was taken as a certain ex-post outcome and did not involve payment for a reduction in risk. The study found that, for a given outcome, respondents were willing to pay more for a personal traffic safety device than for a public road safety program.

On the other hand, Vassanadumrongdee and Matsuoka (2005) asked respondents in Bangkok what they would be willing to pay for a reduction in risks in mortality from traffic accidents and air pollution, using the double-bounded dichotomous choice method. This study found that, despite various differing perceptions about air pollution and road traffic accidents, willingness to pay amounts to reduce risk were similar for both contexts.

A problem with CV research is that individuals find it hard to provide accurate responses to direct willingness to pay questions (such as what dollar amount would you be willing to pay for *X*), especially for unfamiliar options and small changes in risks (Hammitt and Graham, 1999). On the other hand, the provision of monetary cues, such as a list of possible dollar amounts to choose between, tends to bias the results.

Consequently, in recent years a number of researchers have adopted choice modelling (CM) methods. Actually a simple CM study is quite similar to a CV study. Individuals may be asked simply whether they would be willing to pay $*X* more for choice *A* than choice *B*. This is not dissimilar to the referendum (dichotomous choice) model. More complex CM studies have more choice attributes and a more implicit trade-off between money and these attributes. The most common form of choice modeling is choice experiments (CE), which is also known as conjoint analysis. In CE studies, respondents are typically asked to choose between three alternatives that are characterized by various attributes, including a monetary attribute. The choice between alternatives implies a trade-off between the price and other attributes of the good, including health.

For example, in a large CM study in New Zealand (Guria et al., 1999) asked respondents to choose between two hypothetical residential areas, one of which had higher road safety but also a higher cost of living. The answers were used to estimate VSL. Respondents were also asked to choose between various pair-wise options that would reduce a certain number of fatalities, or permanent or temporary injuries (a graded pair approach). The answers were used to estimate the relative values or life and permanent and temporary injuries. Although the study elicited generally realistic responses, the authors observed that some responses entailed very high WTP values that were considered unrealistic. Also, the definition of permanent injury was not tight enough to provide clear answers.

Tsuge et al. (2005) develop a complex choice-set model for valuing reductions in mortality risks due to accident, cancer and heart disease. In this case, respondents had to choose between three options. There were eight questions. For each question, there were two options involving purchase of risk reduction for an unwanted event (an accident or cancer and so on) and a third option of no purchase. The study based in Japan estimated an average VSL of US$2.9 million along with factors causing variations. The study found that VSL varied with the type of population but not much with the type of risk. It also found that the timing of the risk reduction was highly significant, with individuals placing a much higher value on reductions in current than in future risks.

However, there are concerns that respondents may not give accurate answers to questions involving small risk reductions and that answers may depend on the way on which questions are presented (Miller, 2000). Choice modelling studies have produced a wider range of results than revealed preference studies. On the other hand, some recent studies represent sophisticated attempts to deal with these known problems, for example the study by Krupnick et al. (2000) in Ontario, Canada.

Comparing valuation methods. Economists hold various views about the merits of the three main valuation methods. Revealed preference studies in labour or product markets are based on actual behaviour but are constrained by available data and have to make strong assumptions about understanding of probabilities. Stated preference studies can be custom-built and are flexible, but usually offer hypothetical choices and weak or non-existent budget constraints. These problems are generally well known. Good studies of any kind recognise the inherent problems of the method and attempt to deal with them.

Valuing health states

The value of health states can also be investigated by asking people quite directly what they are willing to pay for health. CV studies are the main source of WTP values derived in stated preference surveys. In CV studies, subjects are typically asked what they would be willing to pay for relief from an acute morbidity such as earache or asthma, in some cases for relief from only an additional day of the morbidity (see for example, Loehman et al., 1979, Thayer et al., 1991, Harrison et al., 1992).

In such studies it is important to be clear about what is being measured. For example, we may ask someone what is the maximum amount he or she would be willing to pay to be relieved of pain. Alternately we could ask someone what he or she is willing to pay to avoid pain given the feasibility of averting behaviour. If someone is asked what she would be willing to pay for relief from a headache for a day, she may estimate the value of the relief as $50. On the other hand, she could think that a headache is a more minor problem because she can get rid of the symptom with a few pain killing pills.

SP studies can address the relevant context directly, are flexible, and can present rich information sets. Using the contingent valuation approach, following various contextual questions, individuals are asked simply to state their values for hypothetical goods. For example, Ho *et al*. (2005) asked individuals what they were willing to pay for pain relief from permanently disabling occupational injuries. They found that individuals in Taiwan were willing to pay about US$65 per day for a painkilling drug to alleviate the pain from a permanent disability with no side effects. However, individuals find it hard to provide direct WTP responses to unfamiliar or complex options. On the other hand, the provision of monetary cues, such as a list of dollar amounts to choose between, tends to bias the results. And sometimes respondents object to saying how much they would pay for services that they consider should be free.

Consequently some researchers prefer choice modelling methods. Because there are typically several choices with multiple attributes, this approach tends to be less confrontational than contingent valuation. Valuations of goods can be inferred from the monetary trade-offs implicit in the choices.

Johnson *et al*. (1999) employed a discrete choice experiment approach to estimate what individuals would be willing to pay for improved respiratory and cardiovascular health, including small changes in conditions. The aim of this study was to obtain estimates of the dollar amounts that individuals are willing to pay to avoid various specified injuries, rather than to estimate what individuals would be willing to pay to reduce the risk of injuries. This approach allowed for a rich set of choices and attributes to be examined.

