

A STUDY OF MANUAL MINE CLEARANCE

1. History, Summary and Conclusions of a Study of Manual Mine Clearance



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The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

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Contents

| | |
|----------------------------------------------------------------------------------------|----|
| Foreword | 1 |
| Introduction | 3 |
| Problem statement | 4 |
| Study objectives | 5 |
| Study audience | 5 |
| Study methodology | 5 |
| Layout of the study report | 6 |
| Executive summary | 7 |
| The origins of manual mine clearance | 7 |
| Management of manual mine clearance | 7 |
| Innovative manual clearance techniques | 11 |
| Improving the cost-effectiveness of manual mine clearance | 12 |
| The future of manual mine clearance: the need for an explicit risk management approach | 13 |
| A history of manual mine clearance | 15 |
| The challenge of landmine clearance | 17 |
| Moving into formal “humanitarian demining” | 22 |
| Main study conclusions and recommendations | 27 |
| Annex: Members of the Study Advisory Group | 39 |
| Bibliography | 41 |
| Glossary of abbreviations and acronyms | 47 |

Photo credits:

Cover and Figure 1: British Army mine clearance of a road in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number H 29725. Figure 2: British Army mine clearance in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number B 5539. Figure 5: Mine clearance in Afghanistan in 1992, Paddy Blagden. Figure 6: Mine clearance in Kuwait in 1991, R Keeley.

Foreword

The global effort against landmines and unexploded ordnance (UXO) has progressed for many years, and the industry has been developing rapidly for much of this time. But how much do we really know and understand about the fundamental element of mine action — manual mine clearance? This study, which is long overdue, tries to give answers to these questions and looks at the development of manual mine clearance since the process of removing mines began after the 1939-45 war, through to today's situation. At present, national authorities, non-governmental organisations and commercial companies operate in many of the 90 or so mine-affected countries in the world. While there is growing use of machines and animals, manual mine clearance is still the predominant clearance methodology.

The study reviews the legacy of military mine clearance — something that impacts on all clearance operations today — and notes that operational safety has improved significantly over recent years. It then considers the impact of management on demining operations, followed by a detailed consideration of the basic techniques and processes used in the field. Several case studies of countries and programmes are included where innovation has meant that productivity and efficiency have been significantly improved. Finally, the study looks at the costs of demining, and also into the issue of risk to both the deminers themselves and to the end users of the cleared land.

One of the main objectives of the Geneva International Centre for Humanitarian Demining is to help make mine action cheaper, faster and more effective. This study provides another incremental step forward in the development of more efficient and effective mine clearance programmes, and provides useful guidance to practitioners.

The study was informed by a broad section of the mine action community. I would like to thank the Study Advisory Group and all those who provided comments and input to the study. I would also like to express my appreciation to the Governments of Denmark, Finland, Italy and the United Kingdom for their financial support to this work.



Ambassador Stephan Nellen
Director
Geneva International Centre
for Humanitarian Demining

Introduction

According to the United Nations (UN), mine action is

“not just about demining; it is also about people and societies, and how they are affected by landmine contamination. The objective of mine action is to reduce the risk from landmines to a level where people can live safely; in which economic, social and health development can occur free from the constraints imposed by landmine contamination, and in which the victims’ needs can be addressed. Mine action comprises five complementary groups of activities:

- a) mine risk education;*
- b) humanitarian demining, i.e. mine and UXO survey, mapping, marking and (if necessary) clearance;*
- c) victim assistance, including rehabilitation and reintegration;*
- d) stockpile destruction; and*
- e) advocacy against the use of anti-personnel mines.*

A number of other enabling activities are required to support these five components of mine action, including: assessment and planning, the mobilisation and prioritisation of resources, information management, human skills development and management training, quality management and the application of effective, appropriate and safe equipment.”¹

The most prominent component of post-conflict mine action is manual mine clearance (or manual demining, as it is often called). Manual mine clearance has been undertaken in various forms over many decades. Although it is still sometimes debated exactly when a formalised process of manual mine clearance was first undertaken, most observers credit this to the clear-up immediately following the end of the 1939–45 war.

In most programmes around the world today, manual mine clearance is the “core” activity: the one that employs the most staff, uses the most resources, and clears the most mines. The early UN-sponsored mine action programmes, such as Afghanistan, Cambodia and Mozambique, generally relied on international military expertise to teach processes derived from military mine clearance drills to locally engaged deminers.

1. *Glossary of Mine Action Terms*, IMAS 04.10.

A number of international mine clearance non-governmental organisations (NGOs) also train deminers, often using ex-military expatriate staff.

Since its formation in 1998, the Geneva International Centre for Humanitarian Demining (GICHD) has carried out studies on the use of dogs and mechanical equipment, as well as on many other aspects of mine action. However, until now, no formal study has been undertaken on the fundamental element of mine action—manual mine clearance—although an earlier GICHD study of global operational mine action needs analysed the process of clearance in general and provides a good baseline for further research.²

Problem statement

Manual mine clearance equipment and techniques have evolved over the years by adapting what were basically military skills to the needs of a specialist, largely civilian, activity. But manual clearance is still perceived as slow, repetitive, potentially dangerous and overly expensive, and opinions differ widely on the best ways to conduct clearance operations.

In particular, there are differences of opinion as to the equipment and techniques that should be used. There is therefore scope for closer examination of procedures and techniques to see if improvements can be made to operational efficiency and safety.

At the management level, there are wide variations in the recording of clearance rates (in various soil or vegetation types) and no standardised methodology to calculate the costs and rates of manual mine clearance. Moreover, as Box 1 indicates, there are serious questions as to whether, in some cases, clearance assets are being deployed in the most cost-effective manner.

Box 1. A minefield clearance site in Cambodia

The study team visited a clearance site in Cambodia. The area was marked by a technical survey team as a suspected hazardous area (SHA) and ran from the edge of the main road between Cambodia and Thailand to approximately 10 metres short of the railway line running parallel to the road. The distance between the road and a railway line was approximately 300 metres and the width of the SHA was approximately 700 metres.

A team of 35 personnel had been working on the site for approximately six months and had cleared around 40 per cent of the eastern part of the site and during that time had found some 30 mines. All the mines had been found in a precise straight line leading from the centre of the cleared area out to the edge of the SHA close to the railway line. Clearance was continuing out to the western side of the site and, based on the rate of progress, it was expected that clearance operations would last a further nine months.

It was apparent to the study team and from the results of technical survey that the likelihood of mines being found in the remaining sector of the SHA was minimal. Thus, expensive assets were being used on a site on which the risk of mines being found appeared negligible, while at the same time there were other, high-priority sites waiting for clearance.

2. GICHD (2002).

In sum, although the deminer equipped with a detector and some kind of prodding excavation tool is present in just about every clearance programme throughout the world, to date no systematic international assessment has been conducted on the appropriate management of, and methodologies for, manual clearance. This study aims to fill that gap.

Study objectives

The *Study of Manual Mine Clearance* sets out to clarify some of the basic issues at the heart of the manual mine clearance process. The study examines in detail the drills, techniques, equipment and procedures used for manual mine clearance, and reviews the management of operations. It seeks to define a set of parameters that affect the efficiency of manual mine clearance and to develop a series of benchmarks or planning figures for operations, including clearance rates and costings. It also analyses the issues of risk in relation to both the *process* and the *product* of manual mine clearance.

Study audience

The study has been requested by the United Nations Mine Action Service (UNMAS), located within the Department of Peacekeeping Operations (DPKO), and the findings will be of direct relevance to them. In addition, the study will be of use to mine action operators, national mine clearance bodies (including the military), NGOs, commercial companies and donors.

The conclusions and recommendations will also be of interest to international military forces that have traditionally provided instructors to teach manual mine clearance skills to military and civilian staff in mine-affected countries.

Study methodology

The study brings together a series of assessments and sub-studies of key aspects of manual mine clearance, namely:

1. The history of manual mine clearance;
2. The management of manual mine clearance programmes;
3. Operational systems in manual mine clearance: case studies and experimental trials;
4. Risk assessment and risk management of mined areas; and
5. Manual mine clearance costings and sensitivity analysis.

The study as a whole was managed by Tim Lardner from the Operational Methods Section at the GICHD. Field research for the study was undertaken in Cambodia, Croatia, Iraq, Lebanon, Mozambique, Somaliland, Sudan and Sri Lanka. Input was provided by Nikki Heath, Robert Keeley, Dr Ian McLean, Dr Franco Oboni, Ian Passingham, Dr Rebecca Sargisson and Andy Smith.

To assist the study, a Study Advisory Group (SAG) was established, comprised of mine action programme managers, United Nations mine action agencies, concerned NGOs, commercial mine clearance organisations, donors, and representatives from mine-affected nations. A list of members of the SAG is included in the Annex to this Section.

Finally, the study could not have been undertaken without the significant support from the many mine clearance organisations that supported it, in particular, Accelerated Demining Programme in Mozambique; BACTEC in South Lebanon and the United Kingdom (UK); Bundesanstalt für Materialforschung und -Prüfung (BAM), the Cambodian Mine Action Authority; the Cambodian Mine Action Centre; Cranfield University Humanitarian Resilience Unit; the Croatian Mine Action Centre; Danish Demining Group in Somaliland and Sri Lanka; DOK-ING d.o.o.; European Landmine Solutions; the HALO Trust in Cambodia, Somaliland and the UK; the National Demining Institute, Mozambique; the Lebanese Armed Forces Engineer Regiment; MineTech; Mines Advisory Group (MAG) in Cambodia, Iraq and the UK; the National Demining Office in Lebanon; Norwegian People's Aid (NPA) in Mozambique and Sri Lanka; the Somaliland Mine Action Centre; Qinetiq; the UNDP Mine Action Project in Sri Lanka. and the UN MACC South Lebanon.

The study was funded by contributions from the Governments of Denmark, Finland, Italy and the United Kingdom; their support is gratefully acknowledged.

Layout of the study report

This first section of the study includes an **executive summary** of the complete project, sketches a history of manual mine clearance since the 1939–45 war and the historical legacies that the industry bears and, finally, sets out the main conclusions, findings and recommendations of the study as a whole.

Section 2 addresses the **management** of manual mine clearance operations and organisations. The sub-study on which the chapter is based was conducted over a period of seven months and involved NGOs, commercial companies and military personnel from several countries. The scope of the sub-study includes all aspects of a demining organisation, from the individual deminer through to the headquarters level.

Section 3 sets out the results of an analysis of **operational systems** sub-study into the way clearance organisations carry out their work, and considers whether that work is undertaken in the most effective way possible given the available resources. Following the initial research for this sub-study, comparative trials were undertaken in Mozambique and Sudan to look at the impact of different techniques in different environments.

Section 4 focuses on the assessment and management of **risk**. It considers the level of risk to the deminers while undertaking their work, and then the residual risk to the returning population. Are we clearing every mine? Should we even aim to do so? How does mine clearance compare to other hazardous industries?

Section 5 looks at the **costings** of manual mine clearance, assessing how this links with the risk and management, and how inputs into a programme affect outputs in terms of both costs and productivity. It conducts a sensitivity analysis on different aspects of programme expenditure, and suggests ways to improve efficiency and cost-effectiveness.

Executive summary

The origins of manual mine clearance

Manual mine clearance — the backbone of what is now termed humanitarian demining — finds its origins in the massive clearance operations engaged to address the explosive legacy of the 1939–45 war.

But the genesis of modern humanitarian demining is generally regarded as being in Afghanistan in 1988, around the time of the withdrawal of Soviet forces. The programme's first attempts were well-intentioned but ill-thought-out, foreshadowing some of the challenges that would face all clearance efforts around the world in the years to come.

After the creation of the Afghanistan demining programme came programmes in Cambodia, Angola and Mozambique. Today, there are more than 42 programmes worldwide, assisted by a strong support system within and outside the UN, which has developed a framework of support ranging from the development and implementation of international standards, to technical and logistical support for the implementation of mine action programmes.

Management of manual mine clearance

Organisational management

A number of studies have been conducted on various aspects of the demining community over the past decade. Although demining is an international and multi-million dollar industry, it appears that its culture still encourages a “small-business” approach to management.

The GICHD sub-study on the management of manual mine clearance concluded that the main areas for improvement were not at the individual deminer level, but at middle and senior management levels, where significant wastage of time and resources were observed. These include the management of minefield clearance sites and the decision-making associated with designated areas for clearance.

Apart from a few commercial companies, the sub-study found continuing and clear evidence of poor project management skills, with considerable focus on micro-management. This results in the implementation of *process-driven* rather than *task-focused* management style.

The study notes the military background of the majority of personnel, both international and national, engaged in mine clearance in one capacity or another. It is increasingly understood that **the skills and experience that serving or former soldiers bring to mine action are invaluable in the emergency phase of an operation, but different skills are required in the more developmental-focused period.** What is often missing today is project and programme management experience acquired in the development and/or the commercial sectors, bringing a corresponding drive for efficiency, innovation, creativity and flexibility.

Recruitment

Problems are particularly acute at middle manager level. Although middle managers are ostensibly responsible for running a particular area of responsibility, in many cases they are not equipped with the resources to undertake this task and are often not given the necessary autonomy to do so.

Decision-making needs to be delegated downwards from senior management to middle management for day-to-day issues, such as running a clearance site. However, the middle managers concerned also need to be recruited and trained to be able to take the necessary decisions — and have the support of the senior management in those decisions.

Issues of concern are identified with respect to the recruitment and training of deminers engaged in locating mines and items of UXO, whose work is overseen by middle managers. In particular, manual mine clearance is routine and monotonous, and is often carried out in unpleasant conditions. It requires high levels of motivation for individuals to overcome boredom, to remain alert and to sustain high levels of attention to detail. The employment of ex-military personnel, who are used to living away from home and to more stringent working conditions, may be appropriate. But their motivation may not be suitable for the mundane tasks that continue day-in, day-out. Personality type plays a significant role in the ability to sustain attention, and soldiers recently demobilised after extended time in combat may find such mundane, routine work hard to sustain and therefore tend to lack motivation.

Training

Many organisations have recruited deminers, put them immediately on a salary and sent them on a training course supplied in-house. The average training period is around two to four weeks for completion of a basic demining training course. A recruit seldom fails, even if required standards are not achieved.

Training of deminers on full pay with no standards of entry is generally inappropriate for three reasons: cost, motivation, and the potential for corruption.

In contrast to initial training, refresher training appears not to take place systematically, only on an *ad hoc* basis as and when it is deemed necessary — which appears to be seldom.

Maintaining deminer performance

Many organisations stated that “skill fade” was not an issue as the deminers were doing their task every day. This is a dangerous assumption as each site has different demands and deminers become complacent when working in low-risk areas. **It may be beneficial to provide a short refresher course to all deminers when they start a new site, to raise their awareness of the particular issues relevant to that site.** A number of organisations visited did have refresher training which led towards positive results.

Motivation

In addition to ongoing training requirements, maintaining motivation is of obvious importance. When individuals have no sight of, or feedback on, their performance, and cannot see the benefits or long-term gains, they quickly become disillusioned.

Productivity

The study team found discrepancies at several levels in the quoted figures for square metres cleared. All organisations, without exception, quoted an average clearance rate per deminer of about 50 square metres a day. However, when calculations at individual sites were made on the presented data for total area cleared, divided by days worked, the figures appeared to be closer to 15–20 square metres per deminer per day. This coincided closely with the figures developed during the earlier GICHD study *Mine Action Equipment: A Study of Global Operational Needs*.¹

Combating dehydration

Dehydration has the potential to impact significantly on performance yet is seldom considered. **Greater emphasis should be placed on hydrating deminers, and thermal and physical comfort to aid their performance.** Ways to combat the effects of dehydration include acclimatisation, hydration, loose and lightweight or porous clothing, the application of cold water on skin, air-cooled personal protective equipment (PPE), and drinking water and electrolytes.

Personal protective equipment

The introduction of mandatory PPE has been one of the major safety innovations in recent years. Although PPE plays an important role in protecting the individual, certain factors should be considered when purchasing a particular type, as it can impair performance affecting the wearer in several ways.

For instance, there is an increased risk of error through visual distortion caused by the visor, particularly if it is poorly maintained, scratched or otherwise damaged. **Greater care should therefore be devoted to the storage of facial PPE: ultra-violet (UV) degradation should be kept under control.** PPE also accelerates perspiration and increases the risk of dehydration, which has negative implications on performance.

Broader questions are addressed about the need for, and appropriateness of, PPE. Body protectors are used primarily for **protection** against **fragmentation** rather than blast injuries, which can be best prevented by good lane drills, site management and adherence to the safety procedures in standing operating procedures (SOPs). **The size**

1. GICHD (2002).

and purpose of body protectors should be further examined for effectiveness, and international standards should be reviewed in order to give greater flexibility to operators over which PPE is required and when it should be worn.

Maintaining deminer safety

The role of standards and standing operating procedures (SOPs)

Standards and SOPs are generally believed to have vastly increased deminer safety, as well as the reliability of clearance, in manual mine clearance operations. Although today it is very difficult to extrapolate detailed information on casualties from many programmes, it appears that the average casualty rates for deminers have become much lower in respect of hours worked since 1945.

However, during observations of operational systems of ongoing clearance operations in several countries, the subject of Section 3 of the Study, no demining group was found to be working in complete compliance with their own written SOPs, and some even worked in a manner that was in direct conflict with them.

Clearance methods

The clearance method most likely to involve an accident to the deminer performing it was prodding from the surface of the ground.

The methods most likely to leave mines undetected were *area excavation*, when the required clearance depth was not maintained. Also prone to miss mines were techniques undertaken at *excessive speed*, meaning that deep signals were missed during metal-detector-based clearance.

Clearance drill and lane deployment

The development of clearance techniques has generally been evolutionary. However, in terms of safety, if SOPs are adhered to, the generally accepted clearance techniques do appear to be robust and well proven.

If organisations employ specialist multi-tasked teams, then more downtime is likely. This is particularly the case when clearance sites are spread far and wide, and teams are part of the technical survey team and may be travelling in remote areas. Keeping personnel alert when they are involved with technical survey appears to be harder than if they are dealing with mines on a daily basis.

Working and rest periods

The length of each demining period recommended between rest breaks varies considerably from one organisation to another. **In general, any work requiring sustained concentration benefits from frequent, short breaks.** If, however, the breaks are too long there is a risk of concentration and motivation decreasing.

If workers spend long periods without stimulation between working periods (as in two-man-lane drills) they are more likely to be “out of the loop” when they return to work and will have more frequent lapses and mistakes.

Data gathering

A wide range of issues affect deminer safety. One of the keys to increasing safety is to fully understand why accidents are taking place. There is a need for the demining community to collect, more systematically, data on deminer accidents and injuries. This should build on the work that has already been done in the context of the Database of Deminer Accidents (DDAS), which is being maintained by the GICHD for the UN. In particular, **organisations should collect data related to “casualties per hours worked” and/or “lost hours (because of accidents) per hours worked”**, similar to any other hazardous industry in the world.

Innovative manual clearance techniques

The demining industry is demonstrating a willingness to employ innovative techniques in a number of countries, but some of these techniques were only informally adopted as their use was constrained by written SOPs.

Most innovations were made in order to increase speed, which — cynics might suggest — impresses donors with better clearance figures. For example, several groups reduced the depth of metal-detector search and were prepared to leave small metal indications in the ground.

One of the most effective way of increasing the speed with which suspect land could be released was seen in South Lebanon and Iraq, where the use of post-clearance area reduction (PAR) turned the convention of pre-clearance area reduction upside down and led to a dramatic reduction in the number of square metres cleared for every device found. This appears to work well in relatively predictable situations, such as patterned minefields, but is unlikely to be of significant advantage in more random situations.

Trials were undertaken in south Sudan to test the speculation that there may be alternative innovative techniques that might give more efficient rates of progress for manual mine clearance. Two alternative drills — the “Hybrid” and the “Crab” drill were trialled and a more detailed description of the trials and results are given later in the study. It appears however that the Crab drill does offer some significant advantages by presenting more than one open workface and reducing changeover times between activities.

When clearing land, fragmentation and false alarms are significant contributing factors to clearance rates and costs. Thus, **to improve the efficiency of manual mine clearance using a metal detector, the main area for improvement is the speed with which metal fragments can be identified and removed**. The sub-study assesses the effect of a simple system of magnets on demining efficiency and agrees with a finding of the GICHD *Mine Action Equipment: Study of Global Operational Needs* that, in trials conducted for the study: “... in a heavily fragmented area, the most efficient method of clearance among eight different options was using a metal detector and a magnetic brush-rake.”

Improving the cost-effectiveness of manual mine clearance

Clearance is expensive to undertake but there are very significant differences in quoted costs: these range between US\$0.60 to US\$8.73 per square metre. A number of independent cost-benefit studies have suggested that demining may only be of marginal net benefit unless costs are controlled. This means that the industry should generally develop a clear benchmark of what a deminer should be expected to achieve given a set of criteria, and at what cost.

There is a considerable problem within the demining industry in reporting on areas cleared. Some reports of performance may be considerably overestimated, and confusion abounds between the definitions of areas cleared, reduced and cancelled.

Costings and sensitivity analysis

There is inconsistency within the mine clearance industry on estimating costs. A model that would simulate the costs involved in the operation of a Mine Action Centre (MAC) was used. This "Model MAC" (MMAC) makes a number of assumptions, which are based on real-life examples wherever possible.

To try to determine which elements of the demining process really make a difference to overall costs, the most appropriate economic technique to use was deemed to be sensitivity analysis. Within the specific context of demining, sensitivity analysis can be defined as: *"The measurement of the variation in output of demining processes as a result of variation(s) in inputs, particularly in terms of cost."* Sensitivity analysis is an economic technique that allows programme managers to measure the potential effect of change. It allows users to focus on those items that are likely to make a difference, even when they are not immediately apparent.

Economists use a number of "average" costs: average fixed costs, average variable costs and average total costs, which are measured over the life of a project. The reason for taking an average cost in mine action is that, if an observer looked hard and long enough they would find that every square metre of land took a slightly different amount of resources to clear. However, the capture of such infinitesimal differences is recognised as being more trouble than it is worth. This means that a "total cost per square metre" averaged over an accounting year is probably the most appropriate cost measure in mine clearance, providing that all appropriate factors are included.

This does not allow the calculation of a global, "standard" cost: the sensitivity analysis conducted in this study reveals that, even in one programme, a change in any one of several major factors would result in a significant change in the average total cost of a square metre of land. It would therefore be little use to try to identify any figure that could act as anything more than a very rough estimate in a particular country, and it could be very inappropriate to use the same estimate anywhere else.

Explosives

Explosives are often supplied free by donors. Sensitivity analysis of explosives shows that the provision of free explosives has a very significant effect on price, reducing the

undiscounted price per square metre in a “model” mine clearance programme from US\$1.46 to US\$1.26. This suggests that significant benefits accrue from researching alternative explosive supply methods or other, non-explosive, destruction techniques.

Deminer productivity

The MAC model is also sensitive to changes in productivity: this is because the model is designed to isolate costs accruing to particular activities, and can isolate the effect on the cost of demining of a change in productivity. If clearance productivity for a team increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month per team), there is a 5 per cent decrease in output price.

The future of manual mine clearance: the need for an explicit risk management approach

Sensitivity analysis, although a useful tool, will not address the heart of the challenges that demining faces. The aim of manual mine clearance is the clearance of every mine, and every item of unexploded ordnance (UXO) or abandoned explosive ordnance (AXO), from a given area. So, if a given area of land is declared to have been cleared, then it should, to the best available knowledge, be clear of all explosive ordnance. In this respect, the International Mine Action Standards (IMAS) should remain fixed. Indeed, there are many situations in which such a level of clearance is necessary or is demanded.

But this full clearance standard is not necessarily universally applicable, nor is it by any means universally achieved. For this reason, **the mine action community and its stakeholders need to urgently consider moving to a more explicit risk management approach**, as Section 4 of this Study argues. Moreover, spending months clearing an area and finding no mines — but a lot of pieces of miscellaneous and harmless metal — is a waste of resources, as well as being potentially unrewarding for those engaged in it. Yet, this is exactly what the demining community still does far too often. Area reduction may well form the key to this process, yet is not well understood.

Similarly, in Western Europe a residual risk in areas contaminated by mines and UXO and subsequently released for public use after the 1914–18 and 1939–45 wars persists today. The reality is that mine-affected countries will probably always remain affected to some degree and will always need to apply some level of capacity and resources to the problem. Indeed this Study as a whole argues that **the current “all-or-nothing” approach to manual mine clearance is inappropriate and unsustainable**.

The treatment of land released by methodologies other than the physical processing of land needs to be addressed. Currently, land is declared “clear” only after a physical process is undertaken on it. A process should be implemented that “releases” land which has been determined to have “no known risk” without a formal clearance process. What is important is not to tie up precious resources while lives and limbs are being lost elsewhere.

We have seen how incremental improvements can be made to existing processes for, and management of, manual mine clearance, from the recruitment and treatment of the deminer up through the decision-making chain of command to the senior management level. But the most significant change in demining would be to turn to an

explicit risk management approach for clearance — basing operations and operating procedures on an assessment of the risk and accepting that, even after carefully planned demining interventions, some tolerable degree of risk will still remain. For the mine-affected countries and its people, this would result in greater economic benefit and fewer casualties sooner.

A history of manual mine clearance

Although there is some debate as to when landmines were first used, the general history can be traced with reasonable certainty. Modern landmines are explosive traps, but their lineage derives from non-explosive predecessors such as spikes and stakes used by ancient armies as far back as 2,500 years ago. The four-spiked caltrop, usually made of iron, joined at the centre and arranged so that when thrown on the ground, one spike always points upwards with the other three forming the base, was used as far back as the third century BC and can be closely compared to the present-day landmine in their design and use as a defensive tactic. Caltrops are still used in modern conflicts.

Explosives were introduced at a later stage to make use of their inherent properties in order to improve the destructive capabilities of mines. The earliest explosive-based mines appear to have been used in southern Italy in the 14th century,¹ although these were initiated by a powder trail, which was inherently problematic. In addition, the gunpowder was hygroscopic and therefore could be rendered inert after just a few days, depending upon the weather.

The first pressure-initiated landmine was recorded in 1726 by the German military historian, Freiherr von Flemming, who described the use of a *Fladdermine* (flying mine): *“It consisted of a ceramic container with glass and metal fragments embedded in the clay containing 0.90 kilos of gunpowder, buried at a shallow depth in the glacis of a fortress and actuated by someone stepping on it or touching a low strung wire”*.²

Although noted here in 1726, the concept does not seem to have taken hold until the American Civil War, when Confederate Brigadier-General Gabriel J. Rains ordered his troops to prepare artillery shells so they would explode when stepped on. On 4 May 1862, a Union soldier activated one of these devices close to Confederate lines near Yorktown and gained the dubious epitaph of being the first person recorded to be killed by a landmine.

1. Croll (1998)

2. Flemming, cited in Croll (1998).

Although crude versions of later landmines were used primarily by the German Army on the Western Front in the 1914–18 war (such as buried and “fuzed/timed” artillery shells and pipe mines), the main mining effort was underground — the tunnelling and mining of trench systems in true “sapper” or siege-warfare style. The real evolution in the development of landmines, in the form of both anti-tank and anti-personnel mines, came during the 1939–45 war. It has been claimed that 300 million anti-tank mines were used during that war, with millions more anti-personnel mines being deployed to protect the anti-tank minefields.³

It soon became apparent that anti-personnel mines were much more effective in maiming rather than necessarily killing their victims. This had two distinct advantages as a weapon of war from the user’s viewpoint: the considerable psychological impact on the enemy, and the fact that the severity of the wounds demanded a great deal of treatment and care, thereby putting more strain on the victim’s unit (because of the need for casualty evacuation — CASEVAC) and on the army’s medical services in general. Landmines had the dual “benefit” of both psychological and attritional effects.

By 1945, the United States of America (US) Army recorded that mines had inflicted 2.5 per cent of troop casualties and 20.7 per cent of tank losses.⁴ Within two decades, the US Armed Forces would also discover — to their cost — that landmines, improvised explosive devices (IEDs) and UXO could be a “double-edged sword.” In Korea and Vietnam, US and Australian troops would be confronted by the considerable internal attrition rate and psychological effect of these devices, many of which had been emplaced by their own forces. As an example, mines and booby-traps caused 65–70 per cent of US Marine Corps casualties in Vietnam during 1965, and a significant proportion of these casualties resulted from their own explosive ordnance.⁵ Some 12 per cent of Australian casualties in Viet Nam from May 1967 to the withdrawal in 1971 were caused by their own M16 mines laid in one specific minefield.⁶

It was during this indiscriminate bombing and landmine deployment that the humanitarian tragedy began to unfold. Although the explosives dropped along the Ho Chi Minh trail and the air-delivered mines dropped by the Soviets over the mountains of Afghanistan may have had some effect tactically against the *Viet Cong* and the *Mujahadeen* respectively, the victims were more frequently civilians. When hostilities ceased, civilian casualties mounted rapidly as much of the land in Vietnam, Laos, Afghanistan and Cambodia had not begun to be cleared of landmines. Anti-personnel mines, together with cluster munitions, became the most insidious legacies of the wars, as they were the most liberally scattered and difficult to detect. Worse, being “victim activated” it was civilian workers in the paddy field or children playing in a field who were far more likely to detonate them than were military personnel.

From those beginnings, a global landmine threat has emerged that remains today. There are said to be more than 90 countries and other areas affected by landmines or UXO.⁷ However, classification of the severity of the problem is not straightforward. For example, the UK is on the list because of the mines laid during the Falklands conflict in 1982. Although these have caused no civilian casualties since the conflict, the nation is still categorised as mine-affected.

3. US Defence Intelligence Agency (1992).

4. Croll (1998).

5. US Defence Intelligence Agency (1992).

6. *The Australian*, 13 August 2005.

7. *Landmine Monitor* (2004: 27).

In recent years political progress has helped to address the scale of the problem. Under the terms of the Anti-Personnel Mine Ban Convention, which became international law on 1 March 1999, anti-personnel landmines are now illegal in more than two-thirds of all countries in the world. States Parties “in a position to do so” have pledged to commit resources to mine clearance, mine awareness and the care of and assistance to victims, although the extent of these legal obligations is not specified in the Convention. In addition, the Convention has had an influence on non-States parties, and a number of them also make a significant contribution to mine action.

The challenge of landmine clearance

The first formal process of clearance developed immediately after the end of the 1939–45 war when the huge number of mines that had been laid during the conflict stood in the way of meaningful reconstruction in Europe. The clearance work was based on a pragmatic approach involving the use of the large amount of available manpower, and in many cases the victorious Allies used prisoners of war (POWs) to carry out the work (in possible violation of the 1929 Geneva Conventions).⁸



Figure 1. British Army mine clearance of a road in 1945. Soldiers using their rifles and bayonets to detect mines. This is called the ‘prodding’ method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared.

In France, 49,000 German POWs were employed; in Germany, the allocation of deminers was done through a system of labour units involving POWs (*Dienstgruppen*). Supervised by the occupying armies in Germany, and by the British Army in the UK, these POWs were responsible for clearing millions of landmines.⁹ As an example, in March 1947, 81,000 German POWs were reported as being employed in mine clearance, tree-felling, transport and supply administration.¹⁰

In the Netherlands, a total of 1,162,458 mines were lifted and cleared by the German Engineer *Draeger* Brigade and the Dutch 1st Netherlands Mine Clearing Company (a

8. Following concern about the use of POWs in clearance, Article 52 of the Third Geneva Convention of 1949 specifically prohibits the use of POWs for mine clearance activities unless they are “volunteers”.

9. Some Ukrainian POW assistance was also provided at this time.

10. UK Public Records Office (PRO)/National Archives: Document PREM 3/792 – *Civilianisation of the Dienstgruppen: Report on the activities, organisations and [planned] release of German POWs and Para-Military formations used for Mine Clearance: 1947 to 1948.*

company of locally employed civilians) between the summer of 1944 and the end of 1945. German casualties were “fairly heavy” according to the post-action summary report: of a total of 543 casualties, 162 were killed and 185 were severely wounded from a total of 3,244 men in the Unit. The Dutch Mine Clearing Company suffered 89 casualties, of whom 26 were killed and 42 severely wounded in a similar period.¹¹

Table 1. Estimates of mines cleared and casualties sustained during clearance operations after the 1939–45 War.

| Country/area | Period | Mines cleared (millions) | Deminers killed | Deminers injured | Total | Mines cleared per casualty | Comments |
|----------------------|---------|--------------------------|-----------------|------------------|----------|----------------------------|----------------------------|
| Austria | 1945-75 | 0.046 | 18 | 23 | 41 | 1,122 | — |
| Belgium | 1945-46 | 0.4 | — | — | 286 | 1,398 | — |
| Denmark | 1945-47 | 0.75 | 190 | 250 | 440 | 1,704 | — |
| England | 1944-57 | 0.35 | 155 | 55 | 210 | 1,666 | — |
| Finland | 1945-76 | 0.066 | — | — | — | — | No casualty data available |
| France | 1945 | 13.0 | 2,127 | 3,630 | 5,757 | 2,258 | — |
| Germany | 1945-47 | 0.76 | 108 | 113 | 221 | 3,439 | Op. TAPPET only |
| Guernsey | 1945 | 0.067 | 8 | 14 | 22 | 4,786 | — |
| Netherlands | 1945-46 | 1.162 | 205 | 407 | 613 | 1,762 | — |
| Italy | 1945-46 | 3.0 | — | — | 1,100 | 2,727 | — |
| North Africa | 1943-90 | Est. 1.0 | — | — | Est. 600 | 1,667 | Approximate figures |
| Norway | 1945-47 | 0.75 | 192 | 252 | 444 | 1,689 | — |
| Poland | 1945-56 | 14.76 | 404 | 571 | 975 | 15,138 | Extrapolated figures |
| USSR | 1945-46 | 58.5 | — | — | — | — | No casualty data available |
| Average total | | 94.53 | | | | 3,279 | |

Source: Adapted from Croll (1998).

By 1948, more than 90 per cent of the clearance work in Europe had been completed. The remainder was undertaken at a much slower pace and generally by nationals of their own countries. Much of this clearance was undertaken using simple techniques adapted from the military doctrinal handbooks and experience of that time. The techniques of prodding and using simple metal detectors formed the basis of the processes and, although there were some innovative methodologies introduced, these were complementary to the core manual mine clearance procedures. Once again, the structure of these organisations was based generally on the military structure that many of the managers and implementers had come from and with which they were familiar or experienced.

The number of mines cleared per casualty for the post-war period range between 1,122 and 15,138, but averaged one casualty per 3,279 mines cleared (*Table 1*).¹² The fundamental methodology for manual mine clearance remained largely unchanged for the next 50 years. In terms of casualties, however, it appears that the accident rate has fallen significantly.

11. UK PRO/National Archives Doc WO 205/1186: *Minefield Clearance in Holland*, dated 27 November 1945.

12. Croll (1998).

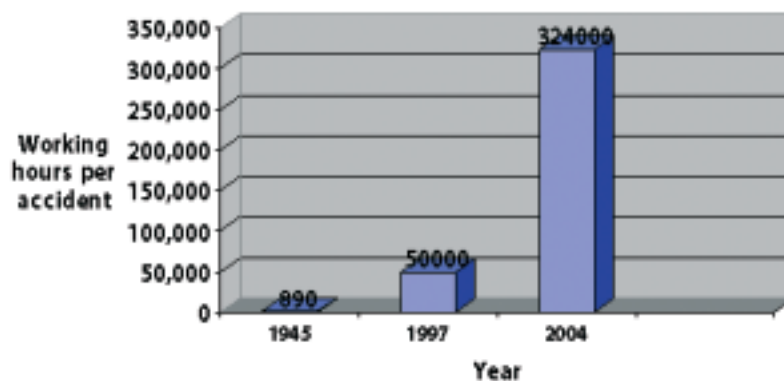


Figure 2. R.E.s (Royal Engineers) searching for mines with mine detectors before a bypass road is constructed around the French village of Douvres-la-Delivrande, 1945.

