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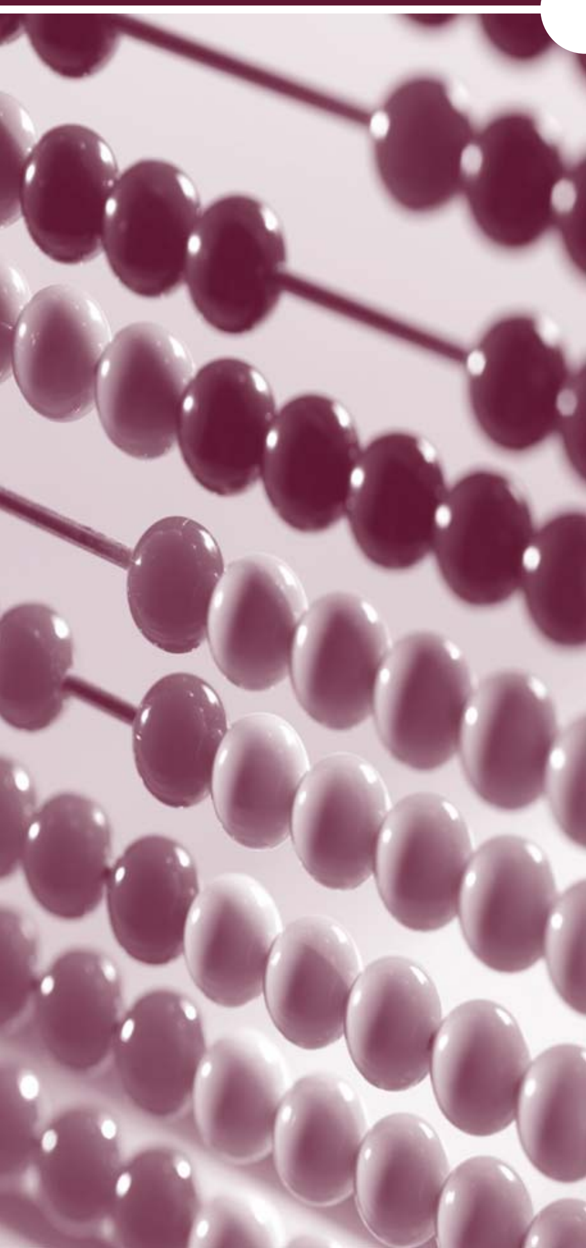
Economic Valuation of Mortality Risk Reduction:

Review and Recommendations for Policy and Regulatory Analysis

Research Paper

March 2009



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About this Report

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Abstract

Government or regulatory programs that address environmental protection, transportation safety, and consumer product safety often involve changes in mortality risks. Thus, quantitative assessments of the benefits of these programs require estimates of the monetary value of reductions in mortality risks. This report updates the previous literature review by Chestnut et al. (1999) and makes new recommendations about appropriate estimates to use when valuing mortality risk changes in policy analyses of Canadian programs expected to reduce mortality risks. This report also provides background information for policy analysts on economic valuation of mortality risk reductions. The average value of a statistical from the Canadian studies is about $6.5 million, which is the recommended central estimate for policy analysis by the authors.

Résumé

Les programmes du gouvernement ou ceux de réglementation qui touchent à la protection de l'environnement de même qu'à la sécurité des transports et des produits de consommation ont souvent une incidence sur les risques de mortalité. Pour en évaluer quantitativement les avantages, il est nécessaire d'estimer la valeur monétaire de la réduction des risques. Dans ce document de travail, une version actualisée de l'analyse documentaire publiée par Chestnut et autres en 1999, on présente également de nouvelles recommandations concernant les données estimatives à utiliser pour chiffrer les changements devant réduire les risques de mortalité lors de l'analyse stratégique des programmes canadiens. Enfin, les analystes de politiques y trouveront des renseignements contextuels à propos de l'évaluation économique des réductions de risques de mortalité. La valeur moyenne d'une vie statistique dans le cadre des études canadiennes est d'environ 6,5 millions de dollars. C'est d'ailleurs le montant estimatif recommandé par les auteurs aux fins d'analyse stratégique.

Executive Summary

Government or regulatory programs that address environmental protection, transportation safety, and consumer product safety often involve changes in mortality risks. Thus, quantitative assessments of the benefits of these programs require estimates of the monetary value of reductions in mortality risks. This report updates the previous literature review by Chestnut et al. (1999) and makes new recommendations about appropriate estimates to use when valuing mortality risk changes in policy analysis of Canadian programs expected to reduce mortality risks. This report also provides background information for policy analysts on the economic valuation of mortality risk reductions.

Cost-benefit analysis compares a monetary measure of the welfare gain for those who benefit from a policy or program to a monetary measure of the welfare loss to those who are harmed or incur its costs. The values of the benefiting public are sought for use in this analysis rather than the judgments of the analyst or the policy maker. The monetary measure used by economists to reflect this value is the maximum payment the individual would be willing to make to obtain that benefit, if such a transaction were feasible. This is what is meant by the term willingness to pay (WTP).

Willingness to pay estimates for reductions in mortality risks are based on studies of people's own preferences regarding trade-offs between reducing risks to their own lives and other uses of their available resources. Willingness to pay values are not independent of the valuation context or of the individual's circumstances, and they may vary for the same amount of risk reduction in different contexts and for different individuals.

There are two general economic approaches for measuring WTP for changes in mortality risks. The first is to analyze actual situations in which WTP for mortality risks may be indirectly revealed; this approach based on actual behaviour is called revealed preference. The second is to have subjects respond to a hypothetical situation that is designed to have them reveal their WTP; this approach based on responses to survey questions is called stated preference.

All empirical studies of WTP for mortality risk reduction estimate average monetary amounts that individuals are willing to pay for small reductions in the risk of death. For example, one study might find an average WTP of $60 for a reduction in the annual risk of dying from contaminated meat from 3 in 100,000 to 2 in 100,000. This means that each individual is willing to pay $60 to have this 1 in 100,000 reduction in risk. In this example, for every 100,000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of $60 over 100,000 people gives the number referred to as value of statistical life (VSL). The VSL estimate in this case is $6 million. It is the aggregate WTP for the group in which one death would be prevented. It is

important to emphasize that the VSL is not the value of an identified person's life, but rather an aggregation of individual values for small changes in risk. The VSL is often used in cost-benefit analysis as follows. The analyst first estimates the number of deaths expected to be prevented in a given year by multiplying the annual average risk reduction by the number of people affected by the program. Then the VSL (either a single number or a range) is applied to each death prevented in that year.

Many unanswered questions still exist concerning the extent to which VSL varies in different contexts and for different population characteristics. Some policies or programs may reduce mortality risk by different amounts for different age groups. One important and controversial question that this raises is whether WTP for mortality risk reduction is expected to vary depending on the remaining life expectancy of the person at risk. If it does, then it may be appropriate to use a monetary value per statistical life-year (VSLY), or to adjust the VSL to reflect WTP values of people at different ages. The VSLY is the aggregate WTP of a group of individuals. It is used to obtain increases in life expectancy that sum to one additional year of life. Studies could be designed to estimate the VSLY directly, but it is usually derived from a VSL estimate based on a set of assumptions. One assumption often made is that the VSLY is a constant value for every year, but this assumption is not required and is not consistent with available empirical evidence.

In the simplest case of a constant VSLY, the VSLY is the VSL divided by the number of life years saved by the reduction in risk (calculated from the remaining life expectancy of the individuals at risk). Thus, using the numerical example for the VSL, if the average remaining life expectancy for the group with the VSL of $6,000,000 is 35 years, then the VSLY is about $171,400 ($6,000,000 divided by 35). The values for future years, however, are usually discounted at some rate of time preference such that years further in the future are given less weight in current decision making than years closer to the present. This results in a higher VSLY for the same VSL. For example, at a 3% discount rate, 35 years of remaining life expectancy is equivalent to 21.7 years and the VSLY is about $276,500 ($6,000,000 divided by 21.7).

The question of how WTP for mortality risk reduction varies with remaining life expectancy is examined empirically by analyzing how WTP varies with age, because age is directly observed and is highly correlated with remaining life expectancy. Although some analysts have presumed that WTP for mortality risk reduction declines with decreases in remaining life expectancy, Hammitt (2007) showed there is theoretical ambiguity about how WTP for mortality risk reduction will change with decreases in remaining life expectancy. He noted that spending money to reduce current risk has two effects on the individual's well-being: It increases the chances of survival, which presumably has greater value if the amount of time remaining is higher, and it reduces the resources remaining to spend on future consumption, which presumably has greater significance if the amount of remaining time is greater. Thus, as life expectancy decreases, these effects on WTP work in opposite directions and the theoretical analysis

alone cannot predict whether the net effect is positive, negative, or neutral. This means that how WTP changes with age can be resolved only empirically.
The empirical results are inconclusive about how WTP for mortality risk reduction varies with age. Some studies find no statistically significant relationship between age and WTP. Others find no effect of age on WTP until late in life. These studies generally find WTP values declining by 20% to 35% after age 60 or 70. Some studies find WTP values for adults increasing with age until about age 40 or 50, and then declining. None of these results are consistent with a constant VSLY throughout a lifetime, because this implies WTP that declines proportionately with age, which none of the empirical studies find.

The average of the mean stated preference result and the mean revealed preference result from the Canadian studies is about $6.5 million, which is the recommended central estimate for policy analysis. It gives equal weight to results from the two types of studies. The recommended low value is $3.5 million, which is close to the adjusted mean estimate from Mrozek and Taylor (2002) for US revealed preference studies, and to the lower of the Canadian stated preference results (Alberini et al., 2004). The recommended high value is $9.5 million, which is representative of the unadjusted mean estimate from the US revealed preference studies, and is in the range of the highest revealed preference results obtained in Canada ($9.0 million and $9.9 million). Table S-1 summarizes the recommended VSL estimates. These values represent a reasonable range for a primary analysis. Higher and lower estimates exist in the literature, so these are not lower and upper bounds. Arguments could be made to defend each of these estimates as a reasonable primary estimate, although the central estimate is the best choice if a single primary VSL estimate is used.

Table S-1. Recommended Primary VSL Estimates for Canadian Policy Analysis (2007 C$ million)

Low	$3.5
Central	$6.5
High	$9.5

Given the uncertainties about how WTP for mortality risk reduction may vary with age, sensitivity analyses are recommended for policies that may reduce mortality risk substantially in different age groups. Some analyses may also be based on life-years saved rather than on lives saved, and these require some estimates of the WTP values for years of life saved. Sensitivity analyses can be used to consider how alternative assumptions would affect the results of the analysis. Analysts may not have great confidence in the alternative assumptions, but they can illustrate how the results would be changed if key assumptions or interpretations changed.

Table S-2 illustrates some estimates of VSLY and VSL that vary with age based on selected results in the literature. These estimates may be appropriate for sensitivity analyses for some policy analyses. Many other estimates and assumptions may be appropriate for sensitivity analyses depending on the nature of the policy and its expected effects on mortality risk.

Table S-2. Illustration of Relationship between VSL and VSLY for Different Age Groups

Age (years)	Remaining Life Expectancy (years)	Discounted Remaining Life Expectancy in Years (using 3% discount rate)	Recommended Central VSL for 45 Year Old, Adjusted to Other Ages Based on Alberini et al. (2006a) Results$ (million)	Corresponding VSLY (using 3% Discount rate)$
45	32.7	20.8	6.5	312,000
55	24.1	17.2	6.0	350,200
65	16.6	13.1	6.4	488,000
75	10.4	8.9	3.7	419,100

1. Introduction

Cost-benefit analyses and other quantitative assessments of public policies to reduce risks to human health and safety require estimates of the economic value of reductions in mortality risk. Programs that address environmental protection, transportation safety, and consumer product safety involve potential changes in mortality risks. Thus, quantitative assessments of the benefits of these programs require estimates of the monetary value of reductions in mortality risks.

Chestnut et al. (1999) reviewed available estimates through 1996 of monetary value for mortality risk changes from Canadian and US studies, and recommended a range of estimates for use in analyses of air pollution control strategies in Canada. Many additional studies have been completed in the last 10 years; this report[1] updates the literature review and makes new recommendations about appropriate estimates to use when valuing mortality risk changes in policy analysis of Canadian programs expected to reduce mortality risks.

First, a background section discusses the conceptual and empirical underpinnings of the economic approach for determining the monetary value of reducing mortality risk for use in cost-benefit analyses of public policies. Analysts must have some understanding of these concepts, because they underlie the approaches used to determine monetary values appropriate for use in cost-benefit analysis. Understanding these concepts will help policy analysts make decisions about how to apply or adapt available monetary estimates for use in specific situations. The report then reviews new empirical studies in Canada on values for mortality risk reduction and recent meta-analyses of these types of studies in the United States and other countries. As in the earlier review, the conclusion is that monetary values for mortality risk reduction in Canada are very similar to those found in US studies, so results from studies in both countries are relevant for this review. Next, specific findings about how monetary values for mortality risk reduction vary in different contexts and for different populations are reviewed, because this is an important issue when applying available estimates in a specific policy analysis. Finally, recommendations for specific estimates appropriate for use in policy analysis in Canada are given.

2. Background on Economic Valuation of Mortality Risk Reduction

Concepts

Cost-benefit analysis compares a monetary measure of the welfare gain to those who benefit from a policy or program to a monetary measure of the welfare loss to those who are harmed or incur its costs. In general, this type of analysis focuses on aggregate costs and benefits, and a program is considered to have a net benefit to society if total benefits exceed total costs. How the costs and benefits are distributed among various population groups is often also assessed, but that is usually treated as a separate analysis.

Cost-benefit analysis measures how those affected by the policy value the costs or the benefits they incur. Thus, the values of the benefiting public are sought for use in this analysis, not the judgments of the analyst or the policy maker. The monetary measure used by economists to reflect this value is the maximum payment the individual would be willing to make to obtain that benefit, if such a transaction were feasible. This is what is meant by the term willingness to pay (WTP). For goods bought and sold in the market, WTP values are revealed by the amounts purchased at various prices. However, for goods, such as health and safety that are not directly purchased, the WTP values must be estimated or inferred indirectly. The WTP measure of value is a well-established concept and is consistent with the goals of cost-benefit analysis in seeking an efficient allocation of resources to maximize society's well-being. The issue is not whether WTP measures should be used, but rather how best to estimate the desired WTP measure.[2]

Willingness to pay values for reductions in mortality risks represent the values to the individuals who experience the reduction in risk in terms of what other goods and services they are willing to give up in exchange for the risk reduction. Willingness to pay values can be expected to reflect all the reasons why people may value a reduction in their own mortality risk, including the value of reductions in the risk of out-of-pocket costs that might be associated with premature death (including medical treatment and lost income) plus the value of reduced risk of the lost enjoyment of life (in the broadest sense).