Alternatively the value of health states can be estimated via a two-step process. The first step involves establish the relative disutility of health states (such as a broken leg or angina) in terms of a quality of life (QoL) index. The second step applies a monetary metric to the index to produce monetary values for each health state.

QoL indices may be derived from surveys of patients or of the general population or the opinions of health experts. In QoL surveys, subjects are generally asked to evaluate health states in utility terms rather than in dollar values. A simple way to do this is the rating scale. Typically respondents are presented with a scale running from 100 for perfect health to 0 for states equivalent to death and asked to indicate where other health states would rank. More complex methods involve gamble, time and person trade-offs (Mathers et al., 1999, p.10). For example, in a time trade-off, the QoL is the ratio of healthy years to less healthy years between which the individual is indifferent. Subjects are asked to choose between an impaired health state for a specified period (say 10 years) and a shorter life in full health. The length of life in full health is varied until the respondent is indifferent between the two. If the life in full health is say 4 years, on a scale of 0 to 1 the QoL index of the impaired state is 0.4 (because 10 less healthy years × 0.4 = 4 healthy years). The annual value of life in this impaired health state is the product of the estimated QoL and VOLY.

Clearly the value of this approach depends on how closely QoL indices reflect the utility of health states. While patients may be expected to understand this best, they may not be representative if the full population. And in some cases health experts may judge the relative utility better than patients themselves.

To estimate the value of a health state, economists then draw on the concept of the value of a healthy life year. If VLY equals $100 000, the value of a year in an impaired state with a QoL equal to 0.8 is $80 000. Conversely avoiding the impairment for a year would be worth $20 000 (0.2 times the value of a healthy year). This approach can be used to value acute as well as chronic health conditions. Suppose that someone has an acute condition for seven days which if experienced for a year would correspond to a QoL of 0.8, the cost of the acute morbidity would be $384 ($20 000 multiplied by 7/365).

This two-step approach to valuing health states process provides a pragmatic alternative approach to valuing health states. But it is premised on the assumption that the QoL indices approximate to WTP values of the health states.

5 Empirical Results

The results of a number of VSL studies are shown in US dollars in Table 1. The dollar values relate to the study year unless otherwise cited (which would typically be a year or two before publication). The studies include survey results from several meta-analyses, mainly of wage-risk studies in the US, CV studies from several countries, and two Australian wage-risk studies.

Table 1 Surveys of selected VSL results

Authors	Year	Original studies	Estimated VSL (US $s)[a]
Kneisner and Leith	1991	Wage risk study, Australia	About $2.2m
Viscusi	1993	24 wage-risk studies, 4 CV studies[b]	Most estimates in $3m-$7m range. Range 1.2m-$9.7m
Jones-Lee	1994	13 wage-risk studies, 7 other revealed preference studies, 8 CV studies	$1.9m-2.2m are median and mean for most reliable results
Jones-Lee et al	1995	CV study, UK	$2.7m
Schwab-Christe	1995	CV study, Switzerland	$7.5m
Desaigues and Rabl	1995	CV study, France	$3.4m
Van den Burgh et al.	1997	10 US and 1 UK wage-risk studies	$3.9m 'most reliable estimate'
Johannesson et al.	1997	CV study, Sweden	$3.8m in 1995 prices
Miller et al.	1997	Wage-risk study, Australia	$11.3m - $19.1m
Desvouges et al.	1998	28 wage-risk studies and 1 CV study, US	VSL of $3.6m, with confidence interval of $0.4m-$6.8m
Day	1999	16 wage-risk studies, 10 US, 2 Canada, 4 UK	$5.6m is best estimate
Guria et al.	1999	CV study, New Zealand	$2.1m
Meng and Smith	1999	Wage risk study, Canada	$5.2m
Krupnick et al	2000	CV study, Canada	$0.5m - $2.0m
Gayer et al.	2000	Property values and waste site cancer risks, US	$4.3m - $5.0m
Baranzini and Luzzi	2001	Wage risk study, Switzerland	$6.3m to $8.6 m
Jenkins et al.	2001	Purchase price of bicycle helmets	$2.1m - $4.3m (for adults)
Mrozek and Taylor	2001	40 wage-risk studies	Approximately $2.0m
Tsuge et al.	2005	Choice modelling, Japan	$2.9m
Andersson	2005	Motor vehicle purchases, Sweden	$1.0m to $1.5m

(a) Values at time that study was made (usually before publication of results).

(b) Excludes two early study outliers with very small samples and extreme results.

The meta-analyses systematically analyse the differences between the studies and attempt to synthesise the results. Typically a meta-analysis uses least squares regression to explain the findings of studies in terms of specific underlying causes and research contexts and techniques. There is some overlap in the studies on which they draw.

Clearly the results range a great deal. This reflects both differences in market conditions and in study method and reliability. Values rise with income. They also reflect differences with regard to worker preferences over risk.

Also quality of study matters. It would be wrong to regard each finding as equally valid. Viscusi and Aldy (2003) provide a comprehensive analysis of the range of studies that have been done and bring to bear on the analysis a high level of expertise in the subject. Accordingly, their conclusions have considerable weight.

Viscusi and Aldy (ibid) review the estimated value of a statistical life in:

- Over 30 U.S. studies of labour markets;
- Twenty other non-U.S. studies of labour markets; and
- Eleven studies of U.S. housing and product markets.