In the clearance of the Netherlands in 1945 and 1946, some 1.16 million mines were cleared in total. Although the historical data are difficult to interpret reliably, a British Government Report on the mine clearance operation in the Netherlands¹³ outlines the details of an operation undertaken by the German *Draeger* brigade between 12 July and 19 October 1945. It used 279,325 operational man hours of work to clear 450,125 mines. The recorded casualties during the period 5 July to 10 October show 311 casualties among mine clearance personnel. From the evidence available, it appears that this was a fairly typical operation of the time. This means that there was one accident for every 890 man-hours worked.

In comparison, figures used in Section 4, *Risk Assessment and Risk Management of Mined Areas*, indicate that the risk of a deminer having an accident during work has changed significantly: from one per 50,000 working man-hours in 1997 in Afghanistan, to one per 324,000 working man-hours in more recent data from Mozambique. Both of these data sets are limited in terms of the reliability of the data and the sample size, but the underlying trend is indeed clear — that the risks to deminers during operations have reduced significantly in comparison with the immediate post-war years. While the data used in this analysis are specific to situations rather than to the global situation (because of the paucity of data), this general trend can be considered meaningful.

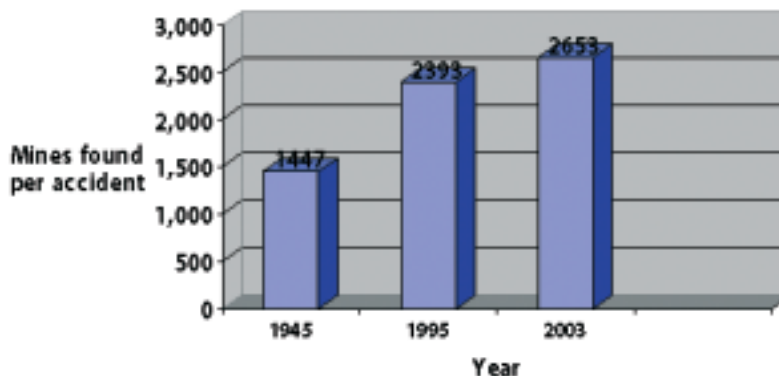
Figure 3. An illustration of the increase in hours worked per casualty during clearance operations



Source: 1945, *Draeger* Brigade, Netherlands; 1997, MAPA (best estimate); 2004, NPA & ADP combined data, Mozambique.

13. UK PRO/National Archives Doc WO 205/1186, *op cit*.

Figure 4. Number of mines found per accident



Source: 1945, *Draeger* Brigade, Netherlands; 1995, UNOCHA Afghanistan Mine Clearance Programme Annual Report; 2003, All Mozambique data.

Evidence of the evolution of manual mine clearance procedures, administration and techniques demonstrates the inevitable links, based on experience, between military manual mine clearance and civilian/humanitarian demining. Six decades ago, POWs and civilians were used or formally employed to assist in the massive task of demining in Italy, Libya and north-west Europe (not to mention the Russian soldiers and civilians on the Eastern Front risking life and limb to clear minefields after the German withdrawal from Russian territory).

Table 2. A comparison of clearance during different periods

| Factor | Post 1939-45 war clearance | Post 1989 clearance |
|-----------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------------------|
| Technology | Most mines having significant metal content. | Many minimum-metal mines used. |
| Laying | Tended towards disciplined armies and good recording. Pattern laid. | Often undisciplined guerrilla forces without record keeping capacities. |
| Risk acceptance | Some risk acceptable. | Perception now that tolerable risk should be extremely low. |
| State structures | Usually undertaken under umbrella of functioning State. | Often begun in stateless or loose administrative States. |
| Time between laying and clearing | Often a matter of months. | Often a matter of decades. |

Having said that, the extant situation in Germany (and indeed the rest of Europe) is entirely manageable. Of the States affected during the 1939-45 war that ended more than 60 years ago some landmines remain, although they have little impact on day-to-day life. This does not mean that there is no need for further operations, merely that the skills and capacity required to deal with the latent threat are small in scale and within the budgets of these States.

For manual mine clearance in the West between 1943 and 1948, although greater risks were acceptable by today's standards, the principle was still to clear 100 per cent of a given area of mines. This is to be contrasted with minefield breaching in

combat, which accepted that only 70–80 per cent would be cleared, and this in only narrow sectors or “lanes” across minefields in order to maintain the momentum of the attack.

The principles in Box 2 for post-conflict manual mine clearance, laid down and applied during the early days of landmine clearance in the mid- to late-1940s, were drawn from wartime documentation reviewed as part of the study¹⁴. What is striking is that so few of the fundamental principles have changed, although they have been refined, revised and reapplied by the military in theatres of combat such as Korea, Vietnam, the Falklands, Kuwait and Lebanon — and, finally and increasingly, for humanitarian purposes from Afghanistan onwards.

Box 2. 1940s principles of demining

1. All activity will take place in “safe” areas, where Allied troops are in full control, (especially in Italy in 1943–44), even though hostilities may be continuing elsewhere, or hostilities have ceased.
2. The type and method of mine clearance will be determined by the nature of the problem.
3. The need is for systematic, 100 per cent clearance of affected land, which generally results in a decision to conduct manual mine clearance.
4. Manual mine clearance is, by nature, slow (and therefore extremely time-consuming), dangerous and expensive, but is believed to be the only guaranteed method of 100 per cent clearance.^{a)}
5. For the purposes of non-military manual mine clearance, training and supervision of the locally employed force will be by experienced US Engineer/UK Sapper or equivalent unit personnel. However, locally employed demining personnel will select team or group leaders, who will be given more specialised training. (As Public Records Office/National Archive documentation underscores, German POWs had a proportion of experienced combat engineers who were already trained in mine clearance and who were particularly familiar with their own and Allied landmines and their usage.)
6. Regardless of political or higher-military-authority pressure to complete clearance operations in the swiftest practical time, all mine clearance activity will take place in daylight hours (there being no tactical requirement for night operations).
7. Casualty rates among manual mine clearance personnel are to be kept to a minimum by first-class training, teamwork (usually a clearance “pair” with a more experienced supervisor for each clearance lane) and good immediate medical support on site and full medical facilities within easy distance for CASEVAC.

a) Despite this laudable principle, few experts or commentators on manual mine clearance would unequivocally declare that 100 per cent clearance rates are always possible — for a multitude of reasons.

Historically, these principles represent “best practice” for manual mine clearance and have been observed in both military and civilian circles (including among POWs) since the latter part of the 1939-45 war.

14. Drawn from UK PRO National Archives document reference WO 205/801, *Disposal of Allied Unexploded Bombs*.

Moving into formal “humanitarian” demining

The more recent platform for the humanitarian¹⁵ sector came from action in Afghanistan in the late 1980s. Following the withdrawal of the Soviet troops from Afghanistan in February 1989, it was realised that the country faced a huge problem from the presence of landmines. Initially, military personnel trained Afghans who had been displaced to Pakistan in clearance techniques to help the process of mine eradication in Afghanistan. The techniques taught were based firmly on the procedures used by the Western Allies to clear Europe in the 1940s. Then, before and during *Operation Salam*,¹⁶ serving military trainers¹⁷ developed a formal training programme for Afghans. This was the foundation of what is now the largest mine clearance programme in the world, the Mine Action Programme for Afghanistan (MAPA).

In 1989, the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) in Afghanistan planned to train 15,000 Afghans in basic manual mine clearance. Although the plan was rather naïvely produced, given a general lack of knowledge of how to deal with such an issue, it did have the merit of being the first serious attempt to carry out and run a humanitarian mine clearance programme.

The initial plan was for various military contingents to train large numbers of community deminers in Afghanistan, with a view to the Afghan trainees then working as unpaid volunteers to demine areas around their own villages. These deminers would receive an attendance allowance during the short training period but once training was completed no salary was to be paid. No protective equipment or material was supplied other than a prod and explosives for mine destruction. Explosives and detonators would be replenished if and when the deminers returned to the demining training facilities in Pakistan. At the same time, MAG and the HALO Trust were setting up small-scale programmes to attempt to survey or clear specific areas in Afghanistan.



Figure 5. Mine clearance in Afghanistan in 1992.

This approach to clearance relied heavily on persuading volunteers that minefield clearance would be a continuation of the *Jihad* (holy war) against the Soviet forces, which by then had withdrawn from the country. Many thousands of deminers were trained,¹⁸ but the programme quickly ran into a number of problems. Military

15. Of course, in addition to humanitarian demining, manual mine clearance is also carried out for reconstruction, development and commercial purposes.

16. *Operation Salam* was the UN programme set up to assist refugee return and the rehabilitation of Afghanistan following the Soviet withdrawal in February 1989.

17. From countries including Australia, Canada, New Zealand, Norway, the UK and the US. Pakistan provided training and support.

18. The exact figure is not known although the operations manager of one Afghan NGO, OMAR, suggests that it was around 12,000.

contingents were not allowed into Afghanistan to oversee activities; there was no prioritisation, survey or record keeping, and thus no clear picture of what was being done. For the deminers, the lack of enforcement of SOPs and the absence of protective equipment and medical support made the job extremely dangerous. Although no reliable information is available on the casualty rate, anecdotal evidence suggests that this was very high.

Following a number of reviews, the UN changed the concept and oversaw the establishment of specialist Afghan NGOs so that demining work could be done on a more organised and controlled basis. In the absence of a recognised government, the UN provided the central coordination, training, quality assurance and funding, while the NGOs undertook clearance, survey or mine awareness projects in regions of the country assigned to them. Emphasis was placed on the standardisation of procedures, techniques and equipment, and priority setting was mainly driven by predicted refugee return.

Over the next decade or so, the Afghan programme grew to become the biggest mine action programme in the world and currently employs around 8,000 Afghan staff with a budget in the Afghan financial year 2004–05 of more than US\$97 million. The MAPA coordinates all mine action activities in Afghanistan and is beginning a process of planning for a full transfer of responsibility for coordination of national mine action activities, primarily manual clearance assets, but also including dogs and mechanical equipments to the Government of Afghanistan.

Kuwait

In 1991, following liberation from Iraqi occupation, the oil-rich State funded a huge mine and UXO clearance operation resulting from the conflict. Around US\$700 million of Kuwaiti reconstruction money was allocated to commercial organisations from the US, UK and France (many of which were set up specifically for the operation) as well as troops from Bangladesh, Egypt, Pakistan and Turkey on a semi-commercial basis, to clear the debris of the war.

Many mistakes were made and many deminers' lives were lost in the ensuing operation. This was perhaps the catalyst for significant developments in manual mine clearance operations, and many of the basic tenets of manual mine clearance came into being during this period, particularly on the commercial side.

In the aftermath of the Coalition conflict with Iraq, many retired military specialists and an equal number of then-serving military personnel left their armies to work as mine clearance contractors in Kuwait, with the incentive of extremely high salaries. Kuwait was the first operation where commercial organisations were formed specifically for the purposes of mine clearance.



Figure 6. Mine clearance in Kuwait in 1991.

Unfortunately, in this unsavoury “free-for-all”, inexperience and poor management exacerbated by commercial secrecy and competition often overrode common sense and best practice in manual mine clearance. As a result, the accident rates in clearance operations in Kuwait were very high. Nevertheless, the more enlightened organisations realised that there were important moral issues involved, not just in Kuwait, but also across the many other countries affected, and in recent years international standards (*Box 3*) have been developed to bring some regulation into what had previously been an unregulated industry.

Beyond Kuwait

After the creation of the Afghanistan humanitarian demining programme came Cambodia, Mozambique, Angola and many others. Each of these operations was established in a broadly similar manner, but with limited lessons being passed on between programmes. There were two distinct groups of expatriate advisers and operators who worked in the industry at this stage. First, serving military personnel from Western armed forces were operating sometimes within, sometimes outside, the scope of UN peacekeeping operations. The second group was made up of former and serving military personnel typically working for NGOs.

Teams were organised and structured in the manner of the military, even to the extent that some teams were called “platoons” and “sections”: deminers were issued uniforms and instructed to parade in formation at the beginning of each day. This ethos was developed because there was a belief that military discipline was the bedrock of an efficient and safe organisation. There were no benchmarks at this time and nothing against which to compare the operations.

This expansion in capacity was additionally supported by the growth of a number of specialist NGOs who provided mine clearance in parallel with the UN operations. MAG, NPA and HALO Trust were at the forefront of this rapid expansion.

The industry has rapidly professionalised and probably the most significant development has been the production and expansion of international standards (*Box 3*). In 1997, a group of NGOs and UN staff developed the first set of international standards which, although with hindsight flawed, paved the way for further development of what is now the accepted norm of International Mine Action Standards (IMAS). IMAS today provides a comprehensive framework of standards to assist the wider community, in particular to help countries develop their own national standards.

In 1998, the GICHD was established as an initiative of the Swiss government, with the aim to support the fight against anti-personnel mines by seeking practical and concrete solutions to the problems posed by landmines and UXO.¹⁹ The GICHD has subsequently developed into a independent and neutral resource centre for mine action internationally, and is now financed by more than 20 countries. It is active in research, operational assistance and supports the implementation of the Anti-Personnel Mine Ban Convention.

For the first five to ten years of mine action after 1988, continuity in encouraging and executing demining programmes came from the management, administration,

19. Fact Sheet, Secrétariat Général du DMF Politique de Sécurité et Politique Militaire, Bern, 4 September 1997.

supervision and training by individuals and groups with a strong military background. Indeed, given the historical precedents, it is likely that many key personnel working in the mine clearance industry will continue to be former military.

Box 3. The development of international standards for mine action

International standards for humanitarian mine clearance programmes were first proposed by working groups at an international technical conference held in Denmark, in July 1996. Criteria were prescribed for all aspects of mine clearance, standards were recommended and a new universal definition of “clearance” was agreed. In late 1996, the principles proposed in Denmark were developed by a UN-led working group and the *International Standards for Humanitarian Mine Clearance Operations* were developed. A first edition was issued by the UN Mine Action Service (UNMAS) in March 1997. The scope of these original standards has since been expanded to include the other components of mine action and to reflect changes to operational procedures, practices and norms. The standards were re-developed and renamed as *International Mine Action Standards (IMAS)*.

The United Nations has a general responsibility for enabling and encouraging the effective management of mine action programmes, including the development and maintenance of standards. UNMAS, therefore, is the office within the United Nations responsible for the development and maintenance of IMAS. The IMAS are produced with the assistance of the GICHD.

The work of preparing, reviewing and revising IMAS is conducted by technical committees, with the support of international, governmental and non-governmental organisations. The latest version of each standard, together with information on the work of the technical committees, can be found at www.mineactionstandards.org. The IMAS are evolving documents which are progressively reviewed to reflect general changes and developments in the implementation of mine action activities and to incorporate changes to international regulations and requirements.

The International Mine Action Standards follow the internationally accepted ISO format and build up a series of individual “standards” that aim to cover the scope of mine action. IMAS illustrate and specify best practice and are available for use and application to fit individual programme situations.

The principles of the past “best practice” of humanitarian manual mine clearance should continue to stand the test of time for the very reason that they have their roots firmly planted in the experiences of the 1939–45 war, and the bridge between military and non-military approaches to the solution of the worldwide mine clearance problem. Although society has evolved significantly since 1945, within mine action, little appears to have changed and the problems we are dealing with today are very similar to those encountered two generations ago. The current principles of most clearance organisations have been significantly influenced by the military legacies endowed to them.

There are some form of coordination and planning bodies in place in 42 mine-affected countries.²⁰ The mine action community has developed into a largely competent body of professionals, “operating in around 65 countries and seven non-recognised States”,²¹ with resources of more than US\$250 million a year.

20. Landmine Monitor (2004).

21. *ibid.*

Main study conclusions and recommendations

Conclusion 1

Manual mine clearance has been undertaken in various forms since at least the end of the 1939–45 war. Based on the data available, the level of injuries to mine clearance personnel has decreased significantly since that period.

Findings

Manual mine clearance is routine and monotonous and is often carried out in unpleasant conditions. It requires high levels of internal motivation for individuals to overcome boredom, to remain alert and to sustain high levels of attention to detail.

Today, many organisations recruit deminers, put them immediately on a salary and send them on a training course supplied in-house. The average period is around two to four weeks for completion of demining training. A recruit seldom fails, even if standards are not achieved.

In contrast to initial training, refresher training appears not to take place systematically, often only on an *ad hoc* basis as and when it is deemed necessary — which appears to be seldom. Many organisations stated that “skill fade” was not an issue as the deminers were doing their task every day. This is a dangerous assumption as each site has different demands and deminers become complacent when working in low-risk areas.

The length of each demining period recommended between rest breaks varies considerably from one organisation to another. In general, any work requiring sustained concentration benefits from frequent, short breaks. If, however, the breaks are too long there is a risk of concentration and motivation decreasing. If deminers spend long periods without stimulation between working periods (as in “two-man-lane” drills) they are more likely to be “out of the loop” when they return to work and will have more frequent mistakes.

Deminers are usually only operational for five hours per day and many organisations stipulate this. At the individual deminer level, it appears that dehydration is a significant factor in the performance and safety of the individual deminer and managers should be aware of rehydration for their deminers.

A wide range of issues affect deminer safety. One of the keys to increasing safety is to fully understand why accidents are taking place. There is a need for the mine action community to collect, more systematically, data on deminer accidents and injuries. This should build on the work that has already been done in the context of the Database of Demining Accidents, which is being maintained by the GICHD for the UN. In particular, organisations should collect data related to “casualties per hours worked” and/or “lost hours per hours worked”, in a similar way to any other hazardous industry in the world.

Although today it is still very difficult to extrapolate detailed information on casualties from many programmes, it appears that the average casualty rates for deminers have decreased since the 1940s. Casualty rates for deminers per hour worked in 1945 were at one accident per 890 hours worked and more recently, in 2004, in two well established programmes, was assessed to be in the region of one accident per 324,000 operating hours. This figure is marginally lower than the forestry industry rates in the US.

Recommendation 1

- a. Criteria for selection of staff need to be established and the practice of full salary payment during training should be re-considered by management.***
- b. Operators should actively consider providing a short refresher course to all deminers when they start working at a new site, to raise their awareness of the particular issues relevant to that site.***
- c. Greater emphasis should be placed on rehydrating deminers, and providing thermal and physical comfort to aid their performance.***
- d. Deminer accident reporting needs to be improved and formalised. Deminer accident reporting may benefit from being centralised. The DDAS is a good basis for such centralised reporting, but should be accorded more attention so that lessons from accidents can be learned and mistakes corrected.***

Conclusion 2

Manual mine clearance appears not to be as dangerous a profession as it is often perceived to be.

Findings

Since the first “serious” manual mine clearance operations were undertaken towards the end of the 1939–45 war, significant improvements have been made in the safety of the mine clearance profession. From the early days, where mine clearance was an extremely high risk occupation, the industry today has developed into one where it appears, given the limited amount of data available to analyse, to be as safe, or safer, than many other comparable industries. If data were to be collected more rigorously, this could well be used to further improve safety for workers. Small policy changes can have significant impacts on the risk workers are exposed to. For example, if malaria is prevalent, a realistic risk reduction measure would be to provide nets for all workers.

Recommendation 2

- a. Data should be collected in a more standard, thorough and rigorous manner in order to undertake a more effective risk reduction analysis. This data should include working hours, and open and honest accident reporting from all organisations.***

- b. Detailed discussions should be held with insurers to explain the relative risks of mine clearance activities to attempt to reduce premiums.*
- c. Managers should consider the inclusion of a risk management policy as an integral part of their management tools and processes.*

Conclusion 3

The International Mine Action Standards requirements for personal protective equipment (PPE) is not always appropriate to the protective needs of the deminers. Current IMAS do not allow operators sufficient flexibility in the use of personal protective equipment. In addition, current IMAS are too prescriptive in the definitions of safety distances.

Findings

The introduction of mandatory personal protective equipment has been one of the major safety innovations in recent years. Although PPE plays an important role in the protection of the individual, certain factors should be considered when purchasing a particular type, as it can have a negative influence on performance, and the wearer can be affected in several ways.

For instance, there is an increased risk of error through visual distortion caused by the visor, particularly if it is poorly maintained, scratched or otherwise damaged.

The advisory default safety distance of 25 metres between deminers is not always applied — with good reasons. But the risk assessment required in IMAS 09.20 is often not carried out, and when it is, it tends to be done in an informal manner.

Recommendation 3

- a. There is a good case for downgrading PPE requirements and giving operators more flexibility not to use some or all PPE as and when appropriate. The PPE and safety distance requirements laid down by IMAS should be reviewed.*
- b. Greater care should be devoted to the storage of facial PPE: it should be stored with care in order to avoid deformations, and UV degradation should be kept under control.*

Conclusion 4

Improved management of manual mine clearance operations could lead to significant gains in productivity. Although perceived by some to have reached maturity and an optimal point of development, this appears not to be the case.

Findings

The Section on the management of manual mine clearance found, apart from a few commercial companies, continuing and clear evidence of poor project management skills, with considerable focus on micro-management. Decision making processes and capacity are also weak. This results in the implementation of a *process-driven* rather than *task-focused* management style.

The majority of personnel engaged in mine clearance have a military background in one capacity or another. It is increasingly understood that the skills and experience that serving or former soldiers bring to mine action are invaluable, but other skills are also required in the development phase. What is often missing today is project and

programme management experience acquired in the development and/or commercial sectors, bringing a corresponding drive for efficiency, innovation, creativity, and flexibility.

Problems are particularly acute at middle manager level. Although middle managers are ostensibly responsibly for running and managing their particular area of responsibility, in many cases they are not equipped with the resources to undertake this task and are often not given the necessary autonomy.

Recommendation 4

- a. Manual mine clearance organisations need to move towards a task-focused management style. One way to achieve this is by bringing in project and programme management experience acquired in the development and/or commercial sectors.**
- b. In all cases, decision-making needs to be delegated downwards and away from senior management to middle management for day-to-day issues, such as running a mine clearance site. At the same time, middle managers need to be recruited and trained to be able to take the necessary decisions as well as having the support of the senior management in those decisions.**
- c. Donors should assist NGOs to be more proactive in their resource planning by offering longer term funding.**

Conclusion 5

Average rates of clearance appear to be in the region of 15 to 20 square metres per deminer per day.

Findings

Although the feedback from many operators on the ground suggested that they believed they were clearing much higher rates, on the evidence of the data gathered and after consultation with several well-documented mine action programmes, the rates for manual mine clearance (as opposed to area reduction, technical survey, battlefield area clearance, etc.), were close to the figures identified in the GICHD study *Mine Action Equipment: A Study of Global Operational Needs*, which were generally less than half of the rates quoted by organisations.

The most effective work is produced from a deminer when he/she is taking frequent short breaks and operating with comfortable PPE, when and where appropriate.

Recommendation 5

- a. Programmes should be more vigilant about effectively recording clearance rates and develop a series of benchmarks to work to.**
- b. Discomfort is inevitable in harsh climates, but can be ameliorated by well-designed PPE. Managers should consider this when purchasing PPE.**
- c. SOPs should be developed to ensure working deminers take frequent short breaks and field management should ensure deminers are maintaining hydration.**

Conclusion 6

Observation of ongoing clearance operations suggest that parts of the mine clearance industry is demonstrating a willingness to employ innovative techniques in a number of

countries. But some of these techniques were only informally adopted as their use was constrained by written Standing Operating Procedures.

Findings

The development of clearance techniques has generally been evolutionary. However, in terms of safety, if SOPs are adhered to, the generally accepted clearance techniques do appear to be robust and well proven.

Research conducted for the study found that most mine clearance programmes included innovative advances, some of which had been adopted only informally. Indeed, the fact that a number of these advances involved procedures that fell outside the perceived or stated requirements of national and international standards led a number of operators to call for revision of the standards to incorporate the flexibility required by an emergent discipline.

Most innovations in manual mine clearance techniques are made in order to increase speed. For example, several groups reduced the depth of metal-detector search and were prepared to leave small metal indications in the ground. Procedures for incorporating innovative procedures into SOPs and having them improved by the national authorities were not streamlined, and were often ignored.

The approach to quality management activities varies between organisations but is generally conducted in-house, as external assessors are few and far between. Within clearance organisations, supervisors seem to be more subject to accidents than deminers. Key to understanding the nature and application of an innovative procedure is a clear description of the situation in which it is being used. For example, formalising the process of reducing areas originally suspected of being mined after the clearance of *known* mines has proven to be very effective in patterned minefields. The follow-up procedure described in Iraq of having a team visually inspect areas after post-clearance area reduction is likely to be perceived as too hazardous in many situations. However, the procedure is acceptable when an appropriate risk assessment has been undertaken.

When clearing land, fragmentation and false alarms are significant contributing factors to clearance rates. Thus, to improve the efficiency of manual mine clearance, the main area for improvement is the speed with which metal fragments can be identified and removed. Indeed, in trials conducted for the purposes of the study, it was found that in a heavily fragmented area the most efficient method of clearance among eight different options was using a metal detector and a magnetic brush-rake.

Recommendation 6

a. Local innovation in mine clearance techniques should be actively encouraged, not discouraged, as long as deminer safety is not put at unnecessary risk. This innovation needs to be rigorously trialled and documented and implementation should only follow careful assessment of the results of such trials. Where this requires changes to national standards or organisational Standing Operating Procedures, such changes should be countenanced.

b. Mine clearance agencies do not routinely have personnel with the skills needed to design and undertake carefully controlled trials. Support from organisations such as the International Test and Evaluation Programme (ITEP) and the GICHD can and should be requested as a part of the trial process.

c. The results of trials of innovative techniques are a valuable resource for the mine clearance community, even if the trials are a failure. Results of trials should be made widely available, for example through placing trial reports onto websites and reporting them at workshops and conferences.

d. There is a need to streamline the approval process for innovative techniques, including developing procedures for having them written into SOPs.

Conclusion 7

The use of magnets and brush rakes as additional tools to the standard manual mine clearance “toolbox” will increase manual mine clearance efficiency in many circumstances.

Findings

Trials undertaken in Mozambique supported operational experience in several countries, that simple magnets and brush rakes can increase rates of clearance. Most mine clearance is undertaken using simple tools, and any opportunity to add a new simple (and cheap) tool to the toolbox should be widely encouraged. In Sri Lanka, one mine clearance organisation eventually rejected metal detectors in preference for a procedure using rakes.

Recommendation 7

a. Mine clearance programmes should be less bound by tradition and consider the integration of “non-standard” tools in order to improve clearance rates in manual mine clearance programmes.

b. Integration of these tools should initially be tempered with a robust full quality management system to ensure safe clearance methodologies.

Conclusion 8

The methods most likely to leave mines behind or lead to accidents are:

- Area excavation in which the required clearance depth was not rigorously maintained;
- Use of metal detectors that are only marginally able to do the required task, because of either design or age; and
- Prodding from the surface.

Findings

All mines missed in the Mozambique trials were buried at a depth of 12 centimetres. Two of the procedures using metal detectors missed mines because of a combination of search speed and the use of metal detectors inadequate for the task. Metal detectors appear to have a four-year lifespan when used regularly. Recent trials of metal detectors suggest that they routinely do not achieve stated manufacturers’ specifications. Mines were also missed using an excavation technique that was not being applied rigorously to the required depth standard. Prodding from the surface could not supply the required detection depth, especially in hard soils.

Recommendation 8

a. Mine clearance agencies presumably only use metal detectors that are inadequate to a task because they have no other options. Regular replacement of metal detectors should be a part of budget planning. Also, metal detectors that are functional in one deployment location may not be

adequate in another. Sponsors need to be made more aware of the limitations of metal detectors and the replacement requirements.

b. Use of prodding from the surface as a standard mine clearance procedure should be reviewed, with a view to minimising use of this potentially dangerous and limited tool.

Conclusion 9

Established procedures tend to become self-maintaining as a result of training and experience, building in extra resistance to change. Mine clearance agencies have little opportunity to compare notes and discuss alternative options. Field managers are in a difficult situation: on one side they are required to adhere rigorously to established procedures (laid down in an approved SOP) yet, on the other side, as a result of experience they can often see options for improving productivity without compromising safety. Although some lag is expected between innovation and the development of SOPs, the evidence in the case studies was that updating of SOPs was viewed as a difficult and low priority task.

Findings

Trials in south Sudan and Mozambique clearly identified opportunities for improving procedures and equipment. Any agency adopting new procedures or equipment will need to do small trials and training, make adjustments as a result of local conditions, and modify and rewrite SOPs. However, the benefits to be gained in terms of productivity appear to be much more significant than the costs involved in making changes.

In all of the case studies, SOPs were found to be out of date or in need of work. There was little motivation to improve them, presumably because this was not seen as a priority at a management level. SOPs are often too rigid and inflexible which prevents innovations and potentially useful changes. SOP changes often require approval from national authorities which may be a bureaucratic and time-consuming process. SOPs should thus allow minor changes without the need to consult mine action authorities on every occasion.

Recommendation 8

a. Current manual mine clearance techniques, although appearing to exist as a result of long experience and trials, can be challenged to achieve a higher degree of efficiency. Trials in this study suggest a significant potential productivity gain. Field managers should investigate the potential for increased clearance rates by carrying out trials and implementing change if appropriate.

b. Field managers and technical advisers should have the opportunity to meet and exchange ideas in a workshop format on a regular basis.

c. Support for trials and modifications should be made available by the wider community in order to assist implementation.

d. Updating SOPs needs to be given a higher priority in order to ensure ongoing compliance with national standards and IMAS. Support from external agencies may be required to ensure that such updating proceeds regularly. National agencies should be more proactive on this issue, perhaps through providing an updating support service.

e. SOPs should be written in less rigid forms which will facilitate a less bureaucratic process of making changes to them.

Conclusion 10

Standard manual mine clearance drills appear to be implemented in a similar fashion in most countries. This is in part due to a perception that the technique is too well proven to be challenged. Two experimental drills show that it is possible to significantly increase the speed of manual mine clearance by adopting an approach allowing multiple working faces to be open at the same time.

Findings

The Hybrid and Crab techniques both proved more efficient than the standard manual mine clearance drills during the trials in Sudan. This appears to be because the technique opens up more operating faces and reduces changeover times. In wet soils, the difference between the Crab and Standard drills were significant, which suggests that the Crab drill may be used permanently both during wet and dry conditions (provided there is a requirement for vegetation cutting). Dry soil conditions where watering is required amplifies this difference significantly. Programme managers should realise that the standard drills do provide inbuilt security and safety measures, whereas Hybrid and Crab drills will need extra procedures introduced to achieve the same levels of security.

The Crab drill is particularly promising and appears to be 30 per cent more effective in wet conditions. In dry soil, however, the potential gain is significantly higher. This technique, or variations of it based around the principle of minimising the time for tool handling, vegetation cutting and watering/soak time, is worth considering by field managers.

Recommendation 10

The Hybrid and Crab techniques should be considered as alternatives or substitutes for the traditional manual mine clearance techniques as they may offer a significant increase in clearance efficiency during most conditions.

Conclusion 11

Modelling the costings of mine action programmes can provide managers with guidance on where expenditure is best used within a programme.

Findings

The link between expenditure in a programme and cost per square metre of clear land might be expected to be directly linked, but in many circumstances, this is not the case. For example, a manager would probably assume that increasing productivity will decrease the cost of the output per square metre (i.e. of cleared land). However, the implications of purchasing more expensive equipment — for example PPE — may well not result in a proportionate decrease in the output costs. If the programme manager takes the time and effort to understand the relationship between the inputs and outputs, it may well provide a clearer indication of the benefits that may be obtained from more efficient expenditure.

Recommendation 11

a. Programme managers should attempt to understand in more detail the relationship between inputs and outputs into their programmes.

Conclusion 12

Manual mine clearance is the most prevalent — and costly — component of mine action. It also appears that there is a considerable problem within the mine clearance industry in reporting on areas cleared.

Findings

Multi-skilled deminers who are on site appear to be a more practical and time-efficient approach. Incentives, such as pay increases and bonuses for conducting successful EOD tasks, may be a useful means of persuading deminers to become multi-skilled. To determine which elements of the mine clearance process really make a difference to overall costs, an appropriate economic technique is sensitivity analysis. Sensitivity analysis on the impact of various costs and overheads on the price of clearance per square metre of land has found that:

- A 75 per cent reduction in **vehicle** purchase price (i.e. a reduction from a new price of US\$20,000 to a used price of US\$5,000) only leads to a US\$0.05 reduction in the undiscounted price of clearance per square metre, even though there is a huge reduction in initial costs. This indicates that, given such issues as reliability and warranties, it may not be appropriate if a programme has sufficient cash flow, to buy second-hand vehicles.
- A 50 per cent reduction in **battery** usage rate reduces the undiscounted output price by US\$0.03 per square metre. This suggests that there is a case for encouraging the adoption of either cost-effective battery charging systems or reducing the electricity consumption of mine detectors.
- **Medics** (if employed solely as such) can be regarded as “overheads” in mine clearance, and, like the provision of PPE, are a fixed cost of meeting safety regulations. Removing the medic from the platoon organisation chart results in a significant reduction in price, from US\$1.46 to US\$1.44. Some organisations are attempting to overcome this problem by adding “dual-role” medics: individuals who operate normally as deminers, but in the event of an accident, step in as a medic. With enough of these dual-role medics, an IMAS-compliant operation can still be undertaken and cost-effectiveness will be significantly increased.
- If **deminer productivity** increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month per team), there is a 5 per cent decrease in output price.

Recommendation 12

a. If mine clearance is to prove cost-effective, costs need to be carefully controlled. The use of sensitivity analysis can be an important element in efforts to control operational costs.

b. Performance must be reported accurately and honestly, if confidence in the mine clearance industry is to be maintained: exaggerated clearance statistics are wholly unacceptable.

Conclusion 13

Most land cleared contains no explosive ordnance. The current “all-or-nothing” approach to manual mine clearance is inappropriate and unsustainable.

Findings

Mine clearance is still largely “input driven” rather than “output driven”, i.e. it is based around the money available, rather than an assessment of how much is needed to reduce risk in a given area to an “tolerable” level. However, it needs to be recognised

that there are practical difficulties in establishing a contractual mechanism that allows an organisation to clear to lower standards, without allowing less scrupulous organisations to take advantage of the situation.

The aim of manual mine clearance is the clearance of every mine and every item of unexploded or abandoned explosive ordnance from a given area. So, if a given area of land is declared to have been cleared, then it should, to the best available knowledge, be clear of all explosive ordnance. In this respect, IMAS 09.20 should remain fixed. Indeed, there are many situations in which such an absolute level of clearance is necessary or is demanded.

But this full clearance standard is not necessarily universally applicable, nor is it by any means universally achieved. For this reason, the mine action community and its stakeholders need to urgently consider moving to a more explicit risk management approach. Moreover, spending months clearing an area and finding no mines — but a lot of pieces of miscellaneous and harmless metal — is a waste of resources, as well as being unsatisfying for those engaged in it. Yet, this is exactly what the mine clearance community still does far too often.

Area reduction may well form the key to this process, yet is typically misunderstood. Area reduction is defined within the IMAS but there is no agreement on how it is best conducted. There is an urgent need to identify appropriate methodologies for quickly and efficiently focusing the scarce manual mine clearance resources on those areas where they are truly needed. Technical survey is not well defined.

