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Valuing Mortality and Morbidity in the Context of Disaster Risks

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Abstract

Benefit-cost analyses of disaster risk reduction (DRR) projects are an important tool for evaluating the efficiency of such projects, and an important input into decision making. These analyses, however, often fail to monetize the benefits of reduced death and injury. The authors review the literature on valuing reduced death and injury, and suggest methods for calculating order-of-magnitude estimates of these benefits. Because few empirical estimates of the Value of a Statistical Life (VSL) are available for developing countries, methods for transferring estimates from high income to middle and low income countries are reviewed. The authors suggest using the range of values implied by an income elasticity of 1.0 and an elasticity of 1.5. With regard to injury valuation they discuss arguments for and against monetizing Quality Adjusted Life Years, and provide shortcuts to valuing injuries that may be used to assess their importance in DRR benefit-cost analyses.

This paper—a product of the Sustainable Rural and Urban Development Team, Development Research Group—is part of a larger effort in the department to pomote the use of benefit-cost analysis as an adjunct to efficienct policymaking. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at mcropper@worldbank.org.

Background paper for the joint World Bank – UN Assessment on Disaster Risk Reduction

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I. Introduction

Since 1960 disasters have killed approximately 5 million people worldwide, and injured millions more. Droughts alone have killed over 2.5 million people, earthquakes over 1 million and storms and cyclones over 750,000. The majority of deaths have occurred in developing countries. Indeed, it is well known (Kahn 2005; Buys et al. 2007) that, although the number of disasters per capita shows little correlation with per capita income, disaster deaths per capita increase as per capita income decreases.

Although the absolute number of people killed in disasters is small relative to total deaths, many disaster-related deaths are preventable. The relevant question for policy is whether the benefits of preventing disaster-related death and injury exceed the costs. Key methods of reducing death and injury in the event of a disaster include the strengthening of buildings to withstand earthquakes and early warning systems to allow evacuation in the event of storms and floods. These measures have been extremely successful in reducing the public health impacts of disasters in the US and other high income countries: deaths from storms in the US have decreased dramatically over the past 50 years (Malilay, 1997a). DFID (2005), in comparing the period 1900-1949 with 1950-1992, reports that the average number of persons killed in an earthquake has fallen from 12,000 to 2,000 in high income countries, but has remained constant—at 12,000 deaths—in developing countries. The question is whether the measures that have proven effective in reducing deaths in high-income countries pass the benefit-cost test in developing countries.

Benefit-cost analyses of measures to reduce losses stemming from damages and losses to financial assets in the event of a disaster are common in developed countries (Rose et al., 2007) and are becoming increasingly common in developing countries (Provention Consortium, 2008). With rare exceptions, however, these studies do not count reduced death and injury among the monetized benefits of ex ante measures to reduce losses in the event of a disaster.[4] The purpose of this paper is to review the literature on health valuation and suggest practical approaches to valuing avoided death and injury that can be applied in benefit-cost analyses of disaster risk reduction projects. Specifically, we suggest methods of estimating the value of mortality risk reductions (i.e., of the Value of a Statistical Life or VSL) and the value of avoided injuries associated with disasters for a wide range of countries.

The paper begins with statistics on the deaths and injuries associated with various types of disasters. Section III presents the framework of a probabilistic benefit-cost analysis of an *ex ante* measure to reduce disaster risk—the framework in which the monetized value of avoided death and injury will be incorporated—and provides examples where incorporating lives saved has made a significant difference in the outcome of the analysis.

Sections IV and V discuss methods of valuing avoided death and injury. Section IV presents a conceptual framework for valuing risk of death and briefly reviews the

[4] Exceptions include studies of building strengthening by A. Smyth et al. (2004a, 2004b) and Ghesquiere et al.'s (2006) study of loss reduction measures in Bogota.

empirical literature on mortality risk valuation. Because few empirical estimates of the VSL are available for developing countries, methods commonly used to transfer estimates – "benefits transfer" – of the VSL from developed to developing countries are reviewed. The most common approach to benefits transfer assumes that the ratio of the VSL to per capita income is constant among countries. (This is equivalent to assuming an income elasticity of the VSL = 1.) Transferring values from the US, where this ratio is approximately 140 to 1, implies that the ratio of the VSL to income is 140 to 1 for all countries. Our analysis suggests that this may overstate the VSL in developing countries. Indeed, preliminary analysis suggests the ratio is closer to 80 to 1 for middle income countries. Pending additional studies in low and middle income countries, we suggest using an income elasticity of the VSL of 1.5 in addition to an income elasticity of 1.0 to provide a range of values of for the VSL in middle and low income countries.

Section V discusses injury valuation. The approach most commonly used to value injury is to estimate the medical costs and lost productivity associated with the injury—the direct and indirect Costs of Illness (COI). The COI, however, fails to capture the pain, discomfort and functional limitations that injuries impose. Estimates of the Quality-Adjusted Life Years (QALYs) lost due to injury attempt to quantify these losses, and their monetary value may be added to COI estimates to provide a more comprehensive estimate of the value of avoided injury. We discuss the approaches to injury valuation currently used in the US, the arguments for an against valuing QALYs, and shortcuts to valuing injuries that may be used as a first pass to assessing their importance in benefit-cost analyses of disaster risk reduction projects. Section VI of the paper summarizes recommendations for including deaths and injuries in benefit-cost analyses of disaster risk reduction projects.

II. What Is to Be Valued? The Mortality and Morbidity Consequences of Natural Disasters

A. Deaths Due to Natural Disasters

Overview

Table 1 summarizes the number of deaths associated with various categories of natural disasters since 1960 and Table 2 the number of disaster deaths that have occurred since 1988. Disasters are classified according to the 2007 classification system of the Center for Research on the Epidemiology of Disasters (CRED, 2007). Over the past 48 years, droughts have caused the largest number of disaster deaths, and most of these have occurred in Africa and Asia. The importance of droughts as a cause of death has, however, been reduced over the past 20 years, due largely to international aid efforts.

Table 1 Number of deaths by natural disaster categories (1960-2007) *(thousand)* [5]

Killed 1960-2007	Climatological	Geophysical	Hydrological	Meteorological
Europe	**83**	**40**	**5**	**3**
Africa	**878**	**23**	**19**	**4**
Asia	**1,532**	**827**	**213**	**692**
Rest of the World	**6**	**163**	**60**	**63**
Oceania	1	1	3	2
Northern-America	3	1	2	12
Latin America and the Caribbean	2	162	55	50
Total	**2,499**	**1,053**	**297**	**761**

Source: EM-DAT

Table 2 Number of deaths by natural disaster categories (1988-2007) *(thousand)*

Killed 1988-2007	Climatological	Geophysical	Hydrological	Meteorological
Africa	**2**	**5**	**15**	**2**
Asia	**19**	**460**	**105**	**209**
Europe	**81**	**29**	**2**	**1**
Rest of the World	**4**	**8**	**46**	**34**
Oceania	0	1	2	1
Northern-America	2	0	1	5
Latin America and the Caribbean	2	7	43	28
Total	**107**	**501**	**169**	**246**

Source: EM-DAT

Excluding droughts, earthquakes account for the largest number of disaster-related deaths. Indeed, over the past 20 years, the number of people killed in earthquakes is approximately equal to the number of people killed in all other types of disasters. The average annual number of deaths due to earthquakes is higher for the past 20 years than for the previous 28. Storms (hurricanes, cyclones and storm surges) account for about a quarter of disaster-related deaths over the past 20 years and hydrological disasters (floods and landslides) for about one-sixth. In terms of annual averages, deaths due to floods have increased over the past 20 years (compared to the previous 28) whereas annual average storm deaths have decreased.

During the past 48 years—and also during the past 20 years—the greatest number of disaster-related deaths have occurred in Asia. This is also true for specific categories of disasters—earthquakes, storms and floods—and remains true on a per capita basis. This is partly explained by geological and meteorological factors. During the past century, earthquakes of magnitude 5.0 or greater on the Richter scale were concentrated along the west coast of North and South Americas, along the east cost of Asia, and the Pacific Rim (Noji, 1997; National Earthquake Information Center, 2008). Cyclones, hurricanes and storm surges are concentrated in the tropics—most occur between 30°N and 30°S. It is, therefore, not surprising that few deaths due to meteorological disasters occur in Europe or Oceania.

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[5] Geophysical: Volcanoes, Earthquake, Tsunamis. Climatological: Droughts, Extreme temperatures, Wildfires. Hydrological: Floods. Wet mass movements (Landslides). Meteorological: Storms (cyclones).

Deaths by region, however, also depend on the nature and pattern of human settlements, and on preventive measures to reduce deaths in the event of a disaster. As noted above, building strengthening measures have greatly reduced deaths per earthquake in high income countries, and early warning systems have reduced deaths due to storms and floods. It is, indeed, the fact that some deaths are preventable that motivates the analysis below.

Deaths by Cause, Age, Gender

Understanding what causes disaster-related deaths is important from the perspective of designing measures to reduce deaths. In earthquakes, the majority of deaths are caused by the collapse of buildings, causing crushing injuries to the head and chest and/or internal injuries.[6] Noji (1997) reports that for the period 1900-1949 and the period 1950-1990, approximately three-quarters of earthquake deaths were due to building collapse.[7] There were, however, fewer deaths during the latter period, as a result of building strengthening, and changes in building materials. Earthquake-related deaths can also result from drowning (when tsunamis occur as the result of an earthquake) and from stress associated with the earthquake, which may result in deaths due to heart attacks or cardiac arrest (Noji, 1997). Most storm deaths are due to drowning, as are flood deaths. In high-income countries, the majority of deaths associated with floods are motorists whose vehicles are swept away by flood waters. It is also true that more deaths are associated with flash floods (floods caused by extreme rainfall) than by riverine floods (Milaly, 1997b).

Less is known about the distribution of deaths by age and gender. Noji (1997) reports that in earthquakes people over 60 years of age, children, women and the chronically ill are at increased risk of death compared to other population groups. Armenian et al. (1997) in the first population-based study of earthquake injuries and deaths, report that persons over 60 had a death rate twice that of persons below 60 in the December 1988 earthquake in Armenia—an earthquake that killed 25,000 persons and injured 130,000. The death rate was, however, approximately constant between ages 0 and 59.

Deaths by gender vary by country and disaster type. In the US and Europe the death rate in floods and hurricanes is higher for men than women (Jonkman and Kelman, 2006). However, in developing countries women often account for a higher proportion of disaster deaths than men. The ADB reports that 61% of the deaths in cyclone Nargis were women, as were 70% of the deaths in the Indian Ocean Tsunami and 91% of the deaths in the 1991 cyclone in Bangladesh (ADB, 2008).

[6] Some building-related deaths may be due to asphyxia, as a result of dust released during building collapse.

[7] Noji (1997) reports that three-quarters of the 795,000 fatalities occurring between 1900 and 1949 and approximately 77% of 583,000 fatalities occurring between 1950 and 1990 were due to building collapse—over 60% due to the collapse of unreinforced masonry buildings.

B. Injuries Associated with Disasters

Tables 3 and 4 present estimates of injuries associated with natural disasters from the EM-DAT database (CRED, 2007). Injuries are defined as those "requiring medical attention." It seems likely that injuries are under-reported, even if only severe injuries are counted: the number of injuries is actually less than the number of deaths between 1960 and 2007, although it is approximately twice the number of deaths over the past 20 years. In the United States, the number of persons hospitalized for injuries is approximately 10 times the number of fatal injuries that occur each year (Segui-Gomez and MacKenzie, 2003). Although the ratio of hospitalized to fatally injured might be lower in developing countries, it is unlikely that the ratio falls below one. Armenian et al. (1997) for example report 831 deaths and 1454 persons hospitalized for injuries in their study population in Armenia.

Table 3 Injuries associated with natural disasters (1960-2007) *(thousand)*

Injured 1960-2007	Climatological	Geophysical	Hydrological	Meteorological
Europe	**3**	**48**	**20**	**2**
Asia	**7**	**744**	**1,030**	**1,092**
Oceania	**1**	**1**	**1**	**3**
Rest of the World	**2**	**411**	**63**	**49**
Africa	1	48	23	8
Northern-America	0	12	0	6
Latin America and the Caribbean	1	350	40	35
Total	**13**	**1,204**	**1,114**	**1,145**

Source: EM-DAT

Table 4 Injuries associated with natural disasters (1988-2007) *(thousand)*

Injured 1988-2007	Climatological	Geophysical	Hydrological	Meteorological
Asia	**7**	**481**	**851**	**390**
Rest of the World	**4**	**68**	**35**	**36**
Europe	2	17	3	1
Oceania	1	1	1	1
Africa	1	11	21	6
Northern-America	0	12	0	4
Latin America and the Caribbean	0	27	10	23
Total	**11**	**549**	**886**	**426**

Source: EM-DAT

Epidemiological studies provide information about the nature of injuries suffered in disasters, as well as about the incidence of illness that may accompany the disruption of water and sanitation services following a disaster. The most serious injuries frequently suffered in earthquakes include crush injuries, fractures (including skull fractures) and internal hemorrhaging. In the 1988 Armenia earthquake, Armenian et al. (1997) report that 37% of injured persons experienced fractures and 27% crush injuries. Noji (1997) reports that the most common injuries among those hospitalized in the 1968 Iran earthquake were skull fractures with intracranial hemorrhage, cervical spine injuries with neurological impairment and internal injuries to the lung, liver and spleen.

