New Zealand Agricultural and
Resource Economics Society (Inc.)

How Can Economists Help Clear Landmines and Unexploded Ordnance?

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

Paper presented at the 2005 NZARES Conference
Tahuna Conference Centre – Nelson, New Zealand. August 26-27, 2005.

How Can Economists Help Clear Landmines and Unexploded Ordnance?

Dan Marsh [1]

Department of Economics
University of Waikato
Private Bag 3105
Hamilton
New Zealand,
dmarsh@waikato.ac.nz,

Summary

Millions of mines lie in or on the ground in 62 countries resulting in thousands of deaths and injuries each year. Most mines are cleared using probes and hand held mine detectors; although sniffer dogs and a variety of machines are becoming more common. Clearing landmines is very expensive with costs often reaching US$10 per square metre; over US$1.5 billion has been spent on clearing mines since 1992.

Most of the organisations involved in mine clearance have concentrated on technical aspects and put less emphasis on the most cost effective way of getting the job done. This paper reviews the contribution that economists can make in the area of humanitarian mine clearance and describes the development of a software package and manual designed to help managers decide which combination of machine and manual methods should be used to clear minefields to the required safety standard at the lowest cost.

Keywords: Mine Clearance, Cost Effectiveness Analysis, Software Model

---

[1] This paper is based on work carried out jointly with John Gibson, University of Canterbury and Geua Boe-Gibson and includes material from Marsh, Boe-Gibson, & Gibson (2002a; 2002b) and Barns et al. (2004).

Introduction

Millions of mines lie in or on the ground in 62 countries resulting in over 15,000 civilian casualties per year, mostly in rural areas of developing countries (ICBL, 2002). They reduce agricultural production and incomes by making millions of hectares unavailable for crop production or livestock grazing (Andersson, Palha da Sousa, & Paredes, 1995). Their impact is felt most by the poor; who are most likely to be forced to work in mine affected areas in search of firewood, drinking water or grazing for their livestock (Roberts & 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). Refugees are often unwilling to return home when their land has not been cleared of land mines thus causing a long term burden on host communities and aid agencies. The world has responded to the humanitarian costs and economic impact of landmines and unexploded ordnance (UXO) by spending over US$1.5 billion on mine and UXO clearance since 1992. The overall trend is for spending to rise, with US$250 million spent on clearance in 2001; yet very little of this spending has been subject to rigorous economic analysis.

There are at least four areas where economic analysis can assist decision making by policy makers. To date, most attention has been focussed on the issue of (1) whether mines should be cleared at all and whether the costs of clearance exceed the benefits. Assuming that clearance is beneficial, then decisions need to be made on; (2) the appropriate standard of clearance; (3) which areas should be cleared first; and (4) which methods should be used.

This paper briefly reviews the economic literature relating to the first three of these areas and then focuses on the analysis of alternative mine clearance methods – through the development of analysis procedures and a software package and manual designed to help managers decide which combination of machine and manual methods should be used to clear minefields to the required safety standard at the lowest cost.

Should Land Mines be Cleared?[2]

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 & Harris, 2001). For Bosnia and Herzegovina Patterson (2003) concludes that demining cannot be justified on development grounds.

Existing cost-benefit analyses of landmine clearance (Elliot & Harris, 2001; Harris, 2000, 2002.; 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

[2] The following two sections draw extensively on work by my co-authors in Barns et al., (2004).

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 Harris's 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 & Stamland, 2002).

Gibson et al (2005) used the contingent valuation method to investigated the VSL for a rural population in Northeast Thailand where the incidence rate of landmine fatalities and injuries is 34 per 100,000 in affected communities (Survey Action Center, 2003). The survey used two series of questions to determine tradeoffs between risk of injury and earnings. 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. The estimated VSL of US$250,000 is around forty times the value of lifetime earnings (US$6,160). Using VSL the value of lives saved from landmine clearance is at least an order of magnitude greater than the values used in existing studies. Applying this VSL to the data used by Harris (2000) for Cambodia suggests that the total value of benefits of mine clearance may be around 36% of the value of costs; compared to 2% of the value of costs using the foregone earnings method.