Recommendation 13

- a. The mine clearance community should move explicitly towards a risk-management approach to addressing explosive ordnance contamination and impact. In doing so, a new standard for the treatment of land contaminated by explosive ordnance should be considered – “released land”. The type of approach to such “area risk reduction” will depend on the context, including the views of the different stakeholders.***
- b. Further research should be undertaken into the appropriate methodologies for conducting area reduction and technical survey.***
- c. The depth at which mines are located should be recorded systematically. This has never been done, but would provide valuable information in order to development a professional risk management approach.***

Conclusion 14

Cost benefit analysis as part of the risk management process may provide a useful tool for making the best use of limited resources.

Findings

There may be merit in considering a “less than perfect” clearance option. The model proposed in Section 4 is just that — a model — but the concept needs to be carefully considered by the community and a clearer model for “tolerable risk” needs to be defined. Data collection is key to allow informed decisions to be made about where and how to approach mine clearance tasks.

Recommendation 14

- a. Data collection should be standardised and improved to allow clearer oversight of cost-benefit issues related to mine clearance. This data should enable detailed analysis of the costs of the land cleared to be drawn.*
- b. A discussion should be initiated in the community about a more realistic approach, in terms of the acceptance of land that may not be completely "cleared" of mines and UXO.*
- c. Terms such as "cleared land", "released land", "mine-free" and "impact-free" need to be more clearly defined.*

Members of the Study Advisory Group

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Glossary of abbreviations and acronyms

| | |
|------------|-----------------------------------------------------------------|
| ADP | Accelerated Demining Programme (Mozambique) |
| APMBC | Anti-Personnel Mine Ban Convention |
| AREA | Agency for Rehabilitation and Energy Conservation (Afghanistan) |
| AXO | abandoned explosive ordnance |
| BAC | battle area clearance |
| BAM | Bundesanstalt für Materialforschung und -Prüfung |
| CASEVAC | casualty evacuation |
| CBA | cost-benefit analysis |
| CBU | cluster bomb unit |
| CCW | Convention on Certain Conventional Weapons |
| CMAA | Cambodian Mine Action and Victim Assistance Authority |
| CMAC | Cambodian Mine Action Centre |
| CROMAC | Croatian Mine Action Centre |
| DDAS | Database of Demining Accidents |
| DDG | Danish Demining Group |
| DPKO | Department of Peacekeeping Operations (UN) |
| EO | explosive ordnance |
| EOD | explosive ordnance disposal |
| FCDB | full costs of doing business |
| FSD | Swiss Foundation for Mine Action |
| GICHD | Geneva International Centre for Humanitarian Demining |
| GRH | Ground Reference Height |
| HALO Trust | Hazardous Areas Life-Support Organization |
| HDU | Humanitarian Demining Unit |
| IED | improvised explosive device |
| IMAS | International Mine Action Standards |
| IND | National Demining Institute (Mozambique) |
| ISO | International Standardization Organization |
| KFOR | Kosovo Protection Force |
| LIS | Landmine Impact Survey |
| LTTE | Liberation Tigers of Tamil Eelam |
| MAC | mine action centre |
| MAG | Mines Advisory Group |

| | |
|--------|-----------------------------------------------------------------------|
| MAPA | Mine Action Programme for Afghanistan |
| MCRA | mine clearance risk assessment |
| MDD | mine detection dog |
| MMAC | Model Mine Action Centre |
| MRE | mine risk education |
| NGO | non-governmental organisation |
| NMAS | National Mine Action Standards |
| NPA | Norwegian People's Aid |
| NSCMA | National Steering Committee for Mine Action |
| PAR | post-clearance area reduction |
| POW | prisoner of war |
| PPE | personal protection equipment |
| QA | quality assurance |
| QC | quality control |
| QRA | quantitative risk assessment |
| RA | risk assessment |
| RCA | root cause analysis |
| RCAF | Royal Cambodian Armed Forces |
| REDS | Rake Excavation and Detection System |
| RM | risk management |
| SAG | Study Advisory Group |
| SHA | suspected hazardous area |
| SME | Subject Matter Expert |
| SON | Study of Operational Needs |
| SOP | standing operating procedure |
| SPLA | Sudan's People Liberation Army |
| TA | technical adviser |
| TRO | Tamil Relief Organisation |
| UK | United Kingdom |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNMAS | UN Mine Action Service |
| UNOCHA | UN Office for the Coordination of Humanitarian Affairs in Afghanistan |
| UNOPS | United Nations Office for Project Services |
| UNTAC | United Nations Transitional Authority in Cambodia |
| US | United States |
| UV | ultra-violet |
| UXO | unexploded ordnance |

Area excavation: in this report, the term “area-excavation” is used to describe the process of removing the entire ground surface to a predetermined depth, and locating any concealed mines or ERW in the process.

Detector-signal investigation: in this report, the term “detector-signal investigation” is used to describe the process of locating metal with a metal-detector, then unearthing and recovering that metal from a discrete location.

Ground Reference Height: a measure of electromagnetic disturbance from the ground. Conventionally made using a Bartington meter or other scientific device, the GRH can

usefully be measured using old Schiebel metal detectors; this was done in most minefields studied.

Post-clearance area reduction (PAR): a formalised procedure for “reducing” remaining parts of a “suspect area” after mine-belts have been located and removed. A twist on the conventional concept of area reduction, PAR involves reducing the originally suspect area as work progresses and the placement of mines becomes clear. Some of the originally suspect area may not be cleared, but will instead be declared to be “No Known Risk” and released to the community after fully informed area-reduction. Area reduction can only be fully informed after the suspected mine-belts have been located (and where mine-belts are the anticipated threat).

Rake Excavation and Detection System (REDS), as devised by NPA with the HDU in Sri Lanka.



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2. The Management of Manual Mine Clearance Programmes



A STUDY OF MANUAL MINE CLEARANCE

2. The Management of Manual Mine Clearance Programmes



The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

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Contents

| | |
|--------------------------------------------------------|----|
| Summary | 1 |
| Introduction | 3 |
| Objectives | 4 |
| Task definition | 5 |
| Historical | 5 |
| Future | 5 |
| Technical survey and risk reduction | 6 |
| Funding issues | 7 |
| Required structure to address tasks effectively | 9 |
| Organisational structure and comparison | 9 |
| Capacity-building | 10 |
| Management differences | 11 |
| Benchmarking | 12 |
| Management tools | 13 |
| Resource planning | 14 |
| Exit strategies and motivation | 14 |
| Planning | 15 |
| Organisational issues | 15 |
| Capacity-building | 19 |
| The deminer | 19 |
| Recruitment | 19 |
| Training | 21 |
| Demining activities and performance | 22 |
| Lane deployment | 24 |
| Working patterns | 25 |
| Dehydration | 26 |
| Combating the effects of dehydration | 28 |
| Effects of personal protective equipment | 28 |
| Influence of management style on performance | 30 |

| | |
|------------------------------------------------------------------|----|
| Team management | 32 |
| Middle management | 33 |
| Other middle management roles | 34 |
| Senior management | 38 |
| Task management | 41 |
| Performance issues | 41 |
| Conclusions and recommendations | 43 |
| Annex: Approach to problem areas in manual mine clearance | 45 |
| Bibliography | 51 |
| Glossary of acronyms | 53 |

Photo credit:

Cover: British Army mine clearance of a road in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number H 29725.

Summary

This section provides the results of a sub-study on the management of manual mine clearance. This section was conducted over a period of seven months, involved non-governmental (NGOs) and governmental organisations, commercial firms and military personnel from several countries and included field visits to three countries.

The scope of this section included all aspects of a demining organisation, from the individual deminer through to headquarters level. Each organisation was assessed on a range of criteria including:

- organisational structure;
- project management skills;
- decision-making and communication;
- management style and performance;
- equipment and personal protective equipment (PPE);
- standing operating procedures (SOPs);
- operational deployment methods;
- career progression, including recruitment and training;
- “top-down” pressures, such as political, donor and financial issues; and
- “bottom-up” pressures, such as the environment, culture and health.

A number of factors made it difficult to study all the stakeholders involved in demining activities. These included the following:

- the study could not be conducted on a “level playing field” because the performance data supplied by organisations was never based on the same criteria and had too many variables;
- complete data could not be collected from all organisations; and
- the figures collected for square metres cleared from some organisations may not be accurate; this is due to a number of factors including an accumulative error budget (i.e. rounding up), which is apparent with each handling of the raw data, from the first assessment at a site up to the reported national figures; and while some organisations made these figures available others did not, meaning that it was difficult to measure performance accurately and compare methodologies.

The section identified many areas where the demining community could improve the efficiency and effectiveness of manual mine clearance. Essentially, the main areas for improvement were not at the individual deminer level — although some issues, such as detector types, drill routines, working practices and personal protective equipment, could enhance performance and assist in error reduction (these issues are expanded on in Section 3).

The management section concludes that the greatest scope for improvements exists at middle and senior management levels, where significant wastage of time and resources were observed. These include management of the minefield site and the decision-making associated with designated areas for clearance. The section also identifies a number of areas such as recruitment and training, team deployment, team and task management and benchmarking where significant improvements could be made.

Introduction

The terms of reference for this section stated that:

“Manual mine clearance equipment and techniques for mine action have evolved over the years from an adaptation of fundamentally military skills to a specialised civilian activity... At the management level, there are wide variations in the recording of clearance rates (in various soil or vegetation types) and no standardised methodology to calculate the costs and rates of manual mine clearance.”

This assertion has been clearly confirmed during this section of the management of manual mine clearance operations. The demining industry has come of age and is now, for the most part, a serious international business, involving considerable investment in equipment and manpower, and management of million-dollar budgets. The evolving nature of the business and the types of location in which it operates should mean that demining organisations must be able to consistently field considerable business, political and technical skills if they are to continue to provide an efficient level of performance.

The manual mine clearance management section looked at many types of demining organisations, but two fundamental desires appeared to be common to all organisations:

- 1. to sustain themselves:** this has different implications depending on the organisation, but the primary focus is on obtaining funds (from donors or by winning bids).
- 2. to provide a demining service:** the delivery style of the service is highly dependent on whether the route to sustaining the organisation is via the availability of donations for specific projects (i.e. is it topical to donors, in which case an exit strategy is not desirable), or whether the route is via a fixed price contract to deliver a site cleared within a specified timeframe.

The different routes to organisational survival have produced different approaches to management policy and organisational philosophies. However, the physical process of conducting manual mine clearance is very similar between all groups.

Objectives

The terms of reference for the section noted wide differences in opinion about the best way to organise mine clearance teams. The aim of the section was to document and analyse the different techniques and methodologies for conducting manual mine clearance operations and to recommend improvements with a view to instituting a more effective management system. In addition, the section was asked to consider how management affects clearance rates.

Data gathering was achieved through visits to Cambodia, Croatia and Mozambique, involving governmental and non-governmental bodies and organisations at national and local level. Interviews were also conducted with commercial demining companies and with relevant UN personnel.

Task definition

Historical

The history of manual mine clearance was reviewed in Section 1, but it is worth restating some important aspects in order to understand the industry's current status.

Mine clearance organisations were set up in response to a specific need to remove explosive remnants of war after conflict, specifically landmines and unexploded ordnance (UXO). Strong-minded and innovative individuals created rapid-reaction, military-style organisations able to deploy anywhere in the world to train local personnel — typically ex-military or ex-combatants themselves — in essentially safe and effective demining practices.

This model was welcomed as it provided employment for former local military personnel, while encouraging further demobilisation and demilitarisation of local forces. It was also a way of gathering local intelligence as to where the hazards may be located.

Such a demining capability is essential as part of a rapid response, but it is not the most effective approach for sustaining a programme. Further, the *ad hoc* manner in which NGOs often deploy once a country needs their services may also contribute to difficulties in making the transition to a long-term model.

In addition, many organisations (commercial and NGO) have expanded rapidly from an initial state where they had one or two programmes to a situation where they are now managing many more, but without necessarily having altered their management structure significantly.

Future

The view is rapidly emerging that as demining programmes become more established they should be considered as part of the overall development effort in a country.¹

1. See for instance GICHD (2001).

Afghanistan's Mine Action Programme has some 8,000 deminers and represents the country's largest employer. The socio-economic and environmental impact that the removal of mines brings to a country is well documented in a recent report² and provides ample evidence to support the view that mine action should evolve as part of a country's overall national development plan.

Current mine action however, demands a coherent and collaborative approach between mine action stakeholders, with enhanced means of collecting and sharing data. These factors appear to be lacking in the industry at present, based on the findings of this section. Currently the industry tends to be *resource*-driven rather than *needs*-driven, which is inappropriate, not least because it contributes to the "disintegrated" nature of the industry.

A number of NGOs reported an emerging lack of trust between the community and the NGOs, as the physical demining process is so slow and the pressure on land so high that villagers are compelled to move into areas before clearance takes place. Experience shows that locals are fully aware of the dangers, but necessity drives them on, sometimes along with political fears of land grabbing.

Technical survey and risk reduction

Technical surveys are an extremely important part of the future of demining, as they can redefine suspected hazardous areas identified in a Landmine Impact Survey (LIS) and ensure that expensive demining resources are targeted at the most necessary areas. Yet, the process of technical survey is not well defined and no definition has yet found consensus within the mine action community. As a result, each organisation refers to it slightly differently. Likewise, the International Mine Action Standards (IMAS) do not offer a clear description of what technical survey should consist of and how it should be conducted.

For such a potentially important activity, it is unclear who is trained for the task, how they are trained, and what the specific skills needed might be. This is clearly an area that can impact on cost-effectiveness and efficiency.

There is a mixed view of area reduction across the industry. It is, however, a highly effective way of ensuring cost-effectiveness, increasing efficiency and releasing low-risk land back to the population, as long as the perception of risk is appropriately addressed. The decision-making associated with area reduction is closely linked to the acceptance of risk by the organisation, the donors and the government. The local population also has to be persuaded to buy into the process and to trust the techniques being deployed.

Area reduction is often carried out on lower-risk land where there have been no incidents and local intelligence is negligible. Processes of reducing the risk on the land are usually a mix of mechanical aids and dogs, or possibly clearing the edges of boxes manually, then if no mines are found the land is declared as having "no known risk". These processes are by no means universal and definitions, some of which are defined in IMAS, are not universally used or understood.

There was evidence to suggest that areas are being cleared that were globally encompassed by the LIS, but with minimal risk of mines, and in some cases, no mines.

2. PRIO (2004).

There are documented cases of large demining units (30–60 deminers plus support) being deployed on areas where subsequently, after complete processing, no mines were found. If this is the case, it is not a good use of scarce resources, nor is it an appropriate response to the urgent need for land to be released for local use. It is also dispiriting for the deminers and the organisations involved. On some sites, confidence was so high that no mines were present that deminers carried on working while animals grazed in front of them.

Clearing areas that are subsequently found to be free of mines is fraught with potential problems, for example:

- the deminer becomes over-confident and takes risks;
- development of lax drills and violation of SOPs;
- loss of motivation (pointlessness of task);
- cost implications;
- loss of confidence of locals in NGOs — frustration; and
- loss of donor confidence in demining management.

One of the most significant and potentially profitable uses of machines may be in area reduction in conjunction with another method, such as dogs. However, the mine action community has yet to universally accept the risk of declaring land treated in this way as safe. The Croatian Mine Action Centre (CROMAC) and the Croatian government have structured an approach to the use of mechanical demining methods for area reduction and the acceptance of risk, in order to advance the completion date of demining in the country.

The topic of risk reduction is one of the keys to the whole mine clearance issue and requires further study.

Funding issues

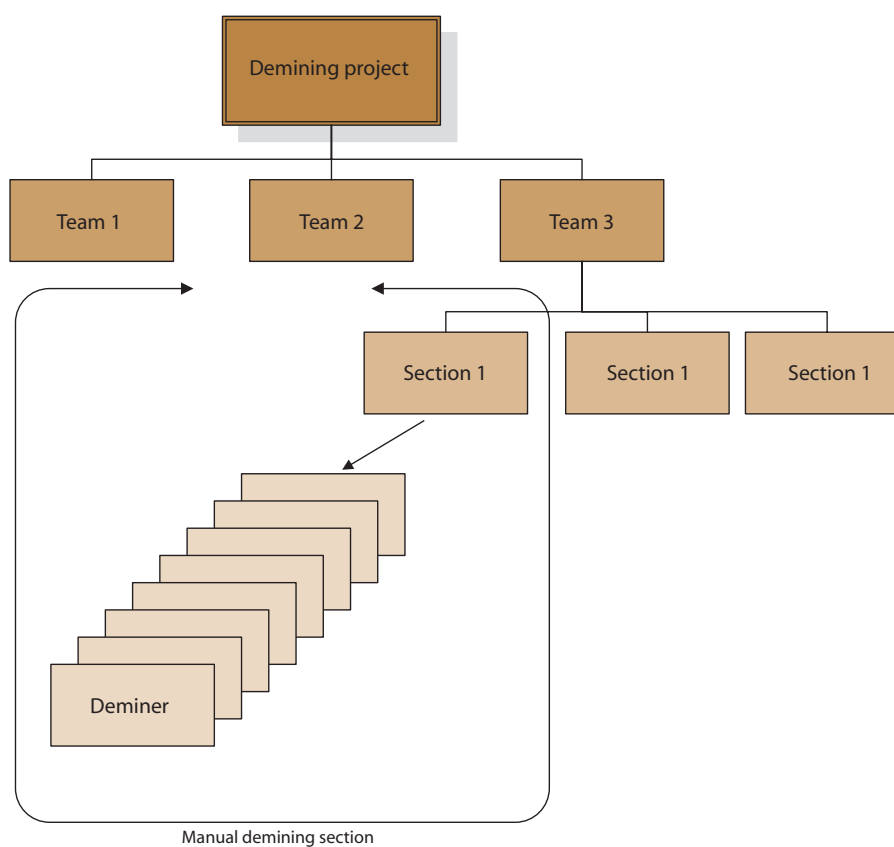
The actions of a donor can inadvertently prevent organisations from conducting efficient programmes. Regular donors and supporters of mine action would help demining NGOs greatly if they were to encourage them to be proactive in their resource planning. Also, if they were to commit funds over several years rather on a yearly basis, this would allow the NGOs to develop a long-term strategy, rather than the current “hand-to-mouth” situations. Donors can inadvertently create additional costs and slow programmes down by placing limitations, conditions and restrictions on the types of activities an NGO undertakes.

Required structure to address tasks effectively

Organisational structure and comparison

A typical example of a demining organisational chart is presented in Figure 1 . Some are much larger and have more layers, but on the whole this is a fair representation across the board for hierarchy and reporting structure.

Figure 1: An example of a typical demining organisation structure



There is a clear divide between NGOs and commercial companies in approach and attitude, although this is primarily affected by local conditions and constraints. This section looks at some of those differences, which primarily are those of management and process, generated by the different philosophies regarding profit. Demining methods and equipment, however, are very similar.

Although the two types of organisation may be complementary, it is worth noting that while the NGOs may appear to be less efficient in the short term, at least when working under a grant with loosely defined performance requirements, in general their capacity development orientation is more significant in the long run. If, as occasionally happens, NGOs engage in competitive contracts then their performance can be similar to commercial companies.

This also works the other way around, and if tenders and contracts are well written, capacities can also be successfully developed by commercial organisations. Many of the current capacities in northern Iraq, for example, were developed by a commercial operator under contract to the UN, which directed the building and transfer of capacity.

Capacity-building

The concept of capacity-building is often cited as the main discriminating factor between NGOs and commercial companies. Capacity-building is viewed as a long-term objective, where the end strategy is for the local population and government to develop the skills required to run their own programmes with their own people. There are very few cases where this has been achieved in its purest form. In some cases it has not been achieved at all, while in the majority of cases a blend of local and expatriate skills continues to work together in different ways.¹

When a foreign NGO leaves a country (which is not often), it appears to prefer to disband its capability rather than hand over the reins to a local project manager for a number of reasons, including lack of funds.

There may be an argument to suggest that the concept of capacity-building in national NGOs is a misnomer, bearing in mind that many commercials will also train local workforces to conduct their demining projects. This view is put forward based on the following assumptions:

- the inflated wages paid to deminers may distort the economy and expectations;
- the skills are not easily transferable to any other job;
- there is no continued professional development of the deminer to encourage him to be promoted and develop a career structure, therefore he is encouraged to stay on, probably well past the age when he is efficient;
- the military style of care (which an ex-soldier may be used to) looks after the individual in one aspect, but does not encourage him to develop civilian skills or to be reintegrated into the community;
- there are few programmes where deminers are offered retraining with other skills so that they can rotate through the NGO into the general population, which would free jobs for new and younger deminers, so spreading the wealth and keeping the demining population young; and

1. UNDP defines capacity development as: *"The process by which individuals, groups, organizations and countries develop, enhance and organize their systems, resources and knowledge, all reflected in their abilities, individually and collectively, to perform functions, solve problems and set and achieve objectives."* See stone.undp.org/undpweb/eo/evalnet/docstore3/yellowbook/glossary/glossary_c.htm.

- there appears to be a higher incidence of HIV-positive deminers than among the general population,² suggesting that the wages and travelling lifestyle promote promiscuity and that HIV/AIDS education programmes are not successful.

Commercial companies operate in one of two ways: (a) they train and employ locally on a fixed contract (as with NGOs), but for a short period of time, using people who live close to the project; or (b) they have a permanent workforce, taking their own deminers who travel the world as part of a team with the organisation. These deminers are given opportunities that others are not, and the organisation gets a trained and efficient workforce that allows it to start demining within minimum timeframes.

The Mines Advisory Group's (MAG) community demining programme in Cambodia addresses the issues described above by employing residents of the village to be cleared for a two-year period, and on lower wages than for a professional deminer. This keeps the income within the community, provides jobs for anyone willing to work (often women), which frees the men to farm or trade. The following points were made by MAG with respect to their community scheme:

- resources on the ground increased by 50 per cent for the same money (and represented true capacity-building, as the work was kept within the community);
- money was injected into the community;
- Employment can be targeted to most needy families (not an exclusive few), allowing them to farm;
- HIV risk-reduction is promoted as workers live at home;
- communities can be given a bonus if deminers attend for whole month, which has reduced sickness rates by up to 70 per cent;
- deminers get written contracts from commune authorities so that they cannot work informally with others in MAG's name;
- it helps to promote the employment of mine victims as deminers; and
- the maximum working life for local deminers is two to three years; MAG claims it takes six months to get a community deminer up to speed.

If, as suggested by a number of organisations, capacity-building is to be a primary focus and discriminator of NGOs in relation to the commercial companies, the demining sector should be educating and preparing its personnel for a role in the outside world after they have left the demining task, rather than continuing to teach them to be dependent both on the levels of care they receive and unrealistic wages. However, the current status is that NGOs tend not to have exit strategies in the same way as commercial companies, so they may not see this as being a problem. The northern Iraq capacity was built by a commercial company with a clear direction and exit strategy.

Management differences

In fact, the most significant differences between the two types of organisation (NGO and commercial company) are the way they are managed, particularly with respect to planning and project management.

Commercial companies can only conduct a demining project if they have won a contract. This means they have developed a plan that addresses the lifespan of the project, and which has been fully costed. If they are not effective at planning, they will

2. This assumption is based on discussions with mine action operators in Cambodia and Mozambique.

not win the bid, and valuable time and money will have been expended to the detriment of the long-term health of the organisation. The other possibility is that they will make a loss for having miscalculated the costs, difficulty or length of the project, which is also highly negative.

NGOs do not make a loss in that way as they do not have to complete a task on fixed timeframes and fixed budgets, so they can adjust their timeframes and raise more cash if required. There is, of course, no reason why commercial projects could not be let on a contract basis with NGOs bidding and indeed in the case of Norwegian People's Aid (NPA) in Iran, in direct support of the commercial oil company, Norsk Hydro, this has happened.

The processes and planning that are required prior to winning a contract become the blueprint for the delivery of the programme. In the case of commercial companies, the project manager must develop a beginning, middle and end in order to be able to monitor the progress and achieve milestones that deliver payments. The need to ensure the company is successful from a commercial, as well as a demining, perspective means that resource planning and allocation must be as accurate as possible. The process influences the manner in which the demining teams are organised and the task is conducted.

In comparison, NGOs tend to develop their programmes in a reactive manner, because they are never sure how much money might be available and therefore do not plan their resource requirements for the following year in the same way as a commercial company. In addition, they often have other developmental aims that are complementary to their demining tasks, but that can confuse any direct comparison with the commercial sector. NGOs do not have the same motivational influence to be as efficient or as financially accountable to themselves: providing they have donor money, they can continue to operate in a manner that enables the donor to see that they are getting a job done.

Benchmarking

The ability to benchmark performances, both from an internal perspective and from an industry perspective, is a valuable asset to any organisation. Benchmarking provides a clear reference against which the organisation can measure itself to determine strengths, weaknesses and promote self-improvement in a structured and informed manner.

Currently there does not appear to be any means of providing this capability and many organisations felt that it was not feasible, given the large number of diverse variables that impact on any one project. However, there are many other international industries that experience similar variables and have been able to formulate criteria against which they can measure performance, such as the oil, mineral and agricultural industries. Without a strong lead from a governing body or from the organisations themselves, getting benchmarks accepted will be difficult.

Certain countries, however, are trying to implement benchmarks. The example of CROMAC and the Croatian government shows that it can be done. In Croatia, the Government of Croatia is represented by the CROMAC council. Demining work in Croatia is implemented on free market principles. CROMAC, as the national mine

action authority, awards demining contracts through public tenders to qualified demining companies. CROMAC selects the best bidders and performs quality assurance of their work.

CROMAC has defined numbers of square metres that can be achieved per deminer per day, given a set number of hours in a working day. They have mandated the pay rate of Croatian deminers (at a cost to the company of around US\$2,000 per month) and they have imposed stringent requirements on any company wishing to conduct demining activities within the country. Despite extremely tight constraints, there are still 27 active demining companies bidding for work in Croatia. Even with the imposed high overheads, they appear to be making a profit (estimated by one source at around 20 per cent) from an average charge of between US\$0.50 and US\$0.80 per square metre, although these figures appear to also take into account large area reduction tasks.

On this basis, and with a strong commitment from the government (both financially and through the acceptance of risk in their approach to area reduction) Croatia sets itself the objective that the country will be free from mines in two to three years. There is a firm commitment to this plan. The commercial company interviewed appeared to be supportive of the approach, and is capitalising on the experience by exporting its remote machinery expertise around the world to diversify its business. In other words, they are preparing to meet the changes in their market.

Commercial companies have to benchmark their performances for internal audits and make use of management tools and processes to ensure they stay on track. This is not something that the NGO management has adopted in its entirety. There appears to be a level of “bashfulness” in sharing some information and, when it is shared, it is often done with a touch of spin. The commercial operator has to be accountable to many stakeholders; therefore he must have processes and audits that are fully transparent.

Management tools

Many organisations, especially companies, but also a number of NGOs, are seeking ISO 9000 accreditation, demonstrating their quality system. ISO 9000 is generally understood to be a sign of a reliable and efficient organisation. Although the philosophy and intent is good, it should be pointed out that ISO accreditation is no indication of levels of performance or efficiency. In some instances, it may be argued that the ISO process increases costs and slows activities down; but it does assist with audits and transparency, which are critical for business.

Another management tool, which is mine-action specific, is the Information Management System for Mine Action (IMSMA). This was designed to help national mine action programmes collate data on work completed and compare it against mine presence and land prioritisation requirements. However, as IMSMA is designed for national use, it relies on data coming upwards from the various organisations conducting mine action, which is difficult to obtain accurately and in a timely and efficient manner.

The current version of IMSMA (version 3) is complex to manage, and data collection is an issue within organisations in terms of quality and availability. Furthermore, many governments feel that this type of information should not be made available generally, and so do not disseminate the data. As the organisations that provide the information

do not benefit from IMSMA, they feel that the costs involved in collating and sending the information represent a waste of time. Indeed without the ability to make use of this information, this appears to be the case.

Resource planning

Resource planning is critical to effective business practice; it helps identify what the organisation's core business is, what it needs to achieve, and its desired status and defined goals. NGO planning tends to be in response to what has been done before in that programme and to be reactive to donor requirements. The policies of donors inadvertently become the driving force behind an NGO's business plan.

Commercial organisations do not have these constraints; they can create a clear marketing and business development plan that allows them to recognise when a bid is no longer viable, and ensure that work undertaken plays to their strengths. They can employ people under short-term contracts, maintain smaller headquarters, and do not require permanent regional offices, thus keeping their overheads to a minimum. They are also able to contract machinery to suit each task rather than purchasing it, although some commercials have chosen to buy. The commercial company's potential weakness is its inability to understand the local politics and develop the networking capability essential to a smooth operation.

Logistics, which are an essential part of planning, could also be improved. One demining organisation visited had 50 separate sites in a single country, widely spread over large and difficult terrain with poor transport systems. This situation appears to have arisen from externally driven requests for responses, rather than from a long-term development plan of the organisation's skills, resources and ambitions. Sustaining such an extended programme is costly, inefficient and unlikely to be effective.

Thus far, no NGO surveyed appears to have conducted a formal exit strategy. NPA in Mozambique is currently planning an exit strategy, but it is in its early days yet.

Exit strategies and motivation

Earlier sub-sections have looked at how current motivational factors in the demining community are inappropriate. NGOs do not have any incentive to finish a task within a country, provided funding is available. They rely on money from donors to clear mines; if demining is completed to a level where the NGO is no longer required then there is no reason for donor funding.

Commercial companies, on the other hand, may be able to offer incentives for early completion as they can recoup costs if the contract is finished ahead of schedule. Therefore, their employees, who were only hired for a set period, can benefit from efficiency, while NGO employees do not.

Deminers naturally will protect their jobs regardless of whether they are good at it, enjoy it, or are physically still able to do the job well. Local government laws often prevent dismissal and legal proceedings are initiated regularly. The development of a workforce that is motivated by pay alone has long been recognised as self-defeating, with focus on self development and advancement being acknowledged as more beneficial to the individual.³

3. Maslow (1970).

Planning

CROMAC, which has stringent rules and regulations about price structure, time and resources when it comes to assessing a bid, declares that the only difference between one organisation and another is in their planning and ability to get the job done. Important bid differentiators for planning were cited as: coordinating with the local police and authorities, developing networks with local communities, management of the logistics of accommodating deminers, and moving resources around a country. This highlights how critical an experienced planner is to the success of a demining project.

During the course of the study, many examples were found of poor logistics and planning, such as the location of accommodation and headquarters in relation to the minefields. A huge amount of time, and money, is spent on unnecessary travelling and transport. Also, lane deployment and site management was not conducted effectively, as is discussed below.

Other areas of concern include procurement and the allocation of essential donor resources to tasks. During a country visit, an area was being cleared that was known to be free of mines, yet the task had been in progress for several months. Once the area was clearly recognised as such, the team should have been immediately moved to a more useful task.

Efficient performance is a mix of understanding local cultures and how business gets done, while sticking to good management practices for global benchmarking and consistency. This includes the ability to deploy teams effectively. To plan the site clearance effectively, making maximum use of resources in relationship to the geographical implications of the site should be fundamental to all demining projects.

Teams

The team structure of deminers varies little between organisations, although numbers vary considerably depending on the task and the location. Teams are often referred to as “platoons” and usually consist of three sections. Each section typically has nine people, i.e. eight deminers and a Section Commander, who may be trained in mine identification and who oversees the process.

In some cases, “multi-skilling” is achieved through combining medical training, explosive ordnance disposal (EOD) skills and machinery operation. This is the most cost-effective and productive approach, as it also allows the deminer to collect skills to enhance pay and promotion prospects (*see section on motivation*). It also ensures that the right skills are available on site and reduces downtime, particularly in the case of EOD. In other organisations, however, skills are kept separate: dedicated first-aid personnel and mechanical operators do not usually conduct other activities.

Organisational issues

The multi-country UN study, *The Development of Indigenous Mine Action Capacities*⁴, published in 1997, made several observations and recommendations about management

4. Eaton et al (1997).

within the mine action community, notably that: “A major impediment to effective mine action programmes is poor management”. It is here that the most significant potential benefits lie. This section attempts to identify some of the key issues.

Inherent skills

Many small demining organisations have evolved into multi-skilled entities that require a significant range of skill sets. Finding these skill-sets locally is not a simple task. Box 1 lists the skills currently required of a demining organisation. It is not exhaustive, but gives some idea of the diverse range of expertise.

Box 1. List of skills required of a demining organisation

- International law.
- International politics.
- Local employment law, and health and safety issues.
- Local culture and environmental knowledge.
- Management when working in hostile environments.
- Safety and Protective measure in hazardous environments.
- Equipment procurement.
- Communications equipment, VHF, HF, etc.
- Logistics, road, freightage, buildings, travel and accommodation, etc.
- Maintenance, fleet and equipment.
- Financial skills of a general nature.
- International fund-raising and fund management.
- Technology-advancing techniques for mechanical.
- Animal husbandry and management.
- Training – varied and non-standardised.
- Management at all levels, resource planning, etc.
- Human resources (total needs for 24-hour care).
- General medical.
- Emergency responses.
- Project management.
- Detailed data management.
- IT – database and Excel.
- Senior management – leadership, business skills, strategic decision-making, communication, organisational skills.
- Middle management – leadership, business skills, tactical decision-making, language skills, teamwork.
- Mapping and survey skills.
- Risk management.
- Driving skills.
- Machinery operation and remote operation skills.
- And, last but not least, EOD and demining skills.

Some NGOs and commercial operators also provide the following as an additional part of their “cross-cutting” mine action capabilities:

- Community liaison teams.
- Mine risk education teams.
- Educators and training skills.
- Health education, such as on HIV/AIDS, malaria and dysentery.
- Life skills, money management, etc.

Quality management

The approach to quality management activities varies between mine action organisations but is normally conducted in-house, as external assessors are few and

far between. In principle, NGOs reported that they were not averse to external quality assurance (QA) and quality control (QC) but “it didn’t really happen” so had not been adequately put to the test. Commercial companies are all subject to external QA.

Some QA activities observed in the field indicated significant skill fade as processes were lax and somewhat *laissez faire*. There were also verbal reports from operators and authorities to suggest that mines are found after land has been cleared, suggesting that manual demining methods still leave a residual risk, while endorsing the view that errors and skill-fade sometimes remain undetected.

Again, training for QA activities appeared to be more *ad hoc* than formal, often with only a few people available to cover not only vast territories but also other tasks such as technical surveys. These individuals may spend considerable time driving between sites and may not be able to conduct QA in a timely manner. Skill fade may be an issue if they are not able to conduct tasks as frequently as they should.

The commercial view is that external QA appears to ensure adherence to SOPs. This view is supported by Section 4 (*Risk Assessment and Risk Management of Mined Areas*).

Capacity-building

The deminer

The person responsible for the physical detection of mines is nearly always employed in-country, although some commercial firms (and occasionally NGOs in start-up operations) move teams from country to country, capitalising on their initial training investment from previous projects.

Recruitment

Recruitment of deminers does not appear to present a problem. There is seldom a shortage of local people willing to offer themselves for training. A major reason for this is probably because average deminer salary is significantly above all national average pay rates. Rates quoted for developing countries were universally US\$150 to US\$250 per month (roughly equivalent to eight times national average pay, and three times more than a teacher in the majority of countries where demining is undertaken). Some organisations questioned paid more, but none paid less than \$150, with the exception of NGOs involved in “locality” demining projects.

There is no industry standard outlining the minimum entry level required of a deminer. The following examples demonstrate this:

- some organisations will only recruit former local military personnel (this applies to NGOs and commercial firms);
- some deminers who are sick may nominate a member of their family to take their place;
- some organisations are happy to recruit women and amputees if they can do the job;
- often, no educational standards are required, even a literacy test;
- there is often no physical standard or test to pass before acceptance as a recruit, the only criterion mentioned was sight; and
- hearing and physical fitness are not always tested.