Although disasters frequently disrupt water and sanitation services, which may lead to an increase in infectious disease, we focus in the remainder of the paper on injuries, rather than on infectious diseases, since the former are likely to have more serious long-term consequences.

C. Injury Classification Schemes

If injuries associated with disasters are to be included in benefit-cost analyses of disaster risk reduction, they must be classified according to standard coding schemes. The two primary, internationally recognized, schemes for classifying injuries—the International Classification of Diseases (ICD9-CM) and the Abbreviated Injury Scale (AIS), both describe physical impairments according to the nature of the injury and the part of the body where it occurs. The AIS also describes injury severity, defined in terms of threat to life. In the ICD-9, the primary system for coding medical diagnoses, injuries (800-999) are classified by the nature of the injury (e.g., fractures, internal injuries) and the site of the injury (e.g., skull, leg, thorax). Three-digit ICD-9 codes are listed in Table 5. Digits 4 and 5 pinpoint the site/nature of the injury more exactly.[8]

Table 5 International Classification of Diseases (ICD-9)

ICD – 9 Three-Digit Injury Codes	
Fractures (800-829)	Skull (800-804) Neck and Trunk (805-809) Upper limb (810-819) Lower Limb (820-829)
Dislocations (830-839)	
Sprains and Strains of Joints and Muscles (840-848)	
Intracranial Injury (850-854)	
Internal Injury of Thorax, Abdomen and Pelvis (860-869)	
Open Wounds (870-897)	Head, Neck and Trunk (870-879) Upper limb (880-887) Lower limb (890-897)
Injury to Blood Vessels (900-904)	
Late effects of injuries and poisonings (905-909)	
Superficial injuries (910-919)	
Contusions (920-924)	
Crushing Injury (925-929)	
Effects of foreign bodies entering through orifices(930-939)	
Burns (940-949)	
Spinal Cord Injuries (950-957)	
Unspecified injuries (958-959)	
Poisonings (960-979)	

[8] Medical diagnoses require at least 4 digits. To illustrate, ICD-9 category 824 describes an ankle fracture, and 824.1 an open fracture of the medial malleolus (end of the tibia).

Source: http://icd9cm.chrisendres.com/index.php?action=child&recordid=8185 ,
http://en.wikipedia.org/wiki/List_of_ICD-9_codes_800-999:_Injury_and_poisoning

The AIS classification scheme describes injuries by body region (one digit), type of anatomic structure (one digit), specific anatomic structure (two digits), and level (two digits). The seventh digit describes the threat to life associated with the injury. This ranges from 1 (Minor Injury) to 6 (Immediately Fatal).[9] The last digit is often referred to as the AIS code. When multiple injuries occur it is common to record the maximum AIS code (MAIS), as is done in classifying road traffic injuries in the US and elsewhere. As will be seen below, estimates of injury costs are often classified by AIS code (i.e., the threat-to-life code), as well as by body part and the nature of the injury (Zaloshnja et al., 2004).

Injuries associated with disasters are studied in the epidemiological literature, which provides information on diagnoses of past injuries. The issue for benefit-cost analysis is at what level of detail injuries avoided by disaster risk management projects can be predicted. In the US, injuries associated with earthquakes, floods and hurricanes are predicted by FEMA's HAZUS model. The model estimates injuries by location, time of day, and population group. The nature of the injury is, however, limited to a four-point severity scale, where 1= minor or moderate injury (AIS 1 or 2); 2 = serious injury (AIS 3); 3 = severe or critical injuries (AIS 4 or 5); and 4 = fatal injury. Section V explores the consequences for valuation of having limited information about the nature of injuries.

III. Benefit-Cost Analyses of Measures to Reduce Disaster Losses

Key measures to reduce losses in the event of a disaster include the strengthening of building to withstand shaking and prevent collapse in the event of an earthquake and early warning systems for floods and hurricanes. To judge whether these projects are efficient, benefit-cost analyses are typically conducted. This section describes the framework of probabilistic benefit-cost analysis, in order to describe how valuation of avoided death and injury may be incorporated into the analysis. This is followed by examples of studies where including avoided deaths as a benefit has significantly altered the benefit-cost results.

An alternate approach (World Bank, 2000) to evaluating the efficiency of projects is cost-effectiveness analysis. Cost-effectiveness analysis calculates the present discounted value of project costs net of non-health benefits (e.g., property losses avoided) and divides these by the reduction in fatal and non-fatal injury, measured by QALYs (or DALYs).[10] The cost per QALY or DALY avoided may then be compared to other projects. Ultimately, however, a value must be placed on a QALY or DALY to determine if the project is efficient.

[9] The categories are: (1) minor injury; (2) moderate injury; (3) serious injury; (4) severe injury; (5) critical injury; (6) immediately fatal (AAAM 1990).
[10] A disability-adjusted life year (DALY) describe the fraction of a life year lost to an illness or injury.

A. The Structure of Benefit-Cost Analyses of Ex Ante Risk Mitigation Projects

Because natural disasters are probabilistic events, the appropriate framework for analyzing the efficiency of loss mitigation projects is probabilistic benefit-cost analysis. Equation (1), adapted from Smyth et al. (2004a) describes the present value of expected losses in the event of an earthquake,

$$PDV(Loss) = \sum_{T=1}^{T^*} (1+d)^{1-T} \sum_i \left[\int_{a_{Min}}^{a_{Max}} f(a,T) P(D_i | a)\, da \right] C_i^D \qquad (1)$$

where
T^* : horizon
d : discount rate
$f(a,T)$: pdf of quake severity a in year T
D_i : damage level *i*
C_i^D : cost of damage level *i*.

To illustrate, Smyth et al. (2004a) consider four damage levels associated with damage to an apartment building in Turkey in the event of an earthquake (see Table 6, adapted from Smyth et al., 2004a). Slight damage results in property loss equal to 1% of the replacement value of the building ($250,000 USD), or $2,500; moderate damage in loss equal to 10% of replacement cost ($25,000); major damage results in the loss of the building ($250,000); and total collapse in the loss of the building and N_L lives, valued at V dollar per life.

Table 6 Levels of Earthquake Damage and Associated Costs

Damage level D_i	**Cost** C_i^D
D_1 : slight damage	$C_1^D = (s_1 \times S) + (0 \times V)$
D_2 : moderate damage	$C_2^D = (s_2 \times S) + (0 \times V)$
D_3 : major damage	$C_3^D = (s_3 \times S) + (0 \times V)$
D_4 : total collapse	$C_4^D = (s_4 \times S) + (N_L \times V)$

Source: Smyth et al. (2004a)

The expected benefits of a building strengthening project are the difference between expected loss in (1) and the expected loss conditional on the project, which would result in a reduction in the $\{C_i^D\}$. Expected net benefits are the difference between expected benefits and the present value of the costs of the project itself. Smyth et al. (2004a) compute the net benefits of three possible strengthening projects for apartment buildings in Turkey. Two such measures (partial and full retrofitting) are assumed to reduce deaths N_L to zero.

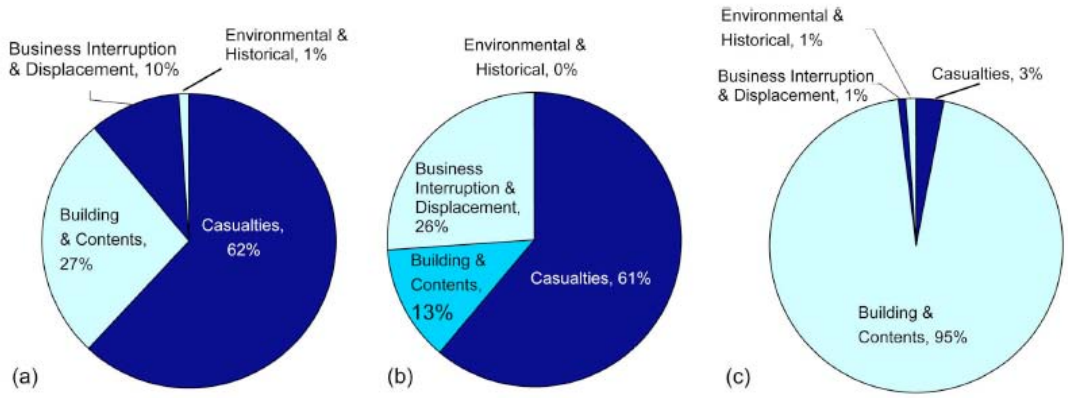
Three comments about this benefit-cost framework are in order. First, it is the expected value of losses that are calculated. The argument for examining expected loss rather than expected utility of loss is based on the notion that losses are spread over many people (Arrow and Lind, 1970). This is a standard assumption in probabilistic benefit-cost analysis of disaster risk projects, although it has been challenged by Mechler (2003). The issue comes down to the magnitude of the loss in question, relative to the incomes and assets of those affected. If it is small, the Arrow-Lind theorem holds; if it is not, equation (1) is not appropriate. Second, the magnitude of the present value of loss depends crucially on the discount rate, especially if the horizon is long. ($T^* > 50$ years is common.) Discount rates in the disaster risk literature are typically low, ranging from zero (Hung and Chen, 2007) to 2-3%. Smyth et al. (2004a) use a discount rate of 3%, citing the public health literature (Gold et al., 1996). The use of 3% as a social discount rate is, however, low for developing countries. The official discount rate used by the Government of India is 12%; in China, it is 8%. Third, the inclusion of lives lost in calculating damages is not standard practice in the international literature. Smyth et al. (2004a), Smyth et al. (2004b) and Ghesquiere et al. (2006) are notable exceptions.

B. Including Avoided Death and Injury Can Make a Difference

Benefit-cost analyses of disaster loss reduction projects in the United States and elsewhere suggest that including the value of avoided deaths and injuries can make a significant difference to the analysis, especially for earthquake and storm mitigation projects. Weiher at el. (2003) report that two-thirds of the value of weather forecasts in the U.S. is due to reduced loss of life. Rose et al. (2007) perform BCAs of 136 disaster mitigation projects in the US. FEMA's HAZUS model is used to estimate fatal and non-fatal injuries associated with earthquakes, floods, and wind hazards and injuries and deaths are monetized using protocols developed by FEMA (1994). Figure 1 (reproduced from Rose et al., 2007) shows the share of distribution of benefits by category of disaster loss mitigation project. Avoided casualties constitute 62% of the benefits of earthquake mitigation projects and 61% of the benefits of hurricane mitigation projects.[11] This suggests the importance of including such benefits in benefit-cost analyses of disaster mitigation projects in developing countries, a point borne out by the studies cited in the next paragraph.

[11] It should be noted that Rose et al. (2007) use a conservative Value of a Statistical Life (approximately $3,000,000 USD).

Figure 1 Contribution to cost-benefit ratio by factor: (a) earthquake, (b) wind, and (c) flood



Source: Rose et al. (2007)

In benefit-cost analyses by Smyth et al. (2004a, 2004b) of earthquake strengthening measures for apartment buildings and schools, none of the strengthening measures considered passes the benefit-cost test unless the value of lives saved is included in the analysis. In the analysis for Istanbul, Turkey two of the strengthening measures pass the benefit cost test when avoided deaths are valued at $1 million USD each. In the case of the school building strengthening program, strengthening measures pass the benefit-cost test when lives saved are each valued at $400,000 USD. The next section provides a framework for judging whether these values are appropriate.

IV. Valuing Avoided Mortality

The benefits of disaster risk mitigation projects are stated in terms of the expected number of deaths and injuries avoided. Since at the time a project is considered it is unknown whose lives the project would save, the expected deaths avoided represent a reduction in the risk of dying that is spread over the population exposed to the disaster risk. To use the example in Section III, the expected number of earthquake deaths in absence of a project is the sum, over the relevant population, of the probability that at earthquake occurs times the probability that an individual dies, conditional on an earthquake occurring. By reducing the probability that an individual dies, conditional on an earthquake occurring, the project will save a number of *statistical lives*, equal to the sum of reductions in risk of death over the relevant population.[12] The *Value of a Statistical Life (VSL)* is the sum of what individuals would pay for risk reductions that,

[12] Suppose that the annual probability of an earthquake occurring is .01 and that each person in a city has a 1 in 1000 chance of dying if an earthquake occurs. The annual chance of dying in an earthquake for each person is therefore 1 in 100,000 (=.01*.001). Reducing the risk of dying conditional on an earthquake occurring to 1 in 2000 would reduce each person's risk by 1 in 50,000. This risk change, times the city population, would equal the number of *statistical lives* saved.

together, sum to one statistical life.[13] The challenge is in estimating what a rational individual would pay for a small reduction in his risk of dying.

In benefit-cost analyses of health and safety regulations conducted in the United States the European Union, and in many other countries around the world, mortality risks are valued using the VSL. When estimates of the VSL are unavailable, the human capital approach (foregone earnings) is often used to place a lower bound on the VSL.[14] This section describes the theory behind the VSL and methods that have been used to estimate it. The paper briefly reviews the empirical literature on the VSL in both high income and developing countries. Because of the paucity of estimates of the VSL in developing countries, analysts often use benefits-transfer techniques to extrapolate estimates of the VSL from high income to developing countries. We evaluate various approaches to benefits transfer, concluding with recommendations for estimating the VSL in benefit-cost analyses of disaster risk reduction projects.

