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Valuing the Risk of Death and Injury from Landmines in Thailand

Sandra Barns
Department of Economics, University of Waikato
e-mail: sab@waikato.ac.nz

Michael Cameron
Department of Economics, University of Waikato
e-mail: mpc1@waikato.ac.nz

John Gibson
Department of Economics, University of Waikato
e-mail: jkgibson@waikato.ac.nz

Steven Lim
Department of Economics, University of Waikato
e-mail: slim@waikato.ac.nz

Dan Marsh
Department of Economics, University of Waikato
e-mail: dmarsh@waikato.ac.nz

Frank Scrimgeour
Department of Economics, University of Waikato
e-mail: scrim@waikato.ac.nz

John Tressler
Department of Economics, University of Waikato
e-mail: tressler@waikato.ac.nz

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Sandra Barns
Department of Economics
University of Waikato
sab@waikato.ac.nz

Michael Cameron
Department of Economics
University of Waikato
mpc1@waikato.ac.nz

John Gibson
Department of Economics
University of Waikato
jkgibson@waikato.ac.nz

Steven Lim
Department of Economics
University of Waikato
slim@waikato.ac.nz

Dan Marsh
Department of Economics
University of Waikato
dmarsh@waikato.ac.nz

Frank Scrimgeour
Department of Economics
University of Waikato
scrim@waikato.ac.nz

John Tressler
Department of Economics
University of Waikato
tressler@waikato.ac.nz

Abstract

This paper presents estimates of the benefits of clearing landmines in rural Thailand using the contingent-valuation (CV) method. The data came from a survey where we asked 341 respondents referendum-type questions that elicit their willingness to pay for landmine clearance. Our estimates imply a value of a statistical life of between US$0.2-0.3 million. The survey also provides estimates of the injury risk-death risk tradeoff and the implicit value of statistical injury. These estimates suggest that the value of lives and injuries saved from mine clearing is likely to be at least an order of magnitude greater than those used in existing studies of mine clearing. Linking a household expenditure survey involving the same sample enables the relationship between the value of statistical life and the characteristics of the households to be considered. The implications of these estimates for cost benefit studies are illustrated using the study by Harris (2000) of mine clearance in Cambodia. It is shown that the value of lives and injuries saved is likely to dominate benefit assessments when VSL estimates are used.

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1. Introduction

Landmines and unexploded ordnance (UXO) are an important source of risk in rural areas of many countries. Every year they kill or injure almost 15,000 civilians in over 70 countries (ICBL, 2002: 40). They undermine the economy and food security of poor countries by making millions of hectares unavailable for growing food and herding livestock (Andersson *et al*. 1995). The feared presence of landmines stops refugees from returning to their homes, causing an on-going burden to host communities and aid agencies. Within mine-affected communities, the dangers are faced especially by the poorest people, who have to roam widely in search of water, fuel and forest foods, increasing the danger of entering unmarked minefields (Roberts and Williams, 1995). Landmines are particularly deadly for children, who have a higher fatality rate from stepping on mines because, being smaller, their vital organs are closer to the blast (Mathieson, 1997).

The world has responded to the risks posed by landmines and UXO by spending over US$1.5 billion on mine clearance since 1992. The overall trend is for spending to rise, with US$250 million spent on mine clearance in 2001. Yet most cost-benefit evaluations of landmine clearance suggest that it is socially inefficient. Harris (2000) estimates that expenditure to remove landmines from Cambodia would produce benefits – in the form of saved lives, reduced injuries and medical costs, and greater agricultural output – that are worth just two percent of the costs. In Mozambique, the benefits would be worth only ten percent of the costs (Elliot and Harris, 2001). For Bosnia and Herzegovina Paterson (2003) concludes that demining cannot be justified on development grounds.

Existing cost-benefit analyses of landmine clearance (Harris, 2000, 2002; Elliot and Harris, 2001; Patterson, 2003) have been constrained by inadequate data, which may have influenced the conclusions. These studies value injuries and premature death from landmines according to the present value of lost earnings (or lost GDP). This foregone earnings approach is no longer popular in developed countries because it ignores risk aversion and greatly underestimates the value of life (Rosen, 1988). Instead, researchers and policymakers now use estimates of the *Value of Statistical Life* (*VSL*), calculated from reports by survey respondents of how much they would be willing to pay to avoid risks or from market based, revealed preference studies. The theoretical superiority of broader measures of the value of life is recognised by Harris (2000), but because no estimates exist for countries with landmine problems the out-dated foregone earnings method was used. Perhaps as a result, saved lives and disabilities are a small part of the calculated benefit of landmine clearance, whereas the value of statistical life is easily the largest benefit of environmental, health and safety rules in the U.S. (Shogren and Stamland, 2002).

While economists may have been underestimating the value of lives saved from landmine clearance, mine clearance agencies may have been overestimating these values, causing them to spend excessive amounts on risk reduction. Most landmines are located in poor countries, but most landmine clearance is paid for by rich country donors and NGOs. Elliot and Harris (2001) suggest that donors may value the lives saved by clearing mines using standards from their own (rich) countries. This also may explain why the standards are so stringent, because the goal of accredited mine clearance agencies is to remove <u>all</u> mines (and unexploded bombs) in an area (UNMAS, 2003). This standard requires expensive manual inspection of almost every inch of ground because existing machines cannot find every single mine. In contrast, the socially efficient standard is to reduce the risk from landmines only to the point where the marginal cost per life saved is the same as for other risk reducing activities (Viscusi, 2000). Hence, in poorer countries, where people face many health risks, less stringent mine clearance standards might allow spending to be diverted to other priorities.

Without reliable estimates of the statistical value of life, any assessment of the benefits of mine clearance is uncertain. This makes it difficult to judge the social desirability of demining particular areas, and the efficient degree of clearance. More generally, mine clearing is one of many development projects or policy interventions, all of which will have different risk reduction and income generation characteristics. Thus, estimates of the relevant risk-income tradeoffs are necessary to judge the desirability of mine clearance relative to the other policy alternatives available.