However, in Croatia, there are stringent selection criteria for all organisations and applicants must have:

- a high school education;
- completed military service;
- no criminal record;
- good physical and mental health; and
- attended a special Police Academy training course (six months) and successfully passed the final examination.

Some organisations do have a minimum age limit of 18. There was no stated upper age limit, although it became clear from research that age is a factor in performance for demining.

Recruitment is often predominantly from the ranks of the local military and in some cases (for example, Cambodia and Mozambique) such recruitment has formed part of the peace accord and demobilisation, both providing employment (thereby promoting demilitarisation) and because many soldiers had been involved in laying the mines and were therefore considered a good source of knowledge as to their location.

In many countries, ex-military males form the core staff. The rationale was that such people would readily adapt to the military style prevalent in demining organisations and that they would be easier to manage and train. This may be a self-fulfilling prophecy. The two organisations (MAG Cambodia and NPA Mozambique) breaking the mould reported that both non-military and female deminers adapted very well to the task. In particular, women, who traditionally in developing countries do menial and repetitive tasks in all climates, have better and more sustained levels of concentration and are more compliant with rules than their male counterparts. Women also tend to be better at sending money back to their families and less inclined to spend their wages on gambling, drink and sex.

One drawback to employing females is the manner in which NGOs typically deploy to minefields, that is, by locating teams around the country rather than training local people. This would typically preclude the involvement of women unless they had either no family or an extended family to care for children.¹ The locality demining projects, which are set up to use local populations to clear their own villages in a formal process — such as those run by MAG and, in Afghanistan, the Agency for Rehabilitation and Energy Conservation (AREA) — provide ample evidence that the proper employment of women can be successful.

Comment

Manual mine clearance is routine and monotonous and is often carried out in rather unpleasant conditions. It requires high levels of internal motivation that allow individuals to overcome boredom, to remain alert and to sustain high levels of attention to detail. Although local employees are used to the conditions, the working rhythms and shift cycle may be alien for agricultural workers and farmers, although they are expert at working the soil for long periods in all conditions.

Personality type plays a significant role in the ability to sustain attention, and soldiers recently demobilised after extended time in high-stress environments may find such mundane, routine work hard to sustain and lack motivation.

¹ Interview with MAG, Cambodia, March 2004.

Some NGOs affirmed that part of their role is to build capacity. It is not clear that recruitment of ex-military personnel supports capacity-building as it keeps the new income from mine action in a small section of the population, which may not, for a variety of reasons, be invested in their families or villages. Additionally, deminers may become stuck in the job as their skills do not easily transfer to other occupations. Thus, the training of demining may well not contribute to capacity-building. An exception is said to occur in Lebanon, where many deminers have left for other employment despite the high wages.²

Training

Typically, organisations that have recruited deminers put them immediately on a salary and send them on a training course supplied in-house. There are small fluctuations in training length, with the shortest period for training a deminer being one week. Additional time is allocated to training EOD skills and for render-safe procedures.

The average training period is about two weeks for completion of demining training. As a general rule, a recruit seldom fails — but just takes longer to go through training, until the requisite standard is attained. This is not efficient as all training is conducted on some pay and, in many cases, full pay. It also suggests that training does not cater to different aptitudes, reinforcing a view that there are no minimum standards of entry at recruitment.

Refresher training was mentioned but did not appear to take place systematically, only on an *ad hoc* basis as and when it was deemed necessary. Many organisations stated that “skill fade” was not an issue as the deminers were doing their task every day. This is often not the case as each site has different demands and deminers may become complacent when working in low-risk areas.

Apart from the initial training at the onset of a demining project, there did not appear to be any further training requirements. Generally, deminers tend to stay not only within the industry, but also within the same organisation for many years and only leave if they are sick or if they are no longer fit for the task. There is, however, no standard by which deminers may be measured as to whether they are fit for the task or not — apart from a complete inability to conduct the activities. There may be a case for clearer guidance to be offered to organisations employing deminers.

Comment

Training on full pay with no standards of entry is generally inappropriate for three reasons: cost, motivation and the potential for corruption. Very few jobs in other domains (except the military) expect to pay new recruits to receive training. The provision of free training without pay provides an incentive for individuals to attain proficiency and move on into the job. The clothing trade in Cambodia, a major employer in the towns, expects recruits to have trained themselves prior to applying. Construction companies canvassed for this sub-study reported that they recruited and provided free training without pay in developing countries, and expected recruits to be trained in developed countries.

Refresher training should be provided regularly, as many of the sites being cleared did not have many mines present. This results in a long-term “de-sensitising” effect where

2. Lardner (2002).

deminers can easily become complacent in their work. Such a situation tends to lower the expectancy threshold, which, if a mine is then encountered, increases the risk of it not being discovered. It may be beneficial to provide a short refresher course to all deminers when they start a new site, to raise their awareness of the particular issues that are relevant to that site, i.e. soil type, detector behaviour, fragmentation management, clearing hilly land, and so on.

There does not appear to be a grading system for deminers that would allow for novice deminers to be “buddied” or supported in the early stages of their career. MAG reported that it takes six months for a deminer to become fully proficient. Salary scales could be graded to reflect this, so as to continue motivation to maintain high standards.

Demining activities and performance

The deminer’s primary tasks are to carefully segment the ground in a marked lane with a metre-long stick, cut vegetation, sweep with a detector and investigate the ground using a prodder or excavator. These activities are fairly universal across all organisations, with only minor differences in tool type. Deminers are provided with a variety of tools. In most cases, a metal detector of some sort is used but this is not universal: detectors are not deemed suitable for some environments and conditions, and in others, there may not be enough to equip every deminer.

Measurement of performance through the number of square metres a deminer clears in a day is one that all organisations have adopted, and was, until recently, also the donors’ preferred measurement of performance. But data is only collected accurately by a few organisations to provide more detailed performance analysis and/or to create a means of incentive for deminers. And the demining industry generally acknowledges that square metreage, on its own, is not a particularly useful measure of efficiency because so many variables affect a deminer’s daily progress. Along with such measures as battery and fuel usage, these figures can form the basis of good planning figures and clear performance indicators need to be defined.

The study team found discrepancies at several levels in the quoted figures for square metres cleared. Virtually all organisations quoted an average clearance rate per deminer of about 50 square metres a day. However, when calculations at individual sites were made on the presented data for total area cleared, divided by deminer days worked, the figures appeared, on average, to be closer to 15–20 square metres per deminer per day. In the more detailed case studies in Section 3, this latter set of data was confirmed as realistic. In terms of planning capacity this represents a significant capacity gap and organisations need to be clearer about their outputs.

In an exception to the norm, the Mine Action Coordination Centre Southern Lebanon has maintained a detailed record of all clearance undertaken under its auspices. This has enabled them to develop a series of detailed planning figures based on previous clearance.³ While clearly rates will be affected by the terrain, degree of contamination and prevailing climate, the Centre uses the following general figures for operational planning for manual mine clearance operations in South Lebanon:

- 20 square metres per deminer per day using a metal detector on military-laid, pattern minefields with low metal contamination;
- 17 square metres per deminer per day using a metal detector on suspected hazardous areas with low metal contamination;

3. MACC South Lebanon, Task Planning calculations, 2004.

- 8 square metres per deminer per day using a metal detector and then excavating signals on suspected hazardous areas with medium metal contamination; and
- 3–5 square metres per deminer per day using full excavation on suspected hazardous areas with high metal contamination.

These rates give an example of “real” clearance rates and are similar to the rates developed as part of the GICHD Study of Global Operational Needs.⁴ This study classified 12 separate terrains and modelled the rates that might be expected to be produced from such terrains. The results are shown in Table 1.

| Type of scenario | Model estimated square metres per day (general) | Model estimated square metres per day (Cambodia) |
|-------------------------|--------------------------------------------------------|---------------------------------------------------------|
| Grassland | 10.0 | 20.7 |
| Woodland | 9.6 | 24.5 |
| Hillside | 9.5 | 12.2 |
| Routes | 7.3 | 0.8 |
| Infrastructure | 4.4 | 0.8 |
| Urban | 3.7 | - |
| Village | 3.5 | 2.0 |
| Mountain | 12.6 | - |
| Desert | 104.2 | - |
| Paddy field | 16.9 | 29.7 |
| Semi-arid savannah | 8.0 | 17.5 |
| Bush | 7.1 | - |

It is worth noting that the figures do give the same order of magnitude to, and compare favourably with, the trials described in Section 3, which reinforces the belief that the actual productivity figures from organisations often lie below the figures quoted by those organisations, and that are often used for planning.

Performance levels are affected by:

- fragmentation levels and contamination;
- soil type;
- topography;
- weather and climate;
- use of mechanical ground preparation methods (a mechanically-prepared area has a huge positive impact on performance);
- area reduction techniques;
- vegetation;
- number of mines present;
- management style;
- detector performance (suitability for soil, sensitivity, weight, etc.);
- personal protective equipment;
- lane management (one-, two- or three-man lanes);
- standing operating procedures (SOPs); and
- the age of the deminer.

4. GICHD (2002).

Comment

The development of demining techniques has been evolutionary. The original military approach has been universally adopted by all companies around the world and is seldom challenged or subjected to analysis for alternative approaches. However, in terms of safety, if SOPs are adhered to, the military approach does appear to be a robust method that is well proven. Nonetheless, a number of countries with particular environmental issues have developed different techniques; for example, in Sri Lanka, operators employ raking techniques because of soil type, and the technique works well. However, such a technique would not work in hardened soils or in areas where there is heavy root growth, for example.

The day-to-day monitoring of metres cleared per deminer on each site is a useful means for providing an intra-team comparison of deminer performance. As data is collected it can be used as a benchmark to inform performance expectations at other sites and projects, and to improve the management's ability to plan, and predict timescales and costs.

Data also provides the management with a clearer understanding of individual performance levels. This data can be used to build better teams and to enable fair and accurate motivational schemes to be implemented. It also supports more accurate data collection of total area cleared. But, of course, this only works if the reporting system is meticulously implemented and audited. In many instances, the method of data collection as it progresses through the management cycle can only be described as "round up, round up, round up". In one case encountered, Section Commanders were rounding their day's clearance figures upwards and passing to Platoon Commanders. The Platoon Commanders were then rounding their figures up before passing on to the regional office, and this rounding up happened again before the figures eventually made it to the central database.

Although there are no generally accepted standards in terms of the output expected from manual mine clearance deminers, the rates outlined in the Study of Global Operational Needs⁵ and earlier in this section, appear to be reasonable and could offer good planning figures for the community.

Lane deployment

One area where process can differ is the manner in which deminers are deployed in a clearance lane. The traditional post-1945 methodology was that of using a number of men (two or three) in one lane, with roles switching in the process was undertaken. As humanitarian demining developed the same principles were applied but, with time, organisations attempted to better focus their efforts by using different numbers of deminers in lanes with different roles. This was considered to be more efficient and cost-effective. However, it became obvious that there was a problem with definitions, as it was not clear exactly what each organisation was describing when it used the term "one-" or "two-"man lane deployment.

The following definitions were identified:

- a) *one-man-one-lane (version 1)*: all deminers work in a single lane (detecting and investigating) and then all rest — little spare capacity (relief deminers only);

5. GICHD (2002).

- b) *one-man-one-lane (version 2)*: one deminer doing all tasks and one deminer resting per lane (this definition appears to be interchangeable with one type of definition for two-man drills);
- c) *two-man lane drills*: one deminer detecting at the front of the lane with the second some distance behind observing and, when a reading is indicated, prodding and investigating the signal; and
- d) *three-man lane drills*: one in the lane either as per (b) or two men as per (c), and one completely resting.

The organisations that have adopted “one-man” methods are, on the whole, those which have enough metal detectors for each deminer in the field and, given no limitations on resources, it appears that the “one-man-one-lane” methodologies have now been accepted as the norm.

While IMAS offers general guidance on the destruction of mines found during operations and suggests that “best practice” is to destroy each item *in situ*, more and more programmes are leaning towards neutralisation and subsequent off-site destruction of mines and UXO, as this is less disruptive to other deminers or to adjacent community activities.

The use of multi-skilled deminers on site appears to be more practical and time-efficient. Incentives such as pay increases and bonuses for conducting other tasks may be a useful means of persuading deminers to become multi-skilled.

The efficiency of site clearance is highly dependent on the layout of the site and forward planning of the Site Supervisor. Multiple lanes must be open to ensure that deminers can continue safely if their original lane has been closed waiting for a mine to be rendered safe or destroyed if “*blow in situ*” procedures are being used. Safety distances between working deminers can limit the number who can be deployed.

Working patterns

Many accept that the local Site Supervisor should use his discretion as to how long each working period should be and how often breaks are implemented. Clearly, climate plays a significant role. However, there was a clear discrepancy at every site visited between the periods claimed by senior management and those actually worked. This has implications for the planning and management of a site and prevents effective benchmarking.

In general, any work requiring sustained concentration benefits from frequent, short breaks.⁶ If the working period is too long there is an increased risk of error through fatigue and loss of attention resulting from dehydration and boredom. If, however, the breaks are too long there is a risk of concentration and motivation decreasing. Optimum attention levels and performance are achieved through maintaining sustainable momentum. Small frequent breaks and sufficient stimulation to maintain interest can achieve this.

If deminers are spending long periods with no stimulation between working periods, (as in two-man-lane drills) they are more likely to be “out of the loop” when returning to the task and will have more frequent occurrence of slips, lapses and mistakes. An

6. Gyllenhammer (1977).

additional factor in two-man-lane drills is the increased potential for communication failures when handing over a lane.

A working day normally consists of transport to the site (outside of working hours), briefing and a seven/eight-hour day in the field (i.e. 7am to 3pm), with breaks. However, many organisations stipulate that a deminer should not physically be demining more than five hours a day. The rest of the working day is designated for personal maintenance of issued uniform and equipment.

Comment

Over recent years, the industry has seen increased use of one-man drills. This has tended to increase outputs but is inevitably linked to increased capital costs due to the increased amount of equipment that needs to be procured. This section did not have the scope to consider this in detail, but it is recommended that every programme manager reviews their programme to undertake some form of cost-benefit analysis before making decisions on this.

For working routines, there should be a balance between breaks and working periods so that they are not too long or too short, and this decision should be made at the local level.

The organisation should also consider seriously (where permissible), the pros and cons of destruction *in situ*, and consider the alternatives available, including neutralisation and removal for bulk disposal.

Dehydration

Nearly all people living in moderate climates have a degree of dehydration of around 1 per cent or more. When dehydration reaches 2 per cent there is a significant impact on performance — in particular cognition — and a fall-off in reactions and mental responses of up to 15 per cent has been recorded in sports and other activities that require attention and decision-making.

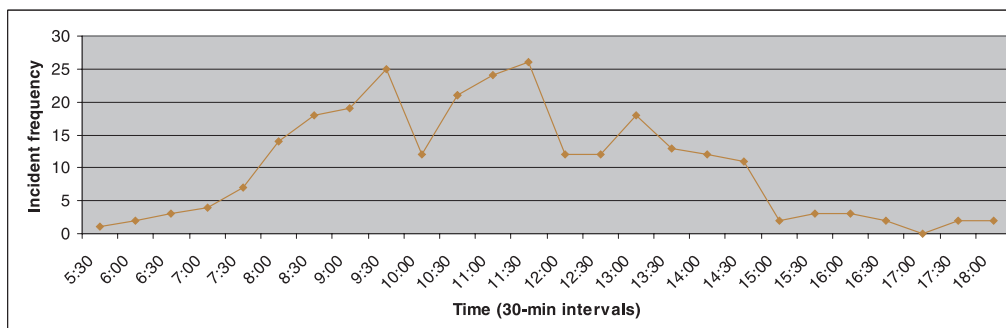
Slow thinking and slow reactions are the least desirable effects for deminers, as they need to be mentally alert to spot very small clues and to discriminate between auditory tones. Fine motor skills are also badly affected by dehydration, which are also critical to deminer safety and effective performance.

Some organisations did not provide water to deminers, who are therefore responsible for ensuring their own water supplies. If a deminer is working in extremely hot conditions, is hung over, has any form of dysentery or any other condition that involves depletion of water from the body, then he/she will experience dehydration, which can be severe.

Given the limited amount of accident data and the lack of standardisation of that data, it is impossible to draw conclusions about the link between error, fatigue and dehydration. Of the 268 (of 409) accidents in the Database of Demining Accidents (DDAS) that have a time linked to them, there is a general trend for more accidents in the period between 9.30am and 12.30pm (*Figure 2*). Unfortunately, because of the variations in working routines and break times, we cannot draw conclusions other than to suggest that demining during this period appears to be more dangerous than

at any other time, perhaps because of the climate or perhaps simply because this is the period when most deminers are working.

Figure 2: Occurrence of accidents throughout working day



The effects of heat

To maintain the required 37°C body temperature, a person's body must continually adapt to changes in:

- air temperature;
- humidity;
- air movement;
- solar radiation;
- barometric pressure; and
- clothing insulation.⁷

Muscular exertion and food intake also increase production of heat, which must be removed from the body. Failure to remove heat results in hyperthermia.

The back and chest have the greatest sweating rates and the arms and legs the least. Sweat evaporates from the heat of the skin and cools it. Evaporative cooling is most effective when the skin remains wet and, in high environmental temperatures and strenuous exercise, liquid loss may be as high as 1.4 to 2 litres an hour.

In hot, dry conditions, evaporation accounts for 85 to 90 per cent of heat dissipation, emphasising the need for wet skin and lightweight, loose-fitting porous clothing. When air temperature and humidity levels are high, means of body cooling are stifled and the body stores most of its heat. PPE prevents heat loss from the body, meaning that there may be a higher risk to the deminer by wearing PPE through error induced by dehydration and/or heat exhaustion than if the deminer were not wearing it.

Physical and psychological effects

The following are the main physical and psychological effects of dehydration:

- heat exhaustion;
- exertional heatstroke;
- heat cramps;
- heat syncope (fainting);
- severe discomfort, and in some cases distress; and
- loss of mental capacity and lethargy.

⁷ Sanders and McCormick (1992).

Combating the effects of dehydration

Plenty of care is taken in the logistical and procedural elements of managing deminers (i.e. parades and inspections, etc.) but not in the general refreshment and comfort of the workers. More emphasis should be placed on rehydration, and thermal and physical comfort to aid performance.

The following are ways to combat the effects of dehydration:

- acclimatisation;
- hydration;
- loose, lightweight clothing;
- porous clothing;
- cold water on skin; and
- drinking water and electrolytes.

Comment

Discomfort is an inevitable consequence of operating outside in harsh environments. In the case of deminers, this is compounded by the heavy-duty PPE generally worn during the course of their work, which contributes to the heat build-up and liquid loss during work.

There are limited mitigating procedures that can be undertaken to overcome these potential problems. Regular water intake, measured workloads and regular breaks will all assist with the problem. But deminers should not be expected to regulate all these by themselves and managers should ensure that these issues are being dealt with in a sensible manner by the deminers.

There is also a wider question as to the justification for wearing PPE. It is the view of this Study that there should be a full review of IMAS on PPE and that clear guidance be should be given to operators on the factors to be taken into account when planning what PPE to wear.

Effects of personal protective equipment

The introduction of mandatory PPE has been one of the major safety innovations in recent years. However, the degree and standard of PPE vary considerably between organisations. Moreover, although PPE plays a vital role in the protection of the individual, a number of factors should be considered when purchasing a particular type, as it can have a negative influence on performance, and the wearer can be affected in several ways:

- **Increased risk of error through visual distortion caused by the visor**, particularly if it is poorly maintained, scratched or otherwise damaged; this is a main reason for wearers to violate SOPs and lift their visors, putting their eyes and face at risk.
- **Accelerated fatigue**, caused by the body and joints having to work against the weight and bulk; there appears to be an increased risk of trips and falls, in particular if the wearers cannot see their feet when wearing body protector and the visor.
- **Dehydration**: PPE accelerates the sweating process and the risk of dehydration, which has an implication for performance.

- **Increased risk of musculo-skeletal injuries:** the human head is heavy and for demining tasks it has to be extended forward and downward, which, even without a helmet, puts the neck and shoulders under strain as the head is out of balance. Wearing a helmet and visor exacerbates this considerably, which will probably accelerate the effects of fatigue, headaches and muscle strain; this is another reason for lifting the visor as it helps to rebalance the weight on the head.

The DDAS has identified that 27 per cent of demining accidents are caused by missed mines. The majority of accidents cause lower limb injuries, against which there is little physical protection available. Other frequent injuries are to hands and fingers yet gloves are not typically provided, and when they are, they are typically gardening gloves which offer little protection. Visors do protect against the other frequent type of injuries — i.e. those to the face and eyes — but because they are uncomfortable, hot and distort vision they are often not used correctly and thus contribute in a roundabout way to the accidents. Thus, the protection being provided by a body protector does not address the main type of injury being experienced.

Body protectors are primarily designed for protection against fragmentation injuries, which are best prevented by good lane drills, site management and adherence to the safety procedures in SOPs. Body protectors come in many shapes and sizes: some just cover the torso; others the groin and legs. Those protecting the thighs hamper movement and increase exertion, so accelerating fatigue. They also inhibit any airflow around the skin for cooling purposes.

Those at most risk from fragmentation are the supervisors walking between lanes when deminers are working, yet in many observed incidents these were also the very people not wearing body protectors — contrary to SOPs. The size and purpose of body protectors should be examined for cost-effectiveness, as reported body injuries appear to be few, they are expensive,⁸ and they may have a detrimental effect on performance, especially when comparing the protection they actually provide as against a greater threat of injury to other body parts.

In fact, body armour may be a legacy from the military combat role when lane distances could not be sustained as the rate of advance would be a priority and clearance was conducted standing up. In these situations, the risk of injury from fragmentation was therefore much higher. Section 4 (*Risk Assessment and Risk Management*) further supports the view that the necessity of PPE needs to be reassessed.

Comment

There are still several schools of thought on the use of PPE. It is the view of this Study that much more flexibility should be allowed in the use of PPE and, in certain circumstances, there may not be a requirement for body PPE. From the evidence available, it is believed that eye protection is vital and should remain an absolute requirement for deminers. This does not mean, however, that the common visor needs to remain the *de facto* standard.

The Study therefore recommends that the IMAS be reviewed urgently with a view to downgrading PPE requirements. This could perhaps be done through a “risk zoning system”, and a review of safety distances in areas believed to be contaminated to allow for closer working and, by default, easier of site management.

8. Although this appears to make no difference to the output costs of cleared land: see Section 5 on the costings of manual mine clearance.

Influence of management style on performance

Management style has a major influence on the effectiveness of demining at all levels. This section addresses in turn issues of SOPs, working patterns, shift lengths and incentives.

Standing operating procedures

The development of SOPs has been enhanced with the introduction of the IMAS. The SOPs to which the study team had access were detailed — in some respects, perhaps too detailed⁹ — and rigorous. For instance, some of the levels of checking and rigid reference to times and processes could mean that individuals are not given the latitude to ensure that their procedures best fit the situation.

One NGO staff member made the point that the organisation did not update its SOPs as they were constantly out of date and not readily available. However, he also later claimed that all the demining incidents experienced by that organisation were attributable to a failure to comply with SOPs. If, however, SOPs are too detailed then they are likely to be violated or deemed irrelevant to a site.

Many SOPs do not refer to calibration of detectors, testing or any other physical feature of performance by the deminer. Radios and machines are typically covered in detail, but the physical condition of the deminer is not. In general, the more effective SOPs appeared to be those that were short, discrete and which reflected daily realities.

Shift lengths

The regular working schedule for most organisations visited by the study team was a 40-hour working week with a regular five-days-on, two-days-off pattern, plus annual leave. However, there were some variants, such as the HALO Trust, NPA and MgM (Menschen gegen Minen), who work for extended periods and then allow more time off so that deminers can return to their families (i.e. 24-days-on and seven-days-off in the case of HALO, and up to 48 weeks of work a year for MgM¹⁰). However, they still work an eight-hour day on average, with the start/finish time varying with the climate. However, given the various types of drills and rest breaks, deminers generally operate for between four and six hours a day.

The number of days worked consecutively has a significant impact on performance levels over time. It may be that the extended shift routines are detrimental over the long term for the following reasons:

- **Extreme fatigue through accumulation of boredom and no downtime:** people are not good at sustaining quality of work when tasks are not only mundane but also arduous.
- **Too long a break:** the break period means that deminers are likely to switch off completely, therefore taking longer to get back into their routine and increasing

9. For example, the SOPs reviewed were detailed in the conduct of parades and timings but not so detailed in the description of tasks and how to solve problems should they occur.

10. MgM have a structured and military-style day of four-hour shifts, working 20 minutes on and 20 minutes off. The day starts at 6am going through until 6pm. Deminers work seven days a week, relying on weather conditions and machinery breakdown to account for breaks (excursions and sports are also organised). This is a mirror of a military structure, including parades and making camp, with a “lights-out” end to the day. A team is as big as it needs to be for the task.

the risk of error; supervisors of this regime reported higher near-miss incidents during the beginning and end of the shift; this will be true of any shift pattern but will be more pronounced in longer shifts.

- **Too long a period away from family:** causes some degree of anxiety.
- **The boring nature of the job:** this means a higher risk of long-shift employees developing social problems, such as drink, drugs, gambling, etc.; the level of incidence of HIV in the demining population also suggests this may be the case.
- **Infrequent visits to family and increasing “vices”** prevent money from being sent back to the villages and families.

Incentives

A number of organisations work on a disciplinarian model, such as a monetary “fine” for every minor mistake in the field. There does not seem to be any consensus on motivational factors for performance.

Deminers are given sick pay and some have paid annual leave over and above national holidays. One example of an incentive encountered was to set a daily target to be cleared by each deminer, which, when achieved, meant he/she could finish for the day. This created a situation where deminers were encouraged to go faster, and some were achieving their targets within a couple of hours. Such targets are inflexible with regards to ground conditions and are not conducive to positive safety.

The organisation involved felt that quality had not been traded off for speed. This is debatable, however, as in the particular minefield where this incentive was implemented, there were no mines and very few fragments — but there was very clear evidence during our visit of at least one serious safety error being committed with regard to an item of UXO. This may be attributable to the incentive, or reflect the urgent need for refresher training.

Few other incentives are offered, the potential for promotion is low and no cash bonuses are given for a well-cleared area or high performance levels. Some organisations do present a prize for the most productive deminer but, given the variables affecting productivity, this may not be seen as a fair system. The only benefits are sick pay and holidays, a system which may actually promote a “sickness” culture where beating the system for days off is more important than productivity.

A “big stick” approach has long been proven to be an inappropriate management tool for motivating employees over the long-term, whereas job design has shown to be one of the most important aspects in improving performance. Two methods are considered to be most effective: *job enlargement*, which means giving people a wider range of skills – despite the additional training costs, this has shown to be cost-effective in improving performance;¹¹ and *job enrichment*, which adds additional responsibilities and skill requirements or control into the widened range of tasks.¹²

Motivation is multi-faceted and sometimes the different driving factors may conflict — for example, the desire to please one’s employer against the risk of alienating one’s fellow employees by showing them up through excessive diligence and output. An international survey of eight countries¹³ showed that the two most important motivating factors for all nations was achievement and performing interesting work.

11. Campion and McClelland (1993).

12. See, for example, the “Volvo Study”: Gyllenhammer (1977).

13. Elizur et al. (1991).

Sustaining motivation when individuals have no sight or feedback of their performance and cannot see the benefits or long-term gains quickly causes disillusionment. Lack of promotion opportunities in organisations that do not want to decentralise (disseminate responsibility and decision-making) may cause individuals to suffer from burnout, resulting in degradation of performance.

The best practices experienced by the study team were those observed during a visit to a MAG locality demining project in Cambodia. Safety was observed without fail (the only site on which this occurred during research for this sub-study). The area was well laid out and the deminers (of mixed sex and age) were well equipped for the task. They were working near their village and lived and ate in their villages at night.

Pay for deminers working on this MAG locality demining project is considerably less than that earned by a “conventional” deminer and locality deminers are only hired on a two-year contract. As soon as the site is cleared, the deminers can return to farming. The money is spent in the community and no negative side issues were observed. Typical pay for a locality deminer is around US\$80 per month and there seems to be an additional motivation factor in that the deminers are clearing the areas near to where they live. The recent Donor Evaluation of Cambodia¹⁴ reminded the mine action community that the true beneficiaries of mine action should be the local communities, rather than the workforces of the mine action agencies.

Comment

In Section 3 (*Operational Systems in Manual Mine Clearance*) improvements that can be obtained by altering technical issues are clearly identified. It is, however, important to realise that the **key** factor — the factor that will most affect the outputs, productivity, safety and efficiency of demining — is the management of the programme.

Team management

Box 2. A military perspective?

The Section Commander's duty is to actively correct any faults the deminer may commit, and to prevent the deminer from deviating from the SOPs. One Section Commander can supervise up to eight deminers, but in some cases will supervise no more than four. According to some SOPs examined, each deminer is supposed to be checked at least twice every 30-minute period. This means, in these examples, one-fifth of the Section Commander's time (assuming one quarter of time spent observing and some transit time between deminers) is spent watching others work (while typically being closer to operations than the 25-metre safety distance).

In addition, there is often a safety officer who checks on everything, as well as performing quality control. This is the work of the Platoon Commander. A Platoon Commander would also be responsible for the work of the Section Commander (of which there would traditionally be four). This implies that a very large proportion of time is spent checking and overseeing a small number of people.

Box 2 demonstrates the deep-rooted military perspective on demining. The military-style section model described is heavily process- not task-focused. Military lifestyle has

14. Keeley and Griffin (2004).

historically operated the “bull” system:¹⁵ that is, a reliance on meaningless tasks to ensure discipline and order but which are not task-focused and do not contribute to effectiveness. The military organisation may get a job done, but not necessarily as efficiently and effectively as one that is task-focused.

Most former military personnel will recognise the term micro-management, and those who have been subjected to it have usually resented it, but it seems to have found a significant following in the demining community. Such an approach may work in developed countries to a degree, but it is not clear how well it transfers to developing countries.

Middle management

A Field Officer or Site Supervisor is responsible for overseeing the demining site. The Field Officer is typically responsible for destruction of the mines — whether *in situ* or not. Site Supervisors are also trained to make minefield maps, maintain records and check the quality of the work. A quoted salary example in Cambodia for this role was US\$700 per month.

Even though the Site Supervisor is responsible for the running and management of the site they are often not entrusted to make decisions such as risk reduction processes on the site, and is likely not to have received training in decision-making.

A Site Supervisor has a great deal of responsibility and requires a number of skills that are not inherent in a deminer. She/he can make a large difference to the performance of the deminers and the site in terms of timescale, costs and safety. The abilities to complete a large amount of paperwork and to accurately assimilate and estimate lots of data are required on a daily basis. Organisation of the lanes in relation to the topographical features and manpower available and the management of mined areas are specialist skills that need to be trained. The following are examples of some of the skill-sets required of a Site Supervisor:

- calculation of area to be cleared;
- calculation of area cleared;
- site planning — how and where to clear to optimise deminer performance;
- site set-up and ongoing management, including movement of poles, fragment collection and recording, etc.;
- daily clearance rates for each deminer and total cleared — what has been cleared, where has it been cleared, residual issues (trees, mounds, etc.), daily disturbances, mines destroyed or moved;
- map updating;
- Quality Assurance management and reporting: where and what and by whom;
- equipment reports — detectors, PPE, and machines;
- dog performance reports;
- explosives management;
- injury and sickness reports;
- transport reports — mileage and mechanical failures, fuel recording;
- supplies and stores — batteries, food, water, medical supplies (out of date, used);
- pole painting — each organisation appears to have its own marking system;
- management of visitors and recording visitors onto site;
- disciplinary reports; and

15. Dixon (1976).

- decisions about the implications of threats found, their location and type, their possible impact on boundaries and lane clearance, and the allocation of potential mined lanes to deminers who have the right experience and who are not tired or sick.

The Site Supervisor is responsible for a large amount of monitoring, both for safety and to ensure that tasks are done correctly. It was not clear in the organisations studied how these skill-sets and comprehensive knowledge requirements were trained and monitored. Many reported in-house training, which actually translated in practice to on-the-job training.

Comment

Deminers are not inherently managers. Many programmes in the past forgot this and promoted deminers without providing the backstop of training. This has changed to some degree, yet there are still a number of managers without the prerequisite skills to undertake the job they are required to do.

On many occasions, the Supervisor's responsibilities did not appear to be put into practice in the field. A considerable number of errors and SOPs violations appeared to go undetected and uncorrected by the team leaders and supervisors.

For instance:

- large, obvious (almost complete) ordnance, such as mortars, in the fragment bin;
- obvious signs of skill fade (e.g. poor use of metal detectors, prodding techniques, etc.);
- failure to comply with SOPs, no monitoring or overseeing, not stopping work when people came close, no PPE offered when walking in the cleared areas of minefields;
- poor mine area marking;
- poor safety procedures during blowing up *in situ*; and
- very cursory QA and checking procedures.

Other middle management roles

There are several roles within the middle management sector of a demining organisation. As with the Site Supervisor, within the NGOs it is not clear how, and according to what criteria, these positions are filled. These positions are critical to making demining organisations function correctly, as they are responsible for such tasks as technical survey, overseeing mechanical demining, area reduction, logistics and — most critically — the management and flow of information for daily reporting between regional offices and the minefields.

It is also not clear what training is provided within programmes to support the staff who occupy these roles.

Cranfield University's Resilience Centre (formerly Cranfield Mine Action) in conjunction with the United Nations Development Programme (UNDP) and regional delivery partners, runs generic management training courses for middle managers, which aim to develop management skills of managers throughout mine action organisations, but the training does not address these functional field tasks

In-house training appears to be the most popular approach. There is, however, a significant risk of a gradual erosion of content and quality if the training is not conducted in a structured and efficient way, and the influence of external factors such as emerging trends and technologies are not included in a formal manner. In addition, if training is too internally focused it often reduces creativity and fails to detect developing flaws or knowledge gaps.

NGOs and some commercial companies do not appear to have any formal method of recording events and their consequences (at all levels). Failure to do this means that there is often no “corporate knowledge” captured and recorded within the organisation. This prevents forward momentum being sustained and tends to lead to perpetual reinvention of the wheel.

Decision-making

The emerging number of technologies and methods for conducting clearance mean that the middle manager has a growing number of day-to-day decisions to make. If the Site Manager or other middle managers are to be able to conduct their tasks effectively they must be able to make these decisions immediately — and without having to refer up the chain of command. Some of the decisions observed, for which it was not clear where responsibility for determining the answer lay, are listed below:

- choice of detector for a task;
- where to stop and start a minefield’s boundaries;
- the layout of a minefield and deployment of the teams;
- the repositioning of fragmentation dumps and maintaining the site as clearance continues;
- how to approach trees and fallen logs and raised ground; and
- how to deploy operators.

These decisions have a huge impact on efficiency and effectiveness, yet they seem generally to be ignored. Middle managers are not taught how to make decisions, and cultural differences often create problems as it is not customary to contradict or face up to superiors. This is often reinforced by a lack of trust by expatriates who are not confident that local staff can make good decisions.

Training an individual in decision-making relies on trust and the ability to allow the person concerned to gain experience and learn about the consequences. A free and open organisational culture must be established to create confidence to allow open exchanges between managerial levels and create autonomy. If it is not, there is often a resultant “no decision” action, which stultifies and prevents progress being made, and often masks any signs of an unfolding incident. This was apparent at many sites where poor practices were being followed religiously because no-one was confident enough to query prior decisions, despite unfolding evidence that clearly superseded original plans and decisions. In one case, this resulted in leaving a potentially dangerous strip of land between a village and a railway uncleared.