A. The Concept of Willingness to Pay (WTP) for Reductions in Risk of Death[15]

The amount that a rational person would pay to reduce his risk of dying should reflect the enjoyment he will receive over the remainder of his lifetime. This, in turn, should depend on his current age and remaining life expectancy, his expected consumption over the remainder of his lifetime and factors that affect his utility of consumption. The lifecycle consumption model with uncertain lifetime (Yaari, 1965) provides the theoretical framework for examining willingness to pay (WTP) for changes in mortality risk. The implications of the model for valuation are summarized below and the details presented in Appendix A.

The lifecycle model assumes that at age *j* the individual chooses his future consumption stream to maximize expected lifetime utility,

$$V_j = \sum_{t=j}^{T} q_{j,t}(1+\delta)^{j-t} U_t(C_t) \qquad (2)$$

where V_j is the present value of expected utility of lifetime consumption, $U_t(C_t)$ is utility of consumption at age *t*, $q_{j,t}$ is the probability that the individual survives to age *t*, given that he is alive at age *j*, and δ his subjective rate of time preference.[16] Yaari (1965) assumed that utility is maximized subject to a budget constraint that allows the individual to invest in annuities and to borrow via life-insured loans. This is equivalent to assuming

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[13] If each person would pay $10 for a 1 in 50,000 risk reduction, the value of a statistical life would be $500,000 (50,000*$10).
[14] The human capital approach values a statistical life by the present discounted value of expected future earnings.
[15] This section follows Cropper and Sussman (1990). Other analyses of the value of mortality risks in the context of the life cycle model include Shepard and Zeckhauser (1984) and Rosen (1988).
[16] Equation (1) implicitly assumes that the individual has no bequest motive, hence utility of consumption = 0 when the individual is dead.

that the present value of expected consumption equals the present value of expected earnings plus initial wealth,

$$\sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} C_t = \sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} y_t + W_j \,, \tag{3}$$

where r is the riskless rate of interest, y_t is income at time t and W_j is initial wealth. An alternate assumption is that present value of consumption over the remainder of the individual's lifetime equals the present value of income plus initial wealth, i.e., that the individual can borrow and lend at the rate of interest r.

We now define what an individual would pay for a change in D_k, his conditional probability of dying at age k, given that he survives to that age. Since $q_{j,t} = (1-D_j)(1-D_{j+1}). . . (1-D_{t-1})$, any program that alters D_k will necessarily alter the probability of surviving to all future ages. For small changes in D_k, willingness to pay may be written as the product of the rate at which the individual is willing to trade wealth W_j for a change in D_k, which is the Value of a Statitical Life, $VSL_{j,k}$, times the size of the change in D_k,

$$WTP_{j,k} = -\frac{dV_j / dD_k}{dV_j / dW_j} dD_k \equiv VSL_{j,k} dD_k \,. \tag{4}$$

The expression for the VSL depends on the individual's opportunities for borrowing and lending. When the individual can borrow and lend at the riskless rate of interest r the VSL is given by equation (4),

$$VSL_{j,k} = \frac{1}{1-D_k} \sum_{t=k+1}^{T} q_{j,t}(1+r)^{j-t} \left[U_t(C_t) / U_t^{'}(C_t) \right].^{17} \tag{5}$$

The amount an individual should pay to reduce his risk of dying reflects expected discounted utility of consumption over the remainder of the individual's life.

Under certain simplifying assumptions, the theory has direct implications for how the VSL should vary with consumption and life expectancy. If we assume that utility of consumption is iso-elastic—a common assumption the Economics literature—and independent of age, i.e., $U_t(C_t) = C_t^{\beta}, 1 \geq \beta \geq 0,$ then the VSL simplifies to (5),[18]

$$VSL_{j,k} = \frac{1}{1-D_k} \sum_{t=k+1}^{T} q_{j,t}(1+r)^{j-t} \left[C_t / \beta \right]. \tag{6}$$

[17] The corresponding formula in the annuities case is given in Appendix A.
[18] The standard form for the iso-elastic (Constant Relative Risk Aversion) utility function must be modified in this case to make utility of consumption while alive greater than utility of death.

The VSL is proportional to discounted expected utility of consumption, where the factor of proportionality, *1/β*, reflects the individual's risk aversion. For example, if $\beta = 0.2$, the VSL should equal five times the present value of discounted expected lifetime consumption.[19]

The VSL may be further simplified if annual consumption is approximately constant, i.e., $C_t = \overline{C}$, in which case the VSL is proportional to discounted remaining life expectancy, $\sum_{t=k+1}^{T} q_{j,t}(1+r)^{j-t}$,

$$VSL_{j,k} = \frac{1}{1-D_k}\overline{C}\beta^{-1}\sum_{t=k+1}^{T} q_{j,t}(1+r)^{j-t} . \qquad (7)$$

It should be noted that, formally, (7) requires extreme assumptions ($r = \delta$ in the lifecycle model). However, it underlies the common practice (discussed below) of apportioning the VSL into a constant value per life year saved (VSLY).

Equation (7) implies that the VSL should vary across persons in different countries in proportion to consumption (which may, in turn, be proportional to per capita income), but that the VSL may also differ due to differences in risk preferences and discounted life expectancy.

B. The Value of a Statistical Life Year (VSLY)

Equation (7) implies that the VSL is proportional to remaining life expectancy and, hence, that the VSL can be written as the product of discounted remaining life expectancy and a Value per Life Year Saved (VSLY) ($\overline{C}/\beta$).[20] This is a convenient assumption that is frequently used in policy analysis, especially to value QALYs and DALYs. The empirical literature on the effects of age on WTP does not support the notion that WTP falls in proportion to remaining life expectancy, although it suggests that WTP does decline after some age. (Alberini et al. (2004), for example, find that the VSL declines by about 30 percent after age 70 in stated preference studies conducted in the US and Canada.) In spite of lack of empirical support for a constant VSLY, it is often used in practice (Robinson, 2007).

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[19] This assumes that $1/(1-D_k) \approx 1$. Equation (6) also implies that the VSL is likely to exceed the present value of expected lifetime earnings, provided the individual is not a net borrower.

[20] In practice, the VSLY is derived by taking the VSL from an empirical study and dividing the VSL by the discounted expected number of life years remaining for the average individual studied.

C. Empirical Estimates of the VSL

Hedonic Wage Studies

Empirical estimates of the VSL most frequently come from hedonic wage studies, which estimate compensating wage differentials in the labor market, or from contingent valuation surveys in which people are asked directly what they would pay for a reduction in their risk of dying. The premise underlying compensating wage differentials is that jobs can be characterized by various attributes, including risk of accidental death. If workers are well-informed about risks of fatal and non-fatal injuries, and if labor markets are competitive, riskier jobs should pay more, holding worker and other job attributes constant. In order to estimate compensating wage differentials empirically, an equation is estimated to explain variations in the wage received by workers as a function of worker characteristics (age, education, human capital) and job characteristics, including risk of fatal and non-fatal injury (Viscusi, 1993). In theory, the impact of a small change in risk of death on the wage should equal the amount a worker would have to be compensated to accept this risk. For small risk changes, this is also what the worker should pay for a risk reduction.

For the compensating wage approach to yield reliable estimates of the VSL, it is necessary that workers be informed about fatal jobs risks and that there exists sufficient competition in labor markets for compensating wage differentials to emerge. To measure these differentials empirically requires accurate estimates of the risk of death on the job—ideally, broken down by industry and occupation. The researcher must also be able to include enough other determinants of wages so that fatal job risk does not pick up the effects of other worker or job characteristics. For example, since data on risk of injury are usually collected at the industry level, it is important to control adequately for other sources of inter-industry wage differentials.

A typical hedonic wage equation is of the form (8), in which the log of the wage is regressed on fatal risk of death on the job, non-fatal job risk, worker characteristics—including age, race education and years of experience and union status—as well as job characteristics, including industry and occupation.[21]

$$\ln w_i = \alpha + \sum \beta_m x_{im} + \gamma_0 r_i + \gamma_1 q_i + \gamma_2 q_i WC_i + u_i \qquad (8)$$

where

w_i : worker i 's wage rate

α : constant

x_{im} : personal and job characteristics, worker i

[21] The extent to which industry and occupation dummy variables can be included in the equation is limited by the nature of the risk data. If fatal job risk is estimated at the 3-digit industry level, then 2-digit industry dummy variables can be included in the equation, but not 3-digit dummies, to avoid exact collinearity among right-hand-side variables.

r_i : fatal job risk, worker *i*

q_i : nonfatal job risk, worker *i*

WC_i : worker's compensation

u_i : random error term

Results are often sensitive to the equation specification. Clearly, without controlling for other worker characteristics, the coefficient on fatal job risk would be negative rather than positive—jobs with the highest risk of death often pay the least. However, the magnitude of the coefficient on fatal risk (γ_0) is often sensitive to what other variables are included in the equation.[22] Because γ_0 represents the proportionate increase in the wage for a one unit change in fatal job risk on the wage, the VSL is calculated by multiplying γ_0 by the average wage and dividing by a one-unit change in risk.

The published literature includes over four dozen hedonic wage (HW) studies conducted in high income countries.[23] The mean VSL, in 2000 USD, is between $5 and $6 million; however, the range of estimates is large. Four recent studies attempt to explain variation in VSL estimates across studies as a function of study and respondent characteristics (Bowland and Beghin, 2001; Miller, 2000; Mrozek and Taylor, 2002; Viscusi and Aldy, 2003). Using VSL estimates from various studies, the authors run meta-regressions in which the VSL is the dependent variable and covariates include mean worker income, the mean size of the risk reduction, the proportion of workers unionized, whether the study included controls for inter-industry wage differentials or for non-fatal job risk. All four studies find that the VSL increases with the average income of workers in the study, and declines with the mean level of risk, at least after some point. Mrozek and Taylor (2002) find that studies that fail to control for inter-industry wage differentials report larger VSLs.

Meta-regressions are useful as empirical literature reviews—they indicate which factors raise or lower a VSL estimate, holding other features of study design constant. Sometimes they are used to predict the VSL for a preferred set of covariates.[24] However, care must be taken in interpreting the coefficients in a meta-regression. The coefficient on average worker income in a meta-regression should not be interpreted as the income elasticity of the VSL, for two reasons. Because most models use the semi-log specification in (8), the VSL = γ_0*Wage/(one unit change in risk). The elasticity of the VSL with respect to the wage (assuming no other covariates are included in the equation)

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[22] Black et al. (2003), in a reanalysis of data from compensating wage studies requested by the USEPA, show that the magnitude and sign of γ_0 vary significantly depending on whether industry and/or state dummies are included in the hedonic wage equation. In 4 different equation specifications for each of 10 datasets they find only 16 (out of 40) coefficients on fatal risk that are positive and statistically significant for men and 14 (out of 40) coefficients that are positive and statistically significant for women.

[23] Viscusi and Aldy (2003) list 30 HW studies using US data. They also cite 23 HW studies conducted in countries outside of the US, 18 of which were conducted in OECD countries. Kochi et al. (2006) and Mrozek and Taylor (2002)cite 47 HW studies in high-income countries. The five recent meta-analyses are Miller (2000), Bowland and Beghin (2001), Mrozek and Taylor (2002), Viscusi and Aldy (2003), and Kochi et al. (2006).

[24] Both Mrozek and Taylor (2002) and Viscusi and Aldy use the meta-regressions in this way.

would be one—by construction. More importantly, an equation in which the VSL from various studies are regressed on study and worker characteristics does not represent a structural relationship—it does not indicate how, for an individual, the VSL changes with income, or with factors that affect preferences.[25] Thus, the conclusion of Viscusi and Aldy (2003) that the income elasticity of the VSL is 0.5 (a finding echoed by Mrozek and Taylor (2002)) or that it is 1.0 (Miller (2000)) must be viewed with skepticism.