The present paper represents a first attempt to estimate the value of statistical life and injury using the contingent-valuation (CV) method. We focus on the willingness of the rural population in Northeast Thailand to pay for the reduction in risk that would result from landmine clearance. Currently, landmine and UXO incidents cause about 40 deaths and 130 injuries per year in Thailand. Mines and UXO are present in 530 communities, containing just over 500,000 people. The incidence rate of landmine fatalities and injuries is 34 per 100,000 in the affected communities and 0.28 per 100,000 when calculated for the whole country.[1] Landmines are likely to pose a continuing risk for many years because in the three years since mine action units were established, the Thai army has cleared less than one percent of the 2,560 square kilometres of mine-contaminated land.

In addition to contributing to the literature that attempts to analyse the costs and benefits of landmine clearance, our study is also relevant to the broader literature on the value of risk reduction. A key requirement for any rational risk policy is some knowledge of the value to place on lives that are saved by interventions that aim to reduce risk. In contrast to the developed countries, almost nothing is known about the value of statistical life in developing countries. A recent survey of 70 estimates of VSL finds only four that come from countries that might once have been considered as developing (Taiwan and South Korea) and none from currently developing countries (Miller, 2000).

In order to illustrate the implications of the VSL measures obtained for cost-benefit studies of mine clearance, we reconsider the study by Harris (2000) of mine clearance in Cambodia. Harris estimated that a US$3,500m investment to clear 500,000 ha of arable land would have a net present value of –US$3,434m, with the value lives and injuries saved only 8.7% of the present value of benefits. While the use of plausible VSL measures that would follow from our study does not make the present value positive, the present value of benefits is shown to be a much larger proportion of costs. We also show that the value of lives and injuries saved is likely to dominate benefit assessments when VSL measures are used.

The outline of this paper is as follows. Section 2 briefly reviews existing estimates of value of lives saved and injuries reduced in studies of the benefits of mine clearance. The methodology used in the survey to determine risk-money tradeoffs and injury risk-death risk tradeoffs is described in Section 3. The results of the survey are outlined in Section 4 and determinants of

[1] *Landmine Impact Survey: Kingdom of Thailand* (2003) Survey Action Center and Norwegian People's Aid. Available online at www.sac-na.org.

the VSL estimates investigated. In Section 5 the results of the survey are compared with VSL estimates in the literature and possible biases are considered. A cost-benefit study by Harris (2000) is reconsidered using our VSL estimates in Section 6. Section 7 concludes the paper.

2. Previous Valuations of the Life Saving Benefits of Landmine Clearance

Table 1 summarises the ways in which lives saved as the result of landmine clearance have been valued in existing studies. All of these studies have treated the benefit resulting from the saving of lives as the present value of lifetime income foregone. However, it has long been recognised that income forgone or net income forgone, obtained by deducting some allowance for consumption, are inadequate as a basis for assessing the value of statistical lives saved. These measures fail to place value on life itself, the trauma of death, or the psychological affect of living in fear of premature death resulting from a particular risk.[2] Perhaps because of this, the value of lives saved is only a small proportion of the estimated benefits in existing studies of mine clearance.

There is now a substantial body of literature that addresses the value of risk to life and health. Contingent valuation or revealed preference methods have been used to estimate the VSL in a large number of countries and for a wide variety of risk.[3] Miller (2000) uses 68 studies, 38 outside the U.S., in his study of the relationship between the VSL and income. This study clearly shows that the values of statistical life obtained using contingent valuation or revealed preference methods are not close to estimates based on the present value of lifetime income foregone. For the world as a whole suggested VSL estimates are between 137 and 195 times GDP per capita, or approximately 14 to 20 times the present value of lifetime GDP per capita for a 40 year working life and 10% discount rate. The ratio of VSL measures to GDP per capita is likely to be higher for developing economies.

Table 1: Value of Lives Saved in Previous Economic Evaluations of Landmine Clearance

Author (year)	Country	Valuation concept	Annual value [Lifetime PV][a]	Notes
Harris (2000)	Cambodia	GDP per capita	$134 [$1310]	NPV of -$3,434m on investment of $3,500m
Elliot and Harris (2001)	Mozambique	GNP per capita	$140 [$1370]	NPV of -$28m on $31.4m investment
Harris (2002)	Afghanistan	Average wage rate	$550 [$5,400]	NPV of $1,265m on investment of $100m
Patterson (2003)	Bosnia-Herzegovina	Annual labour income	$2,065 [$20,200]	n.a.

[2] For an excellent survey of early studies of the valuation of life and a critique of these studies see Jones-Lee (1976). Harris (2000), Harris (2002) and Eliot and Harris (2001) do not value the psychological costs associated with the risk of death.
[3] For a now dated, but useful review see Viscusi (1993). For a recent critical review of market based estimates see Viscusi and Aldy (2003).

Notes: All present values are calculated at 10% discount rate.
[a] Based on a 40 year working life.

3. The Survey

3.1 Outline of the Approach

A contingent valuation survey was carried out by the authors in Khon Kaen province in September 2003, with the assistance of local interviewers. While mine-affected communities are in 27 of Thailand's 76 provinces, we deliberately chose a province that does not contain minefields but is adjacent to mine-affected areas (Figure 1). Thailand is unusual amongst mine-affected countries because most of the costs of mine clearance are supported by the national budget rather than by foreign donors and NGOs. Therefore, the valuation that Thai taxpayers place on the lives and injuries saved by mine clearance should be relevant to the decisions about the social attractiveness of mine clearance versus the other risk reduction activities of the Thai government. In future extensions of this research, we plan to repeat the CV survey in mine affected communities along the Thai-Cambodia border and in Cambodia to see how the VSL estimates differ.

The general methodology chosen for the survey was based on that used by Viscusi *et al* (1991) in studying chronic bronchitis and auto fatality risk in the U.S. Perreira and Sloan (2002) have also used this approach in considering disability and death risks in the U.S. The survey design and its application were adapted to enable this approach to be applied in low income rural communities, and to address the issues of concern in this study.

The core of the survey used two series of questions to determine tradeoffs between alternatives. The first of these related to the tradeoff between decreases (increases) in the risk of death resulting from landmine accidents and income, i.e. a "risk-money" tradeoff. A further set of questions was used to determine the tradeoff between the risk of injury from a landmine accident and the risk of death, a "risk-risk" tradeoff. Viscusi *et al* (1991) also considered chronic bronchitis risk-dollar tradeoffs. We did not consider injury risk-money tradeoffs, although these tradeoffs can be determined indirectly from the results of the survey.