There were many examples witnessed of poor site management, for example:

- confusing marking and clearance methods for fallen trees, earth mounds, or undulating ground;
- a lack of consistent mine or lane marking methods;
- poor site layout, or a failure to update the site layout to match progress;

- safety measures varied hugely between organisations and sites; and
- standards of mapping and date recording at some sites were poor.

Other examples of problems of decision-making at the junior or middle management levels can be found in some of these case histories:

- Money is often the primary factor in decision-making. A deminer in Cambodia suffered more damage to his hand than he should have done because, instead of the helicopter being called out (when freely available), he was driven six hours to hospital. Therefore his perception of senior management is “cost first, human safety second”, which appears not to be the senior management’s intentions at all.
- Middle management reports did not include anything more significant than a request for additional paint to paint mine marking sticks, and the requests are justified with long detailed explanations. Again, money is deemed to be the overriding factor, no queries or questions were raised in any other areas.
- Suggestion boxes limit themselves to similar levels of management. When asked why, it was because staff did not want to rock the boat or imply criticism. This was observed in both Cambodia and Mozambique.
- There was no evidence of good communication between senior and middle management but junior managers are often caught in the middle and don’t wish to be seen to be disloyal to one or other of their managers. They become frightened of which policy to adopt so do nothing, or adopt a half-way position.
- Cultural issues often prevent explanations of why they appear to have disobeyed orders and there is resultant resentment and distrust.

Comment

The biggest area of saving may be achieved by addressing the problems at middle and senior management levels. Apart from a few organisations, there was clear evidence of poor project management skills, with considerable focus on micro-management. This results in the implementation of process-driven rather than task-focused management style.

This is not to say that process is undesirable in the demining community: it is. However, because of the variables involved with every task and the number of uncontrollable elements, the process should support adaptability and flexibility, not rigidity. Process must be relevant to the situation, not too specific or at too low a level, and must be easy to administer given the distributed nature of the organisation and the communications issues that prevail. A great deal of effort has been put into the detail of operating a platoon, such as command structure, shifts, manning levels, pay, parades, transportation and accommodation. Far less attention appears to have been focused on recruitment, training, human factors of the deminer or the career and performance of the supervisors and their managers.

Although demining is an international and multi-million dollar industry, the culture is still largely to operate using a “small-business” approach to management. The culture of the demining industry promotes success of strong-minded and independent individuals who are able to raise the profile of their individual organisation through sheer force of personality. This often results in a general reluctance to comply with anything that is perceived as “big brother” or meaningless process. If the industry is to avoid donor fatigue, and continue to develop the programmes in a safe, efficient manner, then organisations with the will and ability to deal with this issue are likely to be the ones that continue to prosper and grow.

If we follow the assumption that demining will eventually become part of an overall national development programme, all demining organisations will need to develop internal structures to support the more stringent management skills of conglomerate organisations. If this is to work — and it is probably the most constructive and effective way to develop the demining industry — then change is required in all NGOs if they are to compete with the better developed management skills of commercial demining companies.

A few organisations, both commercial and NGO, are starting to appreciate the benefits of employing the services of external non-military personnel with no demining experience. They have identified the need for a fresh approach and understand that commercial understanding and programme management are complex skills and are not easily home-grown. At the middle manager level, skills and training need urgently to be addressed. Decision-making needs to be flowed downwards and away from the senior management level for day-to-day site running issues. There are, of course, also former military personnel who have taken the time and effort to expand their education to broaden their perspective.

At the lower management levels and at the deminer levels it may be constructive to compare the approaches adopted by other commercial non-demining organisations that operate in similar environments. Discussions with them highlighted the following:

- they recruit locally or get personnel to relocate; they expect the person to pay for their own training i.e. to come already qualified for the job, or not to receive wages until they have completed training, or to complete a more menial job until they have completed their training in their own time;
- they expect employees to be responsible for their own transport to and from the main workplace;
- they expect employees to be responsible for their own food and accommodation;
- they develop a career structure for their employees;
- they have some means of performance evaluation;
- they consider motivational issues and get employees to buy in to their strategy;
- they develop skills within the organisation through external training;
- they put more emphasis on the effectiveness and completion of the plan from start to finish, rather than just the start; and
- they promote an open philosophy.

While not all the above bullet points are appropriate all the time, it is worth noting all these issues for consideration when reviewing an organisation's management policies.

Error budgets

Discrepancies were often apparent between the actual area cleared and the area reported to have been cleared. This appeared to continue throughout the system, often being rounded up generously at every stage in the process. In general, data recording was suspect, in that some areas being marked as cleared were not representative, and some of the figures were clearly inaccurate, i.e. the area cleared was larger than the actual stated minefield size. This clearly distorts upward reporting.

In one case, a single person received 32 calls every evening from survey teams, site managers, mechanical teams and dog teams. Every evening he had to manually collate

the data into a meaningful picture of what had been achieved that day. This entailed converting verbal reports into visual mapping of areas identified for clearance, areas reduced by dogs and mechanical means, and areas manually cleared at three sites. The ability to interpret such a large amount of verbally reported information of this nature correctly is almost impossible, and certainly more than one person should have to manage every week, let alone every evening. The potential for serious errors in data recording is quite considerable.

This phenomenon was not limited to one organisation although it is less likely to occur in commercial settings as companies typically have more tangible targets and more developed reporting systems. If data is not being collected and reported accurately, organisations cannot predict or provide accurate figures for their own records.

Practical site layouts for all environments appear not to be taught in the official courses available and nor are they included in IMAS. Thus, for example, poor allocation of resources in the field results in time-consuming and ineffective use of assets such as machinery or the inefficient use of dogs.

Senior management

Many senior management posts in international demining organisations are filled by expatriates. There is a concerted effort in all organisations to keep the number of expatriates to a minimum, due both to the costs and to the aim of capacity-building. All international NGOs have headquarters in other countries where the central coordination and administration takes place, and where other senior management personnel are based.

Nearly all international NGOs and commercial firms are staffed by international ex-military people, and few heads of any major clearance organisation do not have a military background. In addition, there are currently only five UN-employed Senior Technical Advisers (effectively programme managers and political advisers) out of 30 who are non-military and, as far as this Study believes, only a small proportion of technical advisers in the field are non-ex-military.

A number of demining organisations have an individual strong leader, who is not running a small business in terms of size and turnover, yet still persists in running it with a small business philosophy. The risk of having a complete community run by one group of like-minded individuals is the threat of “group think” and a lack of innovation and creative problem-solving.

The most critical role identified in a demining organisation was that of Project Manager. This person requires a multitude of inward- and outward-facing skills, including:

- financial;
- planning and scheduling;
- logistics;
- process, including ISO accreditation;
- people management;
- coordination and communication skills;
- networking;
- creativity;
- attention to detail;

- understanding the big picture;
- ability to delegate;
- leadership;
- team-building;
- inward-facing;
- information technology (IT) skills; and
- domain knowledge of demining.

The ability to conduct demining tasks is not seen as a priority and there are usually Subject Matter Experts (SMEs) available to provide the detail of the day-to-day running of a project, although the Programme Manager must clearly have some technical background, if not necessarily in demining *per se*.

The current project management role may need to be altered to meet the changing demands of the mine action community as it evolves. This is something that some commercial firms are already addressing as they have to meet the stringent demands of large conglomerates in order to win business. For example, one commercial firm has implemented a deliberate policy of employing project managers from the construction industry for running demining projects.

Task management

Performance issues

Deminer performance

Section 3 (*Operational Systems in Manual Mine Clearance*) attempts to go some way to developing a set of benchmarks for clearance rates and, earlier in this section, a number of examples were given identifying orders of scale for clearance rates. The industry may benefit from developing a clear benchmark of what a deminer should be expected to achieve given a set of criteria, and at what cost. The example of Croatia, which has taken a firm grasp of its demining requirement, has enabled the Croatia programme to understand exactly how much it should cost to clear a piece of land and how long it should require. CROMAC has understood the acceptance of risk and has developed a methodology that has enabled the release of mine-suspected land if it passes several tests.

Interestingly, CROMAC has the information available to compare the common features of several companies, such as skill levels, working hours, equipment, etc. As CROMAC estimates how much a square metre in a particular area should cost and how long it should take to clear, it is able to identify the variations in their hidden costs and to compare their performance levels. CROMAC reported that the only difference in performance, apart from costs (these costs are dictated by the efficiency levels and overheads of each company), was the management structure. The major differences were stated as being forward planning for:

- accommodation — poor accommodation/site selection can lead to additional costs and labour;
- medical support;
- transport;
- coordination and communication;
- local councils if roads or services need to be disrupted (there are delays in getting appropriate licensing or ensuring the right authorities provide the necessary support if local utilities or amenities have to be disrupted); and

- networking to gain support of local agencies.

The implications of this may be that a stable government and legal system are necessary in order to achieve the level of reporting required for a well informed evaluation to be made.

Data gathering to support management

Statements to the study team confirmed that reports of performance may be overestimated by as much as 50 per cent. There was also evidence to support claims that there is sometimes clearance for clearance's sake, such as area clearance undertaken in areas with no potable water and therefore unsuitable for resettlement, or areas with no mines. This is often a matter of poor tasking and planning and should be reflected in a revised risk assessment.

There appears to be a general lack of trust between national government organisations, such as the Mozambican IND (National Demining Institute) and the Cambodian Mine Action Authority (CMAA), on the one hand, and the operators, on the other. This creates tensions that impact on QA, information flow and survey/site allocation. It was not immediately clear whether these organisations were in fact fulfilling the role for which they had been created, or were contributing to the management conflicts.

Implementing change

A number of studies of the demining community have been conducted over the past few years, and it is fair to say that there appears to have been a concerted effort from the operational community to respond to the findings and implement changes. The general findings however imply that significant problems remain at the management level and that the demining community is mostly too conservative and inward-looking.

There is a general belief in many management models that efficiency comes from control, and that by producing standardised "best practices" and routines all problems will be solved. However, sometimes these "best practices" can prove to be "grooved and inflexible".¹ Because the demining community is so diverse, a grooved and inflexible approach to management may only serve to undermine its members' ability to be adaptive.

The demining community is clearly entering a period where external issues are creating a need for change. It is not clear if current studies have addressed future impact and evolution, therefore if organisations have responded to the calls for change from previous studies, but have not considered the impact of the future, they may be asked to change yet again. As this iterative process continues, cynicism about change sets in. The general perception is that the industry as a whole is resistant to change.

The argument for using a change approach is also supported by other factors — such as manual demining activities not being able to keep up with clearance requirements of expanding population when war has ceased and refugees return and families reunite. The mismatch encourages village demining to be conducted through desperation. Therefore the policy on technical survey, area reduction and attitude to risk may have to change if this is to be addressed.

1. Anderson (1999: 113–152).

Conclusions and recommendations

Conclusion 1.

The management of manual mine clearance operations could be improved and this would lead to significant gains in productivity.

Findings

Apart from a few commercial companies, there is continuing and clear evidence of poor project management skills, with considerable focus on micro-management. This results in the implementation of a *process-driven* rather than a *task-focused* management style.

This section has noted the military background of the majority of personnel engaged in mine clearance in one capacity or another. It is increasingly understood that the skills and experience that serving or former soldiers bring to mine action are invaluable, but they are also insufficient. What is often missing today is project and programme management experience acquired in the development and/or the commercial sectors, bringing a corresponding drive for efficiency, innovation, creativity and flexibility. Deminers typically are only operational for five hours per day and many organisations stipulate this. At the individual deminer level, it appears that dehydration is a significant factor in performance and safety.

Funding for mine action projects is often short term and limits the abilities of programmes to plan in any long term manner.

Training also appears to be an issue in some cases. It may be beneficial to provide a short refresher course to all deminers when they start a new site.

Problems are particularly acute at middle manager level. Although middle managers are ostensibly responsible for running and managing their particular area of responsibility, in many cases they are not equipped with the resources to undertake this task and are often not given the necessary autonomy.

Recommendation 1.

- a. Manual mine clearance organisations need to move towards a task-focused management style. One way to achieve this is by bringing in project and programme management experience acquired in the development and/or commercial sectors.*
- b. In all cases, decision-making needs to be delegated downwards and away from senior management to middle management for day-to-day issues, such as running a demining site. At the same time, middle managers need to be recruited and trained to be able to take the necessary decisions as well as having the support of the senior management in those decisions.*
- c. Greater emphasis should be placed on rehydrating deminers, and on their thermal and physical comfort to aid their performance.*
- d. Donors would assist NGOs to be more proactive in their resource planning if they offered longer term funding.*

Conclusion 2.

Actual average rates of clearance appear to be in the region of 15 to 20 square metres per deminer per day.

Findings

Although the feedback from many operators on the ground suggested that they believed they were clearing much higher rates, on the evidence of the data gathered and after consultation with several well documented mine action programmes, the rates for manual mine clearance (as opposed to area reduction, technical survey, battlefield area clearance, etc.), were close to the figures identified in the GICHD Study of Operational Needs.

The most effective work is produced from a deminer when he/she is taking frequent short breaks and operating with comfortable PPE, when and where appropriate.

Recommendation 2.

- a. Programmes should be more vigilant about effectively recording clearance rates and develop a benchmark to work to.*
- b. Discomfort is inevitable in harsh climates, but can be ameliorated by well-designed PPE. Managers should consider this when purchasing PPE.*
- c. SOPs should be developed to ensure working deminers take frequent short breaks and field management should ensure deminers are maintaining hydration.*

Annex

Approaches to problem areas in manual mine clearance

| Number | Problem area | Problem focus | Level of source of problem | Solution |
|--------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | Inflexible management style | (a) Leadership and team work (b) Failing to adapt to meet differences between Immediate Response and Sustained operations or future requirements. One size fits all approach. | International and national HQ | <ul style="list-style-type: none"> · Implement change management to meet future demands to reflect identified vulnerabilities, such as culture, communication and management style. · Communication techniques must be improved – e.g. use of tools such as advanced team decision-making. · Improve team working skills throughout the organisation – tools as above. · The organisation should be flattened and less hierarchical to aid communication and the risk of messages failing to be passed on from fear of retribution and cultural norms. · Encourage a more open and less defensive organisational culture. · Develop SOPs for immediate response. · Develop guidelines for sustained development operations. · Conduct gap analysis and implement transition strategy. |
| 2 | Military management model | (a) Incentives and motivation (b) Not cost effective (c) Trust and delegation | National management, task management National management Task management | <ul style="list-style-type: none"> · Devise career structures, diversify tasks and delegate. · Improve communications, information flow and decision-making policy. · Importation of skills from outside the military community (may bring some valuable management insights). · Outsource. · Improve logistics. · Improve planning. · Incorporate developing country problems into plan and mitigate not accept. · Reduce micro-management reduces flexibility (see number 1). · Implement external training for middle management. · Decentralise decision making. · Increase accountability. · Increase individual task type. · Reflect cultural issues. |
| 3. | Benchmarking | (a) Resistance to agreement of common standards | International management, national management, task planning | <ul style="list-style-type: none"> · Strong leadership for change and development of criteria for benchmarking. · Educate all stakeholders in management techniques that permit benchmarking and benefits of implementation. |

| Number | Problem area | Problem focus | Level of source of problem | Solution |
|--------|--------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4 | Recruitment and Training | (b) Criteria to enable bench-marking (c) Capacity-building issues | International & national management International, national, local | <ul style="list-style-type: none"> · Identify and agree influencing criteria at appropriate level (international and national). · Develop matrix of impact of conditions and methodologies. · Agree costings and performance levels associated with each cell. · Understand the real costs and benefits of capacity building approach. · Employ a systems approach to cost/benefit analysis (e.g. is national capacity better developed as a military capability, enhancing the peacekeeping skills and role of national military personnel, and using a more commercial approach to support National Development Programmes as part of a larger picture). |
| | | (a) Entry skills | Local management | <ul style="list-style-type: none"> · Define qualities required of a deminer (fitness, age, hearing, attitude, etc.). · Conduct physical tests on entry. · Recruit from entire population. · Recruit locally for defined contract period (i.e. two years). |
| | | (b) Initial training | Local management | <ul style="list-style-type: none"> · Standardise training syllabus and time scales. · Develop levels of training. · Candidates must be able to fail. · Candidates should not be paid during training to provide motivation to achieve performance levels and give a sense of achievement. |
| | | (c) Use of in-house training | Local management | <ul style="list-style-type: none"> · Not self-critical and often perpetuates problems. Gradual degradation occurs naturally, and there are no external benchmarks for standards and assessments. · Outsource training, or · Create dedicated peripatetic training team that is kept current and is fully qualified to train. |
| | | (b) Refresher training | Local management | <ul style="list-style-type: none"> · Should be provided: <ul style="list-style-type: none"> · on starting a new site (specific training for site conditions). · if deminers are working in a low mined site. · when changing detector types. · when in two or three man lanes if metal detectors not used frequently. |

| Number | Problem area | Problem focus | Level of source of problem | Solution |
|--------|--------------------|----------------------------|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | (c) Management training | National, local management | <ul style="list-style-type: none"> · Ensure all practical management skills are taught in context specific manner (not general management). · Employ naturalistic decision-making training (e.g. advanced team decision-making tool). · Train fully in site management and layout. · Communication skills. · Use external providers who can bring experience of other organisations and cultures. |
| 5. | Project Management | (a) Recruitment and skills | International, national | <ul style="list-style-type: none"> · Recruit from outside industry. · Seek innovative and flexible attitudes. · Good communication skills. · Ensure planning and predictive skills available. · Apply benchmarks. · Apply exit strategy - these should be included for all operators, time limits with end dates which are adhered to, should be mandated with penalty clauses. This should improve the inaccurate square metreage calculations and enable better planning. |
| 6. | Efficiency | (a) Area reduction | International, national | <ul style="list-style-type: none"> · Agree acceptable risk - use different criteria to determine risk. · Determine methodologies to be used in area reduction, conduct cost benefit analysis. · Agree effectiveness and acceptability of dogs in area reduction to help understand benefits/offset costs of their deployment. · Use of machines - which ones should be used and how they are deployed. · Agree and define acceptable levels of fragmentation residue. |
| | | (b) Technical surveys | International, national | <ul style="list-style-type: none"> · Agree definition and goals. · Standardise methodologies. · Employ structured training (mapping, site marking, etc.). · Standardise international approach for site marking, post painting (if there is one it is not employed). |
| | | (c) Methodologies | International, national, local | <ul style="list-style-type: none"> · Employ multi-skilling approach. · Agree and define lane working methods and expected performance given terrain and use of equipment (see benchmarking). |
| 7. | Human factors | (a) Dehydration | National, local | <ul style="list-style-type: none"> · Identify impact of dehydration and effect on performance. · Identify impact of clothing on dehydration. · Ensure water is supplied by organisation. |

| Number | Problem area | Problem focus | Level of source of problem | Solution |
|--------|--------------|----------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | (b) PPE | National, local | <ul style="list-style-type: none"> · Examine benefits of use for electrolytes in certain conditions. · Understand the real effects of PPE and clothing on performance. · Conduct performance/cost/safety/benefit analysis. |
| | | (c) Age/length of demining service | National | <ul style="list-style-type: none"> · Develop performance criteria derived from benchmarking to determine when a person may have increased error risk through fatigue, burn-out, etc. · Introduce physical tests for fitness to work. · Use of multi-skilling/job rotation/promotion structure should increase deminer lifecycle. |
| | | (d) Shifts and work patterns | National | <ul style="list-style-type: none"> · Recruitment of local deminers should enable 5-6 day working shifts, reduce travel and subsistence costs and reduce sick rate. · A working day may benefit in this case from two shorter periods of 3-4 hours divided by a longer period off mid day. · Extended shift lengths are not advisable. |
| 8 | Donors | (a) Donor support to planning and management | International | <ul style="list-style-type: none"> · Provide donors with education of how they can influence and support good management practices. |

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Glossary of acronyms

| | |
|--------|-----------------------------------------------------------------|
| AREA | Agency for Rehabilitation and Energy Conservation (Afghanistan) |
| CMAA | Cambodian Mine Action Authority |
| CMAC | Cambodian Mine Action Centre |
| CROMAC | Croatian Mine Action Centre |
| DDAS | Database of Demining Accidents |
| EOD | explosive ordnance disposal |
| IMAS | International Mine Action Standards |
| IMSMA | Information Management System for Mine Action |
| IND | National Demining Institute (Mozambique) |
| ISO | International Standardization Organization |
| LIS | Landmine Impact Survey |
| MAG | Mines Advisory Group |
| NGO | non-governmental organisation |
| NPA | Norwegian People's Aid |
| PPE | personal protective equipment |
| QA | quality assurance |
| QC | quality control |
| SME | Subject Matter Expert |
| SOP | standing operating procedure |
| UNDP | United Nations Development Programme |
| UXO | unexploded ordnance |



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A STUDY OF MANUAL MINE CLEARANCE

3. Operational Systems in Manual Mine Clearance: case studies and experimental trials



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3. Operational Systems in Manual Mine Clearance: case studies and experimental trials



The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

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Contents

| | |
|------------------------------------------------------------------------|----|
| Summary | 1 |
| Introduction | 3 |
| Case study 1 | |
| Sri Lanka: Norwegian People's Aid and Danish Demining Group | 5 |
| Local demining organisations and controls | 5 |
| Demining procedure: The Rake Excavation and Detection System (REDS) | 6 |
| Quality assurance and quality control of the REDS system | 8 |
| DDG variations to the NPA REDS | 9 |
| Use of water | 9 |
| Conclusions from the Sri Lanka case study | 10 |
| Case study 2 | |
| Iraq: Mines Advisory Group | 11 |
| MAG's expansion | 12 |
| Manual mine clearance procedures | 13 |
| Post-clearance area reduction | 15 |
| Deminers and battle area clearance | 17 |
| Conclusions from the Iraq case study | 18 |
| Case study 3 | |
| Cambodia: Cambodian Mine Action Centre | 19 |
| Manual mine clearance procedures | 20 |
| Mechanical assistance | 22 |
| Post-clearance area reduction | 23 |
| Quality assurance and quality control | 23 |
| Efficiency plans and trials | 23 |
| Conclusions from the Cambodia case study | 24 |

| | |
|-----------------------------------------------------|----|
| Case study 4 | |
| Sudan: Norwegian People's Aid | 25 |
| Local demining administration | 25 |
| Quality assurance and quality control | 26 |
| Conclusions from the Sudan case study | 26 |
| Trial 1 | |
| Comparing alternative manual drills in Sudan | 27 |
| Objectives of the trial | 27 |
| Drills | 28 |
| Data recording and sampling | 29 |
| Results | 30 |
| Discussion | 34 |
| Trial 2 | |
| Comparing manual clearance systems | 37 |
| Introduction | 37 |
| Methods | 39 |
| Data recorded | 40 |
| Rate of progress | 41 |
| Safety | 42 |
| General patterns in the results | 42 |
| Prodding | 43 |
| Discussion | 44 |
| Conclusions and recommendations | 45 |
| Annexes | |
| 1. Interpreting statistical analyses | 49 |
| 2. Hybrid and Crab drills trialled in south Sudan | 53 |
| Bibliography | 61 |
| Glossary of acronyms | 61 |

Photo credits:

Cover: British Army mine clearance of a road in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number H 29725. All other photos ©"AVS consultants Limited".

Summary

This Section reports on the results of a study of operational systems in manual mine clearance. As part of the study, descriptive field studies of manual mine clearance methods were conducted in 2004 in Iraq (July/August), Sri Lanka (September), Cambodia (September) and in 2005 in Sudan (April and June). Management of operations was studied and the work of individual deminers was observed in detail.

The study found that many mine clearance programmes have developed innovative changes in techniques, some of which are adopted only informally. Thus, several of the procedures observed during the four case studies conducted for this study fell outside the perceived or stated requirements of national and international standards: this led a number of operators to call for a revision of the standards to incorporate the flexibility required by an evolving discipline.

Few groups provided all the safety equipment or worked strictly to the safety regimes required by the International Mine Action Standards (IMAS) or in many cases, the National Mine Action Standards (NMAS). Furthermore, no mine clearance group studied was working in complete compliance with their own written standing operating procedures (SOPs) and several were working in a manner that conflicted directly with them. Reasons given included a lack of time and/or relevant writing skills to introduce the changes, internal decisions to accept the changes and implement them immediately, and delays in getting SOP amendments approved by national mine action authorities.

A series of comparative trials of manual mine clearance systems was undertaken in southern Mozambique and South Sudan. All systems tested, except prodding from the surface of the ground, were effective at locating mines, although some deeply buried mines were missed. In a heavily fragmented area, the most efficient method of clearance involved the use of small powerful magnets as part of the system.

When a metal detector was not used, the method of clearance that optimised productivity, quality and safety involved an ordinary garden spade used as a horizontal "excavator" combined with conventional investigation tools. The "REDS" system (a

garden rake combined with excavation tools) was excellent for confidence and quality assurance/quality control requirements but was very slow.

When working a lane alongside a safe lane, the deminer had more flexibility of movement, and a number of efficiency improvements were obtained relative to the standard manual demining lane. This allows for the development of new and more efficient drills.

During the trials of different manual clearance systems, the rates achieved by the deminers varied from 1.6 square metres to 17.4 square metres in four working hours.

Prodding was most likely to involve an accident to the deminer. Prodding at 30 degrees to the ground achieved an average clearance depth of less than four centimetres, and all the mine surrogates that were located during the trial had been damaged by prodding on to their pressure plate, raising concerns about safety. After prodding, the method most likely to involve a deminer accident was area excavation using an *enxada* (a mattock), a finding that coincides with an analysis of available accident records in the Database of Demining Accidents (DDAS).¹

Six broad conclusions are drawn from the study, which are presented in summary form at the end of the Section.

1. UNMAS/GICHD Database of Demining Accidents, DDAS, 2005.

Introduction

There is considerable scope for improving productivity and efficiency within most mine clearance programmes. For example, drills could be streamlined in order to minimise time wasting within the drill and/or new types of equipment could be used. Many drills appear to be used because of historical commitment from earlier experiences, and little or no attempt is made to adapt the drill to local conditions in new deployment situations.

The reasons are sensible. Demining is a potentially hazardous occupation and caution dictates that deminers will prefer to continue using a drill that has been used safely in the past. Implementation of a new drill or item of equipment may require trials and retraining, both of which have implications for productivity in the short term. Finally, field managers of demining programmes may have neither the skills to run convincing trials, nor the authority to make changes even if a new concept proves satisfactory.

Despite this, innovative procedures *are* being used by demining organisations. Unfortunately, even if these procedures were the subject of careful trials during the implementation phase, they tend to be poorly reported. Thus they remain unknown to the wider community.

This section examines manual demining techniques with three general objectives in mind:

- to provide descriptions of a range of demining drills;
- to describe innovative procedures being used by organisations; and
- to assess and compare the efficiency of different drills under identical conditions.

In general, the assessments are made with reference to productivity, efficiency and safety. It is well known that manual demining drills are strongly affected by local conditions of vegetation, soil type and environmental conditions (especially rain). Manual demining in soft ground progresses faster and more safely than in hard ground. Vegetation clearance can take up a major proportion of the time of a manual deminer. Clearance of vegetation using machines introduces both costs and benefits that depend on the design of the machine and local clearance requirements.

Risk assessment can lead to actions in one place that would be inappropriate in another place. The SOP can be either obstructive or supportive of safety and productivity, and updating the SOP can be a difficult and challenging process. Thus any assessment of demining drills must be placed into context if the drills are to be properly understood, and some constraints cannot be identified or described during a short visit by an external agency.

It is a challenge for any demining organisation to allow the type of research done for this study. Some comments and descriptions in this study could be interpreted as critical by some, or might be used in a biased way by others. This is not the intent of the GICHD and is inappropriate in any context. The broad objective of this study is to inform field personnel of the ideas and procedures being used elsewhere in the demining community, with some assessment of relative costs and benefits. The methodology used is objective, and could and should be widely used. These studies provide a blueprint for similar studies conducted by others, either as an internal exercise, or as part of cross-fertilisation between agencies. The GICHD encourages and supports such activities.

The study was conducted as:

- a series of four case studies of demining drills and concepts; and
- a series of trials of different drills, some of which included innovative equipment.

In each case study, demining procedures are broken into their component parts in order to provide a fine-scale analysis of the anatomy of the drill. The case studies are primarily qualitative, in that systems are described in context. The trials, on the other hand, are primarily quantitative, in that different drills have been tested under identical conditions. Some of the procedures seen in the case studies have been applied in the trials, and some of the trial procedures were entirely new.

Case study 1

Sri Lanka: Norwegian People's Aid and Danish Demining Group

Sri Lanka is divided between government-controlled areas and areas controlled by the Liberation Tigers of Tamil Eelam (LTTE). After some 20 years of conflict, the fighting appears to have reached a stalemate, with both sides consolidating control in their areas and controlling the passage between them with frequent sandbagged “checkpoints”.

The most common anti-personnel blast mines found in Sri Lanka are the P4 Mk1 & 2, Rangan (Jony) 99, Chinese Type 72A, VS-50, and Jony 95. Anti-tank mines are relatively rare, but when found are usually M15 or Amman 2000 blast mines. Improvised concrete-cased anti-tank mines have also been discovered. Three of the most common mines are classed as “minimum metal” mines and can be very hard to locate with a metal detector.

Generally, mines were only destroyed *in situ* if damaged and their condition gave rise to concern. The two clearance organisations observed dealt with the discovered mines in different ways. The Danish Demining Group (DDG) moved mines without disarming them, transporting them in specially made boxes for later mass destruction. The Tamil Relief Organisation's (TRO) Humanitarian Demining Unit (HDU) working with the assistance of Norwegian People's Aid (NPA) routinely removed the detonator/booster from mines and stored them in the minefield for later mass destruction.

Sri Lanka was visited for the purposes of this study for one week in September 2004.

Local demining organisations and controls

The National Steering Committee for Mine Action (NSCMA) is a national coordination mechanism advised and supported financially by the United Nations Development Programme (UNDP), to which all groups report (including those operating in LTTE areas). The strategy for mine action in Sri Lanka is focused on resettlement and reconstruction.

The Sri Lankan army under the US commercial company RONCO's guidance now uses metal detectors in a disciplined drill designed to comply with the IMAS, and is

complemented by the use of dogs and small flails. When DDG deployed into Sri Lanka at the beginning of 2003, they purchased metal detectors, but had not used them in general demining tasks at the time of the case study research (and have since decided to dispose of them). They, and others, adapted the HDU/NPA raking method (described briefly below) and were using it exclusively.

Demining in Sri Lanka began as an activity implemented by both the Sri Lankan Army and the LTTE. They had very limited funds and extensive human resources, and therefore developed the “raking technique”. In LTTE areas the method originally involved no marking, safety distance constraints or personal protective equipment (PPE). Government forces wore PPE, but otherwise similarly paid little attention to safety distances and marking. A number of disabling accidents and a lack of quality assurance (QA) left concern about the thoroughness of the clearance conducted.

In LTTE-controlled areas, the LTTE have established the HDU, which is supported by various foreign donors and gets both donor support and technical assistance from NPA, Mines Advisory Group (MAG), the Swiss Foundation for Mine Action (FSD) and Danish Demining Group (DDG). The HDU, with the guidance of NPA, developed the raking system described in this report as the REDS system.

Demining procedure: The Rake Excavation and Detection System (REDS)

The Rake Excavation and Detection System (REDS) relies on the use of a “heavy” and a “light” rake. While the terms “heavy” and “light” describe their weight, they do not describe their function. The heavy (Harrow) rake is used to break up the ground and the light (Brush) rake is used to move the loosened spoil back as the excavation advances. While in some cases the soil structure is loose and a harrow-rake may not be needed, the Brush-rake is always required to move loose soil back from the front of the excavation. It can also be used to maintain a channel at the sides of a lane to facilitate QA depth inspections.

When a mine is encountered with the Harrow-rake, the design of the tines and the method of use can lift the mine to the surface, but the intention is to subsequently use other tools (garden shovel, paint brush, bare hands) to carefully lift the mine. Occasionally, in loose sandy terrain, a deminer may lift the mine in the process of using the harrow rake.

When a mine is encountered with the Brush-rake, it is intended to be exposed without applying enough pressure to make it function. The flexible rake tines bend out of the way selectively when encountering a hard object and do not transfer the brushing force to the object. In a demonstration, the Brush-rake was used to expose a Type-72 anti-personnel blast mine with the main charge removed, and then the rake operator attempted unsuccessfully to initiate the pyrotechnic still in the mine casing and at the start of the firing train to demonstrate the small likelihood of initiation. Similar “tests” have been used by NPA as a demonstration of the inherent safety of the Brush-rake.

The REDS system starts by using the rakes to create a “Base-trench” in a safe area at the start of a lane. The Base-trench is similar to a “base-stick”, advancing as the excavation progresses, and replaces some of the functions of the base-stick. It is a trench across the start of the lane that is as deep as the required clearance depth and

30–50 centimetres wide. It has a vertical face on the uncleared side and a sloping face on the safe side.

Harrow-rakes

Harrow-rakes have two tines that are curved back towards the user. The length of the tines varied as a result of wear and of manufacturing variations. The curve was at least enough to lift the small mines encountered in Sri Lanka out of the ground as the Harrow-rake was pulled forward.

The rake is placed on the ground in front of the base-trench (not pushed into the ground in any way) and then dragged towards the user (see *Figure 1*). The tines should dig in automatically and create a pair of furrows in the ground. When the tines encounter light root systems, the user breaks them by pulling. When heavier root systems are encountered, “pruners” are used to cut the roots. Large roots may be cut with a saw.

Stones are raked around, and may be “flipped” out of the ground with the Harrow’s tines. Deminers were very skilled at this and could flip quite large stones (up to 15 centimetres in diameter) as far as 50 centimetres to behind their own feet.

Deminers frequently increased the speed of the process by applying enough downward pressure on the Harrow-rake to make its wooden handle bend perceptibly. Some also became impatient with roots and tugged sharply on the rake handle to try to break them. Unless properly managed, this could well lead to frustration and potentially dangerous practices.



Figure 1. Harrow-rake in use showing the long tines. Metal Brush-rake in foreground.

Brush-rakes

Brush-rakes are made either of sprung-steel or flexible plastic. Designed to brush leaves from a lawn without damaging the grass, their only adaptation before use is the addition of a socket that allows them to be firmly attached to an unusually long (1.6 to 2 metres) and thick wooden handle.

With tines spread in a fan design, the downward pressure applied by the user is spread over a wide area (see *Figure 2*). The easy flexibility of each tine prevents pressure being concentrated in any one place. A slight downward bend towards the end of each tine helps to collect loose spoil and sweep it back towards the deminer.

The Brush-rake is first used to remove any loose vegetation and “leaf litter” from the area in front of the base-trench. If the ground is soft enough, the Brush-rake may then be used to brush the soil towards the base-trench. After the Brush-rake, the Harrow-rake is used in overlapping sweeps leaving small furrows across the area being worked — to a distance of 30 to 50 centimetres in front of the base-trench.

After the Harrow-rake has been used to break up the new ground, the deminer sweeps the loose earth back into the base-trench. The Harrow-rake is then used again and the process repeated until the depth of excavation is achieved and the base-trench extended forward by 30–50 centimetres. The spoil has been moved to the back of the base-trench, which has also moved forward by 30–50 centimetres.

Deminers swept with the Brush-rake very close to their feet when they were packing loosened spoil at the back of the base-trench. That spoil had already been inspected.



Figure 2. Plastic Brush-rake in use.