Willingness to pay reflects all the reasons individuals put a value on a reduction in their own risk of death, and is therefore expected to exceed the value of the financial impact to an individual associated with the change in risk. It is clear that the other common measure of monetary value for human health and safety – cost of illness – does not reflect the full effect of the change in mortality risk on a person's well-being. Cost-of-illness estimates measure medical expenses and lost income due to premature death or illness including the value of reductions in productivity for the patient and any family members providing care. This is a perfectly valid measure of the financial effect of programs that affect public health and safety, but it places no value on the time or the lives of those who are not in the labour market or on the pleasure of just being alive.[3] To count only the cost-of-illness benefits in a cost-benefit assessment of programs to protect public health and safety would clearly lead to an under-investment of society's resources in public health and safety, from the perspective of trying to maximize society's overall well-being.[4]

Approaches for Estimating WTP for Mortality Risk Reduction

Willingness to pay estimates for reductions in mortality risks are based on studies of peoples' preferences regarding trade-offs between reducing risks to their lives and other uses of their available resources. Willingness to pay values are not independent of the valuation context or of the individual's circumstances, and they may vary for the same risk reduction in different contexts and for different individuals. For example, a WTP value is a function of a person's available income and wealth. This is inherent, because it is a measure of the resources a person is willing to exchange for a given benefit, and it will therefore be a function of that individual's total resources. This means that the WTP estimates used for policy analyses should be drawn from studies of populations with characteristics similar to those of the population affected by the policy. Results from WTP studies in the US population may not be appropriate to use in a policy analysis in China, for example. However, for most policy assessments, average WTP values for the general population in that country are used without attempting to adjust for specific variations in population characteristics by location.

Willingness to pay is defined as the maximum price an individual is willing to pay for a good or service, and it is considered a measure of how much the individual values that good or service.[5] It is typically measured by analyzing prices and quantities of goods and services bought and sold in the market. However, such transactions cannot be directly observed for reducing or preventing mortality risk because, for the most part, reduction or prevention of mortality risk is not directly purchased. In economic terms, mortality risk reductions are thus a non-market good.

There are two general economic approaches for measuring WTP for non-market goods, such as changes in mortality risks. The first is to analyze actual situations in which WTP for mortality risks may be indirectly revealed. This category, based on actual behaviour, is called revealed preference. These studies take advantage of instances when the monetary trade-offs people are willing to make between income or expenditure and an associated mortality risk reduction can be observed or measured (e.g., higher wages for riskier jobs or purchases of safety devices). The second approach is to have subjects respond to a hypothetical situation designed to have them reveal their WTP. This second is based on responses to survey questions and is called stated preference.[6]

Wage-risk studies that estimate wage premiums for risks of death on the job are an example of a revealed preference approach. These studies analyze all the factors that determine differences in actual wages between jobs, including on-the-job risks of death.

The amount of additional wages people are paid per unit of additional risk of fatal injury is a measure of the monetary value of that risk increment to the individuals who voluntarily accept that risk increment in exchange for a given wage increment. This goes in both directions. The wage reduction associated with an incremental reduction in on-the-job risk is a measure of the monetary value of the risk reduction to the workers who take the safer jobs.

The primary advantage of a revealed preference approach is that it is based on actual behaviour. The presumption is that people's own choices are the best reflection of their WTP values. The primary challenges of revealed preference approaches to estimate WTP for risk reduction result from the complexities of the choices and behaviours that occur in day-to-day life. It can be challenging to isolate WTP for a risk increment statistically, for example, from other factors involved in the specific behaviour or decision. These studies also assume that people have a reasonably accurate understanding of the risk changes they face with a given purchase decision or job choice.

Stated preference approaches use surveys in which subjects are presented with a hypothetical situation that involves a trade-off between income or expenditures and a change in the risk of death. In a direct contingent valuation approach, subjects are asked to estimate what they would be willing to pay to change their mortality risk by a specific, generally small amount. Choice approaches ask respondents to choose among alternatives with varying costs and levels of risk reduction. The choices they make are analyzed to reveal their WTP values even though the respondents do not explicitly state these. In any stated preference approach, it is important that the situation presented to study subjects be realistic and easy to understand. The primary challenge for these types of studies is to design the surveys so subjects can give accurate responses. An important part of the study design is to evaluate how well this has been accomplished.

Many questions concerning stated preference survey design remain unresolved in the literature. Difficulties in comprehending small risks are frequently discussed and are an especially relevant concern for valuing the type of morality risk reductions associated with many environmental and public health programs. Corso et al. (2001) demonstrated the importance of visual aids to help communicate quantitative risk information. Krupnick et al. (2002) used simple comprehension questions to help identify respondents who seemed unable to understand the quantitative risk information. Their results showed that a small fraction of respondents were confused or were unwilling to put in the effort required, and their responses had to be excluded from the results. It is important that researchers consider this issue and design surveys to include assessment of respondent comprehension and effort.

Finally, some stated preference studies of illness-related health risks have used the purchase of medical treatment options as the payment vehicle (e.g., Johnson et al., 1998, 2000; Krupnick et al., 2002; Alberini et al., 2004), and others have used relocation and cost of living changes (e.g., Viscusi et al., 1991). Only recently has a study compared the two approaches (Chestnut et al., 2004). Krupnick et al. obtained substantially lower mean WTP values for mortality risk reduction than Viscusi et al., but whether this can be attributed to the payment vehicle differences or to other variations in the study design is difficult to determine.

Cost-benefit analyses of programs that reduce mortality risks typically focus on the value of the risk reduction to each affected individual, summed across all affected individuals to obtain total benefits of the risk reduction. Questions are sometimes raised about whether values people hold for risk reductions for others should be added to obtain the total value of the program to society. There is also a question of how the valuation questions should be posed in stated preference studies when results are intended for use in cost-benefit analyses of public programs.

Jones-Lee (1991) presented theoretical analyses that clarify this issue and illustrate the importance of unambiguously defining whose risk is being reduced in a stated preference valuation instrument. His analysis demonstrates the circumstances under which an individual's WTP for other people's risk changes should be added to the individual's WTP for her or his own risk changes to obtain an optimal allocation of resources to health and safety efforts. Jones-Lee evaluated three alternative social welfare conditions: pure altruism, where one's well-being includes the well-being of others; pure selfishness, where changes in the well-being of others have no impact on a person's well-being; and altruism that extends only to the safety of others (i.e., their well-being is not directly valued, just their safety). Jones-Lee (1992) added a fourth special case of pure paternalism, whereby the lives of others affect a person's well-being, but the preferences of others are ignored.

Jones-Lee (1991) demonstrated that if individuals are purely altruistic or purely paternalistic, there is no need to add WTP values for other people's safety to WTP for an individual's own safety in a cost-benefit analysis. To do so would cause an overstatement of the benefits of risk reduction. This result is the same as that obtained in the case of pure selfishness. Underlying these results is the fact that even when well-being is interdependent (i.e., my well-being is a function of your well-being), the well-being of the group is maximized by allowing each individual to choose her or his own maximizing position. It is only when altruism extends specifically to the safety of others[7] that the appropriate WTP measure is not just the sum of everyone's WTP for themselves but rather that sum plus their WTP for all others' safety. Jones-Lee called this paternalistic altruism, because the interdependency is based on the consumption of the others, not their well-being. (For example, parents are happy when their children eat their vegetables regardless of whether the children are happy about it.) Although such values may be important in family decision making, it is not clear that they should be included in cost-benefit analysis of public policy.

The Jones-Lee (1991) conclusions illustrate why it is important that estimates of WTP values for risk reduction be unambiguous regarding whose risk reduction is valued. This is a particular challenge for stated preference studies attempting to define a risk reduction context applicable to public policy decisions. Asking respondents what they are willing to pay to reduce air pollution, for example, presents a context that benefits the entire community, and respondents may answer differently than if only their own risk is being changed.

Uses of WTP Results for Mortality Risk Reduction in Policy Analysis

All empirical studies of WTP for mortality risk reduction estimate average monetary amounts that individuals are willing to pay for small reductions in risks of death. For example, one study might find an average WTP of $60 for a reduction in the annual risk of dying from contaminated meat from 3 in 100,000 to 2 in 100,000. This means that each individual is willing to pay $60 to have this 1 in 100,000 reduction in her or his own risk. In this example, for every 100,000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of $60 over 100,000 people gives the number referred to as value of statistical life (VSL). The VSL estimate in this case is $6 million. It is the aggregate WTP for the group in which one death would be prevented. The VSL is often used in cost-benefit analysis as follows. The analyst first estimates the number of deaths expected to be prevented in a given year by multiplying the annual average risk reduction by the number of people affected by the program. Then the VSL (either a single number or a range) is applied to each death prevented in that year. It is important to note that VSL estimates are derived from estimates of WTP of the individual for changing her or his risk of premature death by a small amount. Although the VSL estimate is applied in an assessment by estimating the number of lives saved and multiplying by the VSL, it is really an estimate of the value for the change in risk to each exposed individual. Using the above example, the VSL is not a $6 million value for the single life saved, but rather a $60 value to each of the 100,000 individuals who experience a 1 in 100,000 reduction in annual mortality risk. It is not known whose premature death is avoided. The concept of VSL is based on the values of individuals for changes in risk rather than on the values for identified lives.

Those who criticize the VSL estimate because lives are never really “saved,” just extended, misinterpret the VSL estimates. The VSL is an aggregate measure of value for a change in the annual survival probabilities. A reduction in the annual mortality risk for a population means that some deaths shift from the current year to some future year. When the VSL is used in a policy assessment as a monetary value for each life saved, it is simply a way to scale the WTP estimates for valuing different magnitudes of risk changes. Its use in this way implies that WTP to reduce risk is the same per unit change in risk regardless of the cause or context of the risk. All the literature reviews concerning the use of these estimates to evaluate public policy options note that an important criterion is that the change in risk to the individuals in the exposed population caused by the policy decision must be small, similar to the small magnitude of risk for which the WTP estimates were originally estimated. Although empirical evidence concerning how VSL values may vary for substantially different risk change magnitudes is very limited, applying the available VSL estimates to changes in risk on the order of 1 in 100 or 1 in 10, for example, would be highly questionable. Fortunately, most public policy programs involve small changes in risk to the exposed individuals, similar to or smaller than those evaluated in the original WTP studies available in the literature.

Many unanswered questions exist concerning the extent to which VSL varies in different contexts and for different population characteristics. Some policies or programs may reduce mortality risk by different amounts for different population age groups. One important and controversial question that this raises is whether WTP for mortality risk reduction is expected to vary depending on the remaining life expectancy of the person at risk. If it does, then it may be appropriate to use a monetary value per statistical life-year (VSLY), or to adjust the VSL to reflect WTP values of people at different ages. The VSLY is the aggregate WTP of a group of individuals to obtain increases in life expectancy that sum to one additional year of life. Studies could be designed to estimate the VSLY directly, but it is usually derived from a VSL estimate based on a set of assumptions. One assumption often made is that the VSLY is a constant value for every year, but this assumption is not required and is not consistent with available empirical evidence.

In the simplest case of a constant VSLY, the VSLY is the VSL divided by the number of life years saved by the reduction in risk (calculated from the remaining life expectancy of the individuals for whom the VSL was originally estimated). Thus, using the numerical example for the VSL, if the average remaining life expectancy for the group with the VSL of $6,000,000 is 35 years, then the VSLY is about $171,400 ($6,000,000 divided by 35). The values for future years, however, are usually discounted at some rate of time preference such that years further in the future are given less weight in current decision making than years closer to the present. This results in a higher VSLY for the same VSL. For example, at a 3% discount rate, 35 years of remaining life expectancy is equivalent to 21.7 years[8] and the VSLY is about $276,500 ($6,000,000 divided by 21.7).

The question of how WTP for mortality risk reduction varies with remaining life expectancy is examined empirically by analyzing how WTP varies with age, because age is directly observed and is highly correlated with remaining life expectancy. The current evidence on how VSL varies with age and other factors is discussed extensively in subsequent sections of this report. This evidence is also relevant to the question of whether VSLY can be reasonably treated as a constant. Current evidence suggests that WTP for mortality risk reduction may vary somewhat with age, but it is not proportional to remaining life expectancy. This means that VSLY is not a constant over a person's lifetime, so simply dividing VSL by remaining life expectancy and applying this VSLY to any year of life saved is not an accurate reflection of people's preferences.

Limitations and Concerns with the VSL Approach

Concerns and questions about the VSL approach for valuing mortality risk changes associated with public policies mostly come down to questions about the basic assumptions in how these values have been applied. One assumption is that WTP to reduce or avoid a unit change in mortality risk is the same regardless of the type of risk. Another assumption is that the average WTP for a population is the same regardless of the characteristics of the population at risk. One or both of these assumptions is implicit whenever a VSL value is applied in any context that differs from the context in which it was originally estimated. It becomes a concern when the population whose mortality risk is affected by a policy is substantively different from the population from which the VSL estimates have been obtained. It is also a concern if the type of risk is different from the context in the original WTP studies.

Many available empirical WTP estimates are for risks of accidental death in circumstances where individuals are voluntarily exposed to risks (e.g., choosing a job or driving in a car). Some potentially important differences exist between the contexts of these available estimates and the contexts of most health risk changes being evaluated in a cost-benefit analysis of a public health or consumer safety program. For example, environmental health risks are primarily related to illness rather than accidents. Deaths may be fairly quick, such as with heart attack or pneumonia, or may involve prolonged illness with associated pain and loss of quality of life, such as with cancers or chronic respiratory disease. There may also be a substantial lag between the timing of a change in policy and the timing that a noticeable change in health is realized, such as with cancers that may occur many years after a harmful exposure. All these factors represent differences as to the nature of the risk that could potentially result in a different WTP for an equivalent magnitude reduction in risk.

Value of statistical life estimates drawn from wage-risk studies, the most common source of VSL estimates in the literature, are for working-age adults in good enough health to be employed. Risks associated with many public policy decisions, however, may fall disproportionately on the young or the elderly, or on those with already compromised health. Differences in the characteristics of the individuals at risk, such as their ages and their health status, may result in differences in their WTP to reduce their risk.

This report discusses some of the new directions researchers have been taking for monetary valuation for reductions in mortality risk, motivated by these questions regarding how we should approach the valuation of changes in mortality risk in different contexts. This is important research, but a note of caution is warranted. Before assigning different monetary values for mortality risk reductions in different contexts, or for different population groups, we need to be sure we understand the reasons for these differences, and that these reasons are consistent with public health and safety policy goals. Different values placed on risk reductions in different contexts could result in changes to program priorities such that for a given expenditure fewer lives are saved.

For example, if the public were to express greater WTP to reduce the same magnitude of mortality risks from air pollution exposure than from transportation accidents, this could lead to spending much more per life saved for air pollution control than for transportation safety. On a fixed budget for these two efforts, this would mean fewer total lives saved. It behooves the policy maker to be sure of the basis for these kinds of choices before they are adopted. Many of these kinds of findings of apparent differences in WTP for different kinds of risks are based on stated preference studies, and more work is needed to be sure that analysts correctly interpret respondents' answers to these sometimes difficult questions.