The risk-money and risk-risk tradeoffs were determined by asking respondents to state their preferences for two different areas in which their village might be located. For the risk-money tradeoffs the areas differed by the risk of death and cash income. For the risk-risk tradeoffs the areas differed by the risk of injury and the risk of death. Thus, in determining risk-money tradeoffs the respondents were not directly asked about their willingness to pay for a reduction in risk, or the amount required to accept an increase in risk. This approach makes it possible to avoid issues associated with who will or should pay, how payments will be made, and exactly what the payments are for. These types of issues would be important for the communities involved in this survey. The statement of alternatives also makes clear the precise nature of the change in risk to be considered.[4]

[4] In communities without significant experience with landmine problems risk comparisons are less likely to be influenced by actual perceptions of landmine accident risk.

Although the survey did not directly ask respondents for their willingness to pay to reduce risk or willingness to accept risk, the way in which the alternatives were presented could be interpreted in these terms. Viscusi *et al* (1991) note the possibility that the way in which the alternatives are presented may affect results, since risk increases may be valued differently from risk decreases. In low income rural communities these differences could be particularly pronounced. To provide a test of the sensitivity of results to the way in which the alternatives are presented two questionnaires were used in this study, one that could be interpreted in "willingness to pay" terms and one with a "willingness to accept" focus.

The results of the survey enable us to address the following questions for rural Thailand:

1. What is the distribution of landmine death risk-money tradeoffs?
2. What is the distribution of landmine injury risk-death risk tradeoffs?
3. What is the implicit distribution of landmine injury risk-money tradeoffs?
4. How does the distribution of landmine death risk-money tradeoffs differ when alternatives are presented in a "willingness to pay" form compared with a "willingness to accept" form?
5. What demographic and economic variables influence the value of statistical life?

3.2 Methodology

There is now a substantial body of literature that notes the sensitivity of VSL estimates based on CV methods to the nature of the risks considered, the way in which risks are presented, the size of the risk change and many other factors.[5] In low income rural communities these factors are likely to be even more significant. Particular concerns with survey approaches to health risk are limitations on the ability of individuals to understand the evaluation tasks that they are presented with, and to interpret the risk information that is presented (Viscusi, 1993). In this study risks were not presented in terms of annual probabilities of death or injury, but in terms of the frequency of occurrence of an event, e.g. a change in the risk of death from 4 per year in a population of 10,000 to 2 per year. In an attempt to further simplify the statement of risk, respondents were asked to consider 10 villages each with a 1,000 inhabitants and a particular number of deaths or injuries across the villages each year.[6] Showcards were also used to explain and compare risks.[7]

Viscusi *et al* (1991) and Perreira and Sloan (2002) use cost of living differences to represent the money component of risk-money tradeoffs. In low income rural communities subsistence agriculture provides a substantial proportion of income, and there is no housing market for ownership or rental that is similar to markets in high income economies. Thus, the cost of living concept is both difficult to explain and hard for the respondents to interpret. In this survey cash

[5] See for example Beattie *et al* (1998) who show that significant anomalies may remain even when respondents are given the opportunity to discuss issues relating to the survey and have the ability to revise initial responses.
[6] This would be a reasonable village size in mine affected communities in Thailand, although the most common village size would be smaller than this, see SAC (2003).
[7] An example of a show card used is provided in Figure 2.

income and the change in cash income between areas was used to represent the money component of risk-money tradeoffs.[8]

To check comprehension the respondents were initially asked for their preference between alternatives in which one area was dominant, since it had a higher cash income level and lower probability of death, or lower probabilities of both death and injury in risk-risk comparisons. If a respondent failed to select the dominant area the nature of the risk and the selection task was explained again. The interview was terminated if the respondent failed on a second attempt.

Landmine accidents cause a variety of injuries of different severity, including loss of legs, feet, arms, hands and sight. In Thailand amputations have resulted from over 50% of mine accidents (SAC, 2003). The loss of a leg, either above or below the knee, is the most common serious injury sustained. In this survey the respondents were asked to treat all injuries as involving a loss of a leg below the knee. They were shown a picture of a mine accident victim whose leg had been amputated below the knee. Clearly, different injuries would generally be associated with different tradeoffs.

Respondents were initially asked a set of questions designed to determine their experience of landmines, including their awareness of landmine affected areas, their travel time distance from these areas, and knowledge and association with those injured or killed by landmines. Familiarity with landmines and landmine accidents is likely to influence preferences, and thus the VSL estimates and risk-risk tradeoffs. To help respondents think about their current income levels respondents were asked about their family's cash expenses during the last month and the crops they produced for consumption.[9]

Studies in the U.S. such as Viscusi *et al* (1991) and Perreira and Sloan (2002) have been able to use multimedia tools to explain the risks and tasks involved, and interactive computer programmes in administering questionnaires. This study was based on personal interviews. Interviewer teams were recruited from local villages and were trained to explain the nature of risks involved and the tasks required of the respondents.

3.3 Risk-Money Tradeoffs

The first set of questions in the core of the survey was designed to determine for each respondent the value of income that would make Area A and Area B indifferent given a specified difference in the risk of death from a landmine accident. This then enables the VSL to be calculated. Following Viscusi *et al* (1991), assume that risk preferences can be represented by the utility function $U(H,Y)$ if the individual is healthy or $U(D,Y)$ if death occurs from a land mine accident, where Y is total income. Let I_a and I_b be the cash income levels in areas A and B and W be the common value of income from other sources (in our case this would include income from

[8] Since respondents were asked to state preferences for alternatives that involved cash incomes that were generally different from their own, this approach changes the interpretation of any analysis of the relationship between income or expenditure and estimates of VSL.