Stated Preference Studies

Hedonic wage studies are termed a revealed preference approach to estimating the VSL, because they rely on observed behavior. Compensation for fatal job risk is, however, “revealed” only by controlling for other variables, and is therefore plagued by econometric problems, some of which have been discussed above.[26] An alternative is to use direct questioning approaches when valuing mortality risk, which can be tailored to the age at which risk reductions occur and to the nature of the risks valued. Contingent valuation (CV) (or stated preference) studies have both advantages and disadvantages. One advantage of a contingent valuation study is that is easier to see how WTP for a risk reduction varies with age and income.[27] A disadvantage of CV studies is that they often make apparent respondents’ difficulties in consistently valuing small probabilities.[28]

Because contingent valuation studies ask hypothetical questions, it is standard practice for these studies to include tests of internal and external validity of responses. External scope tests vary the size of the risk reduction valued across respondents to see whether WTP increases with the size of the risk reduction. Failure of WTP to increase with the size of the risk reduction suggests that respondents do not perceive risk changes correctly, or are valuing a generalized commodity (“good health”) rather than a quantitative risk reduction. Internal scope tests check to see whether WTP increases with the size of the risk reduction for a given respondent. Tests of external validity also include checking whether responses vary, as expected, with income.[29]

Kochi et al. (2006) in their meta-analysis of VSL studies from high income countries draw on 18 contingent valuation studies, and 42 HW studies. When the point estimates from the studies are combined using empirical Bayes methods (i.e., weighting the VSL estimates in inverse proportion to their precision), the mean VSL from CV studies is significantly lower than for HW studies, a result noted by others. Specifically, the

[25] Recall that income is endogenous in an hedonic labor market. To estimate the impact of changes in non-wage income on compensating wage differentials requires estimating workers’ marginal bid functions as a function of non-wage income. See Biddle and Zarkin (1988).
[26] Other problems include non-classical errors in measuring fatal job risk, and the endogeneity of the risk variable (see Black et al., 2003).
[27] Recall that, in an HW study, income is endogenous. Estimating the impact of changes in non-wage income on compensating wage differentials requires solving the identification problem in hedonic markets (Biddle and Zarkin, 1988).
[28] For example, WTP for a reduction in risk of death seldom increases in proportion to the size of the risk change, which suggests that respondents do not perceive risk changes as economists expect them to.
[29] The results of CV studies are also sensitive to the specification of models used to analyze the data; see, for example, Alberini (2005).

authors report a VSL of $2.8 million (2000 USD) (S.D. = $1.3 million) based on 18 CV studies and a VSL of 9.6 million (2000 USD) (S.D. = $4.9 million) based on 42 HW studies. Their final estimate, which weights study estimates in inverse proportion to their variance, yields a VSL of $5.4 million with a standard deviation of $2.4 million (2000 USD). The Kochi et al. study is the only meta-analysis that weights VSL estimates in inverse proportion to their variance and that uses stringent criteria for the inclusion of studies in the analysis. We therefore focus on this estimate as representing the state of the literature in high-income countries.

D. Empirical Estimates of the VSL in Developing Countries and Benefits Transfer

There are published estimates of the VSL for all of the countries listed in Table 7. However, the number of studies per country—and their quality—varies widely. Viscusi and Aldy (2003) cite only 5 HW studies conducted in non-OECD countries—India, Korea and Taiwan. Miller (2000) includes 29 studies from 12 countries outside of the US in his 2000 meta-analysis; however, only two of these (Taiwan and South Korea) are not high-income OECD countries. Robinson (2008) summarizes results from 11 CV studies in developing countries.

Table 7 Countries with Published Estimates of the VSL[30]

High Income OECD Countries	Other Countries
Austria (2)	Chile (2)
Australia (2)	China (3)
Canada (8)	Hong Kong (1)
Denmark (1)	India (5)
France (1)	Malaysia (1)
New Zealand (3)	Mexico (1)
Sweden (4)	Poland (1)
Switzerland (2)	South Korea (2)
United Kingdom (10)	Taiwan (5)
United States (40 +)	Thailand (3)

What is clear is that the developing country literature at this point is not sufficiently mature to provide estimates for individual countries. This suggests transferring estimates from countries where better studies exist to countries for which there are no empirical estimates of the VSL.

[30] As cited by either Miller (2000), Viscusi and Aldy (2003) or Robinson (2008). This list is not intended to be exhaustive.

The Standard Approach to Benefits Transfer

Due to the limited number of empirical estimates of the VSL in developing countries, economists have frequently used benefits transfer to estimate developing country VSLs. Most transfers are based on income differences between countries: As the lifecycle model suggests, the VSL should depend on consumption and, hence, on income. If risk preferences, discount rates and survival probabilities were the same in all countries, equation (7) would imply that the VSL should be proportional to consumption/income. The standard approach to benefits transfer treats the ratio of the VSL to per capita income as constant across countries, and uses estimates of the VSL from high income countries to estimate the VSL in middle and low income countries. We discuss the implications of this approach and then ask whether the empirical evidence from mortality risk studies in middle income countries supports it.

The simplest approach to benefits transfer is illustrated by equation (9), which says that the VSL in India—measured in US dollars—equals the VSL in the US, multiplied by the ratio of per capita income in India (Y_{India}) to per capita income in the US (Y_{USA}). ε is the income elasticity of the VSL. The equation assumes that preferences, e.g., attitudes

$$VSL_{India} = VSL_{USA} * (Y_{India}/Y_{USA})^{\varepsilon} \qquad (9)$$

towards risk, are the same in both countries. When $\varepsilon = 1$, the equation implies that the ratio of the VSL to per capita income is the same in both countries.

$$VSL_{USA} / Y_{USA} = VSL_{India} / Y_{India} \, . \qquad (10)$$

Equation (10) is consistent with the simplified version of the life cycle model (equation (7) above) if consumption is proportional to per capita income. The life cycle model implies that the VSL is proportional to current consumption *if people have the same discount rates, survival probabilities and the same risk preferences in both countries.*

One approach to benefits transfer would be use equation (10) with VSL_{USA} based on Kochi et al. (2006). Transferring a VSL of $5.4 million (2000 USD) to Turkey would imply a VSL in Turkey of $960,000. The corresponding figure for Colombia would be $640,000. Both figures are consistent with the VSLs used by Smyth et al. (2004a) and Ghesquiere et al. (2006). It should be noted that the VSL/Y ratio implied by the use of Kochi et al. is approximately 140:1, a figure that coincides with Miller's (2000) recommended approach to benefits transfer.

Equation (10), however, assumes that risk preferences, discount rates and survival probabilities are constant across countries, which may, however, be unjustified. One way of testing this assumption is to examine the ratio of the VSL to per capita income based on available studies. Is it approximately constant? Miller's (2000) ratio of 140:1 is based on studies from 13 high income countries. Averaging the VSL/Y ratios reported by Robinson (2008) from 11 studies in middle income countries, however, implies a VSL/Y ratio closer to 80:1. For example, Liu, Hammitt and Liu (1997) find a ratio of 77:1 in

Taiwan in 1990 based on their HW study. Wang and Mullahy (2006)'s stated preference study in China implies a ratio of about 70:1. Vassanadumrongdee and Matsuoka (2005) in a stated preference study of WTP in the context of traffic accidents report a much higher ratio (158:1); however, Bhattacharya, Alberini and Cropper (2007) report a VSL for commuters in Delhi, India of $150,000 USD, implying a VSL/Y ratio of only 15. These results suggest that the VSL/Y ratio may be lower in middle than in high income countries.

How Should Benefits Transfers Be Conducted?

In practice, benefits transfers are likely to be based on income, with the elasticity of the VSL (ε in equation (9)) capturing differences in other factors—attitudes toward risk, discount rates, survival probabilities—that vary across countries and may be correlated with income. The preceding paragraph suggests that, interpreted in this way, $\varepsilon > 1$. There is, however, no reason to believe that the income elasticity of the VSL is constant, as equation (9) assumes. It could vary with income, increasing as income decreases.

Given these considerations, how should benefits transfers be conducted? Transferring VSL estimates using equation (10) is likely to overstate the VSL in low and middle income countries. One possibility is to use a ratio of VSL/Y in middle income countries of 80:1, based on Robinson (2008). Another possibility would be to transfer VSL estimates from the US to other countries using an elasticity of 1.0 and an elasticity of 1.5 to provide a range of estimates.[31] Table 8 illustrates the implications of this transfer for different groups of countries. The range of VSL values for a middle income country with per capita GDP = $5,700 is $257,000 to $710,000 (2000 USD), while it is between $730,000 and $1.4 million (2000 USD) for an upper-middle income country with per capita GDP of $11,400.[32] For a country with PPP per capita GDP of $1,150, the mean 2007 per capita income of "least developed countries" according to the UN definition, the VSL ranges from $23,000 to $143,000 (2000 USD).

[31] Some support for the 1.5 elasticity is provided by Costa and Kahn (2005) and Hammitt, Liu and Liu (2000) who use time series variation in the coefficient of risk in an hedonic wage equation (γ_0 in equation (8)) to infer the elasticity of the VSL with respect to per capita GDP. The authors estimate a series of hedonic wage equations at different points in time—Costa and Kahn using micro data for the US (1940-1980) and Hammitt et al. (2000) using micro data for Taiwan (1982-1997). The elasticity of the VSL with respect to per capita GDP is approximately 1.5 in Costa and Kahn and 2.0 in Hammitt et al. (2000).

[32] The transfers in Table 8 are based on 2007 PPP per capita GDP figures and a US VSL of $5.4 million (2000 USD) from Kochi et al. (2006).

Table 8 VSL transfers using alternate income elasticities

Country Name	2007 GDPPC	GDPPC ratio (country/USA)	(Y/YUS)^1.5	VSL ε=1.5	VSL ε=1	
	(in PPP, US$ constant 2005)		(million US$)			
High income	34,187	0.791	0.703	3.798	4.271	
High income: non - OECD	30,028	0.695	0.579	3.127	3.751	
High income: OECD	34,683	0.802	0.719	3.881	4.333	
United States	43,227	1.000	1.000	5.400	5.400	
Middle income	5,677	0.131	0.048	0.257	0.709	
Upper middle income	11,416	0.264	0.136	0.733	1.426	
Lower middle income	4,318	0.100	0.032	0.170	0.539	
Low income	1,437	0.033	0.006	0.033	0.180	
Least developed countries (UN classification)	1,147	0.027	0.004	0.023	0.143	

Source: WDI, World Bank and authors' calculations

E. Valuing Mortality Risks to Children

The preceding discussion pertains to valuing mortality risks for adults. The life cycle model assumes a rational, adult individual who earns income and allocates consumption over the life cycle. The empirical VSL literature reviewed in sections C. and D. attempts to measure what adults will pay for changes in their own mortality risks. Valuing mortality risks to children is difficult because children are often viewed as lacking the knowledge and the judgment needed to trade money for risk of death. There is also the question of budget constraint: on whose income is a child's WTP for mortality risk reductions based?

Two perspectives can be taken with respect to valuing children's health (USEPA 2003). The most common is to use parents' valuations—i.e., to ask parents what they would pay for changes in mortality risks to their children. This acknowledges that parents are responsible for their children's welfare and assumes that WTP is constrained by the household's budget. An alternate approach is to ask what a rational child would be willing to pay to reduce his risk of dying—often referred to as the "adult as child" approach. This approach works well when individuals are risk neutral (when $\beta = 1$ in equation (6)), implying that the VSL is equal to discounted expected earnings. In this case, the VSL can be calculated for a child, given assumptions about survival probabilities and earnings opportunities over the child's lifetime.

In either case, the important question for policy is whether the VSL for children should differ from the VSL used for adults. The official policy of the USEPA is to use the same value for children and adults, on the grounds that there is insufficient literature to warrant setting a separate VSL for children. We briefly review this literature below.

Parents' WTP for Children's Mortality Risk Reductions

There is a small but growing literature on parents' WTP to reduce health risks to their children, including mortality risks. In the US and Europe, revealed preference studies have used information on the purchase of car seats and bicycle helmets to infer WTP for reduced death and injury.[33] Other studies are based on parents' WTP for chelation therapy for children with body lead burdens. Some of the literature relies on stated preference studies. As stated in a recent OECD volume on children's health (OECD 2006) only 15 studies directly compare parents' willingness to pay for improvements in their own health with WTP for improvements in their children's health. Many of these studies value reductions in acute illness, and only one study was conducted in a developing country (Liu et al., 2000).

The consensus from these studies is that parents are willing to pay more to reduce health risks to young children than to themselves—generally about twice as much—but that this effect decreases with child age. The result is also not universal: Jenkins et al. (2001) and Mount et al. (2001) find that parents are willing to pay more to reduce mortality risks to themselves than to their children. Only one of the studies cited by OECD (2006) was conducted in a developing country. Liu et al. (2000), in a stated preference study in Taiwan, find that mothers are willing to pay about twice as much to avoid a day of acute illness in their children as they are to avoid the day of illness themselves.

The Adult-as Child Approach

The adult-as-child approach would attribute a VSL to children by extending the life cycle model backwards in time. This raises the question of budget constraints: out of whose income does a child consume when young? Nevertheless, one could use equation (5) [or (6)] above, contingent on assumptions about the child's consumption over his lifetime, to calculate a VSL for children. How this would compare to the VSL for an adult would depend on the level consumption over the child's lifetime—is it expected to be higher than for an adult due to income growth?—as well as on the discount rate and survival probabilities used. If the analyst is willing to make the assumptions necessary to simplify the VSL to equation (7), it is almost surely the case that the VSL used for children would be higher than for adults, given that children have a high discounted remaining life expectancy than adults.

V. Valuing Injuries

A. Principles of Valuation

In principle the value of avoided injury should be measured by what an individual is willing to pay to avoid it.[34] Willingness to pay (WTP) should capture the value of the pain and suffering avoided, as well as the value of time lost due to injury (both leisure

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[33] The assumption in these studies is that if a safety device is purchased, the marginal benefit of the device—the VSL multiplied by the size of the risk reduction—must exceed the marginal cost. For the parent who just finds it worthwhile to purchase the device, the cost of the device divided by the risk reduction achieved provides an estimate of the VSL.

[34]For minor injuries, this is the amount a person is willing to pay to avoid illness with certainty; for serious injuries by the WTP to reduce the *risk* of injury.

and work time) and the costs of medical treatment. If some of these costs are not borne by the individual, and are therefore not reflected in his willingness to pay, the value of the avoided costs must be added to WTP to measure the social benefits of reduced injuries.