Quality assurance and quality control of the REDS system

As with most manual excavation clearance methods, the excavated spoil is moved back inside the originally suspect area. It may contain high levels of metal contamination or be comprised of soil with a high Ground Reference Height (GRH) (electromagnetic signature). The work cannot be subjected to post-clearance sampling and quality control (QC)/QA using a metal detector. Post-clearance sampling requires using the REDS system. On land recently raked and root free, QC using REDS should be comparatively fast and effortless, so may sometimes be appropriate. Ground that had not been raked would be readily apparent and the working depth could be reliably verified with random sampling.

NPA used a side-of-lane ditch system to allow post and tape marking to remain in place during raking and to facilitate internal QA checks of the required excavation depth. Side-of-lane ditches were only “lost” when cleared areas were raked over after QA. The process was an effective method of allowing realistic internal QA by Section Leaders, giving confidence in the maintenance of the clearance depth (Figure 3).

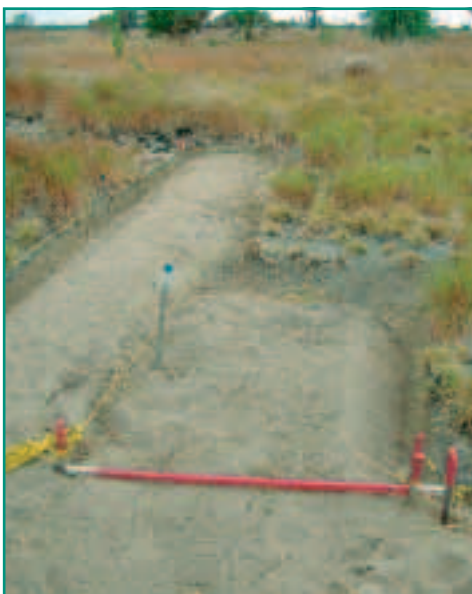


Figure 3. NPA marking and side-ditches supporting effective internal QA checks.

External QA is provided by UNDP teams reporting to the local authorities. QA and QC are conducted during the work rather than sampling after completion and use the same methods as the clearance operations.

DDG adopted the NPA REDS system one year before the study. Internal QA procedures are undertaken by the section leader and team leader while demining is in process.

The overall work is overseen by a field operations officer and an international technical adviser, and is subject to external QA.

DDG variations to the NPA REDS

DDG adopted the NPA REDS system one year before the study. Internal QA procedures are undertaken by the section leader and team leader while demining is in process. The overall work is overseen by a field operations officer and an international technical adviser, and is subject to QA.

DDG has developed a four-tine rake (to speed up the process), which has been used in limited areas where the ground is suitable (*Figure 4*). Looking like a reinforced garden rake, its tines are short and would not lift a mine to the surface as the curved two-tine NPA rake did.



Figure 4. A four-tine adaptation of the Harrow-rake developed by DDG.

Use of water

NPA did not use water to soften the ground during the study, although use of water was covered in the SOPs. Use of small quantities of water (by bucket) was seen on one DDG site. At a second DDG site, water was available in large quantities from hose systems and pumps attached to several 2,000-litre water tanks positioned outside the mined area. (In the Sudan case study, water was used regularly to soften hard ground and appeared to improve the conditions for using excavation tools. See Sudan case study, page 27.)

At the DDG site, 6,000 litres a day was applied over an area in which there were 19 deminers working. After water began to be delivered, they cleared an average of 110 square metres a day, so presumably the water was applied to less than 150 square metres in a ratio of around 40 litres to the square metre. The site was steep, so water run-off would have limited the time for soil absorbance.

The advantage of using water on hard ground may justify the investment in water tanks, water supply and water pumping methods, but it was not possible to gather data on clearance rates in the presence and absence of water to make a full assessment. An internal report provided by DDG for the donor of the water and pumping equipment claimed that, in an unusually hard area, speed of clearance had been increased from 0.35 to 0.65 square metres an hour by the application of water.

Conclusions from the Sri Lanka case study

The sites visited included a site with dense-vegetation, extensive root systems, hard ground and many large rocks. While slow, the rakes were used effectively under these different conditions (and any other excavation method would also have been slow). The rakes used in this system are simple and reliably achieve clearance to a set depth when integrated with conventional manual mined-area drills (area marking, safety distances, internal QA, etc.).

The two-tine Harrow-rake performed well at scarifying the ground and raising mines out of loose ground. The fan-tine Brush-rake performed well at moving loosened spoil back in the base-trench and so advancing the excavation. No accidental initiations had occurred while using the brush-rake, which is believed to be inherently “safer” than designs which concentrate weight and force in the small area at the point of a few tines. Accidental initiations had occurred while using the Harrow-rake, but the length of the handle prevented severe injury when PPE was being used properly.

The REDS system gives high confidence that the ground has been cleared of all explosive remnants of war to the required depth. The safety of the cleared area for end-users relies (as with all other methods) on a correct assessment of the threat depth. With that limitation, the method is at least as safe as any other in terms of the safety of the end-users of the land.

Case study 2

Iraq: Mines Advisory Group

Mines Advisory Group (MAG) has operated in northern Iraq for 12 years, maintaining a demining presence through periods when Kurdish areas of Iraq were difficult to access, very difficult to supply and politically volatile.

Prior to the US-led invasion of Iraq, security was an issue and the use of armed guards on demining sites was common. MAG had sought to develop an indigenous capacity and its international staff numbers were few, falling to zero during and immediately after the conflict.

Following the US-led intervention into Iraq, the number of high-priority tasks requiring attention multiplied dramatically. Military positions along the notional “green line” between the North and South had been attacked, abandoned and looted. The Iraqi border minefields now served no military purpose and the land was being rapidly reclaimed. In addition to minefields, bomb and cluster bomb strike areas also needed to be cleared, along with vast areas around military forts and stores where munitions in unstable condition were spread. Because the minefields had been used to defend military sites, mixed contamination including mines and ordnance was common.

Characteristics of the context include:

1. MAG had responsibility for all levels of survey and clearance, including QC/QA (no external QC/QA was taking place) and had prioritised their own tasks.
2. In all the areas visited, the mines had been laid by military forces in predictable positions and patterns to protect assets. This is the norm in this particular operation.
3. Most mines had been laid in a disciplined manner in rows, and the rows were usually marked with barbed wire, in coils or single stands.
4. No mines were reinforced, booby-trapped or fitted with anti-handling devices.
5. The hillsides were rocky and hard to dig, and the minefields did not have to be concealed. Many anti-personnel blast mines were placed on or flush with the surface of the ground and were visible after the light undergrowth was burned off.
6. The ground was frequently contaminated with metal fragments and short lengths of barbed wire.

7. The fragmentation mines used were POMZ-2M and VALMARA-69 (V-69). No POMZ-2M remaining on a stake was seen. The V-69 anti-personnel mines were laid with up to 10 centimetres of the main body above ground, giving a tripwire height of between 10 and 20 centimetres. They were almost always visible after the undergrowth had been burned. Intact tripwires were very rare. Samples of tripwire collected were of soft mild steel that had originally been painted.
8. The anti-personnel blast mines used were VS-50, TS-50, PMN and Chinese Type 72A. PMN mines were not mixed with other mine types. Chinese Type 72A mines were also laid in discrete rows. VS-50 and TS-50 mines were sometimes mixed, and the difference between their metal content meant that a VS-50 row was always treated as a minimum-metal threat because of the risk of some TS-50s having been used.
9. In many cases tripwire-initiated illumination flares were used among the mines (and were counted among the mines during clearance). The flares were used because the mined areas were intended to always have "covering fire", so a tripped flare would provide early warning to alert the defenders.
10. Following the conflict, some wire defences had been removed, and paths through the mine-belts had been made by members of the public moving mines aside. The moved mines were usually left in an obvious position on the surface and often marked with a pile of stones. Frequently, they had been disarmed. In a few areas entire rows of obvious mines (usually V-69s) had been removed and partially destroyed (left in a damaged and presumed sensitive condition).
11. As economic activity increased, the national pastime of taking Friday picnics in the hills was practised by increasing numbers of civilians. Picnicking amid the old hilltop defensive positions surrounded by minefields had become increasingly common.
12. Erosion had moved some mines, although disruption of the array structure ensured that the displacement was easily identified.

Iraq was visited for the purposes of this sub-study from 14 July to 6 August 2004.

MAG's expansion

Despite considerable security problems, MAG was rapidly expanding its programme to meet the increasing needs. Seven expatriate Technical Field Managers, a Technical Operations Manager, a Programme Manager and other mine risk education (MRE) staff were in place. Two ARMTRAK 100 flails had been ordered (only one was in country at the time of the visit) and one was being tested while its operators were being trained. Large two-man Ebinger UPEX 740M locators had been imported for deep submunition searches and the first operators were being trained.

A subcontracted dog team (two Bosnian handlers and four dogs) became operational during the visit and were being used in advance of squads of deminers in Post-clearance Area Reduction (PAR) activities, described below. A training course for new deminers was under way and 54 deminers passed the course just before the study ended.

Manual mine clearance procedures

Breaches were cut through the suspect areas to locate the mine rows. In the areas observed, no one-metre-wide clearance lane extended for more than 10 metres before it was widened to 2 metres by cutting an adjacent lane. When mine rows were located, the breach continued to the opposite perimeter.

When the breaches were completed, the clearance plan was refined to make allowance for the known mine rows, which were cleared with a 5–10 metre-wide “security” swathe on each side. Cross breaches were made to join up the original breaches in a grid designed to locate any partial mine-belts that may have been missed. The grid of breaches left areas that were either 10 or 20 metres wide (the required width of these areas was under review). Any areas where mines could have been moved by environmental conditions, such as snow-melt and rainwater run-off, were included in the manual search when mines anticipated in the patterned rows were absent.

Breaches were extended to reach all surface mines that were moved from the belts by people using the area. Areas between breaches were finally “reduced” using the PAR methods.

Manual mine clearance was usually carried out using metal-detector drills. When the level of scrap metal made that impossible (six detector readings in a square metre in one particular example), full manual excavation was carried out. Undergrowth was either burnt off or cut with hand tools as work progressed. At all sites visited, the undergrowth was limited to dry grass and very small thorn bush easily cut with secateurs (pruners).



Figure 5. An excavation lane with spoil placed behind the deminer.

Figure 5 shows an excavation lane where the spoil was placed behind the deminer in the cutting. Any metal contamination remained in the spoil, limiting the capacity for later QA beyond checking that the depth of excavation had been achieved.

The old Schiebel AN/PSS-12s detector in use required that the search-head was close to the ground without touching it. To ensure that the required proximity was achieved consistently, the deminer used small rubber ties (cut from tyre inner-tube) trailing from the search head (*Figure 6*).



Figure 6. Head of Schiebel detector with guiding ties.

Ceia Mil D1 detectors were used when breaches were being cut where the mine-type had not been identified, and were used to clear mine-belts believed to contain low metal VS/TS-50 mines and Chinese Type 72A mines.

When a metal-detector signalled, the deminer scanned the ground for surface fragments and removed any that were visible. When no surface fragment was the cause, the deminer pinpointed the reading and placed a single wooden cube (painted red) on the centre of the indication.

When the marker for an indication was in place, the deminer put the detector in a safe area (which was in a cleared area alongside or behind him in his lane) and brought forward a small plastic bucket, a prodder and a trowel. He started to prod 20 centimetres back from the marker. Loosened spoil was removed with the trowel before prodding again.

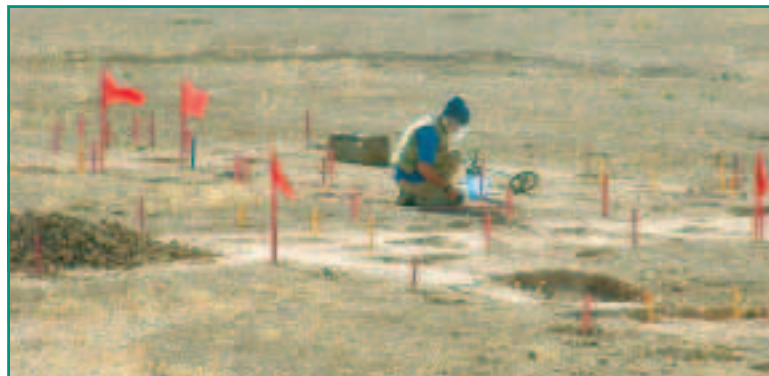


Figure 7. A deminer investigating a metal-detector reading. Yellow stakes show where mines were located.

In *Figure 7*, the deminer is on his knees prodding. The “berm” on the left is the spoil from excavated detector readings. Berms were made in “safe-lanes” (at least two metres wide) that had already been subjected to internal QA.

The deminers tended to use a one-handed stabbing motion that rarely penetrated more than two centimetres into the ground. The prodder used was thick (12 millimetres) and made from a mild steel. Trowels and prods were locally made. Some toolkits included short secateurs rather than the grass-cutting “hook” seen in *Figure 8*.

After jabbing at the ground repeatedly, the deminer used the trowel to dig away the spoil and scrape across the face of the area, advancing towards the detector reading. Water was sometimes used during excavation. In the examples seen, insufficient time was left for the water to soften the ground and the main advantage was to prevent dust rather than increase the rate of progress.

Excavations towards detector readings were 12 centimetres deep or less when examined.

Post-clearance area reduction

The concept of post-clearance area reduction (PAR) was developed and implemented in South Lebanon and is also used in Iraq. It involves reducing the originally suspect area as work progresses and the placement of mines becomes clear. Some of the originally suspect area may not be cleared, but will instead be classified as “No Known Risk” and released to the community after fully informed area-reduction. Area reduction was only fully informed after the suspected mine-belts had been located (and where mine-belts were the anticipated threat).



Figure 8. Hand tools used by a MAG manual deminer.

PAR formalises practices that other groups routinely carry out in a less structured manner. MAG staff believe that PAR makes more sense than extensive area-reduction because the suspect area is covered more thoroughly.

The three methods of “post-clearance area reduction” (full-visual, dogs and the flail) are all intended to give an extra level of confidence *after* the clearance of identified mine-rows.

Machines and PAR

MAG had recently purchased ARMTRAK 100 flails (Figure 9), intended to allow reduction of the manual-clearance margins outside the mine-rows from 5–10 metres down to two metres. The area around the belt would be traversed by the flail or the dogs, before being subjected to a “full-visual” search.



Figure 9. The ARMTRAK 100 flail in action in Iraq.

Use of the machine had been accredited by the regional MAC after a trial devised by MAG. The flails may also be used in wider area coverage as part of PAR, although some concern about the environmental impact of the flails had been raised.

It was accepted that the flail alone could not “clear” any ground and Figure 10 shows a picture of a V69 that has been crushed into the tracks of a flail.



Figure 10. The body of an unexploded V69 is crushed into the tracks of a flail.

Dogs and PAR

Two dog sets (two handlers, four dogs) were being deployed as part of PAR during the case study research (Figure 11). The sets deployed at first light and stopped work before 08:30 due to high temperatures. They were working in 20-metre-wide “boxes” between two-metre-wide breaches, and were entering the boxes from both sides in order to ensure full coverage. Two dogs were run over an area before it was considered clear.



Figure 11. Long-lead MDD at work in Iraq.

“Full-visual” search

Post-clearance reduction of areas that were no longer suspected of being mined, but were within the original suspect area, was carried out using “Full-visual” search. The manual deminers formed a rank (hand to shoulder spacing) and walked across the area between breaches examining the ground (Figure 12). Mines on the surface (moved by local people) were found, along with surface ordnance and battlefield debris. Each deminer carried a sack in which the debris was collected. Visors were raised during the visual scan but as soon as one man spotted something to pick up, the rank stopped and all visors were lowered. The Team Leader walked behind the rank, and side marking stakes were driven in at 25-metre intervals to ensure search overlap as they returned on their next pass.

A “full-visual” search was only conducted in a suspect area when the site managers were confident that all mine belts had already been located and cleared. Their confidence was based on survey and local guide information as well as clearance results. The site threat assessment was constantly updated and the area to be searched with metal detectors or manual excavation was changed when appropriate.



Figure 12. "Full-visual" search.

If a mine or mines were located or suspected, the "full-visual" search would be suspended and manual clearance using metal-detectors or full-excavation would take place.

Deminers and battle area clearance

MAG Northern Iraq did not have dedicated battle area clearance (BAC) teams. Instead demining teams were assigned BAC tasks when appropriate. The number of BAC tasks was high, with battle UXO compounded by tens of square kilometres of land contaminated with ordnance from arms dumps (either scattered by combat strikes or by looting after the conflict).

BAC tasks usually involved a "full-visual" search and could also include metal-detector search in areas where it was suspected that munitions have become concealed. Submunition strike areas were a priority because of the sensitivity of the BLU-97 and KB-1 submunitions used.

Up to the time of the case study, MAG had cleared CBU strike areas with patient excavation. The deepest BLU-97 they had uncovered at that time was at a depth of one metre, but that was very unusual.

The national mine action centre (MAC) had introduced a clearance depth of 50 centimetres for BLU-97 strike areas, and MAG had responded by introducing a two-man large-loop detector (Ebinger UPEX 740M) to help them achieve this depth with confidence (Figure 13).



Figure 13. The Ebinger UPEX 740M in use.

The Ebinger UPEX 740M is not designed to locate anti-personnel mines or any device that presents a threat to those walking on the ground. Its first use in Iraq was to provide a second “deep-search” pass on submunition strike areas.

Conclusions from the Iraq case study

MAG was purchasing replacements for their older metal-detectors, PPE and tools during the study. Meantime, their use of the old Schiebel detector in areas where no minimum-metal mine threats were anticipated allowed rapid clearance of mine-belts while leaving small metal indications behind. In the context, that appeared both practical and safe. They had developed a technique for tuning the Schiebels to ensure that each deminer worked to the same standard, and which allowed internal QA. The adjustment was so successful that they had asked the manufacturer of the detector replacements to devise a similar “tuning-down” adjustment for their new detectors.

When conducting metal-detector search inside known mine-rows, the vast majority of detector signals were on metal fragments, many of which were on or close to the surface. Magnets were not used to reduce the signal investigations that followed, but could have improved productivity as these signals took up the majority of each deminer’s working time.

Mechanical assets and dogs were both being introduced during the study period and their deployment to assist PAR was under investigation. The PAR concept had very significantly reduced the clearance of areas where there was no threat and so had increased efficiency dramatically. To date, PAR had relied on boxing areas and using deminers to make a “full-visual” search as they traversed a formerly suspect area. It was reported by MAG that there had been no accidents while doing this search, which they presented as evidence of the quality of the approach.

Case study 3

Cambodia: Cambodian Mine Action Centre

CMAC has been operating in Cambodia since the end of the United Nations Transitional Authority in Cambodia (UNTAC) in 1992, and currently employs the largest number of deminers in the country. CMAC is divided into six Demining Units (DU1 – DU6). The work of DU3 in Pailin District (near the Thai Border) was studied. Pailin District was one of the last areas controlled by the Khmer Rouge and so one of the last in the country in which demining could start. The border with Thailand is particularly heavily mined, along with roads, road-verges and some villages.

The donor supporting DU3's work at the time of the trial also supported an independent QA capacity via the commercial company QAsia.

Anti-personnel mines found in the area were Type 72A, POMZ-2M and Type 69 mines (without tripwires and in a corroded condition). PMN and PMN-2 mines were also expected. TM-46 anti-tank mines had also been found, along with UXO (mostly 60 and 82 millimetre mortar bombs).

Although survey could be used to predict the presence of a threat, mines tended not to be laid in patterned minefields, or in predictable arrays. When combined with the relatively abundant UXO, the problem is very different to northern Iraq, where patterned minefields were typical.

Cambodia was visited for the purposes of this study on 16–26 September 2004. The rainy season was under way and some rain fell during the study.

Operational background

CMAC's methods have evolved over 13 years and it has operated with very limited technical assistance from the UN over the last four years. At the time of the study, the CMAC management had made significant changes to old working methods and were planning several trials of new drills/techniques intended to increase operational efficiency.

To save money, CMAC had stopped deploying ambulances to each site. Instead each site has a medic and trauma kit. Emergency evacuation is by air ambulance (helicopter) and each site had a helicopter landing grid marked out for that purpose. Driving conditions in Cambodia are difficult and most roads are poorly maintained, thus rapid evacuation by road would not normally be possible.

In all the areas visited, the threat assessment included the condition of the mines encountered. As a result, safety distances were reduced from those recommended in the IMAS because fragmentation mines were not in a functional condition and so their accidental initiation was assessed as a very low risk. Required safety distances between demining pairs were also “flexible”, with the team leader having authority to reduce distances if safety was not compromised.

Manual mine clearance procedures

CMAC operated a one-person drill in two-person teams, primarily because of a shortage of metal-detectors and PPE. Electromagnetic ground disturbance is common in Cambodia, requiring sophisticated metal detectors which were in short supply.

The second deminer waited in a rest area from which they were supposed to monitor their working partner. Effective monitoring was often impossible because direct line of sight could not be maintained and, even when it could, the second deminer was often only able to see the partner’s back.

All CMAC clearance lanes were about 1.5 metres wide (as opposed to the international norm of one metre). The preferred stance of all deminers was to squat, although some placed a knee on the ground at times (*Figure 14*).



Figure 14. A CMAC deminer squatting to cut undergrowth.

Undergrowth was usually cut with secateurs (long handled and short) and conventional garden shears.

CMAC deminers usually cut all the undergrowth to a height of 8–10 centimetres, then removed those cuttings by hand or by “hooking” the cuttings away with secateurs or shears. They then cut again to ground level in order to get the metal detector search-head close to the ground to maximise the search depth. The second phase (and the removal of the cuttings and leaf-litter) took significantly longer than the first phase of vegetation cutting.

Loppers and shears were commonly used to rake undergrowth cuttings and leaf-litter back towards the base-stick.

Although tripwire-initiated mines were present, threat assessments determined that tripwires were no longer intact and functional, and tripwire feeler drills were not conducted on any of the sites studied.

Area excavation

Clearance was being conducted with a mixture of area excavation (*Figure 15*) and metal-detector work. When metal fragmentation was high or expected to be high (as was the case at the sides of roads) area excavation (solely) was carried out. The excavations observed were to a shallow depth (less than 10 centimetres). Neither the deminers nor their supervisors had any means of measuring the depth to ensure that it was adequate or constant.



Figure 15. A CMAC deminer conducting area excavation.

Normally, the use of a long-handled tool for excavation can increase safety by keeping the users hands away from an initiation, and outside the inverted cone of environmental fragmentation that accompanies anti-personnel blast mine detonations. In *Figure 15*, one hand is dangerously close and both are inside the fragmentation cone. Vertical digging like this was common.

Metal-detector search

The detectors in use by CMAC were Minelab F1A4 models purchased in 1999/2000. They had seen heavy use and their signals were erratic. During the study, detectors “drifting” and requiring recalibration was common and sometimes held up progress significantly.

Metal-detector signal investigation

Before using tools to loosen and remove soil following a signal, the CMAC deminers used a magnet (or piece of magnet) by rubbing it over the signal area. The magnet was moved around in the surface soil or leaf-litter to attract ferrous material.

The magnets used were speaker magnet rings (many were broken parts of rings). Fragments located were largely bullet casings and unidentified fragments of rust (*Figure 16*).

If fragments were located, the deminer used the detector again to check whether the source of the detector indication was still present. When no obvious metal was attracted, deminers often attached the magnet to their CMAC trowel and used the tool to lightly scrape the ground where the metal-detector had signalled. Spoil was then tipped off the trowel and over the magnet to try to catch any ferrous fragments that had been just below the surface. Ferrous fragments were frequently located successfully without the need to investigate the detector signal any further.



Figure 16. A CMAC deminer's signal-investigation tools. Both the prodder and the CMAC trowel were locally made and details varied. A "doughnut" speaker magnet is in the centre of the picture.

When the metal detector continued to indicate the presence of metal after the use of the magnets, the deminers began a signal investigation drill.

CMAC's signal investigation drill involved digging an excavation trench a safe distance (20 centimetres) from the reading with a sloping back (towards the deminer) and a vertical face (Figure 17).

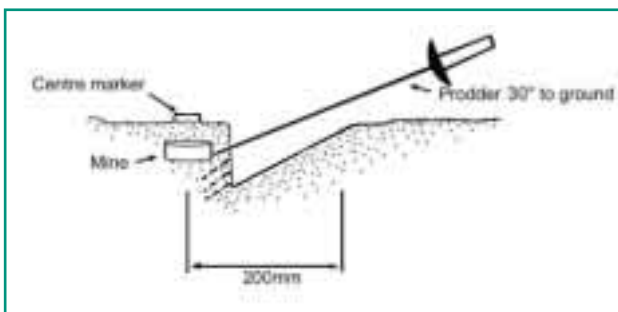


Figure 17. Signal investigation.

The face was prodded from the bottom up before slicing away the prodded ground and advancing towards the reading. While prodding, the deminer gripped the prodder shaft to record the depth of insertions. The deminer then laid the prodder on the surface, pointing ahead of the excavation face by the extent of the prodding depth. A line was scratched at the prod tip allowing the face to be dug away up to that mark using the trowel.

The magnet was also used (sometimes attached to the trowel) to try to find the signal source in the loosened spoil as an investigation progressed.

Mechanical assistance

In one area studied the suspect area had been prepared by a large Hitachi BM307-SG16 machine which cut undergrowth. The machine had left a mess of cuttings and churned, wet ground. Although the machine provided rapid clearance of vegetation, its wheels had churned the ground and some mines may have been driven deeply into the mud. Piles of vegetation half as high as a deminer were left in the working area.

At another site, a petrol driven (2-stroke) manually operated "Weed-whacker" vegetation cutter was being introduced. It was used to cut undergrowth from the area adjacent to a cleared lane (Figure 18).



Fig. 18. Weed-whacker in use.

One operator moved around the site cutting vegetation in front of all the deminers. The cutting width out from the safe lane was 1.5 metres, but the reach of the machine made this width difficult to achieve.

Post-clearance area reduction

A CMAC document entitled *Proposed Concept Area Reduction By Manual Deminers*, in which ideas for “post-clearance area reduction” were proposed, was made available to the case study team. The aim was to provide field deminers with rules allowing areas to be reduced while they worked and so to avoid clearing more land than was necessary. The proposed method was necessarily generic and somewhat inflexible, because it attempted to set rules that could be applied anywhere in Cambodia.

Quality assurance and quality control

Internal QA on areas cleared using a metal detector involved supervisors checking 20 per cent of all cleared areas a second time with the detector. External QA was provided by the commercial company QAsia during the study period.

As with all the case studies reported here, there was some variation between what was described in the SOPs¹ and what was done in the field. The differences caused the external QA company problems, because they were tasked to report all violations of the approved SOPs. These breaches of SOPs were not necessarily dangerous, careless or unplanned. Most were clearly planned and the SOPs were simply out of date.

Efficiency plans and trials

A new manual demining drill being trialled had both deminers in the lane at the same time, with one deminer using the detector and the other investigating any readings. Both deminers would remain in the lane, and the person investigating the reading would watch the detector to confirm the position of a detector indication. The detector user would remain present to reconfirm indications and accelerate the investigation by being ready to check moved spoil.

1. CMAC SOPs for Manual Demining, revised on 28 January 2003.

The new drill was projected to save time in changeovers, in the routines of detector recalibration involved at each change-over, in time taken to exchange tools and in the investigation of readings. The main time cost was that both deminers would rest together at regular intervals. The planned trial would determine whether the gains and losses resulted in an overall gain in the speed of clearance over a given area.

It was argued that CMAC lanes were already 1.5 metres wide, allowing two deminers to work side by side, and that the requirement for both deminers to wear PPE would assure safety.

Conclusions from the Cambodia case study

CMAC had an impressive array of assets including Explosive Detection Dogs, deep-level search locators, brush-cutting machines and manual deminers. An integrated use of these assets was still in development.

The use of a magnet to help reduce the ferrous fragmentation during metal-detector clearance was successful and improved deminer efficiency.

Apart from the magnets, which have been in use for some time, CMAC is being innovative in other areas. In particular the attempt to introduce PAR is a valuable efficiency exercise. As with most of the case studies, SOPs lagged behind innovations at a field level.

Case study 4

Sudan: Norwegian People's Aid

A long war between the Government of Sudan and the Sudan People's Liberation Movement/Army (SPLM/A) has killed an estimated two million people and displaced four million others. Both parties appear to have recognised the need to find a lasting peace and there is a genuine belief that the peace agreement recently signed will be effective. The peace agreement allows the South of Sudan (New Sudan) to choose to become a self-governing State six years after the implementation of the peace process, signed at the end of 2004.

Norwegian People's Aid has been working with the SPLM/A for more than 20 years to provide humanitarian assistance to the people of South Sudan, and in the last 18 months has begun a programme of mine clearance that is currently based in Yei village, South Sudan.

The impending peacekeeping operation (PKO) in South Sudan will inevitably create an influx of returning refugees. Many will return to areas where there is a risk of mines and UXO, and there is a strong drive to open the roads up before the influx begins in earnest.

Two visits were made to NPA Sudan: 4–8 April 2005, during which general procedures were observed, and 6–16 June, during which structured trials of two experimental demining drills were conducted. April was towards the end of the long dry season (about nine months), and June was early in the rainy season. Considerable rain fell during the trials in June.

Local demining administration

NPA has recently set up a mine clearance organisation currently based in Yei village, South Sudan.

NPA is currently planning for a considerable expansion but at the time of the visit, the demining team consisted of 40 deminers plus management staff. There are four sections of ten deminers who have a section commander to oversee the operations of the section.

Each section operates five lanes, which means that half the deminers are resting at any given time. Work starts at 8am. The first two shifts are for two hours each, after which the deminers change every hour until work ceases at 4pm. Each deminer therefore works a total of four hours a day (excluding short scheduled breaks).

Demining procedure

NPA uses SOPs developed from another NPA programme, and operates using basic drills that have proved effective in many situations. They aim to work in accordance with IMAS. The drills are essentially one-man one-lane, with the deminer clearing vegetation, detecting, investigating signals, watering and clearing signals.

During the nine-month dry season in South Sudan the ground is extremely hard. Prodding and excavation are therefore almost impossible without pouring water on the soil to soften it. Normal procedures require the deminer to move down a standard one-metre-wide lane, cutting vegetation, detecting forward of the base stick, following up investigations and, once the area has been sterilised of metal fragments, the base-stick is moved forward 30 centimetres to begin the process again.

If the ground being investigated is too hard to prod or excavate, water is applied to soften it. There is then a soak period of 5-10 minutes, during which the deminer waits. In areas with significant numbers of indications, considerable time was spent waiting for the ground to soften.

Quality assurance and quality control

The SOPs for the programme state that “*random testing of all demining procedures*” shall be carried out to ensure the quality of the produced land. In reality this means that the section commander checks over the deminers work several times a day. At handover, the incoming deminer “takes over” the land that his partner has cleared and checks the ground again.

Conclusions from the Sudan case study

The drill observed in Sudan was a standard manual demining drill, as used by most programmes worldwide. It appeared that significant delays were introduced during the dry season due to the requirement to water ground and wait for the water to soak before excavation. The trials conducted in June were designed to test alternative procedures in order to address that problem (*see below*).

Trial 1

Comparing alternative manual drills in Sudan

During observations of the NPA manual drills in Sudan made during the dry season on 4–8 April 2005, preliminary tests were conducted of two experimental drills designed to minimise time lost to watering of indications. Full trials of these drills were undertaken on 6–9 and 13–16 June 2005.

Sixteen NPA deminers were used for the trials. All deminers spent one morning in training and practice on the new drills. The deminers then spent 150 minutes (five 30-minute sessions) working each drill in lanes that were placed at least 15 metres apart. Data were obtained for each individual deminer using each drill under essentially identical conditions.

Objectives of the trial

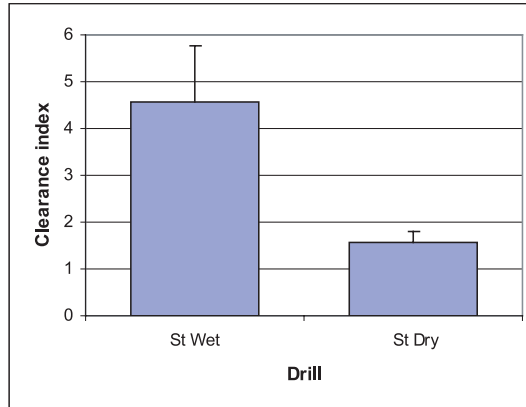
Preliminary results during dry conditions in April 2005 suggested that considerable time was saved using the experimental drills (relative to the standard drill), but too little time was available for a full study. The preliminary clearance data for Standard drill from April, when 4 samples were obtained, are compared in Figure 21 with the clearance data obtained from the more detailed study in June. Clearly, there was more land cleared (275 per cent) in June, when the ground was soft, than in April, when the ground was dry and hard.

The primary objective in June was to explore the use of each drill in greater detail than was achieved in April. Aspects of each drill other than watering and soak time also potentially introduced delays or efficiencies, and two objectives were defined for the study:

- to explore all aspects of the dynamics of the drills; and
- to investigate the effects of watering on clearance rates for each drill.

The study in June was conducted after rain, when the ground had softened, and was therefore conducted under conditions of no delays due to watering. The situation allowed a direct comparison of the three drills under essentially equivalent conditions, without any effect on the data from the known delays caused by watering.

Figure 21. Amount of land cleared (indexed to make the data directly comparable) using Standard drill (St) when ground conditions were wet and dry (normal drill)



Drills

For standard manual mine clearance drills performed on hard ground in a lane, the only option when watering hard ground is for the deminer to wait for the water to penetrate. Moving past the indication site is impossible within safety requirements. Especially for areas with larger numbers of indications, significant delays are the consequence. However, if the deminer can somehow bypass the indication site safely, then detection work could continue while the water is penetrating.

The Crab and Hybrid drills were developed to address the problem of delays during watering. Both require a safe lane along the side of the demining lane, allowing the deminer to bypass an indication. However, as a working lane can be placed next to a previously cleared lane, there is normally no difficulty obtaining such safe access.

Both of the experimental drills commence with the marking of a 50 cm wide strip parallel to a cleared lane. Up until the point of divergence between the drills noted below, the deminer works laterally from the safe lane in 1 m blocks.

- The 50 cm wide strip is cleared of tripwires and vegetation in one run.
- Then the deminer works laterally with a metal detector. Surface signal points are removed immediately by hand. Buried signal points are marked (and watered if the ground is hard) and the deminer moves on to check the entire lane.
- It is at the point where clearance of buried signals begins that the two drills diverge in procedure. Annex 2 gives full details of the two drills.

The Crab drill involves the deminer continuing to work laterally. The deminer returns to the marked signal sources and clears each one. Intervening spaces between indications are not checked again. If more watering is required, the site is watered and the deminer moves on laterally to another marker, returning to the watered site after a few minutes. If watering is required, no time is spent waiting for water to penetrate the soil.

The Hybrid drill combines elements of Standard and Crab drills. Instead of working laterally while dealing with indications, the deminer works forwards only, stepping into the lane as they work. In the version of the drill used here, the entire lane was checked again with the metal detector as the deminer worked forwards. In principle,

this additional metal detector search could be eliminated with the deminer moving directly to each indication. The deminer does not step outside the lane, so if more watering of sites is required, some additional delay is likely.

Data recording and sampling

The deminers were required to prepare the land by searching for tripwires, cutting and removing vegetation before using standard detection and clearance techniques and equipment to clear the land. Cutting and removal of vegetation could proceed ahead of mine clearance for the Crab and Standard drills (because of the adjacent safe lane), and in some cases slightly more land was prepared than was cleared using these drills.

Records were made of the total amount of land prepared, cleared and subjected to QC checks, and of the number of indications found during clearance.