The high costs of clearance and lack of net benefits from comprehensive mine clearance underline the importance of considering the benefits of alternative uses of mine clearance funds. For example Lim (2004) suggests that "opening up alternative safer income sources, such as factory work located away from landmines, may prove to be a quicker and more cost-effective way of reducing landmine casualties than traditional demining activities". It should be noted that such an approach would be contrary to Article 5 of the Ottawa Convention (United Nations, 1997) in which "Each State Party undertakes to destroy or ensure the destruction of all anti-personnel mines in mined areas under its jurisdiction or control, as soon as possible but not later than ten years after the entry into force of this Convention for that State Party."

What is the Appropriate Clearance Standard?

It has been suggested that mine clearance agencies may overestimate the benefits of clearance, 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 all 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.

Which Areas Should Be Cleared First?

Assessment of priorities for mine clearance is essentially little different to any other prioritisation exercise. Methodologies are well developed and with appropriate modifications can be applied to this field. Examples of this kind of exercise are described in GICHD (2001). Often this has involved Landmine Impact Surveys "to provide a ranking of communities by severity of mine impact that can inform the allocation of mine action resources". These surveys use three main indicators to estimate a composite Mine Action Score that is used in order to create the ranking. The indicators are: the nature of contamination (e.g. type and density of mines), the types of livelihoods and infrastructure to which mines block access and the number of recent victims. In a world of perfect information prioritisation might be based on reduction in loss of life and health (measured as the difference between the number of victims before and after demining); and the net present value of demining (defined as the difference between the present value of income streams from demined land and infrastructure with and without demining, minus the cost of demining them)[3]. GICHD suggest that the indicators used in the Mine Action Score provide a cost effective prioritisation scale that can be related to these underlying variables.

Which Methods Should be Used?

Mechanical mine action equipment has been used by demining organisations almost since the beginning of the humanitarian mine action movement in the late 1980s. Initial mechanical clearance approaches often relied on equipment whose design was influenced by the military objective of clearing a navigable path through a minefield rather than on the humanitarian objective of removing all mines in an area. More recently, special purpose mine clearance machines have been developed, but none of these have been deemed effective enough to conduct full clearance without follow-up by either manual demining teams or mine dog detection teams.

The apparently limited success in the use of mechanical clearance methods means that most demining organisations continue to rely heavily on manual clearance techniques. While manual techniques may be a reliable way of ensuring that acceptable clearance standards are met, they can be slow, expensive and dangerous. Using current methods it may take many years beyond the target in the Ottawa Treaty (United Nations, 1997) for the goal of a "mine free world" to be realised. Indeed, to help speed their operations and reduce danger, some mine clearance organisations do use machines in a limited support role for manual deminers (e.g., for removal of vegetation and trip-wires).

The growing number of purpose-built mechanical mine clearance machines in use and under development and the increasing variety of ways in which machines are used to support mine clearance suggested a need for the collection of information on the cost effectiveness of alternative methods of mechanical mine clearance. Such information can serve at least two purposes. First, a greater awareness of the cost effectiveness of various methods of mine clearance may help demining agencies to use their existing resources more effectively. Second, more widely available and standardised data on the cost effectiveness of mechanical equipment relative to other clearance methods could help planners and developers allocate support to the

[3] Adapted from GICHD (2001).

machines and techniques that offer the greatest promise.

Against this background the Geneva International Centre for Humanitarian Demining (GICHD) commissioned the Management Research Centre of the University of Waikato to provide advice on the appropriate methods and standards for analysing the cost effectiveness of mechanical mine action. In support of this advice, the commission also included a requirement to provide a software tool that demining organisations could use for carrying out their own cost effectiveness analysis. Staff from the university and GICHD visited mine action agencies in Bosnia and the Cambodian border region in order to develop an understanding of the key variables affecting cost effectiveness. A Cost Effectiveness Model (CEMOD) was then developed as a macro that could be run in Microsoft Excel. A key objective throughout this process was to develop a practical system that would require little additional data and that could be used by field management staff without additional training.