3. Review of the Empirical Literature

This chapter first summarizes estimates derived from earlier Canadian and US studies and then reviews Canadian studies since 1995 that estimate WTP for mortality risk reduction. These are compared to results from earlier studies. Recent meta-analyses of WTP studies for mortality risk reductions in the United States, Canada, and other countries are also summarized. A meta-analysis is a quantitative, usually statistical, analysis that combines the results of multiple studies on the same topic. These analyses put the Canadian results in a broader context and show that their results are very similar to those obtained in the United States, where many more studies have been done. This suggests it is useful to consider results for all Canadian and US studies rather than considering only those done in Canada.

VSL Estimates Previously Selected for Canadian Analyses (Chestnut et al., 1999)

Value of statistical life estimates selected previously for Canadian analyses were based on a review of then available US and Canadian studies. Because of the comparability between the US and Canadian study results, low, high, and central estimates were selected from results in both countries.

The low and high estimates represent not absolute lower and upper bounds, but rather a range of results from the literature that are realistic and plausible alternative estimates depending on how one interprets the available literature. A range of numbers was selected rather than a single point estimate, because there is a range of results in the literature and it is hard to say that one single number is the correct estimate to use in policy analysis. The central estimate can be used as a single "best" estimate. However, some analysts want to conduct quantitative uncertainty analyses and a range of values is useful for this purpose. This allows the analyst to report a range of results with greater confidence than can be placed on a single point estimate.

The selected VSL estimates based on the available literature were adjusted to 2007 Canadian dollars, $3.8 million for the low, $6.5 million for the central, and $13.0 million for the high. The VSL estimates available from the literature were based primarily on samples of working-age adults. A few of the stated preference studies available at the time of the review included individuals of retirement age, but this age was not well represented in the mean VSL values. These selected VSL estimates were therefore applied only to the under 65-year-old population.

Available evidence suggested that WTP for small changes in risks of death for people over age 65 could be expected to be lower than WTP for the same change in risk at age 40; however, there was considerable uncertainty about how much lower. The most relevant direct evidence suggested that the decline in VSL with age may be relatively small (e.g., 90% of the age 40 WTP at age 65). The evidence strongly suggested that a linear decline in VSL with age would significantly understate actual VSL over age 65. Based on the Jones-Lee et al. (1985) results, an adjustment to VSL for those 65 and older of about 75% of the average VSL for adults under 65 was made.

An age-weighted average VSL was then calculated on the assumption that 85% of the pollution-related deaths are experienced among people 65 and over.[9] Table 1 shows the results. The focus in this previous assessment was on the mortality risk associated with air pollution. Other policy analyses are likely to involve risk reductions that are distributed differently across age groups.

Table 1. Monetary Values for Mortality Risk Changes Previously Selected (Chestnut et al., 1999)

Population Group	Selected VSL Estimates (2007 C$ million)		
	Low	**Central**	**High**
65 + years old	$2.9	$4.9	$9.8
<65 years old	$3.8	$6.5	$13.0
Age-weighted average VSL[a]	$3.0	$5.1	$10.3
Probability associated with the estimates for uncertainty analysis	33%	50%	17%

Note: a. Assuming 85% of deaths are individuals aged 65 and over.

Probability weights were selected for each estimate for use in quantitative uncertainty analyses. These weights reflect a judgment about how likely each is to be correct. The selection of probability weights for the low, central, and high estimates was somewhat arbitrary, because there are many uncertainties in using these estimates for policy analysis for which no quantitative information is available. The selected weights therefore reflect the uncertainty in the underlying WTP estimates for small changes in risks of accidental death for working-age adults, but do not fully reflect the uncertainty in applying these estimates in policy analyses. The weight selected for the central estimate was 50%, because the underlying WTP estimates were predominately in the $3 million to $7 million range. A weight of 33% was given to the low estimate and a weight of 17% was given to the high. This reflects the fact that the high estimate was drawn from fewer studies and that there was a skewed distribution in the available WTP estimates toward the lower end of the range. These weights resulted in a weighted mean value that approximates the selected central estimate.

Some analyses have used distributions of VSL estimates rather than point estimates and ranges. For example, the US *Clean Air Act* cost-benefit report (EPA, 1997) characterized the VSL values as following a Weibull distribution. The Weibull distribution takes into account that the majority of the available VSL estimates cluster in the $3 million to $7 million range and that the distribution has a fairly long tail to the right representing a few estimates that run substantially higher than the majority. Based on 26 individual study estimates of VSL selected as appropriate for policy use, the US Environmental Protection Agency determined the VSL estimates had a mean of $4.8 million and a standard deviation of $3.2 million (1990 dollars). Using a distribution gives quantitative weight to the likely accuracy of each value within the range, based on how often it has been found in the underlying literature. A distribution therefore communicates more quantitative information than a central point estimate with a selected high and low range.

Recent (1995-2004) Studies in Canada

This section describes five Canadian study efforts since 1995 that provide new estimates of economic welfare based measures of monetary value for reductions in mortality risk. The results of some of these studies are reported in multiple publications or reports, as noted in this section. Three of these are stated preference studies that have included applications of the same survey instrument in other countries in addition to the Canadian applications. The results from all the countries are discussed here, because they have some bearing on the Canadian results and provide opportunities for a direct comparison of WTP estimates in Canada and elsewhere. A tabular summary of the key findings of these studies is also provided in this section.

Lanoie et al. (1995)

This study included a stated preference component and a wage-risk study component, using the same sample of workers at 16 companies in Montréal. The authors used a survey instrument similar to one developed by Gerking et al. (1988) in a US study. In this Canadian application, both English and French versions are available. The surveys took place in 1990 with 191 completed interviews. The surveys were administered in person at the workplace with confidentiality promised and random recruitment of participation at selected employers with more than 100 employees.

A wage-risk analysis was conducted with the same sample of individuals using a measure of on-the-job risk obtained from survey respondents. A stated preference question also asked directly about the amount of wage the respondent would willingly give up to obtain a risk reduction. A second stated preference question asked about WTP for risk reduction by purchasing automobile air bags. The risk reduction considered was 2 in 10,000 for the automobile air bag question, and the work place risk reductions varied up to 2 in 10,000. The direct WTP questions were open-ended. Table 2 summarizes the results.

Table 2. Mean VSL Results from Lanoie et al. (1995) (2007 C$)

Annual Risk Change	WTP $ million	WTA $ million
2 in 10,000 – air bag	2.7	4.8
On-the-job wage-risk analysis (perceived risk – unionized manual workers)		30.9
On-the-job stated preference question	40.0	44.4

Note: Updated from 1986 C$ using the Canadian consumer price index; the adjustment factor is 1.677.

The small sample size and non-random nature of the sampling limit the usefulness of the specific quantitative results. The authors concluded that the WTP estimates for the air bag risk reduction were different from both the wage-risk analysis (with perceived risk) and the stated preference question responses regarding on-the-job risk, which are an order of magnitude larger. The authors did not provide enough information to understand fully why the air bag results were so much lower that the on-the-job risk results. The latter are substantially higher than those obtained in most previous wage-risk studies. Possibilities include the following:

- The mean risk reduction results are larger in smaller VSL. (This is seen in many studies.)
- It is not clear what the risk reduction is in the wage stated preference question. The authors described it as one step on the ladder, but this seems to vary in terms of the on-the-job risk reduction it represents.
- There might be concerns about the injury risk from air bags or about their effectiveness.
- There might be some expectation about what is a reasonable price for air bags that influences the WTP responses.

Meng and Smith (1999)

Meng and Smith (1999) conducted a wage-risk study focusing on the effect of workers' compensation on wage premiums for on-the-job risks. They hypothesized that compensation paid to workers who are injured on the job and cannot work may offset the ex ante compensation workers may require to accept on-the-job risks of injury. They found that adding the workers' compensation variable to the wage model did reduce the wage premium for non-fatal injury risks, by about half, but had little effect on the wage premium for fatal injury risks.

The data used for this study were from the 1986/1987 Labour Market Activity Survey conducted by Statistics Canada. The sample size for the study was 1,503 blue collar or service workers in Ontario in the mining, manufacturing, or logging industries. The age range was 20 to 64 years and the sample consisted of about 75% male workers.
One unique contribution of the analysis is the definition of an individual-specific variable to represent the value of the workers' compensation benefit. The authors also noted that

availability of workers' compensation should affect wages only if there is a positive degree of risk; otherwise there is no expected benefit to having workers' compensation. Meng and Smith also defined wages for this analysis as after-tax wages. This and the inclusion of the workers' compensation and non-fatal injury variable suggest the wage premium results for fatal risks should be conservative. The results are fairly central relative to other results in the literature with a mean value of statistical life of about $7.4 million (in 2007 C$).

Krupnick et al. (2002), Alberini et al. (2004), and Alberini et al. (2006a)

Krupnick et al. (2002) reported the results of a stated preference study conducted in Hamilton, Ontario in 1999. Alberini et al. (2004) reported the results of a study using essentially the same instrument in the United States with a nationwide Internet sample in 2000 (with Knowledge Networks). They included comparisons to the results in Canada. Alberini et al. (2006a) reported the results of applications of the same instrument (with translations) in the United Kingdom, France, and Italy. The instrument was self-administered by computer in all these studies.

In Hamilton, subjects were recruited via random digit dial telephone calls and paid to travel to a central site for the survey. There were 930 completed surveys in Hamilton; 24 surveys were excluded because of failure of a comprehension test. The response rate was 26% of those contacted and eligible. There were 1,200 completed surveys in the United States; 44 surveys were excluded, because of failure of the comprehension test, and 11 surveys were excluded for being over the target age limit of 79 years. The response rate was 67% after three days when the target sample was reached, using the Internet survey panel already established by Knowledge Networks. Both samples were limited to adults ages 40 and older. The mean age was 54 in both samples, ranging from ages 40 to 74 in Canada and from ages 40 to 79 in the United States. The samples in Europe were similarly restricted to adults over age 40, and respondents travelled to a central location in each city to answer the questionnaire on a computer, as was done in the Canadian study.

The commodity was a reduction in the risk of dying, but the specific cause was not stated. The study considered a 5 in 10,000 and 1 in 10,000 reduction in the risk of death every year during a 10-year period. Payments were specified as annual for a "product" that reduces risk and examples given were different types of preventive medical treatment. The analysis assumed the risk reductions were spread equally across all 10 years. The elicitation method was double-bounded dichotomous choice,[10] with follow-up open-ended questions for the no-no and yes-yes respondents (although the open-ended responses were not included in the estimation of WTP). This means that subjects were asked if they would be willing to pay a specific amount; if they said "no," they were then asked if they would pay a specified lower amount and, if they said "yes," they were asked if they would pay a specified higher amount.

The results (Table 3) showed fairly high percentages of respondents in Canada and the United States saying they were not willing to pay anything for the product, and are fairly similar across the two countries.[11] Table 4 gives the mean VSL results for the US, Canadian, and European studies (an average across the three countries). Alberini et al. (2006a) reported European results only for the 5 in 10,000 annual risk reduction.
The mean results in Canada were lower, but the differences with the US results were not statistically significant. This means there is enough variability in the responses in both countries, that the difference in the mean results is not statistically meaningful.[12] Sampling in Canada is a concern, because it is limited to Hamilton and to people willing to come to a central location, which raises some questions about how representative of the nation the results are. The high percentages of respondents in both countries who said they are not willing to pay anything for a product to reduce their risk suggest some respondents may have rejected the premise of the question, but this was not directly assessed and all these respondents are included in the mean values. Respondents sometimes say they are not willing to pay anything, because they don't accept the question, not because they do not value risk reduction. This may lead to a downward bias in the mean WTP values if all these respondents are counted as having zero WTP values.

Alberini et al. (2004) found statistically significant higher WTP for the larger risk reduction, but not proportionately higher. Willingness to pay increases by much less than the amount it would have to increase by to be proportional. The results show WTP increases by about 0.1% to 0.2% for every 1.0% increase in risk, when just the first choice responses are compared for all respondents. When all responses are pooled, the authors report results implying that WTP increases by about 0.2% to 0.4% for every 1.0% increase in risk.

Willingness to pay with respect to income is statistically significant in the United States, with WTP increasing about 0.3% for every 1.0% increase in income. In Canada, WTP increases with income, but the coefficient is not statistically significant. The results in Europe showed a statistically significant relationship with income, with WTP increasing by about 0.4% for every 1.0% increase in income at mean income levels in the sample. They found the effects of income increases were smaller at lower income levels.

Table 3. Percentages of Respondents Not Willing to Pay Anything

	Canada %	United States %
1 in 10,000	37	38
5 in 10,000	20	22

Source: Alberini et al. (2004).

Table 4. Mean VSL Results (2007 C$ million)

Annual Risk Change	Canada $	United States $	Europe $
5 in 10,000	1.4	2.2	3.6
1 in 10,000	5.4	7.0	
Average	3.4	4.6	

Note: Conversions based on purchasing power parity for 2000: US$1 = C$1.23 and an inflation adjustment to 2007 of 1.158; the conversion from the Euro to Canadian dollars is 1.42 for 2002, with an inflation adjustment of 1.108.

Sources: Alberini et al. (2004) and Alberini et al. (2006a).

Willingness to pay with respect to age was examined using 10-year age group dummy variables in Canada and in the United States. The only significant difference from WTP for the 40-49 age group is for adults ages 70 and older, and this difference was negative and significant in several models. The combined effect for both countries is about a 25% lower WTP for this age group, but the coefficient for this oldest age group was not statistically significant in the US sample. This is notable, because this age group is much larger in the US sample than in the Canadian sample. Age effects were generally not statistically significant in Europe, although the WTP was similarly lower for those in the oldest age group.

Willingness to pay results were statistically significant for a family history of chronic heart or lung disease (increased WTP by 26% in Canada and by 37% in the United States). Respondents who had been admitted to the hospital (in the past year) or the emergency room (in the past five years) for a heart or lung condition were willing to pay 63% more to reduce fatal risk (but only in the US sample; the coefficient was near zero in the Canadian sample). The authors noted that these respondents were no more likely to accept or reject the baseline risks presented than others.

Krupnick et al. (2002) reported higher WTP in the Canadian study for those scoring higher (better) on the mental health or emotional (effects on functioning) scores. These were not mentioned in the US study results.

Chestnut et al. (2003) and Chestnut et al. (2004)

This stated choice study was conducted using the same instrument in the United States (nationwide sample) in May 2002 and in Canada (nationwide sample except Quebec) in April 2003. There were 641 completed surveys in Canada, with a 52% response rate from a panel previously recruited to answer Internet-based surveys. There were 1,437 completed surveys in the United States, with an 80% response rate from a panel recruited, trained, and equipped with WebTV (Knowledge Networks). Both were self-administered by a computer in the respondent's home over the Internet, and were customized to the individual's age and gender, and randomized for the version.