[9] This survey was undertaken in conjunction with a detailed survey of household expenditure. As further results of this survey become available it will be possible to analyse the relationship between expenditure variables and the VSL estimates obtained in this survey.

subsistence scources). The probabilities of death in areas A and B are X_a and X_b respectively. Indifference between the two areas implies that

$$X_a U(D,W+I_a)+(1-X_a)U(H,W+I_a)=X_b U(D,W+I_b)+(1-X_b)U(H,W+I_b). \qquad (1)$$

As in Viscusi *et al* (1991), if the utility function is additively separable in health status and income, and the marginal utility of income is constant and equal to one for the range of income changes considered, then

$$u(D)=u(H)-L, \qquad (2)$$

where

$$L=\frac{I_a-I_b}{X_a-X_b}, \qquad (3)$$

and $u(.)$ is the utility function for health status.[10] For example, if I_a=B20,000, I_b=B18,400, X_a=0.0004 and X_b=0.0002, then L=B8,000,000 or $u(H)=u(D)$+B8,000,000.[11]

In order to determine the income difference that would make Area A indifferent to Area B for a given change in the risk of death a respondent was presented with an initial alternative that was then adjusted given the area that was preferred.[12] For example, in Questionnaire One the initial alternatives were:[13]

Area A	**Area B**
Cash Income of B20,000 per year Risk of Death per year of 4/10,000	Cash Income of B18,400 per year Risk of Death per year of 2/10,000

If Area B was selected as the preferred area, the cash income in Area B was revised down by B400 and the respondent was asked to reconsider the alternatives. This process was continued through a series of up to four iterations until preference switched to Area A or the income in Area A reached B16,800. Any switch in preference provides a range within which the income level that would make the areas indifferent should lie. The respondent was then asked what level

[10] In Viscusi *et al* (1991) I_a-I_b=Z, the difference in the cost of living between Area A and Area B.
[11] This would correspond to a VSL of US$197,016 using the average exchange rate over the period during which the survey was undertaken of US$0.024627 per Baht.
[12] Respondents were asked to assume that all other aspects of the areas considered were similar except for the cash income levels they would earn and the risk of death, and that these other aspects of the areas were similar to the present location in which they lived.
[13] Ideally the initial alternatives would be selected after pretesting to ensure that each area would be chosen by approximately half the respondents. This would reduce the likelihood of starting point bias and minimise the number of iterations required to establish indifference. For this survey pretesting in Thailand was not possible. Nonetheless, all the areas presented in both sections of the two questionnaires were selected by at least 19% of the participants. The probabilities were chosen to present an easy to interpret, small change in risk, while avoiding zero risk alternatives. The Landmine Impact Survey for Thailand, SAC(2003), proposes an estimate of 34.35 mine incident victims for 100,000 people per year. These mine incidents include injuries. In highly impacted communities the probability of mine accidents would be much higher.

of income in Area B would make the areas equally desirable. If this value was inconsistent with the range of incomes implied by the preference switch, then this survey response was disregarded. This process provided an additional consistency check. [14] If Area A was selected given the initial alternatives, the cash income in Area B was revised upward by B400 through a series of up to four iterations until Area B was selected or the level of income had reached B20,000. Again, the respondent was asked for the value of income in Area B that would make the areas equally desirable. Questionnaire One is said to have a "willingness to pay" format since the income that was revised was that in Area B which had a lower risk of death, although clearly the respondent could have chosen increased risk and higher income by selecting Area A on any iteration.

Questionnaire Two followed a similar procedure to establish indifference. For this questionnaire the initial alternatives were:

Area A	**Area B**
Cash Income of B20,000 per year Risk of Death per year of 2/10,000	Cash Income of B21,600 per year Risk of Death per year of 4/10,000

Since the income in Area B was adjusted to achieve indifference this questionnaire is said to have a "willingness to accept" format given the higher risk of death in alternative B. The two questionnaires were allocated randomly to respondents.

3.3 Risk-Risk Tradeoffs

The second set of questions was designed to determine the willingness of respondents to tradeoff the risk of injury from a landmine accident for increases in the risk of death from a landmine accident, or for a given population the tradeoff between injury and death. Given two alternative areas A and B, the questions sought to find the risk combination that would make Area A indifferent to Area B, assuming that all other aspects of the areas are identical. Following Viscusi *et al* (1991), consider a state-dependent utility model where $u(D)$ is the utility associated with death from a landmine accident, $u(J)$ the utility of living with an injury, and $u(H)$ the utility associated with full health.[15] Let X_a and Y_a be the annual probabilities of death and injury in Area A and X_b and Y_b be the corresponding probabilities in Area B. Given indifference between Area A and Area B

$$Y_a u(J) + X_a u(D) + (1 - Y_a - X_a)u(H) = Y_b u(J) + X_b u(D) + (1 - Y_b - X_b)u(H). \quad (4)$$

It follows that

$$u(D) = tu(J) + (1 - t)u(H) = u(H) - t(u(H) - u(J)), \quad (5)$$

[14] Less than 10% of responses were disregarded in each of the questionnaires as a result of this consistency check and the corresponding consistency check for the risk-risk tradeoff.
[15] These utilities can be treated as those derived from the two variable utility function used above under the assumption of additive separability. For risk-risk comparison the values of total income in the two areas are identical.

where

$$t = \frac{Y_a - Y_b}{X_b - X_a}. \tag{6}$$

The tradeoff between injury and death is defined as t. For example, if for Area A $Y_a = 0.002$ and $X_a = 0.0002$ while for Area B Y_b=0.0012 and X_b=0.0004, then indifference between the areas would imply an injury-death tradeoff of 4.0.[16]

The procedure used to determine the risk-risk alternatives that made Area A and Area B indifferent for the respondent was based on the same procedure as used for risk-money choices. For this set of questions Questionnaires One and Two were identical. The initial alternatives used were:

Area A	**Area B**
Risk of Injury per year of 20/10,000	Risk of Injury per year of 12/10,000
Risk of Death per year of 2/10,000	Risk of Death per year of 4/10,000

If Area A was chosen the number of injuries per 10,000 in Area B was revised down until preference switched or there were zero injuries.[17] The respondent was then asked what number of injuries per 10,000 would make the areas indifferent. As above, this provided a consistency check. If Area B was chosen the number of injuries per 10,000 in Area B was revised up in a similar way until preference switched or the number of injuries reached 20.