Estimates of individual WTP to avoid injury can be measured using revealed or stated preference approaches; however, empirical estimates of WTP to avoid risk of injury exist for very few categories of injury. This is in part due to the wide variety of injuries to be valued (see Table 5). The more common approach is to produce an estimate of the medical costs and lost productivity associated with an injury—the so-called direct and indirect Costs of Illness. Cost of Illness (COI) estimates may either be used as a lower bound to WTP or may be supplemented with estimates of the quality-adjusted life years (QALYs) lost due to the injury. QALYs measure the extent to which an injury (or illness) limits physical or social functioning or causes discomfort. QALYs are often monetized, using the VSLY, and monetized QALYs added to COI estimates to produce a more comprehensive estimate of the value of avoided injury.

This section discusses both components of injury costs—estimates of the Cost of Illness and monetized QALYs. We review COI estimates of injury costs in the US and discuss sources of data for estimating these costs in developing countries. This is followed by a brief discussion of QALY indices and their application to measuring healthy life years lost to injury. The practice of monetizing QALYs is controversial; however, failure to monetize QALYs often results in using only COI estimates, which are a lower bound to the value of avoided injury. The issue of monetizing QALYs is discussed in Section D. Because of the effort involved in computing bottom-up estimates of injury costs for a variety of injuries, it may be useful first to compute back-of-the envelope estimates of injury costs. Approaches to computing rough estimates of injury costs are suggested in section E., based on the results of US studies.

B. Cost of Illness Estimates

Estimates of the medical costs associated with an injury depend on the level of treatment received as well as on the unit costs of medical personnel, emergency room visits and hospital stays. In the United States large-scale health surveys are used to estimate the costs of hospitalized and non-hospitalized injuries, by ICD-9 code (Corso et al., 2006). These surveys describe both the level of treatment received for an injury, a doctor diagnosis of the injury and the costs of treatment.[35] Corso et al. (2006) use these data to estimate the costs of all injuries in the United States for 2005, by ICD-9 and AIS threat-to-life code. Robinson (2007) summarizes the present value of lifetime medical costs of injuries reported in Corso et al. (2006) by AIS code. Medical costs per person increase from $1,000 for minor injuries (AIS 1) to $67,000 for critical injuries (AIS 5).

There is, however, significant variation in medical costs by body region, holding AIS code constant. Table 9, from Zaloshnja et al. (2004) shows medical cost estimates for road traffic crash survivors, broken down by AIS code and body region. Spinal cord

[35] The Medical Expenditure Panel Survey (MEPS) is once source of information and the Healthcare Cost and Utilization Project another.

injuries are much more costly than injuries to the lower extremities or abdomen, holding AIS constant. This suggests that estimates of injuries may need to distinguish type and location of injury as well AIS as threat-to-life code.

Estimates of lost productivity include temporary work losses associated with an injury, and losses associated with long-term disability. In the United States, estimates of the number of days of work lost immediately following the injury come from population-based surveys and are valued at the average wage. Estimates of the earnings loss associated with permanent long-term disability are calculated by multiplying the present value of foregone earnings by the probability of permanent disability, for each injury type. For partial disability, the present discounted value of lost earnings associated with partial disability and the probability of partial disability are multiplied to estimate the productivity loss (Corso et al., 2006; Zaloshnja et al., 2004).

It is, in principle, possible to compute medical costs and productivity losses associated with various injuries in developing countries. The World Health Organization (WHO) has recently published estimates of the cost of a hospital day (classified by type of hospital) and a doctor's visit, for all WHO member countries (see Appendix B.) Estimates of productivity losses could be estimated by multiplying estimates of foregone earnings by the probability of full or partial disability associated with a disease. In the US, detailed estimates of the probability of full or partial disability exist for injuries classified by ICD-9 diagnosis and AIS threat-to-life code (Miller et al., 1995; Spicer and Miller, 2008). Whether these estimates could be transferred to other countries remains an open question.

C. Estimates of QALYs Lost Due to Injury

One way of capturing the lost quality of life associated with an injury is to estimate the fraction of a healthy life year lost each year, over the remainder of the individual's life, due to limitations imposed by the injury. Health-Related Quality of the Life (HRQL) indices assign a Quality of Life (QALY) index to various health states, which ranges from 1 (perfect health) to 0 (death). Health states are described by scores assigned to various dimensions of functioning (e.g., mobility, ability to eat or dress oneself, absence of pain). Comparing the QALY index for an injury (e.g., a severed spinal cord) with the QALY index associated with normal (or perfect) health provides an estimate of the utility loss associated with the injury.

Constructing a QALY index for an injury is accomplished in two stages. It is first necessary to select an HRQL index from the literature that will be used to measure the QALYs associated with different health states. Different HRQL indices include different dimensions of functioning, but measures commonly included are the ability to walk, bend and stoop (mobility), the ability to eat, speak, or dress oneself. (Appendix C lists the different domains included in various survey instruments.) In some instruments, the ability to function socially, or cognitively, or the absence of pain, constitute a separate domain. The number of domains times the number of levels within each domain determines the number of possible health states in the survey instrument. For example, the EuroQoL (EQ5-D) consists of 5 domains—mobility, self-care, usual activities, pain and discomfort, and anxiety and depression—each of which can assume 3 values, implying a total of 243 health states.

The different possible health states corresponding to different levels of functioning are compared—by experts or individuals—in order to place each health state on a 0 to 1 scale, where 1 corresponds to perfect health and 0 to death. The comparison of health states can be accomplished by asking individuals to place them on a visual scale, or by using time trade-offs or standard gambles.[36] The utility weights assigned to individuals to different health states make it possible to construct a QALY index, lying between 0 and 1, for each possible health state.

Once an HRQL instrument has been chosen, the limitations imposed by the injury must be rated along the various dimensions of functioning used to construct the QALY index. This can be done by doctors, or by persons who have experienced the injury. These ratings define a health state, which has an associated QALY index. The difference between the QALY index corresponding to the injury and a QALY index of 1 represents the fraction of a year of perfect health lost due to injury. The pattern of QALYs lost after an injury occurs will likely vary over time, as the injury heals and/or the individual adapts to it.

QALY indices can in principle be computed using any of the HRQL instruments in common use—the EuroQol (EQ-5D), the Functional Capacity Index (FCI), the Health Utility Index (HUI), the Quality of Well Being (QWB) Scale, or Disability Adjusted Life Years (DALYs). However, these instruments vary in their ability to capture aspects of functioning that are likely to be important when people are injured. The FCI, which measures physical and cognitive functioning in 10 domains, was developed specifically to rate injuries (MacKenzie, 1996; Segui-Gomez and MacKenzie, 2003).[37] The Injury Impairment Index (III) (Miller et al., 1995), which addresses mobility, cognitive functioning, activities of daily living, pain, sensory and cosmetic aspects of functioning, was also developed specifically to rate injuries.

Injuries, classified by ICD-9 and AIS codes, have been mapped to both the FCI and III, taking into account the number of years since the onset of the injury (Miller at al., 1995; Spicer and Miller, 2008). Injuries have also been mapped to DALYs (see Appendix D), with DALY weights distinguished according to age and whether the individual was hospitalized. DALY weights, however, do not vary according to the number of years since the onset of the injury.

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[36] In a time trade-off individuals are asked how many years in health state i are equivalent to x years in perfect health. If y years in health state i are equivalent to x years in perfect health, x/y is the QALY weight assigned to state i. A standard gamble asks the respondent what risk of death p he would accept in an operation that would restore him from state i to perfect health. The QALY weight assigned to state i is 1-p.

[37] The 10 domains include eating, excretory function, sexual function, ambulation, hand-wrist movement, bending/lifting, vision, hearing, speech, cognition. The FCI does not measure pain, or psycho-social functioning.

Table 9 Costs per non-fatality injured victim of a highway crash in the US, by body region and maximum severity (in 2000 US$)

Source: Zaloshnja et al. (2004)

Body Region and MAIS		Medical	Police & Fire Services	Household Work	Wage Work	Insurance Administration	Legal / Court	Property Damage	Total Monetary	Quality of Life	Comprehensive
Spinal Cord	MAIS 3	359,615	368	108,107	173,355	59,081	89,752	6,799	797,077	185,337	982,414
	MAIS 4	816,663	830	160,039	282,893	91,788	106,494	9,833	1,468,540	1,618,924	3,087,464
	MAIS 5	1,133,725	852	224,711	347,470	105,822	106,494	9,446	1,928,519	2,307,627	4,236,146
Brain	MAIS 1	42,148	97	3,342	11,044	5,131	2,012	3,844	67,620	48,415	116,035
	MAIS 2	27,617	212	7,498	27,740	8,558	7,191	3,954	82,770	212,788	295,558
	MAIS 3	148,425	368	18,103	67,488	26,820	27,806	6,799	295,808	331,761	627,569
	MAIS 4	187,120	830	42,439	167,938	45,237	52,648	9,833	506,045	717,272	1,223,317
	MAIS 5	249,894	852	316,985	796,696	85,179	112,478	9,446	1,571,530	1,786,858	3,358,388
Lower extremities	MAIS 1	1,244	97	343	1,070	559	94	3,844	7,250	3,996	11,246
	MAIS 2	8,351	212	10,225	32,368	8,804	6,581	3,954	70,494	49,062	119,557
	MAIS 3	31,244	368	30,099	108,477	24,548	20,972	6,799	222,507	124,036	346,543
	MAIS 4	30,059	830	53,795	308,375	41,144	54,137	9,833	498,173	212,788	710,961
	MAIS 5	209,623	852	127,643	420,307	59,189	104,564	9,446	931,623	102,752	1,034,375
Upper extremities	MAIS 1	1,280	97	566	1,854	686	135	3,844	8,462	3,949	12,411
	MAIS 2	5,575	212	7,192	21,972	4,566	1,980	3,954	45,451	86,650	132,101
	MAIS 3	11,612	368	17,950	60,615	14,302	9,322	6,799	120,967	172,387	293,354
Trunk and Abdomen	MAIS 1	1,346	97	748	2,263	761	170	3,844	9,229	3,716	12,945
	MAIS 2	10,657	212	9,192	36,398	9,017	6,269	3,954	75,701	57,196	132,897
	MAIS 3	34,396	368	17,534	64,295	18,554	15,427	6,799	157,373	98,568	255,940
	MAIS 4	53,508	830	22,209	80,945	23,617	21,165	9,833	212,107	165,514	377,621
	MAIS 5	61,648	852	56,339	172,787	36,644	40,134	9,446	377,850	213,777	591,627
Other Head/Face/Neck	MAIS 1	1,037	97	456	1,530	607	96	3,844	7,667	5,135	12,801
	MAIS 2	8,955	212	6,964	30,663	7,942	5,851	3,954	64,540	44,219	108,759
	MAIS 3	56,184	368	17,232	65,507	20,506	18,809	6,799	185,406	104,024	289,430
	MAIS 4	159,986	830	21,581	101,178	36,603	39,026	9,833	369,037	674,162	1,043,199
Minor External	MAIS 1	1,085	97	302	887	515	65	3,844	6,794	3,156	9,950
Burns	MAIS 1	9,310	97	3,791	10,281	2,421	382	3,844	30,126	37,739	67,865
	MAIS 2	62,411	212	7,628	21,571	9,295	7,349	3,954	112,420	132,691	245,111
	MAIS 3	198,791	368	26,270	93,733	34,405	44,002	6,799	404,368	453,693	858,061
	MAIS 5	92,098	852	32,370	130,861	36,866	35,242	9,446	337,734	507,472	845,206
Fatal Injury		20,685	833	280,638	802,262	36,068	102,138	10,273	1,252,897	1,905,655	3,158,552

D. Valuing QALYs

QALYs are typically valued using the Value of a Statistical Life Year (VSLY), calculated on the assumption that the VSL is strictly proportional to remaining life expectancy (equation (7)). As noted above, the assumption of a constant VSLY has not been borne out by the empirical literature (see, e.g., Alberini et al., 2004). It is also inappropriate to use a VSLY because it is based on a tradeoff of consumption/wealth for longevity, whereas a QALY measures the tradeoff between health and longevity. Hammitt (2002) discusses the theoretical difficulties in using the VSLY to monetize a QALY, and a recent NAS-IOM panel has cautioned against this practice (Miller et al., 2006). Nevertheless, the practice of valuing QALYs (or DALYs) using a VSLY is practiced by the US Department of Transportation, and other agencies (Robinson, 2007). At this point, the alternative is to use estimates of the medical costs and productivity losses associated with injury as a lower bound to the value of an injury, which would under-value injuries relative to lives saved.

E. Lessons from the US Re: Injury Valuation

As noted above, there have been detailed analyses of the costs of injuries in the US, especially for injuries associated with road traffic crashes. The results of these analyses indicate the relative importance of various components of injury costs (medical costs, productivity losses and QALY losses) and whether total costs vary in proportion to one component of costs, thus suggesting a possible rule of thumb for computing costs. The analyses also indicate how costs vary with injury severity level. The latter information can be used to determine equivalent lives saved, for various injury severity categories.