The samples were limited to adults ages 35 to 84, and the sampling was stratified to get higher than population percentages of adults ages 65 and over. The mean age in the US sample was 57 years, and the mean age in the Canadian sample was 59 years. Respondents were presented with options for an annual payment for a preventive health care program ("treatment" in Canada). In the United States, about a third of the respondents received an alternative version that presented an alternative payment and risk reduction mechanism: an annual cost of living increase for a location with lower risk. The study considered 5 in 10,000, 2 in 10,000, and 1 in 10,000 annual risk reductions for the remaining lifetime, with annual payments. The cause of the risk change was specified as the risk of dying from either cancer or a heart attack. The relocation version in the United States also included the risk of a fatal motor vehicle accident. Respondents were given four or five paired choice valuation questions with two alternative risk reductions and costs in each question. Each paired choice was followed by a status quo follow-up question that asked respondents if they would prefer their previously selected choice or another choice of no change in risk with no new cost. A separate payment card question followed all the choice questions. Results were calculated separately for the paired choice and payment card responses. The analysis of the paired choice responses included the responses to the status-quo follow-up question.

Responses to the payment card question allowed examination of the zero WTP responses to evaluate potential protest answers. These are answers the analyst determines are based on rejection of the question rather than a true zero WTP (or alternatively a true very high WTP). Once identified, these answers need to be removed from the analysis, because they do not reflect an accurate measure of WTP for the individual. Table 5 summarizes the results of this evaluation. About 10% of respondents refused to answer, gave zero WTP, or gave unrealistically high WTP answers relative to income. After the evaluation, about 5% (in both samples) were dropped from the analysis of the payment card results. This information was also used to help identify potential problematic responses to the choice questions. The mean VSL results are presented in tables 6 (payment card) and 7 (paired choice). Results for cancer and heart attack were statistically not significantly different and are averaged.

The Canadian and US results for VSL were very similar and statistically not significantly different. The effects of the valuation question format (payment card or paired choice) and the payment vehicle (medical care or cost of living) were both significant, with paired choice results being higher than the payment card results and the cost of living payment vehicle results being higher than the medical care (treatment) payment vehicle.

Table 5. Percentage of Respondents Giving Problematic or Zero Value Responses – Payment Card Results

	Refused to Answer %	Retained Zero %	Protest Zero Dropped %	Suspect High Value Dropped %
Canada	1.1	2.6	3.6	0.5
United States	1.5	6.3	2.4	1.0

Source: Chestnut et al. (2004).

Table 6. Mean VSL Results (2007 C$) – Payment Card, Health Care Vehicle, Illness Cause of Death

Annual Risk Change	Canada $ (million)	United States $ (million)
5 in 10,000	1.6	2.0
2 in 10,000	3.2	3.1
1 in 10,000	5.8	5.3
Average	3.6	3.4

Source: Chestnut et al. (2004).

Table 7. Mean VSL Results (2007 C$) – Paired Choice, Health Care Vehicle, Illness Cause of Death

Annual Risk Change	Canada $ (million)	United States $ (million)
5 in 10,000	3.6	3.4
2 in 10,000	6.6	6.1
1 in 10,000	10.9	9.4
Average	7.0	6.3

Source: Chestnut et al. (2004).

The results show statistically significant higher WTP for larger risk reductions, but not proportional increases in WTP. Thus, VSL is lower for a larger risk reduction. For example, the mean annual WTP estimate for the Canadian sample for the 1 in 10,000 risk reduction is about $109 and for the 2 in 10,000 risk reduction is about $132. The associated VSLs are $10.9 million and $6.6 million, respectively, as shown in Table 7. The Canadian payment card results show WTP increasing 0.2% to 0.3% for every 1.0% increase in the risk reduction, and the Canadian choice model Canadian results show WTP increasing about 0.2% for every 1.0% risk increase. The US payment card results show WTP increasing about 0.4% to 0.5% for every 1.0% increase in risk reduction and the US choice model results show WTP increasing about 0.3% for every 1.0% increase in risk reduction.

Household income is statistically significant in all models and showed a WTP increase by about 0.5% for every 1.0% increase in income in both countries. Willingness to pay with respect to age was examined using 10-year age group dummy variables and as a continuous, non-linear variable. The US payment card models showed that WTP increases slightly with age until age 75, after which it decreases, but the effect of age is not statistically significant in all the models. The Canadian payment card results showed virtually no relationship between age and WTP responses other than a positive effect for those over age 75. The authors expressed scepticism about the latter result, because of a concern that the sample drawn from individuals who already have Internet access may not be representative of the typical population in this age group. Age was not statistically significant in any of the choice models. Overall, these results suggest that there may not be a statistically meaningful variation in WTP by age.

DeShazo and Cameron (2004) and Cameron and DeShazo (2004)

This stated choice study used the same instrument in the United States (nationwide sample) and in Canada (nationwide sample), both in December 2002. There were 1,109 completed surveys in Canada, with a 22% response rate from a panel previously recruited to answer Internet-based surveys. The sample consisted of those who already had Internet access and were contacted via e-mail. The response rate was somewhat lower in Quebec where only an English version of the survey was available. There were 1,619 completed surveys in the United States, with a 79% response rate from a panel recruited, trained, and equipped with WebTV (Knowledge Networks).[13] The authors noted that they excluded 820 US respondents for one of three reasons: a rejection based on not believing the risk reduction program would work, failing the risk comprehension question at the end of the survey, or a programming error that resulted in increased life expectancy for some illness profiles.

In both countries, the surveys were self-administered by computer, customized to the respondent's age, and randomized for the version. The samples were limited to adults ages 25 to 93. The mean age of US respondents was 50 years; the mean age of Canadian respondents was 49 years.

The commodity presented was a reduction in the risk of getting some kind of illness (12 types of illness were specified, such as cancer, diabetes, Alzheimer's), each with a profile that included illness name, age at onset, treatment(s), illness duration, level of pain and disability, and outcome (recovery or death). Included in the set were some illnesses that caused sudden death and some that caused no change in the risk of death. Only realistic combinations were included to prevent rejection, because of implausibility (e.g., one doesn't recover from Alzheimer's).

The quantitative risk presentation included a risk grid similar to that used by Krupnick et al. (2002) along with numerical and descriptive explanations of the risk reductions. A tutorial on the illness profiles, with explanations of the time sequence of the health states, was given before the choice questions.

Payment was specified as a co-payment for a program that combined diagnostic testing, drug therapies, and lifestyle changes to reduce the risk of a specific illness. Costs were presented in monthly and annual terms. Payment (and program) would continue annually for the remainder of life unless the illness occurs. Risk is reduced now or at some time in the future, as specified in each profile.

The valuation questions were structured as stated choice questions, with five pairs of risk reduction profiles in each version of the survey. Each of the five choice questions included a status quo option.

The authors used conditional logit models for estimation, and parameter estimates were used to calculate predicted “value of statistical illness” estimates. These were calculated from a large number (more than 10,000) of random draws from the joint distributions of illness profiles and population characteristics. Reported values are medians of the distribution, with 5 and 95 percentiles. (These are present values using a 5% discount rate.)

The analysis is structured on an indirect utility model of health risk through a person’s lifetime that considers the earlier life-cycle consumption models that treat health as either alive or dead, so the changes in the probability of death affect the probability of future consumption. The more recent Ehrlich (2000) model is also used, which takes into account how the health state affects the utility of consumption, and allows consideration of morbidity and mortality.

Comparability to previous VSL studies is by looking at the value of statistical illness (VSI) for sudden death in the current period, with the probability set equal to 1 that illness results in death. The authors have presented results in several working papers. Results vary somewhat when different models are used, but the central results remain fairly stable. Table 8 shows a comparison of results from Canada and the United States.

Table 8. VSL Results (2007 C$) for Sudden Death in the Current Year, at Mean Household Income

	Canada $ (million)	United States $ (million)
Mean age	6.3	5.8
45 years	8.4	7.5
50 years	9.0	6.9
70 years	4.9	3.0

Note: The authors reported results in US$ converted to C$ using the exchange rate of 0.64. We converted back to C$ and converted US results to C$ using the 2002 purchasing power parity value of 1.23, and adjusted for inflation using 1.108 based on the Canadian Consumer Price Index.

Sources: DeShazo and Cameron (2004), Cameron and DeShazo (2004).

Results reported in Table 8 account for the current age of respondents and show a fairly substantial decline in VSL after age 65. In a second paper (DeShazo and Cameron, 2004), the authors estimated a model that takes into account current age and age at which the change in risk of illness takes effect. This is based on the theoretical work of Ehrlich (2000), which shows that when the effect of health state on the utility of consumption is considered, there may be increasing benefits to protecting health as a person ages (until very late phases when the quality of life may be diminished). These increasing benefits may offset the declining benefits of reducing risk of death as the remaining life expectancy (future consumption time) decreases. The authors found results consistent with this. When only current age is included, WTP to reduce health risk declines with age. When age at the onset of risk change is included in the model, the effect of the current age diminishes and WTP to reduce current risk of illness does not vary much with current age (Table 9).

This study included scenarios in which the respondent would begin paying now for the program, but the risk reduction would not occur until some specified years in the future. Sometimes the future risk reduction was presented as starting in 10 years and sometimes it was presented as starting at age 70 regardless of the current age of the respondent. The results show that WTP now for future risk reductions apparently differs depending on current age and on the latency period (the amount of time until the risk reduction starts). Values to reduce risk at age 70 are similar for all current ages and are about half the value to reduce current risk. Willingness to pay to reduce risk in 10 years is also fairly flat with current age until it drops off dramatically at current age 65. This suggests WTP to reduce risk at ages 75 and later (when the 10-year delayed risk reductions would start for those currently 65) may be lower than at earlier ages (which is consistent with results from Krupnick et al., 2002). The Canadian and US results also show a statistically significant effect of income on WTP values, with an elasticity of about 0.5.

Table 9. VSL Results (quadratic, 2007 C$) for Sudden Death with Alternative Models for Age

	Reduce Risk This Year		Reduce Risk in 10 Years from Current Age	Reduce Risk at Age 70
Age now	Modelled with age now effects only $ (million)	Modelled with age now and age at risk change $ (million)	Modelled with age now and age at risk change $ (million)	Modelled with age now and age at risk change $ (million)
45	10.8	4.9	4.7	3.0
55	6.5	5.4	3.6	2.9
65	2.7	4.7	1.8	2.9

Sources: DeShazo and Cameron (2004) and Cameron and DeShazo (2004).

Summary of New Information from Recent Canadian Studies

Table 10 summarizes the results of these recent studies in Canada as well as the results from earlier Canadian studies. Table 10 also includes the results from US applications of the same stated preference survey instruments. Two conclusions are apparent: Canadian results are very similar to results obtained when the same stated preference surveys were done in the United States, and stated preference studies continue to show VSLs generally in the same range as the wage risk studies, but generally at the lower end of the range of wage-risk results.

Table 10. Summary of Canadian Estimates of Value for Mortality Risk Change

Authors	Study Type	Location	Study Sample	Cause of Risk	Mean Annual Baseline Risk	Annual Risk Change	VSL (2007 C$) Range $ (million)	VSL (2007 C$) Mean $ (million)
Previous Canadian estimates								
Meng (1989)	Wage-risk	Canada	Workers	On-the-job accident	0.00019		5.6-6.6	6.2
Meng and Smith (1990)	Wage-risk	Canada	Workers	On-the-job accident	0.00012		1.6-14.0	9.9
Cousineau et al. (1992)	Wage-risk	Quebec	Workers	On-the-job accident	0.00001		–	6.2
Martinello and Meng (1992)	Wage-risk	Canada except Quebec	Workers in logging, mining, and manufacturing	On-the-job accident	0.00025		8.0-10.1	9.0
Vodden et al. (1994)	Wage-risk	Ontario	Workers	On-the-job accident			–	7.6
Canadian studies since 1995								
Lanoie et al. (1995)	Wage-risk using perceived risk	Montréal at 16 companies	191 worker interviews	On-the-job accident	0.00013		29.3-32.5	30.9
Lanoie et al. (1995)	Stated preference (WTP)	Montréal at 16 companies	191 worker interviews	On-the-job accident		0.0001-0.0002	38.9-40.9	40.0
Lanoie et al. (1995)	Stated preference (WTP)	Montréal at 16 companies	191 worker interviews	Fatal automobile accident		0.0002	–	2.7
Meng and Smith (1999)	Wage-risk	Ontario	1,503 workers	On-the-job accident	0.00018		7.3-7.7	7.4

Table 10. Summary of Canadian Estimates of Value for Mortality Risk Change (cont.)

Authors	Study Type	Location	Study Sample	Cause of Risk	Mean Annual Baseline Risk	Annual Risk Change	VSL (2007 C$) $ (million)	
Alberini et al. (2004)	Stated preference: Dichotomous choice	Hamilton, Ontario	930 adults (ages 40-79)	Illness (unspecified)		0.0001-0.0005	1.4-5.4	3.4
Alberini et al. (2004)	Stated preference: Dichotomous choice	United States	1,200 adults (ages 40-79)	Illness (unspecified)		0.0001-0.0005	2.2-7.0	4.7
Chestnut et al. (2004)	Stated preference: Payment card	Canada except Quebec	641 adults (ages 35-84)	Illness (cancer or heart attack)		0.0001-0.0005	1.6-5.8	3.6
Chestnut et al. (2004)	Stated preference: Paired choice	Canada except Quebec	641 adults (ages 35-84)	Illness (cancer or heart attack)		0.0001-0.0005	3.6-10.9	7.0
Chestnut et al. (2004)	Stated preference: Payment card	United States	1,437 adults (ages 35-84)	Illness (cancer or heart attack)		0.0001-0.0005	2.0-5.3	3.4
Chestnut et al. (2004)	Stated preference: Paired choice	United States	1,437 adults (ages 35-84)	Illness (cancer or heart attack)		0.0001-0.0005	3.4-9.4	6.3
DeShazo and Cameron (2004)	Stated preference: Paired choice	Canada	1,109 adults (ages 25-93)	Illness (sudden death)		0.001-0.006	–	6.3
DeShazo and Cameron (2004)	Stated preference: Paired choice	United States	820 adults (ages 25-93)	Illness (sudden death)			–	5.8

Recent Meta-Analyses of the VSL Literature in the United States and Other Countries

Three recent meta-analyses of the VSL literature include many of the same original studies, but they use different analysis approaches and there are some differences in how the VSL estimates were selected from the literature. Mrozek and Taylor (2002) and Viscusi and Aldy (2003) limited their analyses to wage-risk studies. Kochi et al. (2006) included wage-risk studies and stated preference studies and reported results for each type of study, as well as combined results. Mrozek and Taylor (2002) considered only US studies. The other two analyses included available results from studies in all countries. The majority of the studies have been done in the United States and almost all have been done in fairly high income countries.