They find that the value of a statistical life in the labour market (wage-risk) studies in the United States, which they regard as the more reliable, is between US$5 million and US$12 million in 2003 prices, with a median value of about US$7 million.

Turning to studies in other countries, Canadian studies have produced similar results. U.K. studies produced much higher values, which Viscusi and Aldy conjecture reflect some other unobserved returns to the workers. They also cite one Australian wage-risk study (Miller et al., 1997), which estimated a very high implicit VSL of $11.3 million to $19.1 million, but offer no explanation for this high figure.

Based on theory and analysis, Viscusi and Aldy (ibid) suggest that the income elasticity of the VSL is in the order of 0.5 to 0.6. This means that, for every 1 per cent increase in income, WTP values for reducing the risk of death rise by 0.5 – 0.6 per cent. Using cross country analysis, Miller (2000) reported a higher income elasticity of about 0.9.

However, the variations in the results are indicative of limitations in such studies. Most compensating wage differential studies are based on industry-wide occupational averages. Some studies include only deaths directly related to the employment; others include other early deaths. Critically, the studies assume that workers have an accurate idea of the risks. Many studies do not control for all significant socio-economic differentials between workers. Some studies do not control for non-fatal injury risks, which tend to be correlated with fatal risks. Excluding non-fatal risks creates higher values for fatal risks.

There have also been numerous stated preference (SP) studies of the value of safety. de Blaij et al. (2003) cite eighteen SP studies of WTP for road safety alone. They find that SP studies produce slightly higher VSLs than do RP studies.[2] They suggest that this occurs because SP studies deal with hypothetical issues whereas RP studies deal with real expenditures. Another common finding from SP studies is that most individuals place a high value on complete elimination of risk.

On the other hand, Viscusi and Aldy (ibid.) find that product market studies tend to give lower values for a statistical life. The reasons include the discrete nature of the choice (this means that we can infer only the minimum amount that someone is willing to pay for the safety that is purchased); the risky attitudes of some consumers such as smokers (which means that the values of more risk averse individuals are not observed); and the use of imputed time values in some cases (for example to fit seat belts) instead of observed dollar values. As with wage-risk studies, a key issue is whether the relevant individuals fully understand the safety features or risks, in this case whether consumers fully understand the safety features or the lack of them in their purchases. Another issue is whether all the damage costs associated with the safety risks are internalized.

Generally, and crucially for most research in this subject, many public policies or projects involve small changes in risks for already low probabilities of harm for each individual. For example, the risk may change from 2 in 10,000 to 1 in 10,000 for each individual, but if large numbers of people are involved, the changes in risk may involve several fewer deaths in a year. Most people find it hard or even impossible to place values on such small changes in risks. Hammitt and Graham (1999) point out that willingness to pay amounts for safety should be roughly proportional to the change in risk. However, most estimates of WTP for risk reduction are not sensitive to changes in probability — the sizes of changes in WTP are less than the changes in probability.

Also, willingness to pay to reduce the risk of death depends on many factors, including age, income, the type of risk, and type of death. Jones-Lee (1974) argues that WTP is an increasing function of the near-term probabilities of death and of an individual’s wealth. Also WTP for safety rises for risks over which individuals have little control and to avoid deaths preceded by painful chronic conditions.

Jones-Lee et al. (1998) cite studies that show willingness to pay for safety depends on the type of risk, principally on the degree of control and responsibility. Average WTP to reduce risks of death in the London underground is 50 per cent higher than WTP to reduce road fatalities. Pearce (2000) argues that people are willing to pay a high

[2] Krupnick (2004) also reports that SP studies estimate slightly higher valuations than do RP studies.

premium to reduce the risk of nuclear disasters. On the other hand, research indicates a 25 per cent discount for prevention of fatalities from domestic fires, which are held to be the responsibility of the household. Romer et al. (1998) found that WTP to reduce risks from hazardous waste risk sites in Berlin depended on the availability of other means to avert the risks, for example by avoiding contaminated water and food supplies.

Not surprisingly, willingness to pay to reduce the risk of death varies significantly with the type of death. Individuals are willing to pay more to avoid painful, drawn-out death. Tolley et al (1994) estimated that the mean WTP to avoid an unforeseen instant death was US$2.0 million (in 1994), compared with $2.75 million for avoiding death by heart disease and $4.0 million for death by lung cancer. In these cases the WTP values include willingness to pay to avert the pain and suffering of chronic morbidity before death as well as premature mortality.

The value of a life year

Values for VSL and VLY should be consistent. However, if the discount rate is constant, VSL and VLY cannot both be constant with age. If VSL is constant with age, VLY rises with age. On the other hand, if VLY is constant with age, VSL falls with age. Also, to ensure consistency between values of health states, VSL should fall with declining health status.

The assumption of a constant VLY is constant has some policy attraction. However, this implies that the utility of consumption is constant for all ages, which may not be the case. VLY may be higher at some ages than others. Indeed Pearce (2000) suggests that it may be inappropriate to infer VLY from VSL. He argues that researchers should investigate what people are WTP for an extra life year. However, there appears to have been little research into VLY as a concept distinct from VSL. Johannesson and Johansson (1995) appear to be an exception.