Zaloshnja et al. (2004) report per capita injury costs for 137 injuries sustained in traffic crashes, broken down by body part, injury type (fracture/non-fracture) and maximum AIS code.[38] We have used these data to compute the fraction of total injury costs attributable to each cost component, by MAIS code. Two points are noteworthy: First, medical costs constitute, on average, only 16% of total injury costs. Productivity losses constitute 38% of total costs and monetized QALYs 46% of total costs.[39] Secondly, the ratio of each cost component to total costs is not significantly related to MAIS code. Thus, in the US, productivity and QALY losses constitute over 80% of the total costs of road traffic injuries. It is also interesting to note that variation in QALY losses explain 97% of the variation in total injury costs. The ratio of QALY losses to total costs is approximately 1.7:1.

Although there is, admittedly, significant variation in injury costs within an MAIS category, total costs are often summarized by MAIS category and the variation in costs across categories is noteworthy. Table 10 shows the per capita costs of traffic crashes in the US, by MAIS category, for the year 2000.

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[38] The per capita costs for a given injury reflect the age distribution of injury in the United States.

[39] These ratios clearly depend on the VSL used to monetize QALYs, which is $3.3 million USD.

A second approach is to determine the QALYs (or DALYs) lost due to various injuries and to monetize these using the VSLY. The QALY losses associated with various injuries could be approximated by estimates from the US. For example, Table 11 lists the discounted QALYs lost, by MAIS category, for road traffic injuries in the US. QALYs associated with injuries by ICD-9 category are available in Miller et al. (1995). Valuing lost QALYs using a VSL would give a lower-bound estimate of injury costs, which could be adjusted, as suggested above, to account for productivity losses and medical costs.

Table 10 NHTSA VALUES FOR INJURIES AND FATALITIES[40]

(Costs per case, 2000 dollars, 4 percent discount rate)

Severity Category (examples)	Costs of Illness[1] (a)	QALY Costs (b)	Total (c = a + b)	Equivalent of Traffic Crash Ratio (d=c/$3,347,000)
MAIS 1	$ 6,000	$ 4,000	$ 10,000	0.003
MAIS 2	$ 62,000	$ 91,000	$ 153,000	0.05
MAIS 3	$ 178,000	$ 128,000	$ 306,000	0.09
MAIS 4	$ 337,000	$ 383,000	$ 721,000	0.22
MAIS 5	$ 1,078,000	$ 1,307,000	$ 2,384,000	0.71
MAIS 6	$ 958,000	$ 2,389,000	$ 3,347,000	1.00

Sources: Robinson (2008). Dollar values are from Blincoe et al. (2002), Table A-1, p: 62 and exclude travel delays and property damage.

Table 11 Estimated Quality Adjusted Life Years (QALYs) lost per injury[41]

Max AIS	Nonhospitalized Median	Nonhospitalized Q1	Nonhospitalized Q3	Hospitalized Median	Hospitalized Q1	Hospitalized Q3
3% discount rate	Remaining life= 23 years					
AIS 1	0.05	0.04	0.08	0.63	0.63	0.64
AIS 2	0.59	0.42	0.93	1.61	1.39	2.22
AIS 3	1.56	0.72	2.82	2.16	1.58	3.33
AIS 4				5.78	4.62	7.32
AIS 5				13.17	10.84	15.23
4% discount rate	Remaining life= 19.28 years					
AIS 1	0.04	0.03	0.07	0.53	0.53	0.53
AIS 2	0.55	0.40	0.87	1.41	1.21	1.96
AIS 3	1.34	0.63	2.39	1.83	1.34	2.81

Source: Spicer and Miller (2008)

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[40] Notes:

1. Includes medical treatment, emergency services, lost workplace and household productivity, replacement costs for workers with disabilities, legal and court fees from litigation, and administration of insurance claims.
2. Relative values are calculated by dividing the comprehensive costs for the MAIS category by the dollar value of a fatality (i.e. by $ 3,347,000). These fractions are then used in the calculation of equivalent lives saved.

[41] Median, Quartile 1 (Q1), Quartile 3 (Q3); by Maximum AIS and Discount Rate; based on motor vehicle-related injuries, 2000-2006

VI. Summary and Conclusions

A. A Summary of Our Suggested Approach

Avoided injuries and deaths are an important component of the benefits of disaster risk reduction projects, especially for projects to reduce losses from earthquakes and storms. To monetize these benefits requires first that the expected number of deaths and injuries avoided by quantified. Estimating the number of deaths and injuries prevented by a project is difficult; however, it should be noted that this is accomplished in the United States using FEMA's HAZUS model, for earthquakes, storms and floods. It seems possible that similar models could be employed in a developing country context. If avoided deaths and injuries can be estimated by Maximum AIS code (MAIS), then the methods suggested in this paper can be used to produce order-of-magnitude calculations of the value of avoided death and injury associated with a project. These calculations can then be refined if including avoided death and injury among project benefits appears warranted.

Benefits transfer methods will, most likely, have to be used to value lives saved, as few reliable estimates of the VSL exist for middle income countries and none for low income countries. The information available from VSL studies in middle income countries suggests that the ratio of the VSL to per capita income is not constant across countries, as is assumed when the VSL is transferred from country A to country B by multiplying the VSL in A by the ratio of ($income_B/income_A$). Indeed, the ratio of the VSL to income appears to be lower in middle income countries than in high income countries. This may be true for several reasons. First, the elasticity of the VSL with respect to income may, indeed, be greater than 1, especially at low income levels. In addition, other factors that should affect the VSL—attitudes towards risk, the rate at which the future is discounted, and survival probabilities—may vary across countries. If survival probabilities are lower and discount rates higher in low income countries than in high income countries the ratio of VSL to income should fall as income falls.

How should VSLs be transferred from high income to low income countries? We suggest, while awaiting the results of more VSL studies in middle and low income countries, that transfers be made using both an income elasticity of 1, and an income elasticity of 1.5, to provide a range for the VSL. Some support for the 1.5 elasticity is provided by within-country (time series) estimates of the income elasticity of the VSL using data over long time periods. Costa and Kahn (2005), for example, estimate that the income elasticity of the VSL in the US is between 1.4 and 1.7, using data from 1940-1980.

How should avoided injuries be valued? Although there is considerable variation within MAIS category in medical costs, productivity losses and losses in Quality-Adjusted Life Years (QALYs), the Costs of Illness and Lost QALYs vary substantially by MAIS threat-to-life index. Indeed, in the road safety literature (Robinson, 2007; IRAP, 2007), it is common to express injuries in terms of equivalent lives lost, based on the ratio of the total costs of injury (by MAIS) relative to the cost of a fatality. Using US data as reported in Robinson (2007), an MAIS 5 injury is equivalent to 0.71 lives lost and an MAIS 4 injury equivalent to 0.22 lives lost. This provides a quick-and-dirty method of approximating the importance of avoided injuries, given estimates of the VSL.

It is also possible to use estimates of QALY losses associated with categories of injury to approximate injury costs. QALY losses could be associated with MAIS code, or they could be associated with specific types of injuries (e.g., skull fractures, crush injuries) if the number of injuries avoided can be estimated in this way. Mappings from MAIS category to QALYs lost are available in the US, based on road traffic injuries (Spicer and Miller, 2008). Mappings from injuries, classified by ICD-9 code, to QALYs also exist for the US (Miller et al., 1995; Segui-Gomez and MacKenzie, 2003). The Appendix contains WHO figures on DALY losses associated with various categories of injury. Although there are theoretical reasons why QALYs should not be monetized using the Value of a Statistical Life Year (VSLY), the use of the VSLY should provide order-of-magnitude estimates of the value of QALY losses. QALY losses across injury categories explain 97% of the variation in total injury costs for road traffic injuries in the US (Zaloshnja, et al., 2004). However, QALY losses are only about 60% of total costs of road traffic injuries. This suggests that monetizing QALY losses will provide a lower bound estimate to the value of injury.

The methods suggested above will provide order of magnitude estimates of the value of avoided death and injury associated with disaster risk reduction projects. If these benefits are significant, a more careful, bottom-up analysis may be warranted. The methods presented in this paper should, however, allow analysts to determine whether inclusion of avoided death and injury will enable a disaster risk reduction project to pass the benefit-cost test.

B. Concluding Thoughts

Benefit-cost analysis is an important tool for evaluating the efficiency of disaster risk reduction policies, as well as policies in other sectors. Efficiency is, of course, only one criterion by which policies are judged, but it is an important one—especially when resources are scarce. We note that cost-effectiveness analysis is another approach that can, and should, be used in evaluating disaster risk reduction policies. When reductions in injury and death are an important component of project benefits, it makes sense to calculate the reduction in injuries and deaths in terms of QALYs (or DALYs). The costs of the project, minus the non-health benefits of the project, can then be divided by the QALYs saved to calculate a cost per QALY avoided.[42]

One advantage of cost-effectiveness analysis is that it is easy to compare the cost per QALY across policies—across policies to reduce disaster risks and across health and safety policies in various sectors—to encourage consistency in decision-making. To achieve the same consistency in benefit-cost analyses, it is imperative that a consistent

[42] The saving in medical costs should also be subtracted from project costs before calculating the cost per QALY (see Gold et al., 1996 and Miller et al., 2006).

approach to health valuation be used across sectors. Although this paper has focused on reducing disaster risks, the valuation techniques proposed here can (and should) be applied to evaluate risks in other sectors (e.g., road safety, environment) to promote efficient resource allocation.

REFERENCES

ADB. 2008. "Climate Change and Disaster Risk Management: Legislating Gender-Responsive Mitigation, Adaptation and Women's Participation." http://www.adb.org/Documents/Speeches/2008/ms2008075.asp

Alberini, A., M. Cropper, A. Krupnick and N. Simon. 2004. "Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the U.S. and Canada." *Journal of Environmental Economics and Management* 48(1): 769-792.

Alberini, A. 2005. "What Is a Life Worth? Robustness of VSL Values from Contingent Valuation Surveys." *Risk Analysis* 25(4):783-800.

Association for the Advancement of Automotive Medicine. 1990. "The Abbreviated Injury Scale 1990 Revision." Association for the Advancement of Automotive Medicine, Des Plaines, IL.

Armenian, Haroutune K., Arthur Melkonian, Eric K. Noji, and Ashot P. Hovanesian. 1997. "Deaths and Injuries due to the Earthquake in Armenia: A Cohort Approach." *International Journal of Epidemiology* 26(4): 806-13.

Arrow, Kenneth J., and Robert C. Lind. 1970. "Uncertainty and the Evaluation of Public Investment Decisions." *The American Economic Review* 60(3): 364-78.

Bhattacharya, S. A. Alberini, and M. Cropper. 2007. " The Value of Mortality Risk Reductions in Delhi, India." *Journal of Risk and Uncertainty* 34(1):21-47.

Biddle, Jeff E., and Gary A. Zarkin. 1988. " Worker Preferences and Market Compensation for Job Risk." *The Review of Economics and Statistics* 70(4): 660-67.

Black, Dan A., Jose Galdo, and Liqun Liu. 2003. "How Robust Are Hedonic Wage Estimates of the Prick of Risk?" Office of Policy Economics and Innovation, Washington, DC.

Bowland, Bradley J., and John C. Beghin. 2001. "Robust Estimates of Value of Statistical Life for Developing Economies." *Journal of Policy Modeling* 23:385-96.

Buys, Piet, Uwe Deichmann, Craig Meisner, Thao Ton That, and David Wheeler. 2007. "Country Stakes in Climate Change Negotiations: Two Dimensions of Vulnerability." World Bank Policy Research Working Paper 4300, Washington, DC.

Corso, P., E. Finkelstein, T. Miller, I. Fiebelkorn, and E. Zaloshnja. 2006. "Incidence and Lifetime Costs of Injuries in the United States." *Injury Prevention* 12: 212-18.

Costa, Dora L., and Matthew E. Kahn. 2004. "Changes in the Value of Life, 1940-1980." *The Journal of Risk and Uncertainty* 29(2):159-80.

Center for Research on the Epidemiology of Disasters (CRED). 2007. "Annual Disaster Statistical Review: The Numbers and Trends 2007." Center for Research on the Epidemiology of Disasters, Brussels, Belgium.

Cropper, Maureen L., and Frances G. Sussman. 1990. "Valuing Future Risks to Life." *Journal of Environmental Economics and Management* 19:160-174.

Department for International Development (DIFD). 2005. "Natural Disaster and Disaster Risk Reduction Measures." Department for International Development, United Kingdom.

Federal Emergency Management Agency (FEMA). 1994. "Seismic Rehabilitation of Federal Buildings: A Benefit/Cost Model." Federal Emergency Management Agency, Washington, DC.

Ghesquiere, Francis, Luis Jamin, and Olivier Mahul. 2006. "Earthquake Vulnerability Reduction Program in Colombia: A Probabilistic Cost-benefit Analysis." World Bank Policy Research Working Paper 3939, Washington, DC.

Gold, Marthe R., Joanna E. Siegel, Louise B. Russell, and Milton C. Weinstein, eds. 1996. "Cost-Effectiveness in Health and Medicine." New York: Oxford University Press.

Hammitt, James K., Jin-Tan Liu, and Jin-Long Liu. 2000. "Survival is a Luxury Good: The Increasing Value of a Statistical Life." NBER Summer Institute Workshop on Public Policy and the Environment, Cambridge, Massachusetts, August 2000.