3.4 Implicit Value of Statistical Injury

The estimates obtained for the value of statistical life, L, and the injury risk-death risk tradeoff enable the implicit value of a statistical injury to be calculated. From (2) and (5) it follows that

$$u(H) - L = tu(J) + (1-t)u(H), \text{ or}$$

$$u(H) - u(J) = \frac{L}{t}. \tag{6}$$

3.5 Application of the Survey and Sample Characteristics

Three teams of interviewers were recruited locally and trained in data collection methods and interview technique.[18] Recruitment of local interviewers ensured that interpretations and language used for the survey were consistent with those in use in the survey area. This survey was conducted concurrently with a larger household survey conducted in two districts (Ban Phai and Phon) in southern Khon Kaen province from June to October 2003.

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[16] The tradeoff ratio in Viscusi *et al* is the death-injury tradeoff $1/t$.
[17] To reduce the number or iterations the last step involved a decrease of 4 injuries per 10,000.
[18] Only limited pretesting using Thai students in New Zealand was possible prior to this survey.

The households selected for the survey were identified by stratified sampling. Three villages were selected by weighted random sampling[19] from each of the ten sub-districts in Ban Phai district and each of the twelve sub-districts in Phon district. All households in each village were enumerated and then a sample of ten households was selected by random sampling. Participation in the survey was voluntary, but the refusal rate was extremely low. This provided an overall sample of 660 households from 66 villages in the two districts.

The CVM survey was conducted on a sub-sample of 180 households from 18 villages, and was undertaken over a two week period in September 2003. The order that villages in the larger survey were visited was random, so the villages and households used for this survey, when weighted appropriately, provide a representative sample for the surveyed districts. The use of the same interview teams for both the household survey and the CVM survey ensured interviewers had extensive local experience and were able to develop a rapport with respondents which should improve the accuracy of survey responses.

All respondents to the survey were 18 years of age or older, with one randomly selected male respondent and one randomly selected female respondent in each household being interviewed for the CVM survey. Each respondent answered the questionnaire independently, and should not have been able to overhear responses being given by others. Questionnaires One and Two were allocated randomly between respondents. The survey resulted in 311 usable responses.

Table 2: Sample Characteristics and Consistency Checks

	Questionnaire One "Willingness to Pay"	Questionnaire Two "Willingness to Accept"
Number of Respondents	171	168
Had Lived in Landmine Area	2	2
Knew Somebody Killed or Injured by Landmines	6	7
Knew of a Village Affected by Landmines	38	29
Mean Cash Expenditure for the Month	B7,302	B7,310
Number Failing Consistency Checks		
Risk-Money Tradeoff	15	8
Risk-Risk Tradeoff	2	3
Coding Error Rejections	1	1

Table 2 provides a summary of the sample characteristics and consistency checks for responses from the two questionnaires. As the table makes clear, most households had little knowledge of landmines. Few had lived in a landmine affected area or knew somebody who had been killed or injured in a mine accident, and the majority did not know where the nearest landmine affected area was. For those who did know of a landmine affected area, these areas were an average of six hours travelling time away. None of the respondents had experience caring for someone

[19] Weightings were adapted from household numbers data from the Basic Minimum Needs survey conducted by the National Economic and Social Development Board of Thailand in 2002.

injured by a mine. The respondents were asked to estimate their cash expenditure in the month the questionnaire was taken. The estimates given are not representative of average expenditure or income in a typical month for at least two reasons. First, the survey was undertaken during a planting period in which there was higher than average expenditure on fertilizer. Secondly, expenditure is also possible from village or government funds that provide effective subsidies for many households.[20] Less than 10% of the survey respondents failed the consistency checks in either of the two surveys, with most failures occurring in dealing with risk-money tradeoffs. Consistency failures may have resulted from misunderstanding or mistakes by the respondents, or coding errors by the interviewers. Two further responses were not considered as a result of coding errors.

4. Results

4.1 Risk-Money Tradeoffs and the VSL Estimates

To simplify comparisons with other studies all VSL estimates are converted to $US using the average exchange rate over the period during which the survey was undertaken. The first part of Table 3 below gives the means, weighted means, medians and standard deviations of the VSL estimates based on the indifference points estimated by the respondents. The means for the VSL of $201,853 using the willingness to pay format and $304,425 using the willingness to accept format seem plausible for the relatively low income communities surveyed. The weighted means are very similar at $227,223 and $224,225. For 2001/02 the value of income per capita in Khon Kaen was B25,646 or $631.6.[21] For a 40 year working life and a discount rate of 10% the present value of forgone lifetime earnings would equal $6,176, thus the ratio of the VSL using the weighted means to lifetime earnings is around 37 to one.

The results suggest that the VSL varies significantly between respondents. The second part of the table provides the distribution of the income tradeoffs for a change in the risk of death from a landmine accident of 2/10,000, and the associated range for the VSL. This distribution is based on the values of income at which there was a switch in preferences between areas. Again it will be noticed that there is significant variation in VSL estimates across the respondents in the survey.[22]

When the means are corrected for the stratified nature of the sample, there is no significant difference in the results of the two surveys. Thus, this survey provides no evidence to suggest that framing the questionnaire in a "willingness to pay" form rather than using a "willingness to accept" format has a significant impact on the value of statistical life estimates that result. Regression analysis suggests that the difference in the means is almost completely explained by the districts in which the individuals were located.

[20] When the results of the associated household expenditure survey are available more detailed and reliable information will be available on the characteristics of the household that took part in the survey.
[21] Ministry of Agriculture and Cooperatives (2003)
[22] Having stated a preference for one area over another, respondents seemed unwilling to switch their preference for small changes in income. Thus there are few respondents with VSL estimates close to those implied by the initial alternatives.