Drawing on models of lifetime consumption, theoretical studies tend to find that the VSL rises until about age 40 and then falls (for example Shephard and Zeckhauser, 1982; Cropper and Sussman, 1990). However, it is possible to construct models in which willingness to pay for safety continues to increases with age as the marginal utility of consumption rises (with reduced life expectancy) and there is a positive discounting effect as the high value years are closer to the present (Johansson, 2002a).

Most VSL estimates are derived from occupational risk contexts where the average age is about 40 years. However, several studies have attempted to discover the impact of age on VSL. Table 2 shows some ratios of age-specific VSLs to mean VSL, with an index of 1.00 for age 40. Based on these and other empirical studies, Pearce (2000) concluded that WTP falls with age but only after age 70.

Table 2 Estimated ratios of age-specific VSL to mean VSL

Age	Jones-Lee et al. 1989	Jones-Lee et al. 1993	Jones-Lee et al. for Dept of Health, UK 1999[a]	Krupnick et al. 2000
40	1.00	1.00	1.00	1.00
50	0.98	0.99	1.00	1.13
60	0.86	0.97	1.00	1.13
65	0.76	0.95	1.00	1.13
70	0.62	0.92	0.80	0.72
75	0.46	0.89	0.65	0.72
80	0.28	0.85	0.50	0.72
85	0.07	0.82	0.35	0.72

(a) Results quoted by Pearce (2000).

6 Possible Values for Life and Life Years

In evaluating public policy standard economic practice is to derive the values of goods from individuals' own valuations of them. Thus, if estimated average VSL is $3.0 million, society should be willing to invest up to $3.0 million to save a life.

Several questions arise. These include:

- Are individual valuations a complete and appropriate guide to social values for loss of life?
- Should the social value of life be an average VSL or should it vary with:
    - income,
    - type of risk,
    - type of death, and
    - age?
- Given that VSL may substantially exceed average income, can society afford to base public policy on individuals VSLs?

Individual willingness to pay values for safety may not truly reflect social values for two reasons. First, they are generally an incomplete measure of the value of life because they allow only partly for losses to families and relatives. Various studies have documented that family and relatives are willing to pay to reduce the risk of death of close members (Schwab Christe and Soguel, 1995). Jones Lee (1992) suggests that, to allow for altruism, social values should be 1.1 to 1.4 times individual values. This is a conservative estimate designed to avoid double counting as individual WTP values often includes a component to avoid hurt to families. Also society may lose from a loss of a person's productive years, as some of the value of an individual's productivity typically accrues to other economic agents such as employers.

Secondly, social valuations are ultimately ethical judgments. If it so wishes, society may place a higher or lower value on saving lives than is implied by individual willingness to pay values.

Reflecting a social judgment, it is common in cost-benefit studies to adopt an *average* WTP value for life, as for certain other goods such as savings in leisure travel time. This is widely regarded as ethically appropriate. Thus, VSL is generally held constant regardless of the income of any social group either at any point in time or over time.

However, there is an efficiency argument for varying VSL with the type of risk, by increasing VSL for the risks that individuals are most anxious to avoid, notably for risks over which they have little or no control. Strand (2002) found that preventing deaths from environmental causes is more highly valued than preventing deaths from heart attacks or auto accidents. This implies that society would be collectively willing to invest more in some safety policies than in others.

Some analysts also propose that a higher value should be attached to avoiding some types of death, for example cancer deaths, because of the pain and suffering beforehand. However this pain and suffering can be accounted for separately, and in addition to the cost of premature mortality, by including costs for impaired and painful health states. Separating loss of life from pain and suffering in life is a more transparent approach.

Turning to age related VSLs and VLYs, the choices are unattractive, the arguments inconclusive, and the survey and other evidence thin. If VLY is constant, as is often assumed, VSL declines significantly with age. On the other hand, if VSL is constant with age, VLY rises with age. This would imply that an increase in a given number of years (and any given improvement in health status) is more valuable to an old person than to a young one.

If we have to choose between a constant VLY and a constant VSL, a constant VLY seems more attractive. This implies that, other things such as health status being equal, saving more life years is better than saving fewer years. It also means that the value of an improvement in health status is the same at all ages. Cropper et al. (1994) found that people generally favour safety programs that save the lives of young people and it seems likely that most people would favour programs that maximise life years rather than lives saved. However, other possible assumptions about the nature of VLY and VSL over time may need to be examined.

Finally, is it feasible to allocate large amounts of public resources to life and health based on individuals' WTP for marginal changes in safety? If we are concerned only with marginal public decisions, it does not matter that VSL exceeds individual budget constraints. But, in aggregate, groups of individuals cannot spend more than their total income on saving lives. Given the high proportion of GDP spent on health and safety, the aggregate budget implications and feasibility of basing all public policy for safety and health on individual marginal valuations may require consideration. As far as I am aware such a study has not been done.

Some international standards

Most official VSLs are based on an average value for death of a healthy person at age about 40 years. Drawing on 21 wage-risk studies and 5 ‘high quality’ contingent valuation studies, the United States Environmental Protection Agency (USEPA, 2000) recommended general use of VSL of US$6.1 million in 1999 dollars. The USEPA noted that some studies indicate that VSL peaks in middle age and declines thereafter and that VSLs may vary with health status and type of risk. It also noted that VSL is often taken to be the sum of discounted values for each life year with each life year having the same value. This method was used to evaluate the sensitivity of the benefit estimates in the EPA’s retrospective evaluation of the *Clean Air Act* (USEPA, 1997). USEPA (2000) concluded that, given the uncertainties about the determinants of VSL, general use of a single value is preferred along with sensitivity tests, until more is known about how VSL varies with individual and environmental factors.