The Cost Effectiveness Model (CEMOD)

Model Purpose and Overview

Mine clearance is an expensive activity that can often be undertaken using a number of different methods. There is a wide range in the unit cost of these methods; even after adjusting for quality and variation in other key variables. Clearly it is vitally important that scarce mine clearance resources be deployed in such a way as to achieve the best possible outcomes. Cost-effectiveness analysis has a key role to play in achieving this goal.

Cost-effectiveness analysis can be approached in two ways: a) to determine the least cost method of achieving a known goal, in this case mine clearance to a level of at least 99%, the fixed effectiveness approach, or b) to find the policy alternative that will provide the largest benefits for a given level of expenditure, the fixed budget approach. CEMOD follows the fixed effectiveness approach.

The design of the Cost Effectiveness Model (CEMOD) is based on the concept of the ‘mine clearance method’ i.e. any method used to achieve the standard goal of at least 99% mine clearance. There is little point in comparing different machines in isolation if they make different contributions to mine clearance. The only useful comparison is between alternative methods that achieve the same goal. For example a given piece of land might be cleared to the same standard by four alternative methods:

1. manual mine clearance only
2. flail followed by manual mine clearance
3. vegetation cutter followed by manual mine clearance
4. flail followed by dog teams, supported by manual mine clearance

Analysis Functions

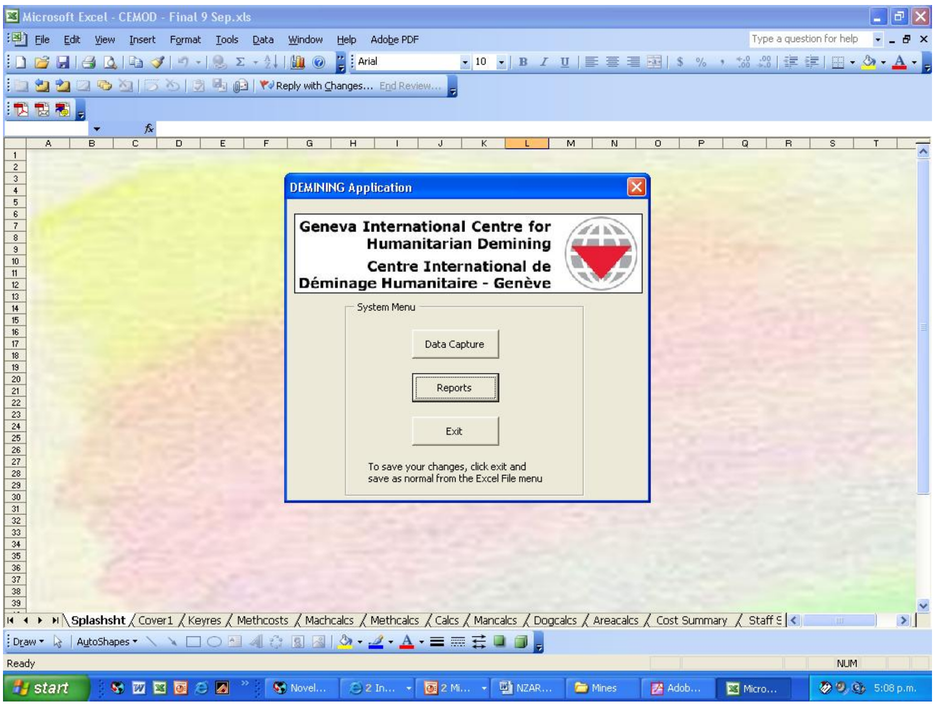
The Cost-Effectiveness model CEMOD may be used for four main types of analysis:-

- *Past Costs*. Implementing organisations can analyse the past cost effectiveness of alternative methods of mine clearance, given the particular conditions faced by their organisation. For example the 'real' cost of donated equipment is not included.
- *Projected Costs*. Implementing organisations may use CEMOD to project future expenditure using existing or new mine clearance methods.
- *Planning (Past)*: Planning organisations can compare the past performance of different implementing agencies, including adjustments to create a 'level playing field'. For example the 'full market cost' of donated equipment is included.
- *Planning (Projected)*. Planning organisations can project the future cost effectiveness of alternative methods of mine clearance, including adjustments to create a 'level playing field'.

Data Entry

When CEMOD is started users are provided with the system menu (Figure 1).