Table 3: Risk – Money Tradeoffs and Value of Statistical Life Estimates

	Questionnaire One "Willingness to Pay"	Questionnaire Two "Willingness to Accept"
Mean VSL ($US)	201,853	304,425
Weighted Mean VSL ($US)	227,223	224,225
Median VSL ($US)	246,270	344,778
Standard Deviation	131,698	104,475
Weighted Standard Deviation	129,190	131,592
Sample Size	154	157
%Selecting the Low Risk Area Initially	61.7	80.3

Distribution-Preference Change

Income Diff. for a Risk Change of 2/10,000 (Baht)	Range of VSL Estimates ($US)	No.	%	No.	%
≤0	≤0	1	0.6	0	0.0
0-B400	0-$49,254	21	13.6	4	2.5
B400-B800	$49254-$98,508	30	19.5	13	8.2
B800-B1,200	$98,508-$147,762	7	4.5	9	5.7
B1,200-B1,600	$147,762-$197,016	0	0.0	5	3.2
B1,600-B2,000	$197,016-$246,270	13	8.4	0	0.0
B2,000-B2,400	$246,270-$295,524	19	12.3	16	10.2
B2,400-B2,800	$295,524-$344,778	42	27.3	46	29.3
B2,800-B3,200	$344,778-$394,032	17	11.0	61	38.9
≥B3,200	≥$394,032	4	2.6	3	1.9

Regression analysis revealed that the characteristics of the respondents had some influence on their estimate of the VSL, and the direction of influence was consistent regardless of whether the questionnaire had a willingness to pay or willingness to accept format.[23] Initial regressions were run on data from each questionnaire against a dummy variable for the district; sex, age, and education (in years) of the respondent; a dummy variable indicating whether the respondent had any prior knowledge of landmines or landmine-affected areas; household size (in terms of number of people) and whether the household included children under the age of 15; self-reported house value (as an indicator of wealth), and self-reported individual monthly cash income for the respondent. In the reported regressions, the district dummy variable, the children dummy variable, and cash income were excluded. A final regression was run on the combined data set, against the same variables, with the inclusion of cash expenditure.[24] Regression results are reported in Table 4 below.

[23] Regressions were conducted on unweighted data.
[24] A dummy variable for questionnaire was not statistically significant and was omitted from the final formulation in the combined regression.

Table 4: Regression results

	Questionnaire 1		Questionnaire 2		Combined	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Intercept	327728.668	0.000	315768.885	0.035	361846.537	0.000
Sex (F=1)	-37201.163	0.075	-16832.615	0.670	-19097.253	0.397
Age	-1177.911	0.170	-1713.304	0.387	-1722.230	0.099
Education	-7050.619	0.039	-7486.933	0.276	-5522.132	0.146
Knowledge	-36223.105	0.136	160825.590	0.002	64714.903	0.019
HHD Size	13793.163	0.050	2117.084	0.883	14471.831	0.094
House Value	-0.223	0.000	-0.063	0.529	-0.114	0.047
Cash Expenditure					-11.001	0.017

While there are no statistically significant relationships in common between the regressions for Questionnaire 1 and 2, it is interesting to note that, with the exception of the landmine knowledge dummy variable, the signs of all coefficients are identical. The negative relationship between household wealth as indicated by house value is not consistent with expectations, since higher wealth and income levels are normally associated with higher VSL estimates. Larger household sizes usually imply the presence of children and a larger number of dependents, which may suggest higher estimates of VSL.[25] Older respondents and women were found to have lower estimates of VSL.

4.2 Injury Risk-Death Risk Tradeoffs

Table 5 provides summary statistics and the distribution for the tradeoffs between the risk of injury from a landmine accident and the risk of death. As noted above, injury here refers to an accident that results in the amputation of a leg below the knee. The summary statistics are based on the indifference estimate provided by the respondents, while the distribution statistics show tradeoff ranges based on the shift in preference between the areas. While 61% of the respondents indicated a tradeoff of less than four injuries per death, there were a number of respondents with a significantly higher tradeoff.

Approximately 17% of the respondents chose a tradeoff ratio of less than one, implying a preference for death over injury. These responses could represent genuine preferences for death rather than injury in low-income rural communities for respondents who view an amputee as having a particularly poor quality of life or as a burden to their family.[26]

Table 5: Injury Risk-Death Risk Tradeoff

Mean	3.80
Weighted Mean	5.00
Median	2.5
Standard Deviation	2.98
Weighted Standard Deviation.	2.98
Sample Size	311
%Selecting the High Death Risk Area Initially	63.9

[25] A separate dummy variable for the presence of children in the household was statistically insignificant in all regressions.

[26] Viscusi et al (1991, p.45) report a similar result involving the risk of chronic bronchitis compared with the risk an auto fatality. They suggest that this could result from the treatment of auto risk as depending on driving habits, while the chronic bronchitis risk is largely involuntary. In this survey both injury and death result from mine accidents. These accidents could be viewed as either voluntary or involuntary accidents.

Distribution-Preference Change

Injuries per Death	No.	%
0-2	78	25.1
2-3	78	25.1
3-4	36	11.6
4-5	6	1.9
5-6	1	0.3
6-7	28	9.0
7-8	40	12.9
8-9	32	10.3
9-10	9	2.9
≥10	3	1.0

Table 6: Implicit Value of Statistical Injury

	Questionnaire One “Willingness to Pay”		Questionnaire Two “Willingness to Accept”	
Mean	$115,834		$211,114	
Weighted Mean	$78,621		$123,049	
Median	$43,097		$123,135	
Standard Deviation	168,168		245,652	
Weighted Standard Deviation	121,269		224,424	
Sample Size	154		157	
	No.	%	No.	%
0-$50,000	90	58.4	51	32.5
$50,000-$100,000	17	11.0	17	10.8
$100,000-$150,000	17	11.0	29	18.5
$150,000-$200,000	6	3.9	21	13.4
$200,000-$250,000	2	1.3	0	0.0
$250,000-$300,000	0	0.0	1	0.6
$300,000-$350,000	2	1.3	4	2.5
$350,000-$400,000	2	1.3	8	5.1
$400,000-$450,000	1	0.6	0	0.0
$450,000-$500,000	3	1.9	0	0.0
≥$500,000	11	7.1	25	15.9
Undefined	3	1.9	1	0.6

4.3 Implicit Value of Statistical Injury

As noted above, the VSL estimates and the risk-risk tradeoffs can be used to determine the implicit value of statistical injury. Table 6 above shows the values for the two questionnaires. Across both questionnaires the weighted mean value of a statistical injury resulting in amputation below the knee is $107,957, while the median is $64,477. These distributions are significantly right-skewed.