Official European VSLs are considerably lower, typically about US$2.0 million.[3] The UK Treasury (2003) reported that the Department of Transport values the reduction in the risk of death from road transport at about £1.145 million in 2000 prices, equivalent to about A$3.0 million in current Australian prices (based on market exchange rates). UK Treasury also notes that the Department of Human Services doubles this figure to allow for the personal costs of death from asbestos-related cancer.

The European Union (2001) recommended a VSL in the range of ε0.9-3.5 million with a best estimate around ε1.4 million in 2000 prices, which would be equivalent to about A$2.5 million in today’s prices. The EU also argues that VSL is likely to decline with age and proposes that for elderly persons likely to be affected by environmental pollution a VSL of around ε1.0 million in 2000 prices be adopted. A cancer premium may be added to reflect the impaired state of health before death. On the other hand, the EU recommends, on ethical grounds, that all EU members adopt a common value irrespective of income differences.

[3] Also, Krupnick et al (2000) note that Health Canada uses an age adjusted VSL of Cnd$4.3 million in 1999 prices.

VSL and VLY values for Australia

There is no general VSL in use in Australia. Here, road agencies have been the main users of VSL estimates. For example, NSW Roads and Traffic Authority (2005) recommends that a VSL of A$1.57 million should be used for fatalities avoided. This figure includes an estimated present value of loss of income and a rather arbitrary amount (a little over $0.4 million) for non-economic costs and loss of quality of life. The latter component was included in the cost of a fatality only in 2002 following a report by Austroads (2002). This VSL is applied to fatalities of all ages.

To estimate the national cost of road crashes, the Commonwealth Bureau of Transport Economics (2000) adopted $1.36 million for loss of life. This included $0.54 million for loss of workplace labour, $0.50 million for loss of home and community labour, and $0.32 million for loss of quality of life. This is essentially an ex-post cost of illness approach rather than a WTP value. The loss of quality of life was based on court damages in cases of extreme health impairment. It is not clear that this is relevant to a fatal accident.

In a number of recent reports for the Australian Department of Health and Ageing, Applied Economics has drawn on the recommendations in Abelson (2003) and adopted a VSL of $2.5 million and a VLY of $108 000 (see for example Applied Economics, 2006).

On the other hand, in a series of reports on the costs of illness, Access Economics has concluded that the VSL range in Australia lies between $3.7 million and $9.6 million and adopted a mid-range estimate of $6.5 million (see for example, Access Economics, 2007).

Given the lack of Australian research on VSL (at least until the NSW RTA study is concluded), Australian estimates of VSL must draw on overseas studies and values. However, given the research findings as a whole (see Table 1 and the discussion following) and the values employed in Europe, *A$3.0 million to A$4.0 million would appear to be a plausible VSL for a healthy prime age individual in Australia at present*.

Allowing 40 years of life lost and a utility discount rate of 3 per cent, a VSL of $3.5 million implies a VLY of $151,000.

Consistent with this approach, age-specific VSLs would equal the present value of future VLYs of $151,000 discounted by an appropriate discount rate, say 3 per cent per annum. This implies that at age 60 and a life expectancy of say 20 years, VSL would fall to $2.25 million. This approach appears broadly consistent with public values, but it may represent a sharper decline in VSL than is socially preferred.

However more research on, and discussion of, these issues and their implications are required.

Health state values for Australia

The reader may also note the estimates of the costs of health states in Australia in Abelson (2003). These estimates were based on the assumption at that time that VLY should equal $108 000. Using various QoL indices, Abelson estimated the costs of a large number of acute and chronic morbidity conditions.

The estimated values for the selected acute morbidities range from $10 per day for mild asthma up to $125 for severe food poisoning. Typical values for relief from acute morbidities such as earache, throat discomfort, eye irritation, and moderate asthma, are around $30 - $50 per day.

The estimated values for the selected chronic morbidities range from around $20 000 for a year of relief from mild bronchitis or medium angina up to $120 000 plus for a year of relief from quadriplegia or severe brain damage. Again, there are many morbidities in the middle of this range, valued at between $60 000 and $80 000 a year, including symptomatic HIV, manifest alcoholism, moderate dementia, severe bronchitis, several forms of cancer, and an injured spinal cord.

7 Applications of Valuations

As we noted at the start of the paper, Australians invest about one dollar in six in some aspect of health and safety. Government directly through its own expenditure or indirectly through regulations is responsible for a high proportion of this expenditure.

Road authorities have long included formal valuations of safety in evaluations of road design and development. Safety is a major issue in most other forms of transport, but tends to be included less formally in evaluation work. In the rail sector large sums are often spent on small increases in safety in the UK and Australia, which imply a higher value on life in rail than in road transport. The value of safety is also a major factor in developing aviation and air space standards, but it is not clear that the Civil Aviation

Safety Authority has consistent values for safety or employs formal cost-benefit evaluation processes.