Many of the original studies reported more than one VSL estimate from different model specifications used to analyze the data. In addition, multiple publications were sometimes based on the same or similar data sources. Each meta-analysis treated these multiple estimates differently. Viscusi and Aldy selected one estimate from each publication based on what the publication authors indicated was their preferred model. Mrozek and Taylor included every estimate from each publication but weighted them by the inverse of the number of estimates from each publication in the meta-analysis. Kochi et al. conducted statistical tests for homogeneity for subsets of estimates by the same authors and took mean values from subsets that passed the test for homogeneity. Using this process, 197 VSL estimates (from 45 studies) were distilled into 60 estimates presumed to be independent for the purposes of the meta-analysis.

The three meta-analyses concluded with mean VSL estimates that vary quite a bit: approximately $4 million, $8 million, and $11 million. However, when results are based on the most comparable sets of studies and analytical approaches, the range of mean VSL estimates narrows considerably. All three meta-analyses report mean results from wage-risk studies in the United States, excluding those that used the inappropriate Society of Actuaries data[14] and those that included only high-risk occupations (such as police officers). These results are shown in Table 11, which illustrates that when the most comparable results from each meta-analysis are shown, the range in mean VSL estimates is narrowed to about $10 million to $13 million.

Table 11. Mean VSL from US Wage-Risk Studies from Three Meta-Analyses

Meta-Analysis Authors	Mean VSL (2007 C$)[d] $ (million)	Number of Observations	Variation Estimate (million)
Mrozek and Taylor (2002)[a]	9.7	91	Standard error = 3.8
Viscusi and Aldy (2003)[b]	10.8	44	95% confidence interval = 4 to 27
Kochi et al. (2006)[c]	12.7	30	Standard deviation = 7.5

Notes:

a. Results are selected for a risk level of 1 in 10,000, which is close to the mean for this sample, and weighted assuming 12% of studies used National Institute for Occupational Safety and Health risk data and 88% used US Bureau of Labor Statistics data. Results from models 3 and 4 are averaged. These are the results with the minimal inclusion of industry variables.

b. These are results from Viscusi and Aldy's Table 8, robust model with Huber weights, US estimates after dropping studies using Society of Actuaries data.

c. Results for US wage-risk studies.

d. All estimates are adjusted from 2000 US$ using the 2000 purchasing power parity: US$1 = C$1.23, and an inflation adjustment of 1.158 from the Canadian Consumer Price Index for 2000 to 2007.

The results reported in Table 11 for Viscusi and Aldy are their primary estimates of mean VSL from US studies. The other two meta-analyses, however, offer additional results, as shown in Table 12. Mrozek and Taylor argued that many wage-risk studies did not include sufficient model specifications to account for unexplained differences in wages across industries. They concluded that this caused upward bias in many VSL results. They use their model to estimate what the mean VSL would be if all the studies included the approach they recommended to control for differences in wages across industries. Their results suggest a mean VSL of about $3.7 million (standard error = 1.3 million), in 2007 Canadian dollars. Viscusi and Aldy pointed out that if unexplained differences in wages across industries are correlated with differences in risks of death from on-the-job accidents, then the industry dummy variables that Mrozek and Taylor recommended could reflect some of the effect of these differences in risk. This could cause downward bias in the risk coefficients in the wage function. It is impossible to tell from the available data which view is correct. The most accurate mean VSL from the US wage-risk studies is somewhere between $4 million and $10 million from these two meta-analyses, but it is hard to say exactly where.

Table 12. Alternative Mean VSL Results from the Meta-Analyses

Meta-Analysis Authors	Mean VSL 2007 C$[b] $ (million)	Number of Observations	Variation Estimate (million)
Mrozek and Taylor (2002), adjusted for differences in wages across industries[a]	3.7	91	Standard error = 1.3
Kochi et al. (2006) stated preference studies	4.0	18	Standard deviation = 1.9
Kochi et al. (2006) combined mean for wage-risk and stated preference studies	7.7	60	Standard deviation = 3.4

Notes:
a. Results are selected for a risk level of 1 in 10,000, which is close to the mean for this sample, and weighted assuming 12% of studies used National Institute for Occupational Safety and Health risk data and 88% used US Bureau of Labor Statistics data. Results from models 3 and 4 are averaged. These are the results with the maximum inclusion of industry variables.

b. All estimates are adjusted from 2000 US$ using the 2000 purchasing power parity: US$1 = C$1.23, and an inflation adjustment of 1.158 from the Canadian Consumer Price Index for 2000 to 2007.

Kochi et al. provided additional information on the VSL literature, because they included results from stated preference studies. When considered alone, the stated preference results have a mean VSL of about $4 million, which reflects the results of eight studies in the United States and other developed countries. These results are thus at the lower end of the range of mean results from the wage-risk studies depending on how the industry variables are handled. It is also important to note that many of the stated preference studies include subjects who are over 65 and thus reflect the preferences of a wider segment of the general population than the wage-risk studies that are limited to working-age adults. The stated preference studies also cover different types of mortality risks, primarily traffic accidents and illness-related death.

Kochi et al. also reported an overall mean VSL based on both types of studies. This mean VSL is $7.7 million, which reflects the results of 45 studies in the United States and other developed countries. However, given that the wage-risk studies seem to provide substantially higher VSL results than the stated preference studies ($13 million versus $4 million in the Kochi et al. analysis), there are important questions about the meaningfulness of this combined mean VSL. The mean across both types of studies is influenced by the relative numbers of each type of study. It doesn't make sense that wage-risk results should be given more weight just because more of those studies have been done. If they are measuring something different, it is more important to ask which type of study is estimating the VSL estimate needed for policy analysis. It is an open empirical question as to why the results are different. It is not clear whether the differences in subjects' ages or in the causes of risk lead to the apparent differences in results, or whether measurement methods cause the differences.

The Kochi et al. results in Table 12 reflect results from US studies as well as studies done in other developed countries. They do not report US-only results for the stated preference studies as they do for the wage-risk studies, and their overall mean reflects studies in all included countries. The comparison to the wage-risk studies is therefore not consistent, because differences in per capita income and other factors could result in systematically different WTP results in different countries. We therefore requested from the authors a list of all the studies included in their analysis, which they provided.[15] That list showed that only three of the eight stated preference studies were done in the United States. We took the results from these three studies and added results from two additional studies done in the United States to calculate a mean VSL for the US stated preference studies. Table 13 summarizes these five studies.

The two studies we added are Alberini et al. (2004) and Ludwig and Cook (2001). Alberini et al. reported the results of a US application of the same survey instrument used in the Canadian study reported by Krupnick et al. (2002), which was included in the Kochi et al. analysis. The Ludwig and Cook results were added, because although Kochi et al. listed the study as not providing a standard error for their mean results, Ludwig and Cook did report a confidence interval from which we were able to calculate an approximate standard error.

When more than one estimate was reported, we calculated an average result for each of the five studies. We then calculated a weighted mean across the five US studies using the inverse of the standard error as the weight. The mean was $7.5 million (2007 C$) with a standard error of $1.4 million (without any adjustment for real income growth). This is considerably higher than the mean reported by Kochi et al. for all eight stated preference studies.

Table 13. US Stated Preference Studies and Selected VSL Results

Study	Risk Type	Sample Size	Sample Characteristics	Amount of Mortality Risk Reduction	VSL (2007 C$) (million)	Standard Error	Comments
Alberini et al. (2004)	Mortality from unspecified illness	About 550 for each subsample	US general population age 40 and over; Knowledge Networks Internet survey panel	5 in 1,000 1 in 1,000 10-yr risk reduction	2.19 6.88 Average: 4.54	0.24 1.05 Average: 0.65	Not included in Kochi et al., although they included the Canadian version of this study (which is very similar). Probably out after their publication cutoff. Results are different for different risk levels, because WTP is not proportional to risk reduction (but statistically, WTP is significantly different for different risk reductions). These two estimates are from different subsamples alternating which risk reduction was asked first. These are mean results.
Corso et al. (2001)	Auto safety-side air bags	275 for this subsample	US nationwide	1/10,000 0.5/10,000 Annual risk reduction	4.27 4.69 Average: 4.48	0.60 0.78 Average: 0.69	Focus of this study was test of alternative visual aids. Kochi et al. included results from all four versions, but one version (dots) gave best results in terms of the scope test, so these are the results selected here. Results for this version are in the same range as the results from other versions. Results are median values, which is all the authors reported.

Table 13. US Stated Preference Studies and Selected VSL Results (cont.)

Study	Risk Type	Sample Size	Sample Characteristics	Amount of Mortality Risk Reduction	VSL (2007 C$) (million)	Standard Error	Comments
Hammitt and Graham (1999)	Auto safety	500 for panel B, survey 2	US nationwide, ages 18-65	1.5/100,000 7.7/100,000 Annual risk reduction	14.86 17.63 Average: 16.24	1.57 6.48 Average: 4.03	Focus of this study was alternative elicitation of risk/WTP trade-off. Indifference risk approach worked best in terms of the scope test, but there were still large ordering effects in terms of which risk reduction was asked first. These are results for the larger risk reduction asked first. Results for other ordering were more than twice as large. These are median results, which is all the authors reported. Kochi et al. included these results and lower VSL results obtained from the other elicitation approach. Kochi et al. did not include the $30 million to $40 million VSL obtained with the second ordering of the indifference risk elicitation.

Table 13. US Stated Preference Studies and Selected VSL Results (cont.)

Study	Risk Type	Sample Size	Sample Characteristics	Amount of Mortality Risk Reduction	VSL (2007 C$) (million)	Standard Error	Comments
Ludwig and Cook (2001)	Gun violence	1,200	US nationwide	All injuries: 2/10,000 households Fatalities only: 0.35/10,000 household	1.79 10.16 Average: 5.97	0.51 2.93 Average: 1.72	Kochi et al reported that this study did not give a standard error, so they didn't use the results. However, the authors did report a confidence interval, which we used to calculate a standard error. WTP values are per household, as are the risk numbers. Authors reported the WTP value per injury avoided. Kochi et al. apparently recalculated this for fatalities only, but this assumes no value for non-fatal injury. In reality, a non-fatal gunshot wound probably has substantial value, so we average the two extremes, which essentially give 2/1 weight to fatal versus non-fatal.
Viscusi et al. (1991)	Auto safety	390	Residents of Greensboro, NC (similar to general population); computer administered at a central site	Varies, but in the range of 1/100,000	16.18	2.85	This is the mean result from the auto death trade-off question with cost of living.

The meta-analyses for US studies show unadjusted VSL means from wage-risk studies that are higher than the mean from the US stated preference studies. The means for the former are about $10 million to $13 million, and for the latter about $7.5 million. The results from the Canadian studies are in the same range, and direct comparisons of the same studies in both countries show no statistically significant differences. However, the means of Canadian wage-risk studies and the Canadian stated preference studies are both a little lower than the comparable US means, at about $7.8 million and $5.0 million, respectively. Mrozek and Taylor raised some questions about whether the wage-risk studies may overstate the estimates of monetary values for mortality risk reductions. They recommended a mean VSL closer to $4 million, although there is the possibility that they have overcorrected for unexplained differences across industries. That the stated preference studies also find VSL estimates that are lower than the unadjusted wage-risk results suggests that the latter may be on the high end of what is appropriate for policy analysis. It is especially significant that many of the recent stated preference studies have included an older age range of respondents than is feasible to include in wage-risk studies.

Emerging Results that Suggest How WTP May Vary in Different Contexts

Recognizing that evaluating the mortality benefits of a program by simply counting the number of lives saved and applying a single VSL (or even a mean and distribution of VSL values) is potentially inadequate for valuing changes in mortality risks in all contexts, analysts have been exploring the dimensions of mortality risk that may be relevant to monetary valuation in policy analysis for programs that reduce mortality risk. The key question is how WTP for mortality risk reduction may vary in different contexts. Economic theory tells us that WTP may vary, but it does not answer the question of exactly how it varies. Thus, it is largely an empirical question. Empirical work has been done, but results are not yet sufficiently robust and consistent to provide a fully adequate basis for a new valuation approach for public policy and program assessments. A few alternatives have been proposed, and their basis may soon be sufficient for use in policy analysis applications as new research efforts are undertaken to further explore these issues.

Ultimately, we would like to be able to extrapolate WTP estimates from one context and one population to another population and context. Such a procedure will become possible only when numerous WTP studies have been conducted on a variety of risk reductions and on a variety of populations, allowing the estimation of an overarching WTP function that links WTP values with the characteristics of the risk and of the affected population.

New stated preference studies are being conducted that estimate people's WTP for reductions in a variety of mortality risks, and these studies explore in more detail than previous research how individual characteristics affect the WTP values. Results of these studies may be used to develop predictions of WTP in specific contexts for specific populations by adjusting for the characteristics of the target population (such as age and health status) and of the target risk reduction.

However, caution is warranted for the time being. Consistency in findings regarding differences in WTP across different populations is needed from many repeated studies with different population groups before confidence can be placed in these kinds of extrapolations. There may also be equity or fairness arguments for not making adjustments in benefit estimates for some kinds of differences in characteristics of exposed populations. For example, adjusting for differences in average incomes of the exposed population could have the undesired effect of allowing pollution exposures to be higher in locations where the population has lower incomes.[16]

An important issue raised is whether the change in mortality risk for the affected population is better characterized as numbers of lives saved or as numbers of life-years saved. The latter reflects the number of people affected and takes into account their remaining life expectancy. A measure of life-years saved is often used in cost-effectiveness analysis for medical treatment options where trade-offs between risks of negative side effects and potential for increased life expectancy are important considerations in assessing treatment effectiveness for patient populations.

Monetary Values for Risk Reductions in the Future

Two different issues are related to valuation of mortality risk reductions in the future. One is for the individual when there is a time lag between the time when a change in exposure is made and when a change in risk manifests itself. Some are essentially simultaneous, such as highway improvements that reduce accident rates. Others may involve a substantial time lag, such as a reduction in exposures to carcinogens versus a change in realized cancer rates. From an individual's point of view, there is a difference between an expense now that causes a risk reduction now versus an expense now that causes a risk reduction at some future time.

The second issue relates to valuation of risk reduction programs that are expected to extend into the future as an ongoing risk reduction effort. In this case, the analyst estimates the value of the risk reduction to individuals in the future whether or not a time lag between exposure change and risk change is involved. In this case, the question is not how people today value a risk reduction in the future, but how people at that future time would value their own risk reduction.