Figure 1: CEMOD System Menu



Users click on "Data Capture" if they want to enter new project data or want to edit values already entered in the model. The "Reports" button takes them to another menu where they can choose to view and print some (or all) of the standardized cost effectiveness and cost comparison reports.

Three types of data are required by the cost effectiveness model: basic information on the location and details of the project and on the type of analysis being conducted (e.g., past costs vs. projected costs); information on area clearance rates and the time inputs (e.g, man-days for manual clearance and days of machine use), which might typically come from log books; and information on costs, which would typically come from project accounts and budgets or equipment catalogs. The data capture menu is used to access data entry screens for each of these three types of data (Figure 2).

In the 'Area Cleared Data Entry Menu', users are asked to attribute areas cleared and time inputs (man-days and machine days) to each of the various methods that their agency has used (for analyses of past costs) or is considering using (for projections).

Figure 2: CEMOD Data Capture Menu

In the 'Costs Data Entry Menu', users are asked to enter data on the actual or projected costs of the mine clearance project. The costs in the model are grouped into four categories: staff salaries; staff allowances; consumables and running costs; and capital equipment. Within each of these cost categories there is no restriction on how many cost items are specified. Thus, the model can handle both analyses of past costs, based on detailed budgets, as well as projected costs where there might be rather less detail available. For each cost item, the user is asked to specify a name or description for the item, the number of items used, and the unit cost per item per year.

For each cost item, the user is asked to allocate the number of units across various cost categories e.g. management and administration, mine survey, medical support, manual mine clearance teams, dog teams and individual machines. This allocation of the number of units of each cost item allows the user to identify which costs are associated with which machines. By identifying costs with machines and other procedures it is possible to identify, from a single budget, different costs for different mine clearance methods. Thus, the allocation of the cost items is a particularly important part of the model.

Further details of CEMOD data entry and operation procedures are provided in Marsh, Boe-Gibson, & Gibson (2002a; 2002b).

Model Output and Interpretation

The reports menu is used to view and print the results of the model's calculations, as well as printing the worksheets that contain the input data on area cleared, days used, and costs by category.

The "Standard Reports" button lets the user view and print four reports:

Report S1	*Key Results* This report provides total cost, cost per m^2, and cost ratio/annual cost saving (compared to base case) for each mine clearance method.
Report S2	*Annual cost, by method and cost category* This report summarizes the annual costs (counting only those attributable to mine clearance) for each method, by six cost categories: salaries; allowances; consumables; capital equipment; medical; and management, administration and mine survey.
Report S3	*Cost per m^2 and potential savings by method and cost category* This report gives cost per m^2 for each method and compares those costs with the base case method. Estimates are also reported for the hypothetical costs, and cost saving, from using each of the methods exclusively. A notional figure of the time taken to repay capital equipment is also provided, which is based on an average across all capital equipment rather than for a particular machine.
Report S4	*Machine demining; annual cost, cost per day and cost per m^2* This report summarizes the costs associated with each mechanical mine clearance machine. The cost estimates are presented on both a per day and per m^2 basis.
Report S5	*Annual cost summary* This report summarizes the annual costs associated with each machine and with the other procedures carried out by the agency. All management and administration costs, rather than just those attributable to mine clearance, are included in this table.

The 'Key Results' report (Figure 3) includes total cost, cost per m^2, cost ratio and annual cost saving. Based on the sample data in Figure 3, use of a flail, followed by a combination of manual deminers and dog teams provides the most cost effective clearance method. Costs per m^2 are US$3.41 compared to US$11.29 using fully manual methods (the base case). Use of this method over the whole area to be cleared would result in a cost saving of US$7.2 million, compared to manual demining.

Figure 3: Example of Key Results Report

Report S1: Key Results

Reporting Period: 2001
Currency US$

Method	Total Cost	Cost per m2	Cost Ratio vs Base Case	Annual Cost Saving
Manual Only	1,128,742	11.29	100%	
Flail + Manual	1,156,574	5.78	51%	5,009,138
Flail, Manual, Dogs	1,365,011	3.41	30%	7,166,151
Vegcut, Manual	365,602	7.31	65%	3,617,597
Area Red'n then manual	304,352	6.09	54%	4,732,347
Vegcutter, Manual, Dogs	247,085	4.94	44%	5,774,610
Area Red'n, MP, Manual	587,267	11.75	104%	-416,703

It must be stressed that Cost per m^2 should only be compared 'where all other factors are equal' i.e. for clearance of mined land of similar characteristics. Differences in cost per m^2 between minefields may be a reflection of changes in mine field characteristics – rather than the cost effectiveness of alternative mine clearance procedures.