5. Discussion

5.1 Comparison with the literature

How plausible is the estimate of the VSL of US$0.2-0.3 million coming from the survey used here? The paucity of VSL estimates from developing countries makes comparisons difficult. We are aware of two studies of compensating wage differentials for risk of fatal and nonfatal injuries in India's manufacturing sector. Simon *et al.* (1999) estimate a VSL of US$0.15-$0.36 million, which is between 20 and 48 times foregone earnings. Shanmugam (2000) estimates a VSL of US$1.4 million, but once account is taken of self-selection bias the estimated VSL jumps to US$4.1 million Shanmugam (2001). This very high VSL for a developing country is 550 times the level of foregone earnings. Our results for Thailand are clearly comparable to those of Simon *et al* for India, but are not comparable with Shanmugam's results. Average income levels in India are significantly lower than in Thailand, at about US$800 per capita in year 2000.

Another comparison comes from Taiwan, where compensating wage differential estimates are available from the early 1980s (Liu, Hammitt and Liu, 1997). At that stage Taiwan might still have been considered a developing country, although even then the average income level was about US$5500 (in year 2000 dollars). The implied value of statistical life from that study averaged US$0.41 million (in 1990 dollars).[27] Given that incomes in Taiwan in the 1980s were about twice those prevailing in Thailand now, this estimate also seems comparable to our results.

Contingent valuation estimates of the VSL for developing countries are rather harder to find. The only estimate that we are aware of is from Zhang and Zheng (2001) who value mortality risk reductions in Beijing. The VSL estimates from their 1999 survey range from US$0.06-$0.2 million, which is comparable to the estimates established for Thailand.

Miller (2000) applies regression analysis to previous VSL studies in order to obtain estimates of the VSL for a number of countries. He suggests a best estimate for Thailand of $380,000 in 1995 US dollars, or around $450,000 in 2003 US dollars. The estimates in this survey for villages in relatively low-income rural areas in Thailand would also seem to be consistent with these results. Miller (2000) also provides elasticity estimates for VSL on GDP per capita which range from 0.85 to 1.00.[28]

[27] Unlike the results of Shanmugam, the correction for selectivity bias in this study reduced the VSL by about 10 percent, so the uncorrected VSL was US$0.46 million.

[28] Viscusi and Aldy (2003) report estimates of 0.5-0.6.

5.2 Possible Sources of Bias in the Estimates

As noted above, VSL estimates based on CV methods have been shown to be sensitive to a variety of factors that may decrease the reliability of the results. In response Beattie *et al* (1998) add the subtitle "Caveat Investigator" to their investigation of scale, scope and framing effects. Here we briefly discuss three issues.

In the approach used in this survey to consider risk-money tradeoffs all respondents were presented with initial alternatives that involved a change in risk of 2 in 10,000 and an income change of B1,600, i.e. all respondents faced the same starting point. The importance of starting point bias has been noted in the literature, although empirical evidence is mixed (O'Brien and Viramontes, 1994 and Stalhammer, 1996). Perreira and Sloan (2002) use randomly selected initial values to avoid this bias. In this survey random starting points would have significantly increased the complexity of the survey for interviewers, and added to the iterations necessary to find indifference. As shown in Table 2, 61% of respondents in Questionnaire One and 80% of respondents in Questionnaire Two chose the low risk alternative initially. This suggests that the initial change in income may have been set too low. It is possible that a higher initial value may have resulted in higher VSL estimates. Certainly, in future surveys it would be desirable to explicitly test for starting point bias.

The theoretical framework on which the VSL estimates are based implies that the subutility function defined over final income is the same in the healthy state as when the individual anticipates death. In a study using data from the chemical industry Viscusi and Evans (1990) find the marginal utility of income given serious injury is less than when healthy, while Perreira and Sloan (2002) find no significant difference in a study of disability risk. If it is assumed that the individual anticipates no additional utility from income if death occurs, then back-of-the-envelope calculations using linear, logarithmic and square root utility functions for the utility of income when healthy suggest that the VSL would be no more than 6% less.[29]

If the VSL measured as L represents the value of statistical life for small risk changes, then provided the change in risk remains "small" the required change in income to compensate for a change in risk should be proportional to the magnitude of the risk change. However, a number of studies have shown that this is often not the case, making the estimated VSL measure sensitive to the size of the risk change considered.[30] For example, Beattie *et al*. (1998) in their survey found that a risk reduction of three times the size led to only a 41% increase in CV, with a number of respondents giving identical CV estimates. Tests of the sensitivity of estimates to the size of the risk change considered would also be important in testing the robustness of the results obtained.

[29] Calculated for I_a equal to B20,000, an income difference of B1,600 and with W equal to less than I_a.

[30] For a survey and study of this issue see Hammitt and Graham (1999)

6. VSL Estimates and Cost-Benefit Studies of Mine Clearing

To illustrate the importance of VSL estimates in evaluating mine clearance policy we use as an example the cost-benefit study of mine clearance in Cambodia by Harris (2000). Our purpose is not to re-estimate the costs and benefits of mine clearance in Cambodia, but simply to indicate the impact of various VSL measures based on our estimates leaving all other aspects of the work of Harris unchanged.

Cambodia has the highest rate of civilian landmine and unexploded ordnance casualties in the world. With over 46 percent of Cambodian villages still contaminated by landmines (CMAC 2002), landmine removal is vital to economic progress in Cambodia's rural areas. But with an estimated 4,500 square kilometres of Cambodian land thought to still be contaminated by landmines (CMAC 2002), Cambodia's limited clearance abilities are a serious hurdle to rural development. The Cambodian Mine Action Centre (CMAC), employing close to 3,000 deminers, has a current clearance capacity of only about 10-12km^2 per year.[31] The number of civilian landmine victims per year has not fallen significantly over the last 10 years of demining activity (CMAC 2002), suggesting that direct removal efforts are slow relative to the total size of the problem.

In his study Harris estimates the cost and benefits of removing mines from 500,000 ha of contaminated arable land, with demining taking place over a period of 25 years.[32] Cost estimates are based on a demining cost of $7,000 per ha, giving a total cost of $3,500m. Although actual expenditure is assumed to be undertaken over the 25 years, the $3,500m is treated as the present value of demining costs. Three major benefits of demining are considered:

- *Saved lives and disabilities*:
  These are valued in terms of the average income earned for the years of productive life remaining. Those injured are assumed to produce half the income of a healthy individual.
- *Medical Costs*:
  These include the initial medical costs of survivors and the on-going costs of artificial limbs for amputees.
- *Gains in Agricultural Output*:
  These are measured as the value-added from previously unused or under-utilized land.