Regarding the first issue, which is sometimes called a cessation lag, we would expect that an individual's WTP for a risk reduction would be influenced by the time when a change in health may be experienced relative to the time when a change in environmental exposure (and associated cost of control) occurs. Some pollution exposures are known to pose risks of immediate health effects, whereas others involve substantial latencies before a change in health that could result in death might occur. For example, a high air pollution episode is associated with elevated mortality rates within days of the change in pollution concentrations, but for some effects on chronic illness, such as heart disease, chronic obstructive pulmonary disease, and cancers, the effects that may result in death do not arise for many years. Conversely, when such exposures are reduced, there may be a lag of several years before the health benefits are fully realized in the population with reduced exposures. The expectation is that the longer the latency period or the cessation lag, the lower the WTP values to reduce current exposure, because of discounting. From the point of view of the individual at risk, it makes sense that one would be willing to pay more today for a risk avoided today than for a risk reduction (of the same magnitude) that will not be realized until many years from now.

Cropper and Sussman (1990) conducted a theoretical analysis to examine the expected relationship between an individual's WTP and the timing of a risk reduction. They found that WTP at age 40 for a risk reduction that occurs at age 60 will be some fraction of the WTP at age 60 for a risk reduction at age 60. Cropper and Sussman illustrated that if a person's decisions were based on only the value of consumption during her or his own lifetime, the rate of discount for future risks to the individual would be expected to be the same as the market interest rate.

A few empirical studies have developed estimates of discount rates of individuals for risk reductions to themselves in the future. Moore and Viscusi (1990) used data from a wage-risk study to estimate implicit discount rates for future years saved by current risk reduction. Using various models, they found discount rates that ranged from 1% to 14%. Horowitz and Carson (1990) found a 4.5% discount rate for future mortality risk reductions. Most recently, Alberini et al. (2006b) reported results of discount rates revealed by answers to WTP questions regarding future mortality risk reductions in their studies in the United States and Canada. They asked respondents younger than 60 whether they would be willing to pay a specified amount for a risk reduction starting at age 70 and lasting 10 years. This question was asked after similar questions about mortality risk reductions starting now (results described earlier). They found that delaying the risk reduction by 10 to 30 years substantially reduced the WTP values. They calculated the implicit discount rates revealed by these responses and found a range of 3.0% to 8.6% in the Canadian sample and a range of 1.3% to 5.6% in the US sample. These results are somewhat higher than the 0.3% to 1.3% discount rates found by Johannesson and Johansson (1996) using similar questions.

Size of the Mortality Risk Change

Most benefit assessments for public policy efforts to improve health and safety have treated the value of mortality risk reduction as a unit value that is proportional to the size of the risk change. This has appeal for its computational simplicity and consistency in making comparisons across different policy choices, but it may not be accurate. Hammitt and Graham (1999) presented a theoretical analysis that concluded that for small changes in probabilities of death, the WTP value is expected to be proportional to the size of the probability change. An exception to this is if the risk change is large enough that the WTP value represents a significant share of income. What constitutes a "significant" WTP value relative to income is an empirical question that is not answered by the theoretical analysis, but it would be something larger than a marginal change and would have some noticeable impact on the household budget.

Empirical evidence on this issue remains somewhat inconclusive, but there is evidence that as risk changes become larger, the WTP value per unit reduction falls. This is a common result for typical goods and services with diminishing incremental pleasure or satisfaction for additional consumption, but as noted above, it is not clear that this is expected with mortality risk. (That is, one may not become satiated with safety the same as one might with steak or bananas.) The empirical evidence on this comes primarily from stated preference studies, and uncertainty remains about whether difficulties for human subjects in answering questions about small probabilities of death may result in insensitivity to the scope of the risk change that reflects difficulty with the questions more than it reflect true differences in valuation. For example, it is typical that stated preference studies find that WTP for a 2 in 10,000 risk reduction is not twice as large as WTP for a 1 in 10,000 risk reduction. Analysts argue that some respondents focus more on what may be a reasonable amount to pay for a safety device or health care product than on the specific risk reduction presented in the questionnaire.

Corso et al. (2001) presented results that suggest that the difficulty with the risk information may affect the sensitivity of the WTP responses to the size of the risk change. They found that when using visual aids, such as dots to illustrate risks or risk ladders to illustrate different levels of risk, the WTP responses showed greater sensitivity to the size of the risk change. This suggests that when more is done to ensure that respondents focus on the size of the risk change, WTP responses are more proportional to the size of the risk change. An elasticity of 1.0 represents proportionality, meaning a 1% change in WTP for every 1% change in the size of the risk reduction. Corso et al. (2001) found the elasticity of WTP with respect to the risk change increased from 0.1 with no visual aid to 0.9 with the most effective visual aid (dots). The results when risk ladders were used were 0.4 and 0.7 with linear and logarithmic ladders, respectively. These are all significant differences from the results when no visual aid was used. On the other hand, Krupnick et al. (2002) and Chestnut et al. (2004) both used dots to illustrate risk change quantities and their results showed elasticities of WTP with respect to the size of the risk change of 0.2 to 0.5. These fairly wide variations in results suggest that considerable uncertainty remains on this issue.

Pattanayak et al. (2002) proposed an approach they called preference calibration that defines a procedure for transferring value estimates from one context to another using a model consistent with economic theory. The model forces WTP values to be held within the budget constraints of consumers. The procedure defines the preference function and uses available information to estimate the preference parameters. The preference function is also “calibrated” to available benefit estimates, allowing unobserved parameters to be inferred.

A key advantage of this approach is that extrapolations of values beyond the range of original estimation circumstances, such as to larger changes in mortality risk, are forced to be consistent with utility theoretic constraints. In practice this means that large changes in risk have lower unit values than small changes in risk, because of the effect of the income constraint. This explicitly leads to differences in program benefits when comprehensive programs (e.g., the entire *Clean Air Act*) are evaluated versus individual programs (e.g., industry-specific regulations). It also makes explicit that there is not a single unit value for mortality risk that applies in all contexts, but that this value is expected to differ in different contexts. A limitation of this approach is that the empirical information available to estimate the preference parameters is limited. It does, however, force the analyst to be specific about assumptions being made in the application of results to a specific policy context.

As a practical matter, this uncertainty is increased when WTP values are applied to risk changes that are much larger or much smaller than those for which the WTP estimates were originally estimated. Most of the literature provides estimates of WTP for risk changes on the order of 1 in 10,000 to 1 in 100,000. When risk changes being evaluated for a given policy assessment are much larger or much smaller than this, the analyst must explore alternative adjustments, and preference calibration provides a structure for doing this.

Cause of the Mortality Risk Change

Available estimates of VSL are based primarily on studies inferring WTP for risk reductions related to on-the-job or transportation accidents. These risk contexts, as well as the characteristics of the populations at risk, are in many cases quite different from those risks related to environmental exposures and other public policy contexts. Some of these differences could mean that WTP to change those risks may also differ.
People’s reactions to, and attitudes toward, risks have been shown in a substantial risk perceptions literature to be affected by many attributes beyond simply the magnitude of

the risk. Attributes that appear to be significant in how subjects rate different risks include dread or fear related to the risk, the source of the risk, its voluntariness, how controllable it is by the individual, and whether the mitigation measures are privately undertaken or are part of a broad government program (e.g., Slovic, 1987). In addition, people seem to have a tendency to overestimate very small, but rather unfamiliar, risks (e.g., nuclear power accidents), and underestimate greater but more familiar risks (e.g., auto accidents). Reasons for these differences are not well understood, but it may be because of numbness toward a familiar risk or because there are perceived differences as to the extent a person controls her or his own level of risk exposure. To the extent that WTP for reducing risks is a function of risk attributes, then reductions in risks with different attributes may be valued differently, but economic valuation studies have only begun to address this question. Just because respondents rate one given cause of mortality risk as more important than another does not mean they hold different values for the same size risk reduction from different causes. However, it is possible that for the same size risk change, WTP may vary. For example, people may place more or less value on a unit reduction in an automobile accident fatality risk versus a cancer fatality risk. Factors that may affect WTP values may include whether the risk is from a familiar or unfamiliar source, whether the individual can do anything to change the exposure or ameliorate its effects, whether exposure is perceived as voluntary or involuntary, and whether the potential death would be quick and painless or slow and painful.

As a practical matter, the key question for policy analysis is whether values for reducing on-the-job risks are different than values for reducing other health and safety risks that may be affected by public policy. These include transportation safety and environmental health risks and occupational safety. There are some expectations that values for reducing environmental health risks may be greater than for reducing risks of accidental death. Two primary reasons are that environmental exposures are viewed as out of the control of the individual, and environmental health risks are related to illnesses that may have an extended period of reduced functionality that precedes death due to prolonged illness and treatment (such as with cancer). On the other hand, for many illness-related risks, there may be a lag between changes in exposure and changes in health risks, because the effects of the exposure are manifest over time rather than immediately. This lag may reduce the value of a current reduction in exposure, because of a common discounting of future outcomes.

These issues are difficult to address empirically and only limited information is currently available. The issues surrounding environmental exposures are especially difficult, because there are limited circumstances amenable to revealed preference analysis, and stated preference analysis is hampered by the public good nature of the risk. Analysts have found that when presented with questions about reducing environmental pollutants, respondents tend to think about the benefits to everyone, not just to themselves. This makes the responses not comparable to those limited to the individual's own risk and presents a likelihood of double-counting the total value if these responses are summed over the entire population (Jones-Lee, 1991).

A few studies have been designed to compare values for mortality risk changes in different contexts, such as for illness-related death versus accident-related death. These studies provide very useful information, because other factors are held constant while the context is changed. In most cases, we must infer the effect of differences in context by comparing results from different studies. There is much more uncertainty in these comparisons, because many factors may be different between studies, including methodological characteristics of the studies. Again, we need to be cautious in attributing differences in results to specific differences in context.

Willingness to pay to reduce the risk of cancer death may be greater than for accidental deaths, for example, because of the lengthy and painful illness and treatment process that frequently precedes death from cancer. Available WTP research is not sufficient at this time to determine the direction or the magnitude of the potential error in applying available VSL estimates to cancer deaths. Jones-Lee et al. (1985) found that the majority of respondents said they would prefer a program that reduced deaths from cancer over a program that reduced the same number of deaths from automobile accidents or heart disease. This finding is not sufficient to conclude that WTP to reduce risks of cancer deaths necessarily exceeds WTP to reduce risks of automobile accident deaths or heart disease deaths, but it suggests that the possibility exists.

Most of the available estimates of monetary value for reducing mortality risk are from the labour market literature that examines the relationship between risk of on-the-job fatality and wages. These are primarily deaths from workplace accidents. The earliest stated preference studies focused primarily on mortality risk from motor vehicle accidents. More recent stated preference studies have focused on risks of death from illness-related causes, and a few have made direct comparisons of the value of risk reduction for different causes of risk. Two stated preference studies (Gerking et al., 1988; Lanoie et al., 1995) estimated WTP to reduce mortality risks from workplace accidents and found results roughly comparable to those obtained from a wage-risk analysis of a similar sample using a measure of perceived on-the-job risk. These results suggest that some conclusions may be drawn from comparisons of studies of different causes of risk using different estimation methods, but of course the strongest evidence is from studies designed to compare different causes of risk directly.

Chestnut et al. (2004) estimated WTP for reductions in risks of fatal cancer and fatal heart attacks in Canada, and these plus fatal motor vehicle accidents in the United States using stated preference methods. They found little difference in results for reducing risks of fatal cancer versus fatal heart attacks, and found that both of these were valued more than reductions in risks of fatal motor vehicle accidents. On the other hand, Magat et al. (1996) found a roughly one-to-one trade-off between reducing the risk of a fatal motor vehicle accident and reducing the risk of a fatal cancer.

DeShazo and Cameron (2004) designed their stated preference study to estimate WTP values for reducing several different causes of fatal risk and varying combinations of morbidity and mortality risks (such as risks of dying suddenly or risks of dying after a lengthy illness period). Their results are not yet fully analyzed for these differences, so conclusions cannot yet be reported.

Lanoie et al. (1995) found WTP results from a stated preference study for reducing the risk of a motor vehicle accident fatality to be about an order of magnitude smaller than WTP results for reducing the risk of a fatal on-the-job accident, using stated preference and wage-risk analyses. However, their sample is quite small (fewer than 200 respondents) and their results for values to reduce the risks of on-the-job fatalities are an order of magnitude larger than most results in the literature. Thus, it is difficult to know how to interpret the comparison of their results.

Studies completed to date do not provide sufficiently consistent quantitative results to support the selection of different WTP values for reducing risks of death from different causes for use in policy analysis. However, the evidence suggests that the values for reducing illness-related risks are likely to be equal to or greater than the values for reducing risks of accidental death. This means that applying results from the literature, which has focused more on accidental death, to policy analysis concerning illness-related risks will not overstate the values because of differences in the cause of death. The basis for observed differences in WTP for different types of risks needs to be better understood before it can be incorporated into policy analysis applications. It is possible that respondents to stated preference questions do not understand very well, or are explicitly sceptical of, the quantitative information on risks that is presented to them, and focus more on what they believe their personal risk exposure to be. If this is the case, then it may not be the attributes of the risk that cause different WTP responses so much as what subjects are thinking about the magnitude of their own risk exposure. For example, if people are told that the average annual risk of having a fatal automobile accident is 1 out of 10,000, they may believe that because they are above average drivers, their risk is less than this. Thus, they may appear to put a lower value on reducing automobile related risks when in fact what they are doing is valuing a smaller risk change than the analyst intended for them to consider. These issues need to be probed in survey development and in follow-up questions to ensure that analysts appropriately interpret the responses.

Differences in Values Due to Age, Health Status, and Baseline Risk

The issues of the effects of age, health status, and baseline risk on values for reducing mortality risk are discussed together, because they are correlated over a person's lifetime and are difficult to separate. These issues are the cause of significant uncertainty when applying values based on risks in the workplace to reductions in risks to public health and safety, because many public policy choices have the greatest impact on risks to children and seniors rather than on risks to working age adults. Therefore, a key analytical question is how the value of reducing mortality risks for children and seniors may differ from the value for reducing mortality risk to working age adults. Definitive answers are not yet available, but recent studies provide quite a bit of new information on this issue.

The previously recommended estimates for use in policy analysis (Chestnut et al., 1999) included lower values for those over age 65 based on the results of Jones-Lee et al. (1985). Their results were consistent with the predictions based on theoretical analysis using the life-cycle consumption-saving model. This model is based on the premise that a person makes consumption and savings decisions over time to maximize personal utility (a term referring to a person's own sense of welfare, satisfaction, and enjoyment). Shepard and Zeckhauser (1982) and Cropper and Sussman (1990) used a life-cycle consumption-saving model to examine how WTP for risk changes might be expected to change through a person's lifetime. These analyses showed that WTP for mortality risk reductions may increase with age, but beyond about age 40, it may decline with the person's age (if the risk reduction takes place immediately). Individual characteristics may also influence WTP for risk reductions.