Obviously, the value of longevity (and of VLY) is fundamental to the use of resources in the health sector. In recent years, the value of statistical life (or life years) has informed many studies commissioned by the Australian Department of Health and Ageing (DoHA). For example to satisfy the requirements of the Commonwealth for a regulatory impact statement, DoHA commissioned Applied Economics (2003) to prepare a cost-benefit study of the proposals to place graphic pictures of diseases on the front of all tobacco products. The major benefit of the regulation was the increase in the years of life of smokers who were expected to quit smoking as a result of the graphic warnings. It is also believed that the Pharmaceutical Benefits Advisory Commission adopts a yardstick dollar amount for a life year that helps to determine PBS approvals. But it is not clear how rigorously and consistently such standards are applied. Perhaps more importantly it is not clear how valuations of life and health affect the allocation of resources in state health care services.

State government regulations of workplaces, the environment and products are also driven to a large extent by concerns about life and health. For example there is currently renewed concern about deaths of toddlers in backyard swimming pools. In 1992, the NSW government required all new backyard pools to be completely fenced off. However, in 2006, 35 infants and toddlers died nationally in water-related accidents, about half of which were in backyard pools. This has led to calls for stricter regulations on pre-1992 backyard pools. Applied Economics (2002) describes an ex-post economic evaluation of the 1992 backyard pool fencing regulations in NSW. The major benefit was the estimated reductions in drownings and near-drownings. Using a VSL of $2.5 million, the report found that the costs of the 1992 regulations slightly exceeded the benefits. A major reason was that the regulations applied to a large number of households who obtained no benefit. However the result was sensitive to the various assumptions used.

In my experience, there is more economic evaluation of environmental policies, inclusive of health effects, than there is of regulations of workplaces and products. There would seem to be considerable scope for more economic evaluations of such regulations.

However, in the first instance it would be useful to survey the use of formal evaluation processes in these and other safety related areas and to identify the areas in which values of VSL and VLY would be most relevant to public policy.

8 Conclusions

Many public policies and much public expenditure are designed to reduce the risk of death and hence to save life and enhance health, but few public agencies have formulated and follow a clear set of values for life and health. In this paper I have attempted to set out the main valuation principles, to survey the main empirical research studies, and to identify possible values for longevity in Australia.

Scores of studies of the value of a statistical life have now been carried out, mainly using wage-risk or choice modelling approaches, though there are apparently only two substantive studies to date for Australia. The VSL to emerge from these studies ranges very widely from about A$3.0 million up to about A$15.0 million.

However, neither the relationships between VSL and age and health nor the value of a life year are well established. VLY is usually taken to be constant annual sum which, taken over a remaining life span, has a discounted value equal to the estimated VSL. Although this assumption does not have strong theoretical or empirical support, it provides a plausible and consistent basis for valuing both life years and health states.

Following our review of research into VSL and VLY and of international guidelines for life and health values, this paper suggests that, in 2007 prices, public agencies in Australia adopt:

- a VSL of $3.5 million for avoiding an immediate death of a healthy individual in middle age (about 50) or younger;
- a constant VLY of $151,000 which is independent of age;
- age-specific VSLs for older persons equal to the present value of future VLYs of $151,000 discounted by 3 per cent per annum.

These proposed values are consistent with economic theory, international research and international practice. However, the suggested values imply critically important value judgements (as would any proposed values) for public policy, most notably towards older people, and have unknown budget implications. These issues and others, such as the relationship between VSL and types of risk and the relationship between health status and VLY, require a great deal of further research, debate and analysis.

References

Abelson, P., 2003, ‘The value of life and health for public policy, *Economic Record*, 79, S2-S13.

Access Economics, 2007, *Painful Realities: The Economic Impact of Arthritis in Australia*, for Arthritis Australia.

Andersson, H., 2005, ‘The value of safety as revealed in the Swedish car market: an application of the hedonic pricing approach’, *Journal of Risk and Uncertainty*, 30: 3 211-39.

Applied Economics, 2002, Preparation of *Guidelines for the Economic Evaluation of Environmental Health*, included economic evaluation case studies on water quality, sulphur dioxide emissions, swimming pool safety and Legionnaires’ disease, for the Commonwealth Department of Health and the EnHealth Council of Australia. The agencies published the report in 2003 in two volumes *Guidelines for Economic Evaluation*: *the Guidelines* and *Case Studies* (see html://enhealth.nphp.gov.au/council/pubs/ecpub.htm).

Applied Economics, 2003, **‘**Cost-Benefit Analysis of Proposed New Health Warnings on Tobacco Products’ prepared for Commonwealth Department of Health and Ageing (see www.treasury.gov.au/documents/790/PDF/Cost_Benefit_Analysis.pdf).

Applied Economics, 2007, *The Annual Cost of Foodborne Disease in Australia*, prepared for the Department of Health and Ageing, Canberra.

Austroads, 2002, *Economic Evaluations of Road Investment Proposals, Unit Values for Road User Costs at September 2000,* Austroads, Melbourne.

Baranzini, A. and G.F. Luzzi, 2001, ‘The economic value of risks to life: evidence from the Swiss labour market’, *Swiss Journal of Economics and Statistics*, 137, 149-70.

de Blaeij, A., Florax, R. Rietvald, P. and E.Verhoef, 2003, ‘The value of statistical life in road safety: a meta-analysis’, *Accident Action and Prevention*, 35, 974-986

Blomquist, G., 1991, ‘Motorist use of safety equipment: expected benefits of risk incompetence’, *Journal of Risk and Uncertainty*, 4, 135-52.

Blomquist, G., Miller, T., and D.Levy, 1996, ‘Values of risk reduction implied by motorist use of protection equipment: new evidence from different populations’, *Journal of Transport Economics and Policy*, 29, 55-66.