Factors Affecting Cost Effectiveness

The cost effectiveness model is designed to provide standardised calculations of the cost of mine clearance using actual or projected data. Many factors are likely to influence the cost effectiveness of particular methods of mine clearance in particular settings (see Table 1). Foremost amongst these will be labour and machine costs, and the comparative productivity levels of manual clearance teams, dog teams and mechanical clearance machines. However, other idiosyncratic factors are also likely to be important and these are not incorporated into CEMOD even though they are likely to be relevant to the decisions that agencies make about the most effective way to clear a given area.

For example, an agency may use different machines to do a similar task (say, vegetation clearance), but on land with different characteristics. While it would be possible to have a model that considers factors such as slope vs flat, dry vs wet, such a model would be quite complicated and it would be more difficult to use the model for planning purposes. Instead, it is expected that when the current model gives costs for each machine, the user can work out if the higher cost for one machine is justified by the more difficult terrain it is working on.

Table 1: Key Variables Affecting Cost Effectiveness

Variable	Remarks
Administration & Support Costs	Substantial variation between countries and organisations
Medical Costs	
Labour Costs	Vary with country, skill levels, employing organisation etc
Machine Costs	Should (in theory) be similar for equipment procured internationally, but transport costs, tariffs/duties, availability of supply etc may cause considerable variation.
Labour Productivity	Key variables include: i. work practices, training and labour turnover ii. weather and seasonal conditions iii. degree of metal contamination (including laterite soils) iv. terrain and amount of vegetation, rubble etc v. number and type of mines present
Machine Productivity	Key variables include those detailed above, and: i. area suitable for demining by that machine ii. feasibility/difficulty of moving machine to site iii. reliability (amount of down time due to mechanical problems iv. clearance depth (see below) v. number and type of mines present

A similar complication comes from the type of mine that is expected in a given field. Mechanical procedures that are feasible when working with anti-personnel mines may not be feasible when working on anti-tank mines and the use of suitably armoured machinery is likely to affect the cost comparisons. Hence, the information provided by CEMOD cannot replace the detailed knowledge of project managers, instead it is designed to provide additional information so that they can make better informed decisions about mine clearance.

There are at least two additional factors that must be considered so that the cost effectiveness calculations can be put in their correct context. First, as noted above, there is no explicit premium for timeliness in the calculations carried out by CEMOD. However, while the reports allow methods to be compared on an area unit basis, they also indicate clearance rates and cost per day, so information on the timeliness of particular methods can be extracted. It is unlikely that a standardised model could provide more detail because local factors (such as the pressure on land) will dictate what value is placed on timeliness. Second, although m^2 seems to be an accepted metric for recording output, there is some argument for considering the depth of clearance. A hidden (dis)advantage of machines may be that they clear to a (lesser) greater depth than is possible with other techiques. A comparison solely on the basis of costs per m^2 will miss this point and may unfairly indicate an advantage for one machine or method in the comparisons.

Conclusions

Many of the key issues around mine clearance are amenable to economic analysis. In this respect mine clearance is no different to any other activity that uses scarce resources. Policy in this field has often been strongly influenced by both military and humanitarian concerns and approaches. Many mine clearance agencies are staffed by ex-military personnel who often see mine clearance as being a technical problem requiring technical solutions. Too often little or no attention has been paid to cost effectiveness in determining the best course of action. Humanitarian concerns have brought the impact of mines to the world's attention and led to the signing of the Ottawa Convention. However the Convention's requirement that all mines be cleared will not always be the best way of improving the plight of those affected by mines. Likewise the UN standard of 99.6% clearance will often be too stringent and will tend to divert funds away from other risk reducing activities where more deaths and injuries could be avoided at lower cost.