Hung, Hung-Chih, and Liang-Chun Chen. 2007. "The Application of Seismic Risk-Benefit Analysis to Land Use Planning in Taipei City." *Disasters* 31(3):256-76.

International Road Assessment Programme (IRAP). 2007. "The True Cost of Road Crashes: Valuing Life and the Cost of a Serious Injury." IRAP, Hampshire.

Jenkins, R.R., N. Owens, and L.B. Wiggins. 2001. "Valuing Reduced Risks to Children: The Case of Bicycle Safety Helmets." *Contemporary Economic Policy.* 19(4):397-408.

Jonkman, Sebastiann N. and Ilan Kleman. 2005. "An Analysis of the Causes and Circumstances of Flood Disaster Deaths." *Disasters* 29(1):75-97.

Kahn, Matthew E. 2005. "The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions." *The Review of Economics and Statistics* 87(2):271-84.

Kochi, Ikuho, Bryan Hubbell, and Randall Kramer. 2006. "An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis." *Environmental & Resource Economics* 34:385-406.

Liu, J-T., J.K. Hammitt, and J-L Liu. 1997. “Estimated Hedonic Wage Function and Value of Life in a Developing Country.” *Economic Letters* 57(3):353-58.

Liu, J.-T., J.K. Hammitt, J.-D. Wang, and J.-L. Liu. 2000. “Mother’s Willingness to Pay for Her Own and Her Child’s Health: A Contingent Valuation Study in Taiwan.” *Health Economics*. 9:319-326.

MacKenzie, Ellen J., Anne Damiano, Ted Miller, and Steve Luchter. 1996. “The Development of the Functional Capacity Index.” *The Journal of Trauma: Injury, Infection, and Critical Care* 41(5): 799-807.

Malilay, Josephine. 1997a. “Tropical Cyclones.” In *The Public Health Consequences of Disasters*, ed., Eric K. Noji. Oxford: Oxford University Press.

Malilay, Josephine. 1997b. “Floods.” In *The Public Health Consequences of Disasters*, ed., Eric K. Noji. Oxford: Oxford University Press.

Mechler, Reinhard. 2003. “Natural Disaster Risk and Cost-Benefit Analysis.” In *Building Safer Cities: The Future of Disaster Risk*, ed., A. Kreimer, M. Arnold and A. Carlin. Washington: World Bank 2003.

Miller, Ted R. 2000. “Variations between Countries in Values of Statistical Life.” *Journal of Transport Economics and Policy* 34(2):169-88.

Miller, Ted R., Nancy M. Pindus, John B. Douglass, and Shelli B. Rossman. 1995. “Databook on Nonfatal Injury: Incidence, Costs, and Consequences.” Urban Institute Press, Washington, DC.

Miller, Wilhelmine, Lisa A. Robinson, and Robert S. Lawrence, ed. 2006. “Valuing Health for Regulatory Cost-Effectiveness Analysis.” Institute of Medicine, The National Academy Press, Washington, DC.2006.

Mount, T., W. Weng, W. Schulze, and L. Chestnut. 2001. “Automobile Safety and the Value of Statistical Life for Children, Adults, and the Elderly: Results from New Data On Automobile Usage,” Paper presented at the Association of Environmental and Resource Economists 2001 Summer Workshop, “Assessing and Managing Environmental and Public Health Risks.” Bar Harbor, Maine, June 13-15, 2001.

Mrozek, Janusz R., and Laura O.Taylor. 2002. “What Determines the Value of Life? A Meta-Analysis.” *Journal of Policy Analysis and Management* 21(2):253-70.

National Earthquake Information Center. 2008. http://earthquake.usgs.gov/regional/neic/

Noji, Eric K. 1997. “Earthquakes.” In *The Public Health Consequences of Disasters*, ed., Eric K. Noji. Oxford: Oxford University Press 1997.

OECD. 2006. *Economic Valuation of Environmental Health Risks to Children*.

Provention Consortium, 2008. http://www.proventionconsortium.org/

Robinson, Lisa A. 2007. "Review of Current Approaches for Valuing Nonfatal Injury Risk Reductions and Their Applicability to Homeland Security Rules." Industrial Economics, Incorporated, Washington, DC.

Robinson, Lisa A. 2008. Personal communication.

Rose, Adam, Keith Porter, Nicole Dash, Jawhar Bouabid, Charles Huyck, John Whitehead, Douglass Shaw, Ronald Eguchi, Craig Taylor, Thomas McLane, L. Thomas Tobin, Philip T. Ganderton, David Godschalk, Anne, S. Kiremidjian, Kathleen Tierney, and Carol Taylor West. 2007. "Benefit-Cost Analysis of FEMA Hazard Mitigation Grants." *Natural Hazards Review* 8 (4): 97-111.

Rosen, Sherwin. 1988. "The Value of Changes in Life Expectancy." *Journal of Risk and Uncertainty* 1:285-304.

Segui-Gomez, Maria, and Ellen J. MacKenzie. 2003. "Measuring the Public Health Impact of Injuries." *Epidemiologic Reviews* 25: 3-19.

Shepard, D.S., and R.J. Zeckhauser. 1984. "Survival versus Consumption." *Management Science* 30: 423-39.

Smyth, Andrew W., M. Eeri, Gulay Altay, George Deodatis, Mustafa Erdik, Guillermo Franco, Polat Gulkan, Howard Kunreuther, Hilmi Lus, Esra Mete, Nano Seeber, and Ozal Yuzugullu. 2004. "Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey." *Earthquake Spectra* 20(1): 171-203.

Smyth, A. W., G. Deodatis, G. Franco, Y. He, and T, Gurvich. 2004. "Evaluating Earthquake Retrofitting Measures for Schools: A Demonstration Cost-Benefit Analysis." Columbia University, New York.

Spicer, Rebecca S., and Ted R. Miller. 2008. "Revised Final Report to the National Highway Traffic Safety Administration: Uncertainty Analysis of Quality Adjusted Life Years Lost and Supplement: Follow-up to the QALY Analysis ("Phase 2")." Pacific Institute for Research and Evaluation, Calverton, MD.

US Environmental Protection Agency. 2003. *Children's Health Valuation Handbook.* EPA-100-R-03-003.

Vassanadumrongdee, S., and S. Matsuoka. 2005. "Risk Perceptions and Value of a Statistical Life for Air Pollution and Traffic Accidents: Evidence from Bangkok, Thailand." *Journal of Risk and Uncertainty*. 30(3):261-87.

Viscusi, W. Kip. 1993. "The Value of Risks to Life and Health." *Journal of Economic Literature* 31(4):1912-46.

Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of Statistical Life: A Critical Review of Market Estimates Throughout the World." *Journal of Risk and Uncertainty* 27(1):5-76.

Wang, H., and J. Mullahy. 2006. "Willingness to Pay for Reducing Fatal Risk by Improving Air Quality: A Contingent Valuation Study in Chongqing, China." *Science of the Total Environment* 367:50-57.

Weiher, Rodney F., Thomas Teisberg and Richard M. Adams. 2003. "Valuing Weather Forecasts." Presentation, Moscow, November 2003.

World Bank. 2000. "Project Appraisal Document on a Proposed Credit in the amount of SDR 0.40 Million (US$0.47 Million Equivalent) to the Republic of Tajikistan for Lake Sarez Risk Mitigation Project." World Bank Report 20427-TJ, Washington, DC.

Yaari, M. 1965. "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer." *Review Economic Studies* 32:137-50.

Zaloshnja, Eduard, Ted Miller, Eduardo Romano, and Rebecca Spicer. 2004. "Crash Costs by Body Part Injured, Fracture Involvement, and Threat to Life Severity, United States, 2000." Pacific Institute for Research and Evaluation, Calverton, MD.

Zhai, Guofang, Teruki Fukuzono, and Saburo Ikeda. 2003. "An Empirical Model of Efficiency Analysis on Flood Prevention Investment in Japan." *Review of Urban and Regional Development Studies* 15(3): 238-254.

Appendix A. The Life Cycle Consumption Model with Uncertain Lifetime

This section uses the life-cycle model with uncertain lifetime to derive WTP for a change in the conditional probability of dying at any age (Cropper and Sussman, 1990; Cropper and Freeman, 1991) and to examine how this might vary with age and remaining life expectancy. The model assumes that at age *j* the individual chooses his future consumption stream to maximize expected lifetime utility,

$$V_j = \sum_{t=j}^{T} q_{j,t}(1+\delta)^{j-t} U_t(C_t) \qquad \text{(A1)}$$

where V_j is the present value of expected utility of lifetime consumption, $U_t(C_t)$ is utility of consumption at age *t*, $q_{j,t}$ is the probability that the individual survives to age *t*, given that he is alive at age *j*, and δ is the subjective rate of time preference. We assume that (A1) is maximized subject to a budget constraint that allows the individual to invest in annuities and to borrow via life-insured loans (Yaari, 1965). This is equivalent to assuming that the present value of expected consumption equals the present value of expected earnings plus initial wealth,

$$\sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} C_t = \sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} y_t + W_j\ , \qquad \text{(A2)}$$

where *r* is the riskless rate of interest, y_t is income at time *t* and W_j is initial wealth.

Now consider a program that alters D_k, the conditional probability of dying at age *k*, given that the individual survives to that age. Since $q_{j,t} = (1-D_j)(1-D_{j+1}) \ldots (1-D_{t-1})$, any program that alters D_k will necessarily alter the probability of surviving to all future ages. For small changes in D_k, willingness to pay may be written as the product of the rate at which the individual is willing to trade wealth W_j for a change in D_k, which we term $VSL_{j,k}$, times the size of the change in D_k,

$$WTP_{j,k} = -\frac{dV_j / dD_k}{dV_j / dW_j} dD_k \equiv VSL_{j,k} dD_k\ . \qquad \text{(A3)}$$

Applying the Envelope Theorem to the Lagrangian function formed by (A1) and (A2), the rate at which the individual substitutes current wealth for D_k may be written (Cropper and Sussman, 1990) as:

$$VSL_{j,k} = \frac{1}{1-D_k} \sum_{t=k+1}^{T} q_{j,t}\left[(1+\delta)^{j-t} U_t(C_t)\lambda_j^{-1} + (1+r)^{j-t}(y_t - C_t)\right]. \qquad \text{(A4)}$$

Equation (A4) says that the value of a change in the probability of dying at age *k* equals the loss in expected utility from age *k+1* onward, converted to dollars by dividing by the marginal utility of income (λ_j). Added to this is the effect of a change in D_k on the budget constraint. Cropper and Sussman (1990) show that, by substituting first-order conditions for utility maximization into (A4) and rearranging terms, the VSL at age *j* for a risk reduction at age *j* equals

$$VSL_{j,j} = \frac{1}{1-D_j}\sum_{t=j+1}^{T} q_{j,t}(1+r)^{j-t}\left[U_t(C_t)/U_t^{'}(C_t)+y_t-C_t\right]. \qquad \text{(A5)}$$

If the individual does not have access to fair annuities, but can save at the riskless rate *r* (i.e., he can never be a net borrower), then the expression in (5) holds without the last two terms inside the brackets.

It is $VSL_{j,j}$ that is estimated in compensating wage studies. Most stated preference studies measure (A3) (with $j=k$). The question is how (A5) changes with *j*. If $U_t(C) = U(C)$ for all *t*, and $r = \delta$, then C_t is constant for all *t*. In the case in which the individual can save at rate r (but never be a net borrower), the term in brackets is constant and $VSL_{j,j}$ becomes

$$VSL_{j,j} = \frac{1}{1-D_j}\sum_{t=j+1}^{T} q_{j,t}(1+r)^{j-t}\left[U(C)/U^{'}(C)\right]. \qquad \text{(A6)}$$

In this special case, if $(1-D_j)^{-1}$ is close to 1, $VSL_{j,j}$ is likely to decline with age, *j*. Since

$$\sum_{t=j+1}^{T} q_{j,t}(1+r)^{j-t}$$

represents discounted remaining life expectancy, $VSL_{j,j}$ is approximately proportional to discounted remaining life expectancy, which would justify the use of a constant VSLY. Equation (A6) is, however, a very special case.

In general, as equation (A5) demonstrates, one cannot make any statement regarding how $VSL_{j,j}$ varies with age *j*. This depends entirely on the pattern of consumption and utility of consumption over the lifecycle.