Chestnut, L.G. et al., 1988, *Risk to heart disease patients from exposure to carbon monoxide: assessment and evaluation*, draft report for USEPA, Washington, D.C.

Commonwealth Bureau of Transport Economics, 2000, *Road Crash Costs in Australia*, Report No. 102, BTE, Canberra.

Cropper, M. and F. Sussman, 1990, 'Valuing future risks to life', *Journal of Environmental Economics and Management*, 19, 160-74.

Cropper, M., Aydede, S. and P.Portney, 1994, 'Preferences for life saving programs: how the public discounts time and age', *Journal of Risk and Uncertainty*, 8, 243-265.

Day, B., 1999, *A meta-analysis of wage-risk estimates of the value of statistical life*, Centre for Social and Economic Research on the Global Environment, University College London, mimeo.

Desaigues, B. and A.Rabl, 1995, 'Reference values for human life: an econometric analysis of a contingent valuation survey in France', in Schwab_Christe, N.G. and N.C. Soguel, (eds:) *Contingent Valuation, Safety, and the Value of Life*, 85-112, Kluwer Academic, Boston, MA.

Desvouges, W., Johnson, F.R., and H.S. Banzaf, 1988, *Environmental Policy Analysis with Limited Information: Principles and Application of the Transfer Method*, Edward Elgar, Cheltenham.

Dorman, P. and P.Hagstrom, 1998, 'Wage compensation for dangerous work revisited', *Industrial and Labour Relations Review*, 52, 116-35.

European Union, 2001, Recommended interim values for the sake of preventing a fatality in DG Environment cost benefit analysis,
http://europa.eu.int/comm/environment/enveco/others/recommended_interim_values.pdf

Gayer, T., Hamilton, J.T. and W.K. Viscusi, 2000, 'Private values of risk tradeoffs at superfund sites: housing market evidence on learning about risk', *Review of Economics and Statistics*, 82, 439-51.

Guria, J., Jones, W., Jones-Lee, M., Keall, M., Leung. J., and G. Loomes, 1999, *The Values of Statistical Life and Prevention of Injuries in New Zealand.* Prepared for the New Zealand Road Safety Trust and the Land Transport Safety Authority, New Zealand.

Hammitt, J.E., 2002, 'QALYs Versus WTP', *Risk Analysis*, 22, 985-1001.

Hammitt, J.K., and J.D. Graham, 1999, 'Willingness to pay for health protection: inadequate sensitivity to probability', *Journal of Risk and Uncertainty*, 8, 33-62.

Harrington, W., Krupnick, A., and W.Spofford, Jr., 1989, 'The economics losses of a waterborne disease outbreak', *Journal of Urban Economics*, 22, 101-112.

Harrison, D., Nichols, A., Evans, J. and J. Zona, 1992, *Valuation of Air Pollution Damages, National Economic Research Associates*, Cambridge, MA.

HM Treasury (UK), 2003, *The Green Book: Appraisal and Evaluation in Central Government*, UK Treasury, London.

Ho, J-J, Lu, J-T, and J-D, Wang, 2005, 'Stated preferences for the removal of physical pain resulting from permanently disabling occupational injuries: a contingent valuation study of Taiwan', *Accident Analysis and Prevention*, 37, 537-48.

Hultkrantze, L., Lindberg, G., and C. Andersson, 2006, 'The value of improved road safety', *Journal of Risk and Uncertainty*, 32, 151-70.

Jenkins, R.R., Owens, N. and L.B. Wiggins, 2001, 'Valuing reduced risks to children: the case of bicycle safety helmets', *Contemporary Economic Policy*, 19, 397-408.

Johannesson, M. and P-O Johansson, 1995, Quality of Life and the WTP for an increased life expectancy at an advanced age, *Working Papers in Economics and Finance, No. 85*, Stockholm School of Economics.

Johannesson, M., Johansson, P-O., and K.Lofgren, 1997, 'On the value of changes in life expectancy: blips versus parametric changes', *Journal of Risk and Uncertainty*, 15, 221-39.

Johansson, P-O, 2002a, 'The value of a statistical life: theoretical and empirical evidence', *Applied Health Economics and Policy*, 1, 33-42.

Johansson, P-O, 2002b, *On the definition and age-dependency on the value of a statistical life (review and extension)*. Working paper 40, Economics and Finance, Stockholm School of Economics, http://swopec.hhs.se/hastef/

Johnson, F.R., Banzhaf, M.R., and W.H. Desvouges, 1999, 'Willingness to pay for improved respiratory and cardiovascular health: a multiple format, stated preference approach', *Health Economics*, 9, 295-317.

Jones-Lee, M., 1974, ‘The value of changes in the probability of injury’, *Journal of Political Economy*, 99, 835-49.

Jones-Lee, M.W, 1992, ‘Paternalistic altruism and the value of statistical life’, *Economic Journal*, 102, 80-90.

Jones-Lee, M.W., 1994, ‘Safety and the saving of life: the economics of safety and physical risk’, pp.290-318 in *Cost-Benefit Analysis*, eds: R.Layard and S.Glaister, Cambridge University Press.

Jones-Lee, M.W., Loomes, G., and P.Phillips, 1995, ‘Valuing the prevention of non-fatal road injuries: contingent valuation vs standard gamble’, *Oxford Economic Papers*, 47, 675-95.