Table 1. Codes and descriptions for sampling the behaviour of deminers using three different demining drills

| Recording Code | Description of Action | Analysis Code | Lumping |
|----------------|---------------------------------|---------------|---------|
| TS | Tripwire Search | TS | TS |
| MEV | Measuring Vegetation to be cut | | VEG |
| CV | Cutting Vegetation | VEG | VEG |
| RV | Removing Vegetation from lane | | VEG |
| MEC | Measuring Clearance | MCL | MCL |
| CT | Change Tool | CT | CT |
| MDT | Mine Detector (turn-on) | | MD |
| MD | Mine Detector | MD | MD |
| MD+ | Mine Detector (positive) | MD+ | MD+ |
| GW | Getting Water | WAT | WAT |
| PW | Pouring Water | | WAT |
| ISP | Investigate Signal (Prodder) | ISP | ISP |
| ISX | Investigate Signal (Excavation) | ISX | ISX |
| ISD | Investigate Signal (Detector) | ISD | ISD |
| PPE | Adjust PPE | PPE | PPE |
| WQA | Waiting for Quality Assurance | | QA |
| QA | Quality Assurance | QA | QA |
| MKG | Marking | MKG | MKG |
| DPI | Detector Problem (Interference) | | DP |
| DPC | Detector Problem (Calibration) | DP | DP |
| DPB | Detector Problem (Batteries) | | DP |
| RE | Resting | RST | RST |

The activities of the deminers sampled were as follows:

- 22 actions were identified and coded (Table 1);
- an observer sat at a position from which four deminers could be continuously observed;
- the observer used a repeating countdown timer to mark time intervals of one minute;

- each minute, the observer scanned the four deminers, recording the action being used at the first moment that the deminer was encountered during the scan;
- each deminer was observed using each drill for 150 minutes (providing 150 scan samples /deminer/drill, and 450 samples in total for each individual);
- some lumping of sampled actions occurred before analysis, reducing the sampled actions to 15 broader activities (Table 1);
- the data were used to calculate the proportion of time spent in each activity during the 150 minutes of work on each drill (reported as a percentage); and
- the calculated proportions for each action were used to compare statistically across drills, using the sample size of 16 deminers.

Results

The data provide a quantitative description of how the deminers distributed their work time during each drill. Despite the identical working conditions, many differences were found between the drills (outlined below). Because of heavy rains during the period of the study, the ground was already soft when the deminers were working and essentially no watering of indication sites occurred (proportion of time watering is in Table 2).

All tests reported below used repeated-measures statistical analyses because all three drills were worked by each deminer. A description of how to interpret the results of statistical tests is in Annex 1 to this Section.

Area cleared and number of fragments

The total amount of land cleared of mines by each deminer using each drill was measured in the field. For the two experimental drills, some small amounts of land on which vegetation was cut but not cleared of mines were subtracted from the total area of land reported as cleared.

Less land was cleared using Standard drill than using the two experimental drills (*Figure 22*). Statistical comparison of each pair of bars indicated that significantly more land was cleared using Crab than Standard drill.¹ Hybrid drill was intermediate and was not statistically different from either of the other two drills.

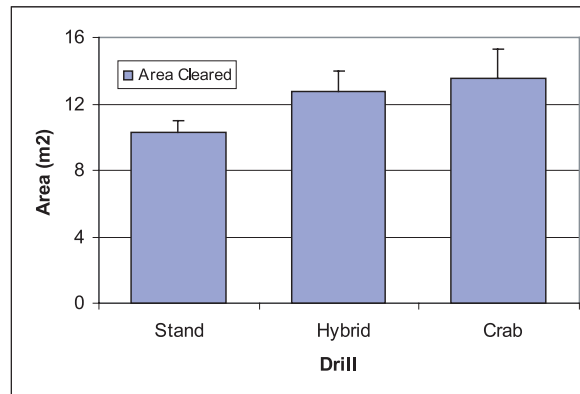
The number of indications is likely to influence the amount of land cleared, because it takes time to deal with each indication. All else being equal, larger numbers of indications should result in smaller amounts of land cleared, and it is possible that differing numbers of indications between drills influenced the result in *Figure 22*.

The pattern in *Figure 22* therefore predicts smaller numbers of indications for the two experimental drills. However, the opposite occurred: the number of indications was higher for the two experimental drills,² but these differences were not statistically different from each other.

1. Duncan's test, $P=0.027$.

2. Mean (\pm standard error) of indications was: Standard = 4.5 ± 1.1 ; Hybrid = 5.1 ± 1.9 ; Crab = 6.1 ± 1.5

Figure 22. Amount of land cleared of mines using each drill.
Bars are mean + standard error.

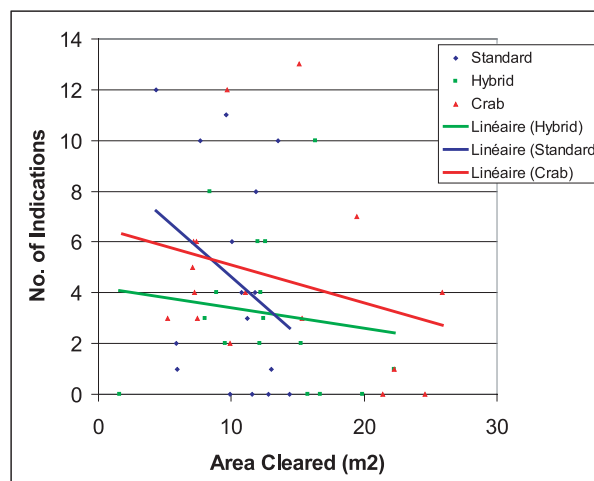


The relationship between area cleared and number of fragments was reviewed in two ways:

- By plotting the relationship between area cleared and number of indications, and inspecting the slope of the curve for each drill (visually, and using regression analysis, which reports a value for R^2 and is most easily understood as a correlation);
- By dividing the area cleared by the number of indications in order to standardise the data, and comparing across drills using analysis of variance.

The relationship between indications and area cleared was explored by plotting number of indications against land cleared for each drill (shown as the trend lines in Figure 23).³ The predicted negative relationship was strong for Standard drill and weak for Hybrid and Crab drills. In effect, higher numbers of indications reduced clearance rates using Hybrid drill, had little effect on the amount of land cleared using Standard drill, and had no effect for Crab drill.

Figure 23. Relationship between number of indications and amount of land cleared for three drills



3. Two extreme values were removed from this analysis.

We conclude here that the two experimental drills resulted in land being cleared at slightly faster rates than for Standard drill in wet soil. The more important result is that numbers of indications had a strong negative influence on clearance rates using Standard drill and less influence on Hybrid and Crab drills. Clearance using the two experimental drills was therefore influenced less by the number of indications and should give more clearance under conditions where high numbers of indications are obtained.

Behaviour of deminers

The 22 sampled actions were lumped into 15 broader activity categories (*Table 1*).

Significant differences were found among the drills for many of the activities (*Table 2*). Of particular interest were:

- Vegetation (more time was spent dealing with vegetation in Standard, (*Figure 24*);
- Change Tool (used twice as much in Standard relative to the other drills, *Figure 25*);
- Use of Metal Detector (used more in Hybrid, *Figure 26*); and
- Marking (done more in Hybrid, *Figure 27*).

Pair-wise comparison of each activity for each pairing of drills indicated that changing tools required significantly less time in Crab than in Hybrid drill, in addition to both being significantly more efficient than Standard drill.

Figure 24. Time spent cutting and moving vegetation in relation to different drills
(Bars are mean + standard error)

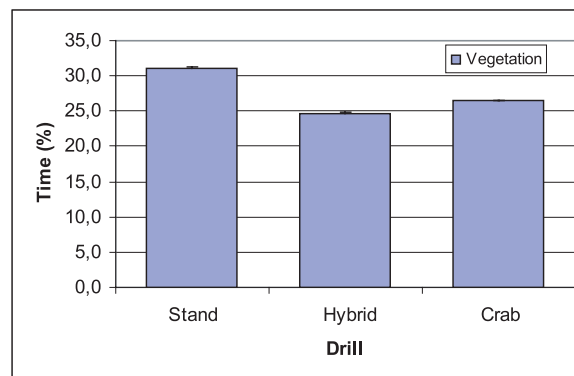


Figure 25. Time spent changing tools, in relation to different drills
(Bars are mean + standard error)

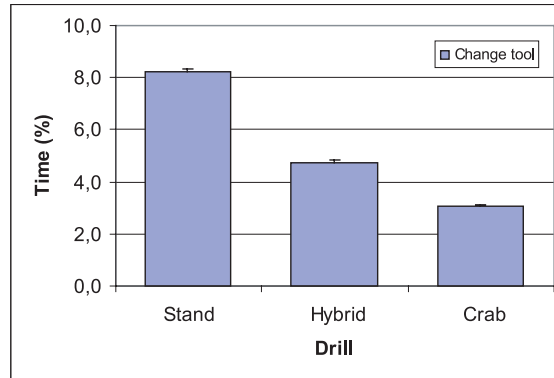


Figure 26. Time spent in standard search with a metal detector, in relation to different drills (Bars are mean + standard error)

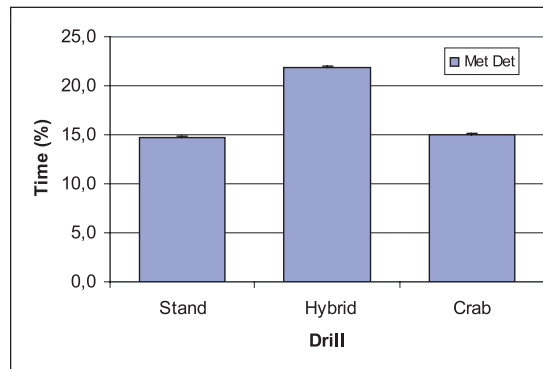
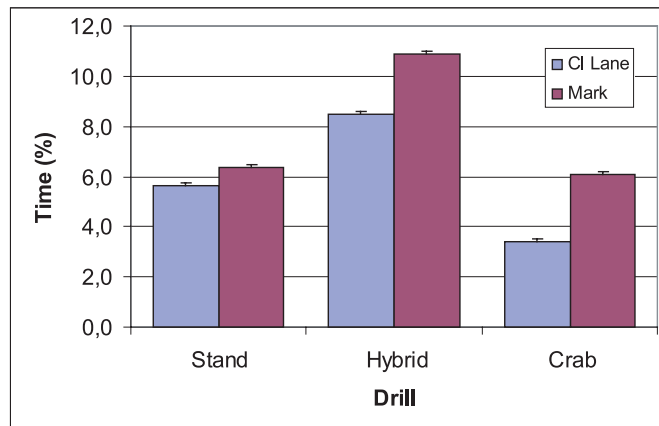


Figure 27. Time spent marking in relation to different drills
(Cl Lane = marking a cleared lane; Mark = marking while working a drill.
Bars are mean + standard error)



Most of the differences found between drills in terms of time spent in each activity have implications for deminer efficiency, and we conclude that differences among these drills offer considerable potential for improving the productivity of manual demining.

Table 2. Proportion (%) of time spent in different activities by deminers using three different drills. Activities and codes defined in Table 1. Values are means (on left) and standard errors (on right).

| Activity | Standard | Hybrid | Crab | SE Stand | SE Hybrid | SE Crab | Significance |
|----------|----------|--------|------|----------|-----------|---------|------------------------|
| TS | 10.7 | 6.7 | 10.8 | 0.12 | 0.10 | 0.11 | $F_2=8.8$, $P=0.001$ |
| VEG | 31.2 | 24.7 | 26.4 | 0.17 | 0.18 | 0.16 | $F_2=5.3$, $P=0.01$ |
| MCL | 5.6 | 8.5 | 3.4 | 0.11 | 0.09 | 0.09 | $F_2=17.8$, $P=0.000$ |
| CT | 8.2 | 4.8 | 3.0 | 0.10 | 0.09 | 0.08 | $F_2=34.3$, $P=0.000$ |
| MD | 14.7 | 21.8 | 15.0 | 0.15 | 0.17 | 0.12 | $F_2=10.9$, $P=0.000$ |
| MD+ | 1.6 | 0.8 | 1.3 | 0.08 | 0.06 | 0.09 | $F_2=1.7$, NS |
| WAT | 0.1 | 0.0 | 0.7 | 0.03 | 0.00 | 0.07 | --- |
| ISP | 2.1 | 1.4 | 3.0 | 0.08 | 0.06 | 0.08 | $F_2=10.1$, $P=0.000$ |
| ISX | 9.8 | 7.1 | 13.0 | 0.20 | 0.20 | 0.17 | $F_2=2.75$, $P=0.08$ |
| ISD | 5.1 | 4.5 | 4.5 | 0.14 | 0.18 | 0.12 | $F_2=0.07$, NS |
| PPE | 0.2 | 0.3 | 0.5 | 0.04 | 0.04 | 0.05 | $F_2=0.9$, NS |
| QA | 3.5 | 8.4 | 11.7 | 0.10 | 0.13 | 0.12 | $F_2=21.0$, $P=0.000$ |
| MKG | 6.4 | 10.9 | 6.1 | 0.11 | 0.13 | 0.10 | $F_2=12.7$, $P=0.000$ |
| DP | 0.7 | 0.2 | 0.6 | 0.07 | 0.04 | 0.06 | $F_2=1.4$, NS |
| RST | 0.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.03 | --- |

Quality checks

The section commander carried out quality control checks on all cleared ground for each drill. Some of the checks were done during the 150 minutes of work time, indicated by the activity data in Table 2, with more time lost to them in Hybrid and Crab drills than during Standard drill. The checks were done to ensure that the drills were not producing unacceptable miss rates, and did not affect other aspects of the results.

Deminers were required to eliminate the cause of a signal during the drill, thus signals found during QC checks imply that a metal fragment was missed. Signals found during QC were:

- Standard: 4 signals by 2 deminers;
- Hybrid: 1 signal by 1 deminer; and
- Crab: 10 signals by 6 deminers.

The higher miss rate using Crab drill is of concern, and is an issue that would need to be addressed during training and development if this drill was adopted for operational demining. It is possible that the explanation for this lies with the unfamiliarity of the detector drills which differ significantly to their normal drills.

Discussion

Although the deminers worked under identical conditions in all drills, differences among the drills were found which clearly influenced productivity. For Standard

drill, the additional wait time cost expected in dry conditions due to watering of hard ground would further decrease productivity.

Extra time was spent in Standard drill on dealing with vegetation and changing tools. These results are because the deminer completes all activities in very small areas before moving on to the next small area, and must remove vegetation to the cleared areas behind, which can involve walking back down the lane. The deminer is constantly changing tools in order to do all required actions before moving forward another 30 centimetres. With Hybrid and Crab drills, the deminer can move vegetation to the cleared land at the side (hence minimising time spent carrying vegetation), and changes tools less frequently because larger areas are worked before a change of tool is required.

More time was spent in Hybrid drill Marking, and using Metal Detector. The extra time costs were presumably because of the additional full search undertaken in this drill as the deminer worked forwards towards the previously found indication sites.

For all of the above activities, Crab drill was either similar to or more efficient than the better of the other two drills — measured as less time spent changing tools, fewer start lines, less marking and less time using the metal detector. Discussion with the deminers indicated that they preferred Crab drill to Hybrid drill.

Although more signals were found during QC for Crab drill than for the other drills, more indications were dealt with during Crab drill overall. Thus the additional missed signals have no influence on the patterns in the data presented here. The missed signals were possibly because there was no final search with the metal detector during Crab drill, and certainly suggest that more training and experience is required for this drill.

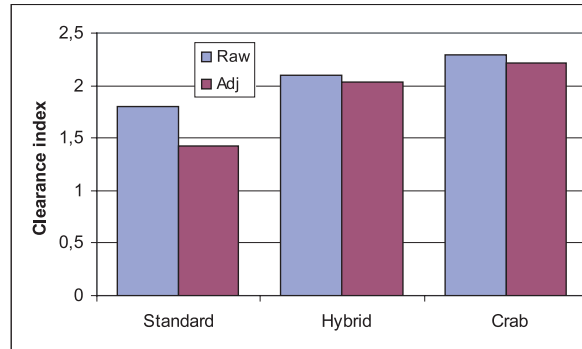
Crab drill appears to offer considerable opportunity for improving efficiency in manual mine clearance. Even when the ground was soft, Crab drill was more efficient than Standard drill on a number of measures. The benefits can be obtained without compromising safety or imposing dramatic changes on the methods used by deminers. It is predicted that the benefits will be even stronger in situations where the ground is hard and watering is required, and once deminers are more familiar and experienced with the new procedure. This prediction is explored next.

Observations made of Standard drill in April 2005 indicated a typical watering/soak time of 10–12 minutes in dry soil, but sometimes was as little as five minutes. For Standard drill, soak time represents a delay. However, for Hybrid and Crab drills soak time is used to carry out other activities, and the delay caused by watering is small. To explore these delays in more detail, the measured clearance values obtained in June 2005 were used to project the time loss under dry conditions, using predicted delays for each indication of five minutes (the minimum expected) for Standard drill, and one minute for Hybrid and Crab drills (*Figure 28*).

Time loss due to watering will depend on the number of indications in the lane; if there are no indications there will be no loss. Thus in *Figure 28*, only lanes in which there were at least three indications in the lanes cleared in June were used to predict time loss. It is the drop between the pairs of bars that portrays the productivity loss due to soak-time delays. The drop is small for Hybrid and Crab drills because only a one-minute loss was predicted. The drop is much bigger for Standard drill because of the five-minute delay. The projected difference represents productivity that can

be obtained **in addition to** the improved productivity arising from differences between the drills already described above. More indications will result in even larger relative gains.

Figure 28. Projected productivity effects of time delays caused by watering in dry conditions



Raw data are from the June 2005 study done in wet conditions. Adjusted (Adj) bars are projected on the basis of a predicted small delay due to watering for the experimental drills, and a predicted larger delay for Standard drill.

It is clear that small changes to drills can have significant effects on productivity, sometimes in unexpected ways. The GICHD encourages demining organisations to test these and other alternatives to standard drills. Other alternatives are explored in the Mozambique trials.

Trial 2

Comparing manual clearance systems

Introduction

Trials of manual mine clearance methods took place in Moamba, Mozambique, in October/November 2004 using a series of drills used by different organisations around the world.

The use of a metal detector and signal-investigation tools was compared with selected other manual mine clearance methods/tools. Each of the eight drills was assessed in a context and under circumstances that were as similar as possible and which closely reflected the realities of mine clearance in Moamba.

The trials allowed a comparative assessment of selected manual mine clearance systems (Table 3). Parameters measured were:

- speed of clearance;
- detection rate of targets within a predefined depth;
- safety of the deminer while conducting each drill;
- deminer comfort; and
- deminer confidence in the technique employed with respect to safety and methodology.

The trials were conducted at a training base in Moamba belonging to the Accelerated Demining Programme (ADP) in rural Mozambique, with assistance from three field mine clearance groups. ADP provided monitoring and evaluation staff, deminers, equipment and a wide variety of other resources.

Deminers were trained or refreshed (as appropriate) to apply each drill in lanes made for the purpose at the site. Training was conducted by experienced trainers from ADP and NPA.

Table 3. Manual mine clearance drills/systems compared in trials in Mozambique

| Drill | Description |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. <i>Standard ADP detector system</i> | Minelab GC (ground compensating) detectors and ADP investigation tools were used to clear the trial areas by two ADP deminers under the supervision of a section commander. The ADP long tools were used to ensure that all tools were identical, apart from those deliberate additions under evaluation. |
| 2. <i>Standard ADP detector system plus magnet clip-on tool</i> | Minelab GC detectors and ADP investigation tools were used to clear the trial areas by two ADP deminers under the supervision of a section commander. The ADP long tools were used as in Drill 1. The trowel was adapted to reflect CMAC's tool with a magnet along one edge. When a signal was encountered, the magnet was used without touching the ground to try to lift any scrap that was present. If that failed, the unmagnetised edge of the trowel was used to lightly scrape the ground surface and the spoil was rolled over the magnetic edge and off the trowel. When that failed to locate a source for the signal, standard signal-investigation procedures were followed and the spoil rolled over the trowel as the deminer worked. |
| 3. <i>Standard ADP detector system plus magnetic brush rakes</i> | Minelab GC detectors were used along with a modified magnet Brush-rake (a two-metre long tool) to clear the trial areas by two ADP deminers under the supervision of a section commander. When there was a detector signal, the ground area was swept with the Brush-rake and the attached magnet picked up ferrous fragments. The magnet Brush-rake was used along with other long ADP excavation tools that had no magnets attached. |
| 4. <i>Detector in low-fragment area</i> | The Minelab GC detectors alone were used, and targets were marked without investigation by two ADP deminers working under the supervision of a section leader. The deminers then swapped working areas, the position of markers was recorded and the markers removed. The drill was then repeated including the investigation of signals using a magnetic trowel in addition to standard ADP long tools. This repeated search tested the accuracy and repeatability of detector pinpointing. Fragments were not placed in this area. The second part of this trial was a "detection reliability" test as described in the European Committee for Standardization (CEN) Workshop Agreement CWA 14747:2003. ^{o)} The part of the trial which included full signal investigation was timed and monitored, and treated as one of the comparative trials. |
| 5. <i>The REDS rake system</i> | The Rake Excavation and Detection System was used to clear the trial area by two ADP deminers under the supervision of a section commander. The method was taught by an NPA trainer who came from Sri Lanka for the purpose. REDS is a system of excavation using two types of rake that is ideal on soft ground, but which is also sometimes used on very hard ground (see <i>Sri Lanka Case Study</i>). |
| 6. <i>Standard ADP spade area-excavation</i> | The ADP excavation-only system (no metal detectors) was used to clear the trial area by two ADP deminers under the supervision of an ADP section commander. This excavation method involved the use of prodders and an ordinary garden spade. The spade was used to cut slices of earth away from the face of an excavation that had been started outside the lane. |
| 7. <i>Standard NPA (Mozambique) excavation</i> | The NPA Mozambique excavation system was used to clear the trial areas by two NPA deminers under the supervision of an NPA section commander/QA person to take part in the trials, using the complete system (including marking) to which they were accustomed. A key feature of the system is a short, purpose-made trowel, used for excavation. |

| Drill | Description |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8. Standard mattock excavation | The <i>enxada</i> (mattock) system was used to clear the trial areas by two ADP deminers under the supervision of a section leader. The <i>enxada</i> excavation method involved the use of prodders and an <i>enxada</i> . Mattocks of various sizes were sourced and the size most closely reflecting the type employed in Mozambique was used. |
| 9. Prodding from the surface | ADP prodders were used to determine the depth that could be prodded in the conditions at the trial site. Two deminers worked on separate areas of a single square metre in which targets had been placed at depths straddling the depth to which it was possible to prod in that ground while using two hands and excessive force. |

a) European Committee for Standardisation (CEN) Workshop Agreement CWA 14747:2003 (available at: humanitarian-security.jrc.it/mine-clearance/cw07/).

These trials were of complete demining systems, not just the tools involved. The system included full field supervision and internal QA methods, without which the deminers would not have declared an area as “clear”.

Methods

Trial lanes

Lanes laid out for the trials were in pairs, each 5 metres long and 1 metre wide. Vegetation in all lanes was cut prior to placing targets. Eight target mines were positioned in each pair of lanes, at depths of 12 centimetres and 1 centimetre (measured to the top of the mine). Four lanes were worked in each trial (although all four were not always completed). Graded scrap fragments collected from minefields were placed in the 12 lanes used for those trials where metal detectors were used. Throughout the trials, the fragments were placed at a density of 7 per square metre. Other metal items may have been present, thus seven items a square metre was the minimum number in the lane.

Surrogate mines (target mines)

Surrogate mines were made from wood to the exact dimensions and approximate weights of Chinese Type 72A and GYATA-64 anti-personnel mines (*Figure 27*). Metal pieces that gave identical signals to the real mines (to the detectors used and at the depths placed) were inserted. The top of each mine was coated in a latex solution producing a “witness-plate” on the top to preserve the evidence of any top impact during recovery. An “initiation” was assumed if the damage to the wood beneath the rubber was in a position that would have applied pressure to the pressure-plate and of a depth that indicated significant force had been applied.



Figure 27. The damage to the top of this surrogate GYATA-64 was not visible before the witness plate was peeled away.

Trial duration

All trials (except trial 9) used two deminers and a supervisor for up to three days or 10 square metres cleared by each deminer (two lanes), whichever was sooner. Thus, trial duration was constrained by both area and time.

Data recorded



Figure 28. QinetiQ representative observing trial.

Data were recorded for each trial by an independent Trial Monitor using a pre-agreed recording format (*Figure 28*). Independent Trial Monitors were ADP, the German University, the Bundesanstalt für Materialforschung und -Prüfung (BAM), and QinetiQ.

Quantitative records were made of: time; area; ambient conditions; concealed mines located; damage to mines located; fragments located; and unusual sub-surface features that affected speed of advance. The method of internal QA/QC was also recorded. After trials using area excavation methods, random depth-achievement checks were made. No depth checks were made during work or prior to the end of the trial in that area.

Through interviews, qualitative assessments were made of: safety of method, comfort of tools used, user confidence in safety and thoroughness, and confidence in internal QA/QC.

When a target mine was located, its position was recorded by the Trial Monitor who then removed the device, taking care not to touch it on the top surface. The discovered devices were placed at the far end of the lane where they remained until the day's work was over. Apparent tool impacts were recorded by the Trial Monitor and later checked by removing the witness-plate and examining the top of the surrogates (this was done to all surrogates regardless of whether an impact was apparent).

All trials using metal-detectors had one or more buckets in which to place the metal scrap located. The total amount of recovered scrap metal was recorded. In trials where magnets were used, each deminer had a second bucket in which to place metal recovered with the aid of the magnets. The number of fragments found with a magnet was also recorded.

Although these trials involved an assessment of the difference made by using different techniques in the same area, the trials were of complete systems, not just the tools involved. The system included full field supervision and internal QA methods, without which the deminers would not have declared an area as "clear".

Drill 9 (prodding only) was also used to investigate the effects of rain. The depth of prodding was measured before and after heavy rain.

A description of how to interpret the results of statistical analyses is in Annex 1.

Four lanes were cleared for drills 1, 2, 3, 4, 6 and 8. Three lanes were cleared for drill 3. Two lanes were cleared for drill 7.

Rate of progress

The time taken using each drill was measured as a function of rate of forward movement in the lane (in centimetres). Considerable variation was found among drills for rate of clearance, with drills using metal detectors tending to be faster than drills in which no metal detector was used (*Figure 29*).

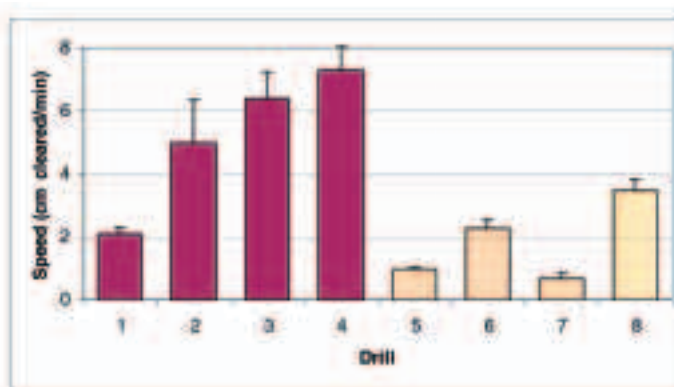
Statistical analysis of the relationships in *Figure 29* showed significant variation (one-way analysis of variance, $F_{1,7} = 17.94$, $P < 0.01$). Post-hoc pairwise tests are used to check for the sources of significant differences in a multiple comparison such as here. Using a post-hoc test, drills 3 and 4 were shown to be similar, and significantly faster than the other drills. The other drills were not significantly different from each other.

The standard ADP drill using a metal detector (drill 1) was similar in speed to the four drills in which no metal detectors were used. The addition of a magnet to the trowel (drill 2) improved performance. Adding a magnet and brush rake (drill 3) improved performance further. The fastest drill (drill 4) was the equivalent of drill 2 applied in an area free of metal fragments.

By using the magnetic brush-rake (drill 3), in terms of clearance rate, a high-fragmentation area (as in drill 1) was effectively reduced to a low-fragmentation area (as in drill 4). These results clearly show that any opportunity to remove metal fragments from a clearance zone should be taken, and demonstrate the value of magnets in high fragmentation areas.

Figure 29. Clearance speed of different manual mine clearance drills (drill types defined in Table 3).

Drills 1-4 used metal detectors; drills 5-8 did not. Bars are mean + standard error.



Although no significant variation was found among the four drills in which no metal detector was used, the data suggest that use of a tool such as a mattock (drill 8) or spade (drill 6) results in clearance rates similar to or slightly better than those achieved with a metal detector and no magnet when many fragments are present. REDS (use of rakes, drill 5) was very slow under the conditions in Mozambique, and was similar to the equally slow Mozambique NPA drill (drill 7).

Safety

With respect to deminer safety, an “initiation” was considered to have occurred when damage to the top of the surrogate mines was extensive enough to make an initiation probable. Drill 4 (standard ADP tools and a magnetic trowel) and drill 8 (mattock) had very poor deminer safety results (Table 4). Deminers believed that the mattock was an inappropriate demining tool and contributed to the poor safety result. However, drill 4 gave a similar result to that found for the mattock, and drills 2 and 4 were identical, with the exception that there were no fragments present for drill 4. These results suggest a much higher accident rate than is normally experienced by the organisations working the drills. The results should be interpreted cautiously as the deminers knew there was no risk during the trials.

Table 4. Safety consequences for deminers and end-users.
Drill types as in Table 3.

| Drill | Initiations/10 m | Mines missed/10 m |
|-------|------------------|-------------------|
| 1 | 0.5 | 0 |
| 2 | 0.5 | 2 |
| 3 | 0 | 0.5 |
| 4 | 1.5 | 0 |
| 5 | 0.5 | 0 |
| 6 | 0.5 | 0 |
| 7 | 0 | 4 |
| 8 | 1.5 | 0 |

With respect to safety of end-users, mines were missed by drills 2, 3 and 7. No mines were missed by the other drills.

Only deep buried mines (at 12 centimetres) were missed. The mine surrogates were all Chinese Type 72A anti-personnel mines which would not normally be planted at that depth, and it is possible that the NPA deminers and supervisor (drill 7, no metal detectors) assumed that mines would be shallower despite being instructed to work to the national clearance depth of 13 centimetres. Type 72A mines are minimum metal and are difficult to detect using metal detectors when buried deep (drills 2 and 3). At least one mine buried at 12 centimetres depth was missed due to assumed detector irregularity.

General patterns in the results

Drill 1 (Standard ADP detector system): an area containing more than seven metal signals /m² was cleared successfully to 13 centimetres using the Minelab F1A4 metal detector and conventional tools for detector signal investigation.

Drill 2 (Standard ADP detector system plus magnet clip on tool): attaching a magnet to a hand-tool used for detector signal investigation in an area containing more than seven metal signals/m² halved the time required to achieve “metal-free” status, although some deep mines were missed.

Drill 3 (Standard ADP detector system plus magnet brush-rake): addition of a magnetic brush-rake to the equipment used in drill 1 in the presence of more than seven metal signals/m² resulted in a clearance rates three times faster than for drill 1.

Drill 4 (Detector in low-fragment area): showed that, when using conventional detector signal-investigation routines, the accuracy with which the detector signal was pinpointed did not affect whether or not the associated device was found. (The trial did not reliably show the effect that a pinpointing inaccuracy would have had on deminer safety had the mines been real.)

Drill 5 (The REDS rake system): the REDS area-excavation system was used successfully in the trial area, and was the only area-excavation process that allowed for realistic field QA without constant supervision. It was also the method that gave most confidence in total clearance (including small items such as fuses) to a given depth, because of the soil-sifting process involved. However, it was one of the slowest methods.

Drill 6 (Standard ADP spade excavation system): the controlled use of a conventional garden spade was the fastest area excavation method under trial. Deminer safety was the same as for the REDS system, and both were safer than the two other excavation methods.

Drill 7 (Standard NPA Mozambique detection system): using a short, purpose-made trowel for area excavation was very slow, and would have resulted in deep mines being missed if continued over the entire lane.

Drill 8 (Standard mattock excavation): using a mattock for area excavation was fast, but dangerous for the deminer because it resulted in severely damaged targets that would probably have resulted in initiations. Despite its relative speed compared to other area-excavation methods, it was slower than clearance systems using a metal detector and magnetic tools.

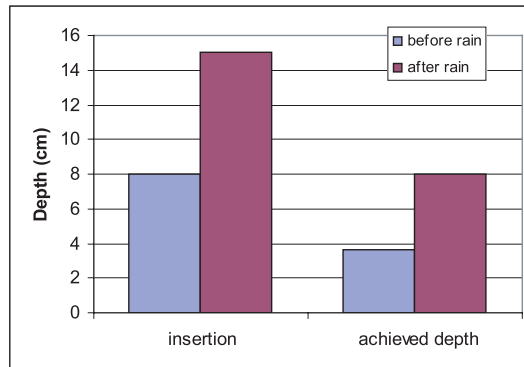
Prodding

Drill 9 was a simple prodder trial, where the depth achieved by prodding in a small area was measured before and after rain. Because prodders are normally required to be used at an angle of about 30°, the apparent depth (length of prodder inserted into the ground) and achieved depth (vertical depth from surface to prodder tip) were measured and calculated. Individual insertions with the prodder were measured, with sample sizes of 16 insertions (before rain) and 18 insertions (after rain) made at two different locations (two of the lanes used in drill 8).

The achieved depths were approximately half the insertion depths (*Figure 30*). The achieved depth after rain was approximately double the achieved depth before rain. The maximum achieved depth after rain was 11 centimetres. These results indicate that prodding in hard soil will result in most mines deeper than about 5 centimetres being missed, whereas prodding in soft soil (after rain) will result in most mines deeper than about 10 centimetres being missed.

The tops of all the target mines that were located during trial 9 (prodding) had been deeply damaged by the prodder.

Figure 30. Insertion depths and achieved insertion depths using a prodder before and after rain.



Discussion

Considerable variation was found in the effectiveness and safety of the different demining techniques studied here. Perhaps most significant in terms of improving productivity in manual demining is the usefulness of a very simple and cheap tool, a small magnet, for dealing with indications from a metal detector.

When no metal detectors are available, the most efficient method in terms of both speed and safety is to use a garden spade to slice thin layers of earth horizontally from the side of a vertical excavation face. This process was a little slower than when a mattock was used, but was considerably safer. The primary advantage of any such excavation system is that the entire ground is turned over, giving very high confidence in the demining product (down to a certain depth).

With respect to QA/QC requirements, REDS was the best system trialled. But under the conditions in Mozambique it was very slow. It is particularly suited to the conditions in Sri Lanka where the soils are sandy and easy to work for most of the year, and there is relatively little ground vegetation. It could have potential for application in some desert and semi-desert situations.

Prodding is an inefficient and dangerous means of locating concealed mines at any depth. It is also essentially impossible to prod deeper than 10 centimetres using standard prodders, and prodding rarely achieves even that depth, especially in hard ground. These conclusions confirm results found previously by Trevelyan (2003).² When linked to excavation using other tools, prodding can be effective at greater depths, but is still slow and dangerous.

1. Trevelyan, J. (2003).

Conclusions and recommendations

Conclusion 1. Manual mine clearance innovations.

The mine clearance industry demonstrates significant innovation. Such innovations are normally a response to local conditions and constraints. While they may only be effective under similar conditions, they could also represent novel ideas with broader potential application. For example, post-clearance area reduction (PAR) is likely to be most effective where patterned minefields predominate and the Rake Excavation and Detection System (REDS) is most effective under conditions of soft soil and limited vegetation cover. Whereas PAR (developed in Lebanon) transferred easily to Iraq, REDS (developed in Sri Lanka) was very slow in Mozambique relative to other drills.