Ehrlich and Chuma (1990) showed, with a less restrictive theoretical model, that the expected effect of age on WTP values is indeterminate, because with reduced life expectancy WTP for risk reduction may decline but the value per remaining life-year may increase as remaining time becomes scarcer.

Economic reasoning further suggests that WTP for risk reductions may be greater when the individual's baseline risk is higher (holding the size of the risk reduction the same), because of the decreasing value to the individual from incremental improvements in safety as baseline safety levels increase. This means, for example, that we are expected to value a mortality risk reduction of 1 in 100,000 more if we start out at a risk level of 1 in 10,000 than if we start at a risk level of 2 in 100,000 (or 0.2 in 10,000). This effect may cause WTP to increase as a person gets older and faces higher risks of death. This remains, however, an empirical question that has not been explored very thoroughly in the literature, and the results are somewhat mixed as to whether WTP varies as expected. Baseline risks are also often compounded with other differences, such as remaining life expectancy and health status of the individual, making it difficult to isolate each effect on WTP.

Recent theoretical analyses incorporated this perspective and demonstrated that when rising baseline mortality risk is taken into account with declining remaining life expectancy, how WTP for mortality risk reduction changes with age is indeterminate. The possibility of decreasing WTP as remaining life expectancy declines is potentially offset by a rising value for risk reduction as baseline risk levels increase. There is also uncertainty about the role of tendencies toward declining physical health as individuals age and how this may affect WTP for risk reduction (Ehrlich and Chuma, 1990; Alberini et al., 2004; Evans and Smith, 2006).

Hammitt (2007) summarized the ambiguity about how WTP for mortality risk reduction will change with decreases in remaining life expectancy by noting that spending money to reduce current risk has two effects on the individual's well-being. One is that it increases the chances of survival, which presumably has greater value if the amount of time remaining is higher. The other is that it reduces the resources remaining to spend on future consumption, which presumably has greater significance if the amount of remaining time is greater necessitating that the individual save more resources for the future rather than spend them on current risk reduction. Thus, as life expectancy decreases, these effects on WTP work in opposite directions and the theoretical analysis alone cannot predict whether the net effect is positive, negative, or neutral. This means that how WTP changes with age can only be resolved empirically and is intertwined with how WTP for mortality risk reduction is affected by baseline risk levels and by health status.

Three types of studies tell us something about the relationship between WTP for mortality risk reduction and age: stated preference, consumer choice, and labour market analyses. Each gives information from somewhat different perspectives.
The conclusions reached by these theoretical analyses of the effect of age on WTP for immediate mortality risk reduction using the life-cycle model show that it is important to consider potential relationships between WTP and age that are non-linear, allowing WTP to have a different slope over different age ranges. Jones-Lee et al. (1985) reported findings that are consistent with the life-cycle models. Respondents to their stated preference survey gave WTP estimates for reductions in highway accident mortality risk, and the answers showed a fairly flat, hump-shaped relationship between VSL and age, peaking at about age 40. The observed decline in WTP after age 40 was, however, not as rapid as that predicted by the life-cycle models. Krupnick et al. (2002), on the other hand, found little relationship between age and WTP for a personal health program to reduce risk of death for a sample of adults aged 40 to 74, except for a decline in WTP after

age 70. Krupnick et al. also found that physical health status had little relationship to WTP responses, but that a positive attitude was associated with higher WTP.

Three recent stated preference studies (Krupnick et al., 2002; Chestnut et al., 2004; and DeShazo and Cameron, 2004) were designed specifically to address the question of how WTP for mortality risk reduction is affected by a respondent's age and other individual characteristics. These studies allow the most direct exploration of this issue, because individual WTP responses (or choices that reveal WTP values) and data on individual characteristics are collected. Results from Krupnick et al. and Chestnut et al. are somewhat similar: they found very little relationship between age and WTP for mortality risk reduction. Krupnick et al. included individuals ages 40 to 79 in their study and found a lower WTP only for those over age 70. However, the results were statistically significant only in the Canadian sample, which had a smaller proportion of respondents in this age group. In the US sample, the reduction in WTP for this age group was about 20% relative to other ages, but it was not statistically significant. In the Canadian sample, the reduction in WTP for this age group was about 35%. Chestnut et al. included respondents ages 35 to 84 and generally found no statistically significant relationship between age and WTP for risk reduction. In the US sample, they found WTP increasing slightly with age until age 75, after which it decreased. In the Canadian sample, WTP was increasing throughout the age range. In both samples, the age coefficients were not statistically significant in many of the models.

DeShazo and Cameron (2004) designed choices to reflect values for reducing current and future risks, and estimated models that included the timing of the risk dimension and the age of respondents now and at potential future risk reductions. Their results suggest some complexity around these factors. When they modelled only current age, they found that WTP to reduce current risk declines by about 50% from ages 50 to 70. However, when they included age at future risk change in the model and current age, they found that WTP to reduce risk in the current year was basically unchanged by the current age of respondents.

Krupnick (2007) reviewed the stated preference literature examining the estimated relationship between age and WTP for mortality risk reduction in 26 studies in the United States and other countries. This review included the Alberini et al. (2004), Chestnut et al. (2004), and DeShazo and Cameron (2004) studies conducted in Canada. He reported that about half of these studies found that statistically WTP was significantly lower for the older age group, which was defined differently in different studies, but generally above 65 or 70 years old. In contrast, about half the studies found no statistically significant relationship between age and WTP for mortality risk reduction. Of those finding a statistically significant effect, the difference in WTP varies, but most of these studies estimated WTP for a 70 year old to be about 20% to 35% lower than that for a 40 year old.

Mount et al. (2003) provided new evidence on the value of mortality risk reduction for children, adults, and seniors from an analysis of household automobile purchase and usage decisions. They used US motor vehicle accident fatality data for specific makes and models of automobiles and data provided by the household about how much time each family was in each automobile to develop age-specific risk factors for each family member. The results revealed implicit VSL estimates for different household members. For families with children at home, average VSL estimates for children are very similar to those for adults ($6.7 million versus $6.1 million). For households with no children at home, VSL estimates are very similar for adults under age 65 and for adults over age 65 ($10.8 million versus $10.0 million). These results suggest no significant difference in VSL for these three age groups. Values from households with and without children are not directly comparable, because the average sizes of the household and per capita income levels are different.

Wage-risk studies provide only limited information about the relationship between age and values to reduce mortality risk, because they are limited to working age adults. Smith et al. (2004) found increasing wage premiums for on-the-job risk of fatal accidents from ages 51 to 65. Aldy and Viscusi (2007) reviewed the wage-risk literature regarding this question of the relationship between age and WTP to reduce mortality risk. They concluded that because most studies considered only a linear relationship between WTP and age, they have for the most part been too restrictive to reveal much information. They argued that an informative analysis requires a specification that allows WTP to rise or fall with a worker's age, and to change direction over different age ranges. They focused on their own analysis presented in Aldy and Viscusi (in press), and noted two important elements that affected the results. One was that they found that mortality risk on the job varies with age, and the other was that it was important to take into account differences in life expectancies according to year of birth. They found a relationship between WTP and age that followed an inverted-U shape, increasing with age until about age 45, and then decreasing. This is consistent with the earlier stated preference finding of Jones-Lee et al. (1985). Further, they found that taking into account the year of birth flattened this relationship and pushed the peak to an older age.

Aldy and Viscusi (2007) used their results to calculate illustrative values for mortality risk reductions under the proposed Clear Skies legislation in the United States. They applied their results for the 55 to 62 age group to all individuals over age 65 and found benefit results similar to what the US Environmental Protection Agency found in their sensitivity analysis that used lower VSL estimates for individuals over age 65. This approach is similar to what was used earlier for Canada. However, it is difficult to place much confidence in the wage-risk results for estimating WTP for individuals over age 65 when the studies do not include people in this age group.

Health status and baseline risk levels tend to be correlated with age, increasing the potential complexities of the relationships with values for mortality risk reduction. When analyzed as simply an issue of preserving remaining life expectancy with varying degrees of quality of life, it would appear that preserving life expectancy with higher quality would have greater value. This is the presumption implicit in the quality-adjusted-life-year (QALY) measure commonly used when comparing the efficacy of alternative medical treatment or preventive health care options. However, that does not mean that a person is willing to invest less of their resources to reduce mortality risk when their health status is lower. Lower health status will also be correlated with higher baseline risk. This can have the opposite effect of causing a person to put a higher value on risk reduction. Again, the issue cannot be resolved with theoretical analysis, but requires empirical assessment. Recent studies have begun to look at this issue. The evidence is not entirely consistent and is difficult to compare, because of different approaches used in different studies. The results suggest, however, that those in poorer health or with higher baseline risk are willing to pay as much or more to reduce their mortality risk. Alberini et al. (2004) reported that US respondents who had been to the emergency room or hospitalized in recent years for heart or lung conditions were willing to pay substantially more to reduce fatal risk, but they reported no difference in WTP values for these individuals in the Canadian sample. Chestnut et al. (2004) found no relationship between self-assessed physical health and WTP values for mortality risk reduction.

Other Individual Characteristics Affecting Valuation for Mortality Risk Reduction

Most studies found a significant relationship between income and WTP values for reducing mortality risk. The recent stated preference studies (Alberini et al., 2004; Chestnut et al., 2004; and DeShazo and Cameron, 2004) found a statistically significant effect of household income on WTP responses, with an elasticity of 0.3 to 0.5. Results were similar in the United States and Canada.

Willingness to pay for risk reductions are consistently found to be positively associated with income. Viscusi and Aldy (2003) reviewed the results of all the wage-risk studies with respect to income and reported an average elasticity of WTP with respect to income of about 0.5. This means that WTP increases by about 0.5% for every 1.0% increase in income. This is consistent with the findings reported by Alberini et al. (2004) and Chestnut et al. (2004) for the stated preference studies in the United States and Canada, who found elasticities of about 0.4 to 0.5 of WTP with respect to income.

The US Environmental Protection Agency uses these results to adjust future WTP estimates for mortality risk reduction for expected growth in real income (not counting any expected effect of inflation). The Agency uses an elasticity of 0.4 for this adjustment, which reflects the expectation that as people become wealthier, they will want to put more resources toward reducing mortality risks and increasing life expectancies. Other socio-economic characteristics of individuals may also be determinants of WTP to the extent that they reflect a person's preferences related to risk. Heterogeneity of preferences with respect to risk reduction is difficult to address. Readily measured individual characteristics, such as gender, education, race and marital status, do not explain much of the differences observed in responses to WTP questions when income is held constant. The differences seem to reflect more of a difference in attitude that is challenging to define, and seem to have something to do with risk aversion or optimism about being able to affect one's future risk. For example, Chestnut et al. (2004) found that respondents who were more likely to say that they did or would take certain preventive health care actions (such as not smoking and getting cancer screenings) also revealed significantly higher WTP values for mortality risk reduction. Smith et al. (2004) used an index measure of risk tolerance based on answers to questions about choices between a secure job for life and a 50-50 chance of two different income levels. They found an association between risk tolerance and wage-risk premiums such that those with less risk tolerance required higher wages to take an increase in on-the-job risk.

Krupnick et al. (2002) reported that a measure of emotional health was positively associated with WTP values, but not a measure of physical health. Chestnut et al. (2004) similarly found an association between higher ratings of enjoyment of life with WTP responses, but did not find a similar association with ratings of physical health. These results are difficult to apply directly to policy analysis, because this kind of information about the general public is not available. However, it points to the importance of allowing for heterogeneity of preferences with respect to risk when analyzing data to obtain WTP estimates.

Willingness to Pay Values for Changes in Life Expectancy

Most available WTP literature focuses on annual changes in mortality risk. These may be one time shifts in survival probabilities, or may continue indefinitely, or for a specified period. Changes in annual probability of death can also be summarized as changes in life expectancy. An ongoing change in exposure to risk causes a shift in future survival probabilities and this can be described as changes in annual mortality risk or changes in life expectancy. Rabl (2003, 2006) argued that changes in life expectancy are a better way to quantify changes in mortality in a population associated with a change in air pollution exposure than calculating the number of lives saved. He argued that the latter will change over time as the age distribution of the population changes, but that an increase in life expectancy is a stable measure of the benefit of a change that reduces mortality risk in a population.

Empirical estimation of WTP values for changes in life expectancy has not been developed in the economics literature as much as WTP values for annual changes in mortality risk. Policy analysts, including Rabl (2006), have often assumed a constant monetary value per life-year saved when using estimates of the life expectancy increases expected for a given program. As noted earlier, under assumptions of linearity a VSL estimate can be converted to a VSLY given an estimate of remaining life expectancy associated with the original VSL. However, this assumes that a VSL is proportional to remaining life expectancy, an assumption that is not supported by available empirical results.

Alberini et al. (2006a) used their results to estimate VSLY for the four 10-year age groups in their study. They first calculated the change in remaining life expectancy implied by the 10-year 5 in 10,000 annual risk change for each age group. The change in life expectancy implied by this mortality risk change varies depending on the age and gender of the individual. They then estimated the relationship between median WTP and the change in remaining life expectancy. They found a statistically significant, but not strictly proportional relationship between WTP and the gain in life expectancy. They reported the implied average VSLY for males from the United Kingdom for each 10-year age group (40 to 49, 50 to 59, 60 to 69, and 70 to 79). These are shown in the second column of Table 14, converted to year 2007 Canadian dollars. The results show VSLY increasing with age for the first three groups and decreasing somewhat for the oldest group. However, the oldest group still has a median VSLY that is higher than for the 40 to 59 year olds.

Table 14. Illustration of Relationships between VSLY and VSL and Remaining Life Expectancy

Age (years)	Alberini et al. (2006a) Estimated Median VSLY (2007 C$)	Remaining Life Expectancy (years)			Implicit VSL (C$) (millions)		
		0% discount rate	3% discount rate	5% discount rate	0% discount rate	3% discount rate	5% discount rate
45	85,600	32.7	20.8	16.1	2.8	1.8	1.4
55	96,100	24.1	17.2	14.0	2.3	1.6	1.3
65	133,900	16.6	13.1	11.3	2.2	1.8	1.5
75	115,000	10.4	8.9	8.1	1.2	1.0	0.9

Table 14 illustrates the relationships between these VSLY estimates and implicit VSL estimates based on average remaining life expectancies at selected ages. Using the midpoint of each age group, the remaining life expectancy for males is shown in the third column. As discussed earlier, there is probably some positive rate of discount for future years reflected in people's valuations of future risk reductions. The fourth and fifth columns show the discounted remaining life years at 3% and at 5%, respectively. Note that Alberini et al. (2006b) found discount rates in this range for WTP for future risk reductions. Summing the VSLY across these various estimates of remaining life-years gives the implicit VSL estimates, shown in the last three columns. Without any discounting, the VSL figures decline with age, but with some discounting the VSL estimates remain fairly close for the first three age groups and decline for the oldest age group. These results are consistent with findings by Alberini et al. (2004, 2006a) showing no significant relationship between age and WTP for annual risk reduction until after age 70.