Appendix B. WHO Medical Costs by Country

	Cost per outpatient visit by hospital level (US$,PPP, 2000)		
Country	**Primary**	**Secondary**	**Tertiary**
Afghanistan	4.92	6.98	10.33
Albania	9.18	13.03	19.27
Algeria	9.62	13.64	20.18
Andorra	42.68	60.54	89.56
Angola	3.98	5.65	8.36
Antigua and Barbuda	24.89	35.30	52.22
Argentina	28.20	40.00	59.18
Armenia	6.62	9.39	13.88
Australia	54.72	77.61	114.81
Austria	53.62	76.06	112.51
Azerbaijan	5.90	8.36	12.37
Bahamas	31.69	44.95	66.49
Bahrain	30.07	42.66	63.10
Bangladesh	3.43	4.86	7.19
Barbados	31.07	44.07	65.20
Belarus	13.81	19.58	28.97
Belgium	54.91	77.88	115.21
Belize	13.10	18.58	27.48
Benin	2.38	3.37	4.99
Bhutan	2.06	2.93	4.33
Bolivia	6.51	9.24	13.66
Bosnia and Herzegovina	12.37	17.55	25.96
Botswana	15.33	21.74	32.16
Brazil	17.15	24.32	35.98
Brunei Darussalam	44.12	62.58	92.57
Bulgaria	10.33	14.66	21.68
Burkina Faso	2.51	3.56	5.26
Burundi	1.58	2.24	3.31
Cambodia	2.48	3.52	5.20
Cameroon	3.62	5.13	7.59
Canada	55.43	78.62	116.30
Cape Verde	8.73	12.39	18.33
Central African Republic	2.60	3.69	5.46
Chad	1.97	2.80	4.14
Chile	21.33	30.25	44.75
China	12.90	18.29	27.06
Colombia	11.19	15.87	23.47
Comoros	2.39	3.39	5.01
Congo	5.21	7.39	10.93
Cook Islands	21.44	30.42	44.99
Costa Rica	17.37	24.63	36.44
Cote d'Ivoire	4.78	6.78	10.03
Croatia	17.39	24.67	36.49
Cuba	11.95	16.94	25.06
Cyprus	36.17	51.30	75.89
Czech Republic	30.13	42.73	63.21
North Korea	2.81	3.99	5.90
Dem Rep Congo	1.26	1.79	2.65
Denmark	56.62	80.31	118.80
Djibouti	5.14	7.29	10.79
Dominica	13.15	18.65	27.58
Dominican Republic	10.32	14.64	21.66
Ecuador	3.58	5.07	7.50
Egypt	8.71	12.35	18.27
El Salvador	10.71	15.19	22.47
Equatorial Guinea	7.02	9.96	14.74
Eritrea	1.84	2.61	3.87
Estonia	20.33	28.83	42.65
Ethiopia	1.09	1.55	2.29
Fiji	12.67	17.97	26.58
Finland	50.96	72.28	106.92
France	50.15	71.14	105.24
Gabon	14.29	20.27	29.99
Gambia	3.06	4.34	6.43
Georgia	10.04	14.25	21.08
Germany	51.63	73.23	108.32
Ghana	3.39	4.80	7.10
Greece	34.86	49.44	73.14
Grenada	16.39	23.25	34.39
Guatemala	10.00	14.18	20.97

Country	Cost per bed day by hospital level (US$,PPP, 2000)		
	Primary	Secondary	Tertiary
Afghanistan	17.718	23.115	31.573
Albania	30.174	39.365	53.769
Algeria	31.393	40.956	55.940
Andorra	112.072	146.210	199.705
Angola	14.783	19.286	26.342
Antigua and Barbuda	70.701	92.237	125.984
Argentina	78.671	102.635	140.187
Armenia	22.807	29.754	40.641
Australia	138.557	180.763	246.900
Austria	136.185	177.668	242.674
Azerbaijan	20.671	26.968	36.835
Bahamas	86.899	113.369	154.849
Bahrain	83.104	108.418	148.086
Bangladesh	13.007	16.969	23.178
Barbados	85.459	111.491	152.283
Belarus	42.745	55.766	76.169
Belgium	138.973	181.305	247.642
Belize	40.859	53.305	72.809
Benin	9.515	12.413	16.955
Bhutan	8.430	10.998	15.022
Bolivia	22.496	29.349	40.087
Bosnia and Herzegovina	38.916	50.770	69.346
Botswana	46.737	60.973	83.282
Brazil	51.435	67.102	91.654
Brunei Darussalam	115.289	150.407	205.438
Bulgaria	33.375	43.542	59.473
Burkina Faso	9.959	12.992	17.746
Burundi	6.708	8.751	11.953
Cambodia	9.867	12.872	17.582
Cameroon	13.617	17.765	24.265
Canada	140.092	182.765	249.635
Cape Verde	28.911	37.717	51.517
Central African Republic	10.273	13.403	18.307
Chad	8.109	10.579	14.450
Chile	61.972	80.850	110.431
China	30.041	39.191	53.531
Colombia	35.713	46.591	63.638
Comoros	9.557	12.468	17.030
Congo	18.593	24.257	33.132
Cook Islands	62.256	81.219	110.935
Costa Rica	51.995	67.832	92.651
Cote d'Ivoire	17.275	22.537	30.783
Croatia	52.056	67.913	92.761
Cuba	37.772	49.278	67.308
Cyprus	97.296	126.933	173.375
Czech Republic	83.228	108.580	148.308
North Korea	10.986	14.333	19.577
Dem Rep Congo	5.544	7.232	9.878
Denmark	142.656	186.110	254.205
Djibouti	18.389	23.991	32.769
Dominica	40.989	53.475	73.041
Dominican Republic	33.345	43.502	59.418
Ecuador	27.129	35.393	48.342
Egypt	28.831	37.613	51.375
El Salvador	34.402	44.881	61.302
Equatorial Guinea	24.003	31.314	42.772
Eritrea	7.652	9.983	13.636
Estonia	59.477	77.594	105.984
Ethiopia	4.894	6.385	8.722
Fiji	39.716	51.813	70.771
Finland	130.387	170.104	232.342
France	128.628	167.809	229.207
Gabon	44.026	57.437	78.452
Gambia	11.810	15.410	21.050
Georgia	32.576	42.499	58.048
Germany	131.842	172.002	234.934
Ghana	12.869	16.789	22.932
Greece	94.274	122.990	167.990
Grenada	49.492	64.567	88.191
Guatemala	32.439	42.320	57.804

Country	Cost per 20-minute visit at health centre by population coverage (US$,PPP, 2000)		
	50%	80%	95%
Afghanistan	6.92	6.92	7.52
Albania	6.80	6.80	7.39
Algeria	6.90	6.90	7.51
Andorra	26.62	26.62	28.94
Angola	6.44	6.44	7.00
Antigua and Barbuda	22.23	22.23	24.17
Argentina	32.05	32.05	34.84
Armenia	6.09	6.09	6.62
Australia	28.93	28.93	31.45
Austria	28.73	28.73	31.24
Azerbaijan	7.35	7.35	7.99
Bahamas	24.10	24.10	26.20
Bahrain	23.68	23.68	25.74
Bangladesh	6.13	6.13	6.66
Barbados	23.94	23.94	26.03
Belarus	7.79	7.79	8.47
Belgium	28.96	28.96	31.49
Belize	24.80	24.80	26.96
Benin	5.42	5.42	5.89
Bhutan	5.17	5.17	5.62
Bolivia	6.06	6.06	6.59
Bosnia and Herzegovina	7.51	7.51	8.16
Botswana	26.14	26.14	28.41
Brazil	8.38	8.38	9.11
Brunei Darussalam	26.92	26.92	29.26
Bulgaria	7.07	7.07	7.69
Burkina Faso	5.52	5.52	6.00
Burundi	4.73	4.73	5.14
Cambodia	5.50	5.50	5.98
Cameroon	6.24	6.24	6.78
Canada	29.05	29.05	31.58
Cape Verde	6.69	6.69	7.27
Central African Republic	5.59	5.59	6.07
Chad	5.09	5.09	5.54
Chile	29.19	29.19	31.73
China	6.79	6.79	7.38
Colombia	7.26	7.26	7.89
Comoros	5.43	5.43	5.90
Congo	7.05	7.05	7.66
Cook Islands	9.03	9.03	9.81
Costa Rica	27.25	27.25	29.62
Cote d'Ivoire	6.85	6.85	7.44
Croatia	27.26	27.26	29.64
Cuba	7.42	7.42	8.07
Cyprus	25.19	25.19	27.38
Czech Republic	32.76	32.76	35.62
North Korea	5.74	5.74	6.24
Dem Rep Congo	4.39	4.39	4.77
Denmark	29.26	29.26	31.81
Djibouti	5.60	5.60	6.09
Dominica	24.83	24.83	26.99
Dominican Republic	7.07	7.07	7.69
Ecuador	6.52	6.52	7.09
Egypt	6.68	6.68	7.26
El Salvador	7.16	7.16	7.78
Equatorial Guinea	7.79	7.79	8.47
Eritrea	4.98	4.98	5.41
Estonia	28.72	28.72	31.23
Ethiopia	4.18	4.18	4.54
Fiji	7.57	7.57	8.23
Finland	28.25	28.25	30.71
France	28.10	28.10	30.55
Gabon	25.53	25.53	27.76
Gambia	5.90	5.90	6.41
Georgia	8.78	8.78	9.54
Germany	28.37	28.37	30.84
Ghana	6.10	6.10	6.63
Greece	24.88	24.88	27.05
Grenada	26.73	26.73	29.06
Guatemala	6.99	6.99	7.60

Appendix C. Number of levels by dimension for selected instruments that value health states

Domain	EQ-5D	FCI	HUI-1	HUI-2	HUI-3	III	QWB	AQoL	15D	HRQoL	SF-36[#]	SF-12	SF-6D	DALY[$]
Mobility	3	6	6	5	5	5	4	4	5		13	3	4	
Cognitive		6	2	4	6	5	2		5					
Self Care	3		2	3		5	2	8	5	31**	3	2	2	6
Hand/Arm		6			4						3			
Bend/Lift		4									5	3		
Sensory			4	4		5								
Seeing		7			5		2	4	5					
Hearing		5			5			4	5					
Speech		4	2		5	2			5					
Fertility				3										6
Sexual		3							5					
Eating		3				2			5					6
Excretory		4			2				5					
Pain	3		2	5	5	5	6	4	5		12	5	6	
Emotional	3		4	5	5		2	4	10	31**	22	16	5	
Work/Social/Role Functions	3		5			*	11	16			18	7	9	6
Cosmetic			2			5	3							
Other Symptoms							7	4	10					
Perceived Health							5		5	31**	14	5		
Energy/Vitality									5		24	6	5	

Source : Spicer and Miller (2008)

EQ-5D = EuroQol Scale, FCI = Functional Capacity Index, HUI = Health Utility Index, III = Injury Impairment Index, FCI = Functional Capacity Index, QWB = Quality of Well-Being Scale, SF-36 = Short Form 36 health survey, AQoL = Assessment of Quality of Life, HRQoL = Health Related Quality of Life measure, SF-12 = Short Form 6 health survey, SF-6D = Short Form 6 health survey, DALY = Disability-Adjusted Life Years; See text below for references.

* = continuous variable, based on vocational assessment of percentage work-related disability.
** = continuous variable, range 0-30 days
# = Validated abbreviated versions exist (e.g.SF-12, SF-6D)
$ = Uses only six “disability classes”, each covers a broad range of domains

Appendix D. Age-specific disability weights for untreated and treated forms of sequelae included in the Global Burden of Disease Study

	Untreated form Age group (years)					Treated form Age group (years)				
Sequela	0-4	5-14	15-44	45-59	60+	0-4	5-14	15-44	45-59	60+
Fractures										
Skull -- Short term	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431
Skull -- Long term	0.411	0.411	0.411	0.410	0.395	0.350	0.350	0.350	0.350	0.404
Face bones	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223
Vertebral column	0.266	0.266	0.266	0.266	0.266	0.266	0.266	0.266	0.266	0.266
Injured spinal cord	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725	0.725
Fractures										
Rib or sternum	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199
Pelvis	0.247	0.247	0.247	0.247	0.247	0.247	0.247	0.247	0.247	0.247
Clavicle, scapula, or humerus	0.153	0.153	0.137	0.137	0.137	0.153	0.153	0.137	0.137	0.137
Radius or ulna	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
Hand bones	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Femur – Short term	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372
Femur – Long term	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272
Patella, tibia, or fibula	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271	0.271
Ankle	0.196	0.196	0.196	0.196	0.196	0.196	0.196	0.196	0.196	0.196
Foot bones	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
Dislocated shoulder, elbow, or hip	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
Sprains	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
Intracranial injury										
Short term	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359
Long term	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359	0.359
Internal injuries	0.000	0.000	0.000	0.000	0.000	0.208	0.208	0.208	0.208	0.208
Open wound	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Injury to eyes	0.354	0.354	0.354	0.354	0.354	0.301	0.300	0.299	0.299	0.299
Amputations										
Thumb	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
Finger	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Arm	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Toe	0.078	0.078	0.078	0.078	0.078	0.064	0.064	0.064	0.064	0.064
Foot	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Leg	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Crushing	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218
Burns										
<20% -- Short term	0.186	0.186	0.186	0.186	0.186	0.158	0.158	0.158	0.158	0.158
<20% -- Long term	0.041	0.041	0.041	0.041	0.041	0.011	0.011	0.011	0.011	0.011
>20% and <60% – Short term	0.469	0.469	0.469	0.469	0.469	0.441	0.441	0.441	0.441	0.441
>20% and <60% – Long term	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255
>60% -- Short term	0.469	0.469	0.469	0.469	0.469	0.441	0.441	0.441	0.441	0.441
>60% -- Long term	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255	0.255
Injured nerves	0.078	0.078	0.078	0.078	0.078	0.064	0.064	0.064	0.064	0.064

Source: www.who.int/entity/healthinfo/bodreferencedisabilityweights.xls