Jones-Lee, M.W., Loomes, G., Jones, S., Rowlatt, P., Spackman M. and Jones, S., 1998, *Valuation of Deaths from Air Pollution*, NERA and CASPAR, report prepared for the Department of Environment, Transport and the Regions and the Department of Trade and Industry, London.

Jones–Lee, M., and G. Loomes, 2004, ‘Eliciting measures of value for health and safety’, 9th Australian Workshop on Safety-Related Programmable Systems, Brisbane, *Conferences on Research and Practice in Information Technology*, Vol. 47.

Kneisner, T.J., and J.D.Leith, 1991, ‘Compensating wage differentials for fatal injury risk in Australia, Japan and the United States’, *Journal of Risk and Uncertainty*, 4, 75-90.

Krupnick, A., Alberini, A., Cropper, M., Simon, N., O’Brien, B., Goeree, R., and M. Heintzelman,, 2000, *Age, Health and Willingness of Pay for Mortality Risk Reduction: A Contingent Valuation of Ontario Residents*, Discussion Paper 0-0-37, Resources for the Future, Washington DC.

Krupnik, A. et al, 2002, ‘Age, health and willingness to pay for mortality risk reductions: a contingent valuation survey of Ontario residents’, *Journal of Risk and Uncertainty*, 234:2, 161-186.

Krupnick, A.J., 2004, *Valuing Health Outcomes: Policy Choices and Technical Issues*, Resources of the Future, Washington, D.C.

Loehman, E., Berg, S., Arroyo, A., Hedinger, R., Schwartz, J., Shaw, M, Fahien, R., De, V., Fishe, R., Rio, D., Rossley, W., and A.Green, 1979, Distributional Analysis of

Regional Benefits and Cost of Air Quality, *Journal of Environmental Economics and Management*, 6, 223-43.

Mathers, C., Vos, T., and C. Stevenson, 1999*, The Burden of Disease and Injury in Australia, Australian Institute of Health and Welfare*, AIHW Cat. No. PHE 17, Canberra.

Meng, R. and D.A. Smith, 1999, ‘The impact of workers compensation on wage premiums for job hazards’, Applied Economics, 31, 1101-1108.

Miller, P., Mulvey, C., and K. Norris, 1997, ‘Compensating differentials for risk of death in Australia’, *Economic Record*, 73, 363-72.

Miller, T., 2000, ‘Variations between countries in values of statistical life’, *Journal of Transport Economics and Policy*, 34, 169-88.

Mrozek, J. and L.Taylor, 2001, ‘What determines the value of life? A meta-analysis’, *Journal of Policy Analysis and Management*, forthcoming.

NSW Roads and Traffic Authority, 2005, *Economic Analysis Manual*, RTA, Sydney.

Pearce, D., 2000, ‘Valuing Risks to Life and Health’, paper prepared for the European Commission (DGXI) Workshop on Valuing Mortality and Valuing Morbidity, Brussels, November, revised December.

Romer, A., Pommerehne, W., and L.Feld, 1998, ‘Revealing preferences for reductions of public risks: an application of the CV approach’, *Journal of Environmental Planning and Management*, 41, 477-503.

Rosen, S., 1988, ‘The value of changes in life expectancy’, *Journal of Risk and Uncertainty*, 1, 285-304.

Schwab, Christe, N., and N. Soguel, *The Pain of Victims and the Bereavement of their Relatives: A Contingent Valuation Experiment*, IDHEAP, University of Lausanne, Switzerland, mimeo.

Schwab Christe, N.G. and N.C. Soguel, (eds:), 1995, *Contingent Valuation, Safety, and the Value of Life*, 63-83, Kluwer Academic, Boston, MA.

Shephard, D., and R.Zeckhauser, 1982, ‘Survival versus consumption’, *Management Science*, 30, 423-39.

Strand, J., 2002, *Public- and private-good values of statistical lives — Results from a combined-choice experiment and contingent-valuation survey*, Hero Working paper 2.

Thayer, M. et al., 1991, *Estimating the air quality impacts of alternative energy sources: Phase II report*, Report to the California Energy Commission, Saramento, CA.

Tolley, G., Kenkel, D., and R. Fabian, 1994, 'State of the art health values', Tolley, G., Kenkel, D. and Fabian R. (eds), *Valuing Health for Public Policy: An Economic Approach*, pp. 323-44, University of Chicago Press, Chicago.

Tsuge, T., Ksishmoto, A., and K.Takeuchi, 2005, 'A choice experiment approach to the valuation of mortality', *Journal of Risk and Uncertainty*, 31, 73-95.

United States Environmental Protection Agency, 1997, *Review of the Clean Air Act*, USEPA, Washington D.C.

United States Environmental Protection Agency, 2000, *Guidelines for Preparing Economic Analyses*, USEPA, Washington D.C.

Van den Burgh, J., Button, K., Nijkamp, P. and G.Pepping, 1997, *Meta-analysis in Environmental Economics*, Kluwer, Dordrecht.

Vassanadumrongdee, S. and S. Matsuoka, 2005, 'Risk perceptions an value of a statistical life for air pollution and traffic accidents: evidence from Bangkok, Thailand', *Journal of Risk and Uncertainty,* 30, 262-287.

Viscusi, W.K., 1993, 'The value of risks to life and health', *Journal of Economic Literature*, XXXI, 1912-1946.

Viscusi, W.K. and J.E. Aldy, 2003, 'The value of a statistical life: a critical review of market estimates throughout the world', *Journal of Risk and Uncertainty, 27*, 5-76.