Some stated preference studies have attempted to directly estimate WTP for increases in life expectancy (Johannesson and Johansson, 1996; Johnson et al., 1998; and Morris and Hammitt, 2001). These studies all defined a change in mortality risk that starts at some future age, such as at 60 or 70 years old. Respondents were asked about their WTP now for a future risk reduction that would start at this future age and increase their life expectancy by a specified amount. All these studies obtained WTP results that imply fairly low VSL estimates. Respondent comments suggest a tendency to view an increase in life expectancy as time being tacked on at the end of life when quality of life is presumed to be low. This is a misinterpretation of a typical change in life expectancy, which usually implies a shift in the survival probabilities over all future periods. That these studies presented this as beginning at some future age held the life expectancy change constant over all respondents, but may have contributed to the perception that this means time added only at the end of life.

Morris and Hammitt (2001) examined two different ways of presenting future mortality risk changes. One was using an annual risk change and the other was using a life expectancy change, both for a hypothetical pneumonia vaccine to be purchased now and given at age 60 or age 70 (varied across respondents). The change in risk was calculated to be equivalent across the two survey versions. The authors found similar WTP results for both versions for those respondents who said they would be willing to pay something now for such a future vaccine. However, a large share of respondents said they would not pay anything now for such a vaccine, and this percentage was higher for those who were presented with the life expectancy change than for those who were presented with the annual risk reduction (33% versus 26% of the sample, respectively). Given that the risk reduction presented was actually quite substantial compared to vaccines people routinely take, these results suggest that both versions were affected by the delay between the payment and the risk reduction, and that the life expectancy version was more so. More empirical survey development work is needed to see how life expectancy change might be more effectively presented to respondents.

4. Conclusions and Recommendations for Canadian Policy Analysis

As the literature on mortality risk valuation broadens and deepens, it becomes clearer that context affects the resources people are willing to invest in mortality risk reduction. A useful tool for policy analysis will ultimately be a database that allows the analyst to input risk and population characteristics for a given policy analysis context and obtain a range of appropriate monetary values for the risk change. However, the current literature is not sufficient to allow development of this kind of tool. We could guess the likely differences in values for some context differences, but there has not been enough verification with repeated findings of similar magnitudes to be able to support such a tool with any reasonable confidence. For policy analysis, therefore, it seems better to state what we can with reasonable confidence than to speculate very far beyond what the empirical evidence supports.

For now, our recommendation is to use the same monetary values for most mortality risk change contexts, with the recognition that considerable uncertainties remain. The next section presents a selection of recommended central, low, and high values of statistical life appropriate for use in a policy assessment. The selected low and high values are not lower or upper bounds, but are alternative values for which reasonable arguments could be made for their use as primary estimates. This is followed by a discussion of uncertainty and sensitivity analyses that may be useful for many policy analyses.

Selected VSL Estimates that Reflect Recent Results in the Literature

Table 10 summarized estimates from all the Canadian studies identified in the literature search for values for mortality risk reduction consistent with the economic welfare definition of monetary value for use in cost-benefit analysis. Previous Canadian estimates were all from wage-risk studies. Since 1995, there have been a combination of wage-risk and stated preference studies, and several of these have included Canadian and US components.

The mean results from each study, or each study component, are presented in the last column. These are presented as the VSL in 2007 Canadian dollars. The mean results from the Canadian studies range from $3.4 million to $9.9 million with the exception of Lanoie et al. (1995) who reported an estimate as low as $2.7 million from their stated preference results for a fatal automobile accident risk to an estimate as high as $40 million from their stated preference results for the on-the-job risk of a fatal accident. This study used a small non-random sample of workers from selected companies in Montréal to compare different methodological approaches for estimating values for mortality risk. Their specific quantitative results are therefore not appropriate for public policy analysis, and are excluded from the summary means discussed below.

The mean VSL estimates from Canadian wage-risk studies average $7.8 million and range from $6.2 million to $9.9 million. The mean VSL estimates from Canadian stated preference studies average $5.0 million and range from $3.4 million to $6.3 million. As was noted earlier, the US stated preference studies using the same instruments as the Canadian studies obtained very similar results. The average of the mean US results in these studies is $5.1 million, almost identical to the average of the Canadian estimates. This, and the similarity of results between Canadian and US wage-risk studies, supports the use of results from US studies to help inform the selection of estimates for use in Canadian policy analysis.

The recent meta-analyses of wage-risk studies in the United States provide somewhat different perspectives about the best estimates from this literature. Viscusi and Aldy (2003) reported a mean VSL of $10.8 million. When they included all the estimates from worldwide studies, the mean became $7.9 million. About 65% of these studies are from the United States and most of the rest are from Canada, Australia, and European countries. Mrozek and Taylor (2002) argued that many wage-risk studies do not sufficiently control for inter-industry differences in wages that they state are correlated with risk levels and thus can lead to an over-statement of the risk premium. They incorporated an adjustment for this into their mean result and obtained a VSL of about $3.7 million for US studies. Without this adjustment, their mean result is $9.7 million, very similar to Viscusi and Aldy's result for US studies. This is quite a substantial difference, and it is not clear which is more accurate. Viscusi and Aldy argued that using industry dummy variables to control for inter-industry differences in wages can cause a downward bias in the risk coefficient, because these dummy variables could pick up some wage differences that are actually due to differences in risks. On the other hand, Mrozek and Taylor made the argument that using no controls for unaccounted for differences in wages across industries could lead to an upward bias in the risk coefficient.

The truth is somewhere in between, which is also where the stated preference results fall. The midpoint between the two wage-risk meta-analyses is about $7 million. This is close to the average of the mean stated preference result and the mean revealed preference result from the Canadian studies, which is about $6.5 million. This is the recommended central estimate for policy analysis. It gives equal weight to results from the two types of studies. The recommended low value is $3.5 million, which is close to the adjusted estimate from Mrozek and Taylor (with the inter-industry adjustment) and to the lower of the Canadian stated preference results (Alberini et al., 2004). The recommended high value is $9.5 million, which is representative of the wage-risk meta-analyses results without the inter-industry adjustment, and is in the range of the highest wage-risk results obtained in Canada ($9.0 million and $9.9 million). Table 15 summarizes the recommended VSL estimates. These values represent a reasonable range for a primary analysis. Higher and lower estimates exist in the literature, so these are not lower and upper bounds. Arguments could be made to defend each of these estimates as a reasonable primary estimate, although the central estimate is the best choice if a single primary VSL estimate is used.

Table 15. Recommended Primary VSL Estimates for Canadian Policy Analysis (2007 C$)

Low	3.5 million
Central	6.5 million
High	9.5 million

The recommended estimates are about the same as the previous recommendation for working age adults (central of $6.5 million) and higher than the previous recommendations for adults ages 65 and over (central of $4.9 million). The current recommendation is that there be no adjustment for age in the primary estimates, based on the evidence summarized in Chapter 3. However, adjustments for age should be considered in sensitivity analyses, especially if the mortality risk reduction expected as a result of a policy under consideration affects some age groups more than others.

Suggestions for Uncertainty and Sensitivity Analyses

Although the previous section makes the case for $6.5 million as a primary estimate for VSL, it is impossible to say with certainty that this is the "right" number. Comparable credible studies offer a range of results, and lower and higher estimates cannot be ruled out as wrong. In addition, there are many uncertainties about how to interpret and apply available estimates in specific policy analyses. Two approaches can be used in policy analysis to address these issues: one is a quantitative uncertainty analysis and the other is sensitivity analysis. It is advisable to do both, especially if costs and benefits are close.

Uncertainty analysis can be used to estimate a distribution of results if one specifies a distribution for the inputs that includes a specification of the probabilities. For example, for a statistically estimated parameter, the uncertainty analysis can use the mean and standard error, which defines the probability distribution around the mean. The VSL estimates do not have a single mean and standard error, because results are drawn from many different studies that are difficult to combine into a single mean and distribution. Only the Kochi et al. (2006) combined meta-analysis revealed preference and stated preference estimates, and calculated a combined mean and standard deviation, but this estimate is dominated by the revealed preference estimates, because there are many more of these.

An alternative to statistically derived standard error is to use analyst judgment to weight alternative estimates. This allows consideration of more factors than statistical variability. This involves a judgment of how likely each estimate is of being the correct estimate. The distribution of VSL estimates from Canadian studies is spread fairly evenly around the mean, which suggests equal weights are appropriate for the high and low estimates. One could argue for equal weight across the three estimates, but the recommended approach would be to give greater weight to the central estimate. Something like 50% probability to the central and 25% each to the low and high estimates would be appropriate.

The VSL estimates presented here reflect WTP values of the general adult population for reducing mortality risk. The literature is inconclusive about whether or how to adjust WTP estimates for different age groups. However, if the policy affects the risk for some age groups substantially more than for others, it is prudent to conduct some sensitivity analyses to consider how alternative assumptions would affect the results of the analysis. Sensitivity analyses can be based on alternative assumptions that the analyst may not have great confidence in, but that can illustrate how the results would be changed if key assumptions or interpretations were changed.

Table 16 shows the estimates from Alberini et al. (2006a) for VSLY as they vary by age group included in their study in the United Kingdom. Given the discounted remaining life expectancy (using a 3% discount rate) from the midpoint of each age group, the implicit VSL estimates for each group are shown. These are substantially lower than the central estimates suggested for policy analysis based on all the available WTP studies. If the central estimate of $6.5 million is assigned to the 40-49 age group, and the same pattern is followed as shown in the Alberini et al. (2006a) results for the different age groups, the associated VSL estimates for the other age groups are as shown in the fifth column in Table 16. The corresponding VSLY estimates for each age group, obtained using a 3% discount rate, are shown in the final column in Table 16. Either of these would be an appropriate choice for a sensitivity analysis, depending on whether estimates of life-years saved or lives saved are available for valuation.

There are considerable differences in the literature concerning the age that WTP for mortality risk reduction begins to decrease and the magnitude of this decrease, if any. The revealed preference studies show a decrease in WTP beginning in the 55 to 64 year old group. Several of the stated preference studies found no decline in WTP until after age 70, if at all. The decline in WTP for the older age groups generally fell between 20% and 35% in those stated preference studies that found a statistically significant decline in WTP after age 70. The results reported by Alberini et al. (2006a) are at the high end of this range. These results provide additional options for sensitivity analyses.

Table 16. Illustration of Relationships between VSLY and VSL and Remaining Life Expectancy

Age (years)	Alberini et al. (2006a) Estimated Median VSLY (2007 C$)	Discounted Remaining Life Expectancy in Years (using 3% discount)	Implicit VSL $ (millions)	Central VSL for 45 Year Old $ (millions)	Corresponding VSLY (using 3% discount) $
45	85,600	20.8	1.8	6.5	312,000
55	96,100	17.2	1.6	6.0	350,200
65	133,900	13.1	1.8	6.4	488,000
75	115,000	8.9	1.0	3.7	419,100

Notes

[1] This review was commissioned by Environment Canada and Health Canada as part of the development of the Air Quality Valuation Model.

[2] Critics of mortality risk valuation sometimes confuse the WTP measure with the methods to estimate WTP, such as contingent valuation surveys. Willingness to pay may be measured by a variety of methods, including analysis of market data as well as contingent valuation surveys. Issues with the measurement of WTP need to be distinguished from issues with the theoretical definition of the measure itself. This report focuses on the issues of how to estimate this measure for mortality risk reduction and how to interpret available studies. The report takes as given the premise that this is the appropriate measure to be using.

[3] The productivity of homemakers is sometimes imputed for cost-of-illness estimates, but the focus remains on the market value of a person's productivity, not the value the individual places on all aspects of her or his health and life, including work and leisure.

[4] An important caveat is that individual WTP values are not expected to reflect the value of reducing medical costs incurred by others. Thus, expected reductions in public health care costs, for example, should be added to individual WTP values to obtain the total social benefit of a given reduction in health risk.

[6] A related measure of monetary value is willingness to accept (WTA) compensation, which is the minimum amount an individual must be paid to accept an increase in risk voluntarily, or some other change that reduces her or his welfare. Some argue that a WTA measure is more conceptually appropriate than WTP when assessing a change in a context where the public is presumed to have some legal or moral right to not be adversely affected. The theoretical expectation is that when these values are small in comparison with income, the difference between them is also small. The WTA concept is problematic in stated preference studies, because respondents tend to give WTA values that are much larger than WTP values for comparable small changes in environmental quality or public safety. Analysts have expressed concern that respondents may overstate their true WTA values in the hypothetical context, because they have a negative reaction to the concept of accepting a loss, such as an increase in pollution or an increase in risk, and because they are not forced to consider a budget constraint when answering WTA questions. Thus, most stated preference researchers prefer to use WTP questions.

[6] This is a brief introduction to these estimation approaches. For more information, see Freeman (2003).

[7] Jones-Lee (1991) calls this safety-focused paternalism.

[8] The formula for calculating discounted remaining life years (DRLY) is:

$$DRLY = (1/r)\ H\ [1 - e^{(-r\ H\ RLY)}]$$

Where r = rate of time preference (discount rate) and RLY = remaining life years (undiscounted).

[9] About 75% of all deaths in Canada and the United States are people age 65 and older.

[10] Respondents are asked whether they are willing to pay some initial dollar amount, and then are asked one follow-up question, which is whether they are willing to pay some higher (lower) amount if the response to the first amount was yes (no).

[11] Alberini et al. (2006a) did not report this result for the European countries.

[12] Alberini et al. (2006a) reported lower VSL results in the United Kingdom than in France and Italy, a result not explained by measured differences in respondent characteristics such as income. This suggests possible differences in attitudes or preferences across countries, but merits further research before being used in policy analysis.

[13] The higher response rate in the United States for this study and for Chestnut et al. (2003, 2004) is due to the nature of the Knowledge Network panel used in both US studies rather than any inherent differences in survey response rates between the United States and Canada. The Knowledge Network panel is recruited using a general population sampling frame. The company provides equipment and training to its members, so no previous Internet experience is needed. The samples in the Canadian portions of these studies are from individuals already using the Internet who agree to answer surveys. Response rates with such panels are not usually as high as with the Knowledge Network panel. There is particular concern about the representativeness of samples taken from people already using the Internet for the older age groups.

[14] Society of Actuaries mortality data include deaths from all causes so they are inappropriate for use in wage-risk studies where what is needed is a measure of the risks of on-the-job fatalities.

[15] R. Kramer, personal communication, 2006.

[16] The equity issue might not be a concern if those whose welfare was increased compensated those whose welfare was reduced by a public policy action. However, this is seldom the case. Decision makers can reasonably weigh many factors in evaluating a proposed program. Economic efficiency (i.e., maximizing net benefits) may be only one of many relevant criteria.

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