The benefits of the first year of demining and the way in which these are calculated are shown in Table 7 below. Over time these benefits compound as more demining takes place.

[31] To give an idea of the number of mines and UXO yet to be removed, from the total of 90+ square kilometres of land that it cleared of landmines/UXO from 1992-2001, CMAC found 148,820 anti-personnel mines, 2,930 anti-tank mines and 667,160 items of UXO (CMAC 2002).

[32] Harris (2000) considers a number of scenarios. We will consider only the base case or Assumption Set One.

Table 7: The Benefits of One Year of Demining ($US)*

Production from Saved Deaths[1]	6,432
Production from Saved Disabilities[2]	3,216
Saved Medical Costs[3]	26,400
Value of Additional Agricultural Output[4]	688,000
Total Benefits	724,048

*From Harris (2000) , Table 1, p. 222.
[1]1/25 of 1,200 deaths x $134
[2]1/25 of 1,200 injuries x $67
[3]1/25 of 1,200 injuries x $550
[4]1/25 of 500,000 ha x 0.40 x $86

Using a discount rate of 10% Harris finds a net present value of -$3,434m on an investment of $3,500m.

The method for determining the benefits of mine clearing used by Harris does not explicitly include a VSL, since estimates are based on the income generated by workers whose lives are saved during the 25 year timeframe. To include VSL estimates we assume that the full value of a life saved is included as a benefit in the year the life is saved. As noted above, in 2001/02 income per capita income in Khon Kaen province was B25,646, or US$631.6 at the exchange rate used in this study. Harris assumed a per capita income of US$134 in Cambodia. Estimates of the elasticity of the VSL with respect to income give some indication of VSL measures that might be relevant given the income base used by Harris. Miller (2002) suggests elasticities in the range 0.85-1.0, while Viscusi and Aldy (2003) report elasticities of 0.5-0.6. The average value of the weighted mean VSL estimates obtained in Questionnaire One and Questionnaire Two is $229,780. Applying elasticities of 1.0 and 0.5 gives VSL estimates of $48,750 and $105,838 respectively.[33] The distribution of the injury risk-death risk tradeoffs shown above is right skewed resulting in a median of 2.5 compared with a weighted of 5.0. We have used the weighted mean of 5.0 in reconsidering estimates of the value of injuries saved.[34]

Table 8 below compares the study by Harris with equivalent calculations based on the VSL estimates obtained. None of these VSL measures are large enough to make the present value positive under the assumptions used by Harris, although the present value of benefits becomes a much larger proportion of costs, 9-34% compared with 1.9% in Harris. However, even modest estimates make the value of saved lives and injuries the dominant benefit. In Harris the present value of the value-added of the arable land brought into production represents 88% of the benefits of mine clearance, and the benefits of saved lives and injuries only 8.7%. When VSL estimates are used the value of lives and injuries saved dominates benefit assessment, representing 80% of the benefits for a VSL of $48,750 to 95% for a VSL of $229,780. These calculations suggest that estimates of the VSL are likely to drive estimates of the benefits of

[33] Alternatively, for Khon Kaen province in Thailand our estimated VSL/income ratio is 364. With an elasticity of one, this ratio would stay the same, thus the estimated VSL=$134*364=$48,776.
[34] Harris (2001) assumes that the value of a saved injury is half the value of a saved life before taking into account the medical costs associated with injuries.

mine clearing, and would be an important part of the determination of the areas that should be cleared and the degree of demining that should be undertaken in a particular area.

Table 8: The Impact of VSL Estimates on the Cost and Benefits of Mine Clearance – The Cambodian Case

	Harris (2001) VSL=$1,338[1]	Elas.=1.0 VSL=$48,750	Elas.=0.5 VSL=$105,838	Ave. Thailand VSL=$229,780
PV of Benefits				
Saved Lives	$3.9m	$197.6m	$429.0m	$931.4m
Saved Injuries	$1.9m	$39.5m	$85.8m	$186.3m
Saved Lives and Injuries as a Percentage of Benefits	8.7%	79.7%	89.5%	94.9
PV of Mine Clearance	-$3,433.8m	-$3,202.5m	-$2,924.8m	-$2,321.9m
Benefits as a % of Costs	1.9%	8.5%	16.4%	33.7%

[1] The counterpart of a VSL measure in Harris (2001), the PV of $134 for 25 years at 10%

6. Conclusion

Reliable estimates of the value of the tradeoff between risk reduction and income generation are necessary to evaluate the desirability of demining in particular locations and the extent of mine clearance that is optimal, and to compare the relative merit of alternative policies that impact on risk, income and economic growth in mine affected communities. Using a survey based approach in Khon Kaen province in Thailand we found estimates of the VSL that are in the US$200,000-$300,000 range. These estimates are broadly consistent with what little is known about the VSL in developing economies, and suggest that the value of lives saved are likely to be 30 to 50 times estimates based on the present value of income foregone. Our work also provides estimates of the injury risk-death risk tradeoff and the value of statistical injury.

Future research will assess the reliability of the estimates given possible sources of bias that have been identified in the literature. Surveys in mine affected areas would also enable the relationships between VSL estimates and knowledge of landmines and risk perceptions to be considered. Estimates of the VSL based on revealed preference or market methods would be useful for comparison purposes.

Applied to a reconsideration of a cost-benefit study of mine clearance in Cambodia, our results suggest that the present value of the benefits are likely to be between 9-34% of costs compared with 1.9% in Harris (2000). This implies that the degree of mine clearing that can be justified on social efficiency grounds is likely to be significantly higher when VSL methods are used to value lives and injuries saved. Our work also suggests that when VSL measures are used it is likely that the value of lives and injuries saved, and not the value of arable land bought into production, will dominate benefit assessments.

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Figure 1: Location of the Survey

Figure 2 Location of the Case Study

Figure 2: Showcard for a Risk of 4 in 10,000