This paper has described the development of procedures and a software model designed to help managers assess the cost effectiveness of alternative mine clearance methods. Feedback received so far has been positive and some managers are reported to be making use of CEMOD. Given the large sums of money involved and the fact that little attention has been paid to cost effectiveness to date, potential cost savings are substantial.

Further uptake of CEMOD may be achieved if appropriate follow-up activities are carried out. Some managers will require advice and support before being convinced of the benefits of cost effectiveness analysis. There may also be areas where managers will require input from a trained economist e.g. in some complex cost allocation decisions. There is also scope to further develop the model based on feedback on the first version.

This paper has demonstrated the importance of economic analysis if scarce funds are to be used efficiently to assist the development of mine affected areas. The key questions to be addressed are: should mine affected areas be cleared; what is the appropriate standard of clearance; which areas should be cleared first; and which methods should be used? Better answers to these questions may provide one of the best ways of assisting the millions of people who live and work at risk of death or injury from mines and UXO.

References

Andersson, N., Palha da Sousa, C., & Paredes, S. (1995). Social Cost of Land Mines in Four countries: Afghanistan, Bosnia, Cambodia, and Mozambique. *British Medical Journal, 311*, 718-721.

Barns, S., Cameron, M., Gibson, J., Lim, S., Marsh, D., Scrimgeour, F., & Tressler, J. (2004). *Valuing the Risk of Death and Injury from Landmines in Thailand.* Paper presented at the Tenth Annual Conference of the New Zealand Agricultural and Resource Economics Society, Blenheim.

Elliot, G., & Harris, G. (2001). A Cost-Benefit Analysis of Landmine Clearance in Mozambique. *Development Southern Africa, 18(5),* 625-633.

Gibson, J., Barns, S., Cameron, M., Lim, S., Scrimgeour, F., & Tressler, J. (2005). *The Value of Statistical Life and the Economics of Landmine Clearance in Developing Countries*. Department of Economics, University of Waikato. (Working Paper in Economics 4/05)

GICHD. (2001). *A Study of Socio-Economic Approaches to Mine Action*: Geneva International Centre for Humanitarian Demining.

Harris, G. (2000). The Economics of Landmine Clearance: Case Study of Cambodia. *Journal of International Development, 12(2)*, 219-225.

Harris, G. (2002.). The Economics of Landmine Clearance in Afghanistan. *Disasters, 26(1)*, 49-54.

ICBL. (2002). *Landmine Monitor Report 2002: Towards a Mine-Free World*. New York: International Campaign to Ban Landmines [ICBL], Human Rights Watch.

Lim, S. (2004). *Partial Landmine Clearance: The Contribution of Manufacturing to Casualty Reduction*. Department of Economics, University of Waikato. (Draft Mimeo)

Marsh, D., Boe-Gibson, G., & Gibson, J. (2002a). *Mechanical Mine Action Study: Cost Effectiveness Component, Draft Final Report*.

Marsh, D., Boe-Gibson, G., & Gibson, J. (2002b). *User Guide: Cost Effectiveness Model For Mechanical Mine Clearance CEMOD*.

Mathieson, M. (1997). *Anti-Personnel Land Mines: A Scourge on Children*. Disability International.

Patterson, T. (2003). *Death, Disability, Displaced Persons and Development: The Case of Landmines in Bosnia and Herzegovina*. Mimeo.

Roberts, S., & Williams, J. (1995). *After the Guns Fall Silent: The Enduring Legacy of Landmines*. Washington: Vietnam Veterans of America Foundation.

Rosen, S. (1988). The Value of Changes in Life Expectancy. *Journal of Risk and Uncertainty, 1(3)*, 285-304.

Shogren, J., & Stamland, T. (2002). Skill and the Value of Life. *Journal of Political Economy, 110(5)*, 1168-1173.

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

United Nations. (1997). *Convention on the prohibition of the use, stockpiling, production and transfer of anti-personnel mines and on their destruction.*: United Nations.

UNMAS. (2003). *International Mine Action Standards*. New York: United Nations Mine Action Service (UNMAS).

Viscusi, W. K. (2000). Risk Equity. *Journal of Legal Studies, 29(2),* 843-871.