Findings

Most mine clearance programmes visited over the course of the study included innovative advances, some of which had been adopted informally. Most of these innovations had been adopted in order to increase the speed of clearance. However, careful testing prior to implementation in order to demonstrate the believed advantages and check safety issues had not always been carried out. Procedures for incorporating innovative procedures into SOPs and having them improved by the national mine action authority (NMAA) were not streamlined, and were often ignored.

Key to understanding the nature and application of an innovative procedure is a clear description of the situation in which it is being used. For example, formalising the process of reducing areas originally suspected of being mined after the clearance of *known* mines has proven to be very effective in patterned minefields. The follow-up procedure described in Iraq of having a team visually inspect areas after PAR is likely to be perceived as too hazardous in many situations. However, the procedure is acceptable when an appropriate risk assessment has been undertaken. The question of whether such a procedure could or would be implemented in an operational environment where there was an effective NMAA is worth considering.

Recommendation 1.

- a. Innovation is welcome at any time and is relatively easy to achieve in mine clearance. However, the new techniques and processes must be***

rigorously trialled and documented, and implementation should only follow careful assessment of the results of such trials.

b. Mine clearance agencies do not routinely have personnel with the skills needed to design and undertake carefully controlled trials. Support from organisations such as the International Test and Evaluation Programme (ITEP) and the GICHD can and should be requested as a part of the trial process.

c. The results of trials of innovative techniques are a valuable resource for the demining community, even if the trial turns out as a failure. Results of trials should be made widely available, for example through placing trial reports onto websites and reporting them at workshops and conferences. The GICHD or equivalent organisations can help with this process.

d. There is a need to streamline the approval process for innovative techniques, including developing procedures for having them written into SOPs.

Conclusion 2. Magnets and brush rakes.

The use of magnets and brush rakes as additional tools to the standard manual mine clearance “toolbox” will increase manual mine clearance efficiency in many circumstances.

Findings

Trials undertaken in Mozambique supported operational experience in several countries that simple magnets and brush rakes can increase rates of clearance. Most demining is undertaken using simple tools, and any opportunity to add a new simple (and cheap) tool to the toolbox should be widely encouraged. In Sri Lanka, one demining organisation eventually rejected metal detectors in preference for the REDS procedure using rakes.

Recommendation 2.

a. All programmes should consider the integration of “non-standard” tools in order to improve clearance rates in manual mine clearance programmes.

b. Integration of these tools should be tempered with a full quality management system to ensure safe clearance methodologies.

Conclusion 3. Risk and quality aspects.

The methods most likely to leave mines behind or lead to accidents are:

- Area excavation in which the required clearance depth was not rigorously maintained;
- Use of metal detectors that are only marginally able to do the required task, because of either design or age; and
- Prodding from the surface.

Findings

All mines missed in the Mozambique trials were buried at a depth of 12 centimetres. Two of the procedures using metal detectors missed mines because of a combination of search speed and metal detectors inadequate for the task. Recent trials of metal detectors suggest that they routinely do not achieve stated manufacturers’ specifications. Mines were also missed using an excavation technique that was not

being applied rigorously to the required depth standard. Prodding from the surface could not supply the required detection depth, especially in hard soils.

Recommendation 3.

a. Demining agencies presumably only use metal detectors that are inadequate to a task because they have no other options. Regular replacement of metal detectors should be a part of budget planning. Also, metal detectors that are functional in one deployment location might not be adequate in another. Sponsors need to be made more aware of the limitations of metal detectors and the replacement requirements.

b. Use of prodding as a standard demining procedure should be reviewed, with a view to minimising use of this potentially dangerous and limited tool.

Conclusion 4. Traditional versus new techniques.

Established procedures tend to become self-maintaining as a result of training and experience, building in extra resistance to change. Demining agencies obtain too little information about the procedures used by other agencies, and/or have too little opportunity to compare notes and discuss alternative options. Field managers are in a difficult situation: on one side they are required to adhere rigorously to established procedures (laid down in an approved SOP) yet, on the other side, as a result of experience they can often see options for improving productivity without compromising safety.

Findings

Trials run in south Sudan and Mozambique clearly identified opportunities for improving procedures and equipment. Any agency adopting new procedures or equipment will need to do small trials and training, make adjustments as a result of local conditions, and modify and rewrite SOPs. However, the benefits to be gained in terms of productivity appear to be much more significant than the costs involved in making changes.

Recommendation 4.

a. Current manual mine clearance techniques, although appearing to exist as a result of long experience and trials, can still be challenged to achieve a higher degree of efficiency. Trials in this study suggest a significant potential productivity gain. Field managers should investigate the potential for increased clearance rates by carrying out trials and implementing change if appropriate.

b. Field managers and technical advisors should have the opportunity to meet and exchange ideas in a workshop format on a regular basis.

c. Support for trials and modifications should be made available by the wider community in order to assist implementation.

Conclusion 5. Standing Operating Procedures (SOPs).

Although some lag is expected between innovation and the development of SOPs, the evidence in the case studies was that updating of SOPs was viewed as a difficult and low priority task.

Findings

In all of the case studies, SOPs were found to be out of date or in need of development. There was little motivation to improve them, presumably because this was not seen as a priority at a management level. SOPs are often too rigid and inflexible, which prevents innovations and potentially useful changes. SOP changes often require approval from national authorities which may be a bureaucratic and time-consuming process. SOPs should therefore allow minor changes without the need to consult mine action authorities on every occasion.

Recommendation 5.

- a. Updating SOPs needs to be given a higher priority in order to ensure ongoing compliance with the International Mine Action Standards (IMAS) and National Mine Action Standards (NMAS). Support from external agencies may be required to ensure that such updating proceeds regularly. National agencies should be more proactive on this issue, perhaps through providing an updating support service.**
- b. SOPs should be written in less rigid forms, which will make it easier to change them when necessary.**

Conclusion 6. Standard drill versus Hybrid and Crab drills

The standard manual mine clearance drills appear to be implemented in a similar fashion in most countries. This is in part due to a perception that the technique is too well proven to be challenged. Two experimental drills – the Hybrid and the Crab drill – show, however, that it is possible to significantly increase the speed of manual mine clearance by adapting an innovative approach to the clearance process. The Crab drill is particularly promising and appears to be 30 per cent more effective in wet conditions. In dry soil, the potential gain is significantly higher. This technique, or variations of it based around the principle of minimising the time for tool handling, vegetation cutting and watering/soak time, should be considered by field managers.

Findings

The Hybrid and Crab techniques both proved more efficient than the Standard manual mine clearance drills during the trials in Sudan. In wet soils, the difference between the Crab and Standard drills were significant which suggests that the Crab drill may be used permanently both during wet and dry conditions (provided there is a requirement for vegetation cutting). Dry soil conditions where watering is required amplifies this difference significantly. Programme managers should, though, consider that the Standard drills do provide security and safety measures; reaching this level of safety would require additional levels in Hybrid and Crab drills.

Recommendation 6.

The Hybrid and Crab techniques should be considered as alternatives or substitutes for traditional manual mine clearance techniques as they may offer a significant increase in clearance efficiency in most conditions.

Annex 1

Interpreting statistical analyses

Reports of statistical results use a technical shorthand that is not generally familiar to those reading reports about demining. Thus a short introduction is provided here.

Statistical tests normally compare two or more groups of data. One group of data constitutes a set of measurements of a variable (e.g. proportion of time spent using a metal detector), usually obtained as one measurement per subject. The number of subjects therefore constitutes the sample size (N). The test itself involves applying a mathematical formula to the sets of measurements in order to calculate a **test statistic** — a number which represents the variability found within and between the sets of measurements.

In simple terms, if the test statistic is small, that normally means either or both of:

- the variability within each set of measurements is large, and
- the difference between the means is small.

Most people understand a mean (or average), but have more difficulty understanding the concept of variability (or variance) around the mean. Table 1 gives a simple example using data from the Sudan study. Two sets of measurements are listed, each giving the proportion of time one deminer (the subject) spent using the metal detector in two drills.

Table 1. Two sets of data for seven subjects with means and variances (calculated as standard deviation)

| Subject | Use MD, Drill 1 | Use MD, Drill 2 |
|------------------------|-----------------|-----------------|
| A | 15.3 | 21.3 |
| B | 17.3 | 20.7 |
| C | 12.7 | 6.0 |
| D | 13.3 | 10.0 |
| E | 8.7 | 10.0 |
| F | 10.0 | 26.7 |
| G | 15.3 | 21.3 |
| Mean | 12.9 | 15.8 |
| Variance (s.d.) | 3.2 | 8.2 |

The means are only slightly different between the two sets of measurements, but the variances are quite different. The reason is easily seen by reviewing the data. In drill 1 (low variance), the measurements range from 8.7 to 17.3. In drill 2 (high variance) the measurements range from 6.0 to 26.7. Just from looking at these data, it is easy to predict that the two sets of measurements will not be statistically different from each other, but that prediction is not made using the rather similar means — it is made by looking at the ranges and variances of the sets of measurements.

When reviewing a set of measurements visually, the range is useful. But statistical tests do not normally use the range in the data. In simple terms, what they estimate is the relationship between the means and the variances. For example, it is quite possible for two means with the values 12.9 and 15.8 to be statistically different — all that is required is that the variances be small (considerably smaller than in this example). In that case, the ranges of the data would also be much narrower or, put another way, the data would be clustered more closely around the mean.

There is no need to understand the mathematics underlying statistical tests in order to understand the results of a test. The calculations have been subject to a long history of development and testing and are standardised in many computer software packages. The package used for the analyses in this report is called Statistica®.

The meaning of “significant”

It is essential to understand the concept of a difference that is “**significant**”. This term has specific technical meaning, and the notion of a statistically significant difference is central to any statistical conclusion.

In essence, increasing differences between the means, and decreasing variances around each mean, together imply an increasing likelihood that the two sets of measurements are **significantly different** from each other in statistical terms.

In Table 1, the means of the two sets of measurements were slightly different, but were they different enough to allow a conclusion that the difference was in some sense real? Statistical testing provides an objective mechanism for addressing that question.

The hypothesis being tested here is that drills 1 and 2 are somehow resulting in a different use of metal detectors. In other words, there is something fundamental to drills 1 and 2 that leads to a real (or statistically significant) difference in the way metal detectors are used.

Statistical testing uses a standard rule: if $P < 0.05$, then the conclusion should be drawn that there is a statistically significant difference. P is estimated using the result of the statistical calculation (the test statistic).

P stands for “Probability”, and the shorthand $P < 0.05$ can be written out in words as: **the probability of the measured difference being due to chance is less than 1 in 20 (5%, or 0.05)**.

A probability of less than 1 in 20 is regarded as unlikely enough to support a conclusion that something other than chance factors are at work. The difference between the sets of measurements is real, i.e. is an effect of the different conditions.

These days, the computer normally reports an exact probability and that probability is then reported as part of the Result, along with the test statistic. Thus a standard statistical report (in this example for a t-test) will be phrased as:

X was significantly bigger than Y ($t = 10.9$, $P=0.004$, Table Z).

An enormous amount of useful information is bound up in this simple sentence. But in essence, it simply says that the difference between X and Y can be attributed to something other than chance, and it also gives the direction of difference: X is bigger. It is appropriate therefore to appeal to the different conditions under which X and Y were measured as the likely source (or cause) of that difference. A summary of the data used to make the test can be found in Table Z. Table Z might alternatively have been a graph.

A t-test is the simplest form of an analysis of variance, because only two sets of measurements are compared (as in Table 1). If more than two sets of measurements are available (i.e. more than two conditions are being compared), then a more general test is required: the standard test is analysis of variance (ANOVA). In the Sudan trials, three conditions were compared, so an ANOVA was used to test the data. ANOVA returns an “F” statistic, which is reported along with the result:

There was significant variation among the three conditions, with X being largest and Y smallest ($F=7.2$, $P=0.008$).

A P value of 0.008 is lower than the $P<0.05$ rule, so the appropriate conclusion is that differences among the sets of measurements are due to something other than chance, hence the use of the word “significant” in the sentence.

Where three or more conditions are being compared, the analyst may want to know which pairs of conditions are significantly different from each other. Say the F test gives a significant result and the means are A:2.4, B:5.8 and C:6.3. Just by looking at these means, it seems reasonable to expect that A and C are significantly different, with B intermediate. B might be significantly different from A but it is unlikely to be significantly different from C. This is the situation that arose in Figure 21 in the Sudan study. The statistical procedure used to assess these pairwise comparisons is called “post-hoc analysis”. In Figure 21, it turned out that A:C was a significant difference, but A:B and B:C were not significantly different.

Annex 2

Crab and Hybrid Drills

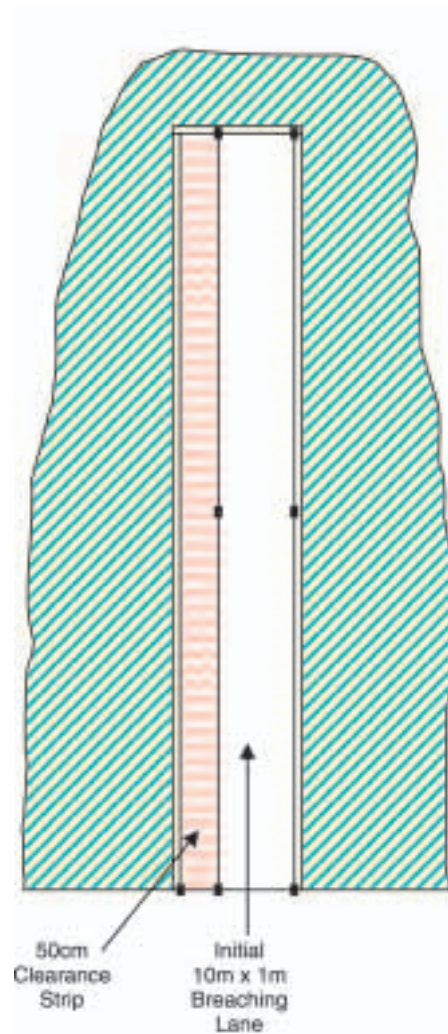


Figure 1. Hybrid and Crab drills.

Both drills extend the initial, 1m wide, breaching lane by 0.5m (+ 10cm overlap) at a time.

A lane marker is placed at the entry point 0.5m in the direction of clearance to delineate the area to be cleared in one bound, and tripwire search and vegetation clearance is carried out.

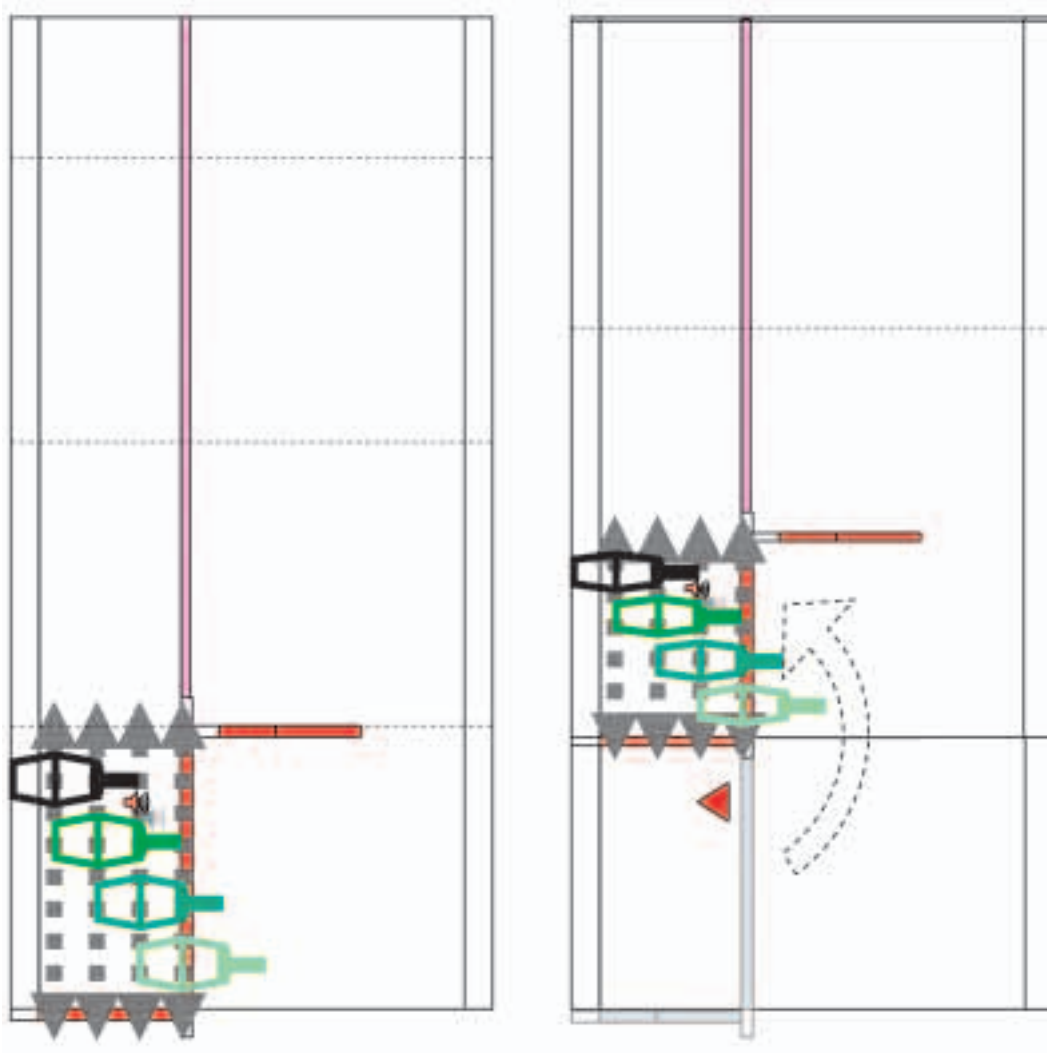


Figure 2. Hybrid and Crab drills

Using a 120cm basestick and two 60cm half-sticks, the 0.5m strip is searched and signals are marked.

A fingertip search is carried out to find and remove surface-laid fragments.

Buried signal points are watered and marked. No excavation takes place at this stage.

Search progresses in 1m intervals

Once the initial search is complete, all signals will have been marked and watered.

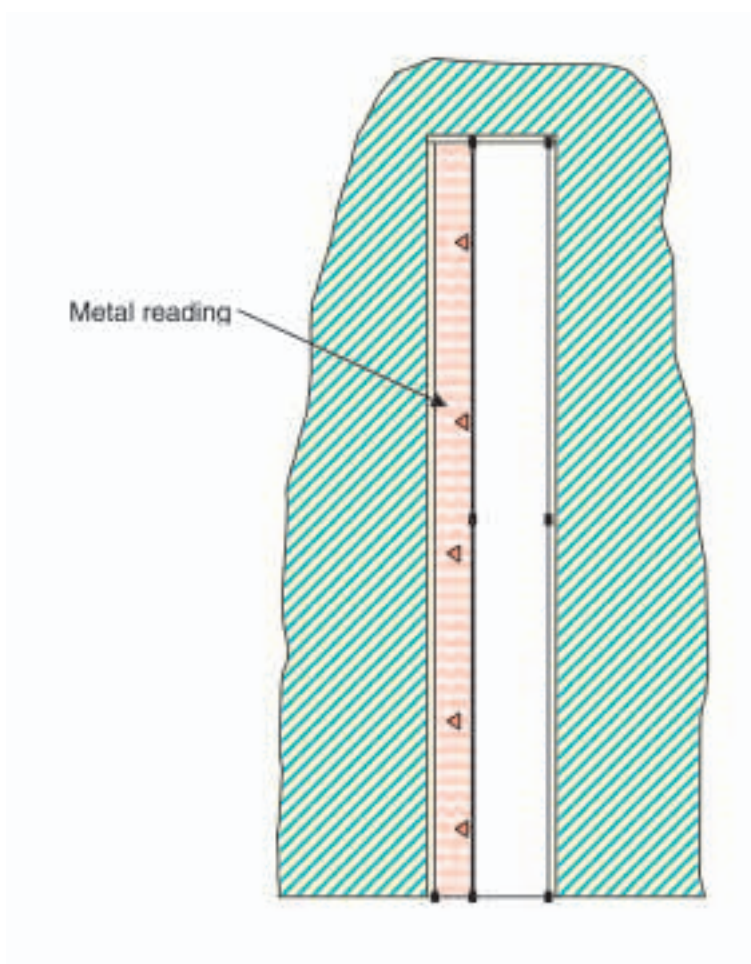


Figure 3. Hybrid and Crab drills

Once the initial search is complete, all signals will have been marked and watered.

Hybrid drill: Search is done relatively quickly because area will be subsequently re-searched.

Crab drill: Search is a full search

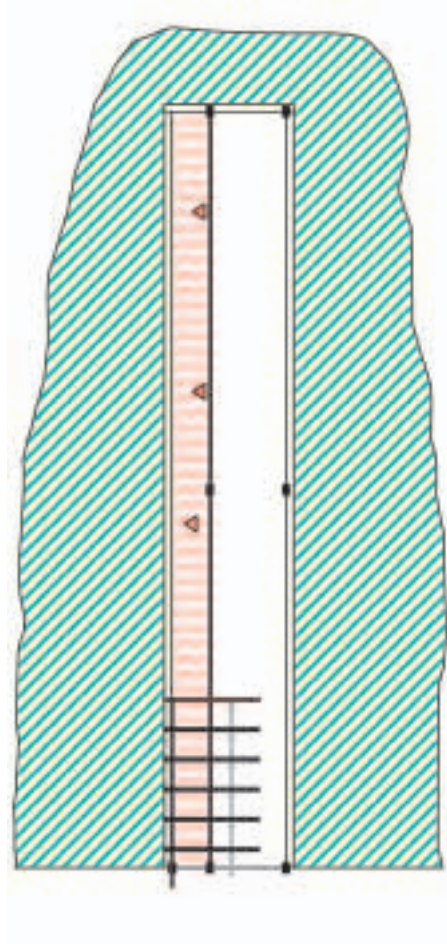


Figure 4. Hybrid drill only

Search progresses along the lane.

Only those signals immediately forward of the basestick are investigated.

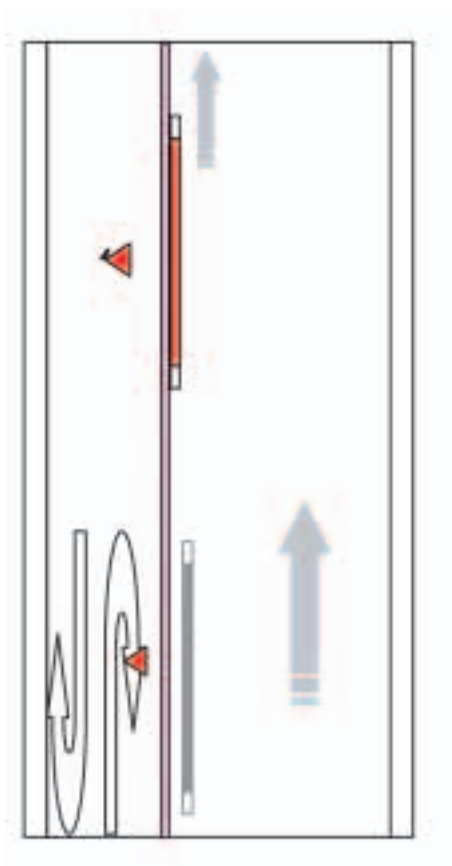


Figure 5. Crab drill only

From behind a 120cm base-stick, placed no further forward than the mine tape boundary, the 0.5m strip is searched.

Individual signal sources are investigated and removed.

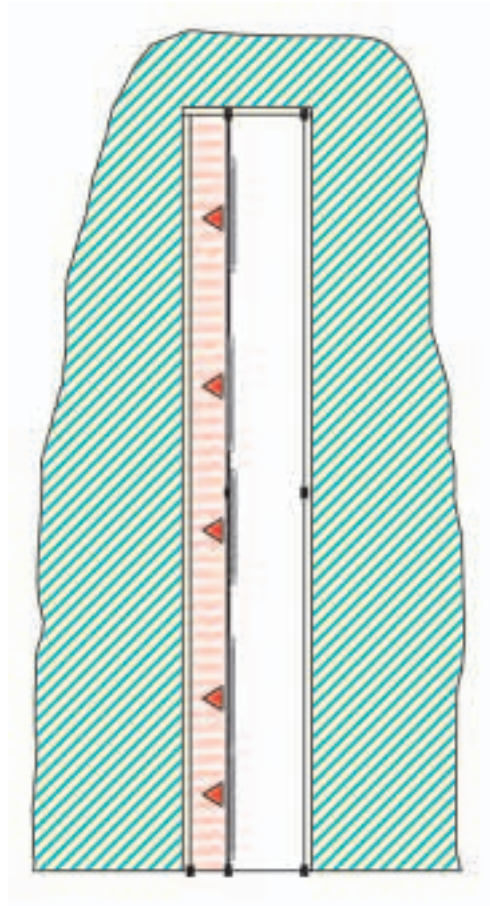


Figure 6. Crab drill only

Only previously marked signal sources are investigated, the intervening spaces are not.

Probing, watering and excavation drills may switch between different signal readings to make maximum use of watering 'soaking in' times.

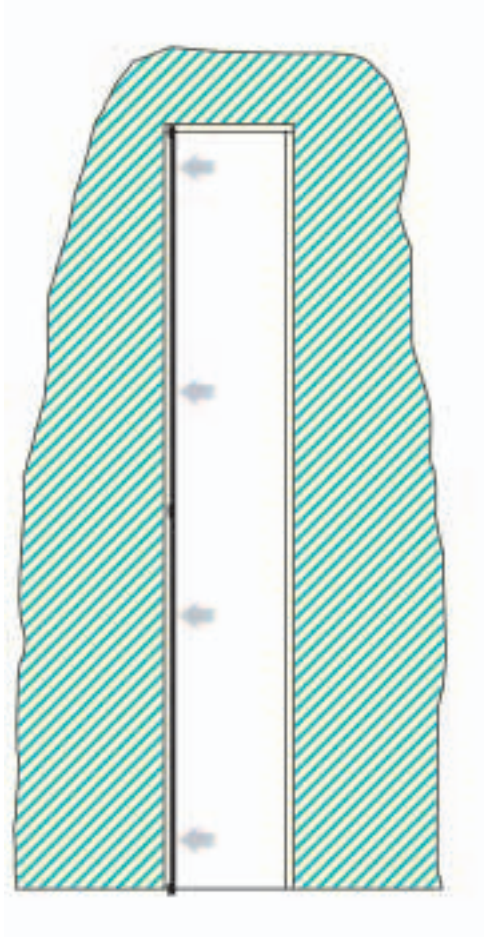


Figure 7. Hybrid and Crab drills

Following investigation and clearance of all signals and a Quality Control check of the lane by the Section Commander, the baseline is moved forward 50cm.

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Proceedings of Eudem2-Scot conference, Brussels, Belgium, pp. 242-248.

Glossary of acronyms

| | |
|-------|---------------------------------------------------|
| ADP | Accelerated Demining Programme |
| ANOVA | analysis of variance |
| BAC | battle area clearance |
| CMAC | Cambodian Mine Action Centre |
| DDAS | Database of Demining Accidents |
| DDG | Danish Demining Group |
| FSD | Swiss Foundation for Mine Action |
| GHR | Ground Reference Height |
| HDU | humanitarian demining unit |
| IMAS | International Mine Action Standards |
| ITEP | International Test and Evaluation Programme |
| LTTE | Liberation Tigers of Tamil Eelam |
| MAG | Mines Advisory Group |
| MCRA | mine clearance risk assessment |
| MRE | mine risk education |
| NGO | non-governmental organisation |
| NMAA | National Mine Action Authority |
| NMAS | national mine action standards |
| NPA | Norwegian People's Aid |
| NSCMA | National Steering Committee for Mine Action |
| PAR | post-clearance area reduction |
| PPE | personal protective equipment |
| QA | quality assurance |
| QC | quality control |
| REDS | Rake Excavation and Detection System |
| SOP | standard operating procedure |
| SPLA | Sudan's People Liberation Army |
| TRO | Tamil Relief Organisation |
| UNDP | United Nations Development Programme |
| UNTAC | United Nations Transitional Authority in Cambodia |



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A STUDY OF MANUAL MINE CLEARANCE

4. Risk Assessment and Risk Management of Mined Areas



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The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

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Contents

| | |
|--------------------------------------------------------|----|
| Summary | 1 |
| Introduction | 3 |
| Methodology | 4 |
| Section layout | 4 |
| Risk management | 5 |
| The risk assessment process | 7 |
| Risk during manual mine clearance | 11 |
| The risk to the manual deminer | 11 |
| Risk from illness | 13 |
| Risk from injury | 13 |
| Risk management applied to process risk | 15 |
| Safety distances | 17 |
| Risk after mine clearance | 19 |
| The applicability of zero-risk approaches | 19 |
| Hazards to clients | 19 |
| Residual (post-clearance/post-treatment) risks | 21 |
| Future reviews and preparedness | 23 |
| Preparing future data gathering | 23 |
| A view on crisis management and expectation management | 24 |
| Conclusions and recommendations | 25 |
| Annex: A model cost-benefit analysis | 29 |
| Bibliography | 33 |
| Glossary of acronyms | 35 |

Photo credit:

Cover: British Army mine clearance of a road in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number H 29725.

Summary

For many years it was assumed that manual mine clearance was a process that produced land that was entirely safe. As time has passed and experience has grown, it has become increasingly apparent that this is not necessarily the case.

This section studies the risks to the deminer as part of the clearance process and considers the follow-on risks on land that has been “cleared”. The section defines some boundaries within the field of risk management and outlines a process of undertaking a risk assessment, which is reinforced with a worked example of the application of this process. It also presents some statistical evidence that the process of manual mine clearance is less dangerous than many perceive it to be.

The Annex to the Section proposes a theoretical cost-benefit analysis showing the results of three different approaches to a mine-affected situation — the “do nothing” scenario, the manual clearance option, and the machine ground processing option, at a lower clearance reliability rate. The results should raise a healthy debate within the demining community about the best way to carry out mine clearance.

Introduction

Mine clearance is essentially a risk-reduction process where hazards (i.e. mines) in an area are removed to a certain level of reliability. Mines and UXO pose a threat to both the people involved in their removal and to the regular users of the land, pre- and post-clearance. This section will refer to *process* and *product* risk. *Process risk* refers to the risk to the manual deminer, while *product risk* refers to the risk to the end user of the land.

While it is natural to assume that mines and UXO represent a process risk, it is also reasonable to expect some residual product risk following clearance. Even though the aim is usually to remove 100 per cent of the mines and UXO from a contaminated area, this goal is probably seldom achieved. Box 1 gives the example of the potential level of (un)reliability of metal detectors.

Box 1. Product risk from manual mine clearance

One trial conducted on the detection reliability of metal detectors has shown that under ideal conditions (experienced deminers, neutral soil without metal contamination and targets that are easy to detect), metal detectors operated by human deminers found only 90 per cent of the mines laid in a test field. Although this trial did not account for the human factor involved in the investigations of these signals, it is still a concern.

The detection rate of the full manual clearance process appeared to be higher than the detection process without excavation because the mere process of excavation allows the deminer to cover more ground in detail. Thus, in spite of the fact that manual mine clearance has been thought of as the most reliable mine clearance technique, it seems that even under the most favourable conditions, some of the mines in a given area will remain after the land has been handed back to the local population.

A balance between minimising risk and maximising gain can be achieved through a process of risk management. While it is desirable to completely eliminate the risk, greater

gains may be possible if resource allocation is informed by a risk management approach. Risk management involves a compromise between available clearance funds, technical feasibility and the intended use of the land. The outcome of any clearance should be a risk that is tolerable to the end users, but which represents the best use of the resources available.

This section investigates the risk associated with manual mine clearance, both the risk of the activity itself, and the risk after clearance. The occurrence of manual mine clearance accidents is compared with that of other industries and situations in different nations. Real and perceived safety measures are discussed and suggestions are made as to how safety can be improved. The advantages of a risk management approach to the product risk are presented in the form of a cost-benefit model.

Methodology

The research was undertaken over a six-month period and involved a desk review, detailed discussions with stakeholders in the mine-clearance industry and a field visit. A 10-day field trip to Cambodia in March 2004 provided the opportunity for the team to visit the Cambodian Mine Action Centre (CMAC), HALO Trust, the Mines Advisory Group (MAG), and other key stakeholders in mine action in Cambodia. Relevant literature and available technical work, accident records and other material were used in order to gain a systematic understanding of the humanitarian mine clearance industry.

Section layout

The section begins by describing the process of risk management and risk assessment, and discusses the need for the collection of data to inform the risk management process. The process of manual mine clearance, as it relates to risk, is then discussed. This involves attention to:

- the risk to the manual deminer;
- how the risk compares to that faced by workers in other hazardous industries; and
- how a risk management approach can help to reduce the risk to the manual deminer.

The section then focuses on the product of manual mine clearance, in terms of the residual risk that remains after clearance. It discusses whether a “zero-risk” policy is feasible, and how resources might otherwise be allocated using a risk management approach.

Following the section’s conclusions and recommendations, the results of a cost-benefit model are presented.

Risk management

“Risk” (R) can be defined as the combination of the likelihood (p_H) of a specified hazard (H) being realised (i.e. a person walking on a mine), and the consequences of the event (harm and/or damage): (C_H). In many instances, if the probability and the consequences are defined numerically, the combination takes the form of a multiplication, leading to an estimation of the risk level:

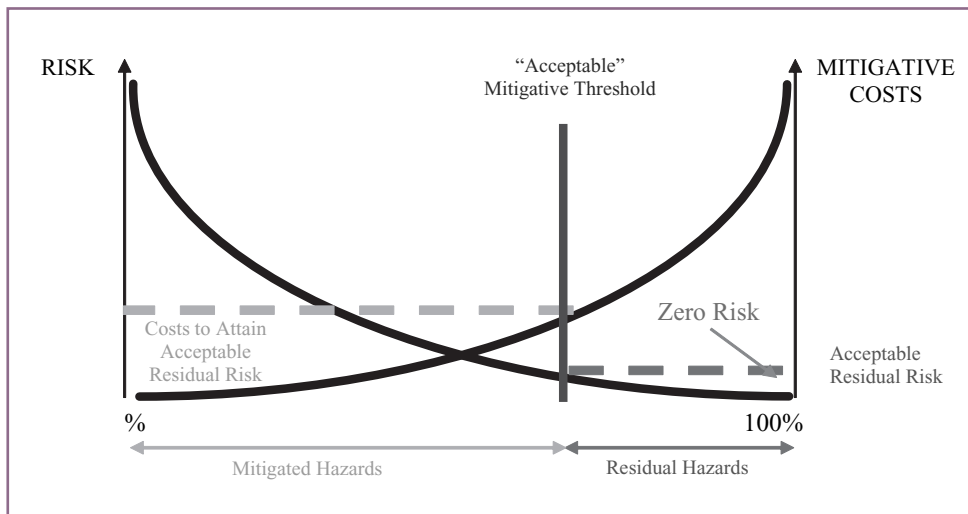
$$R_H = p_H \times C_H$$

Risk management is the process of optimising the use of scarce resources to reduce the risk that a person or community faces from a hazard. In terms of manual mine clearance, the hazard is the presence, or suspected presence, of mines and UXO. Such hazards pose physical risks to local populations, such as the possibility of death or injury, and can result in areas of land which people are unwilling to use.

Manual mine clearance assets represent a limited resource. A risk management process seeks to use mine clearance to best effect, i.e. to apply mine clearance to areas where it can be of most benefit, and in ways that reduce risk effectively and rapidly. While it may be possible to completely eliminate a risk, the cost of doing so must be traded off against the benefit of using the resource in a different way. For example, the same mine clearance investment, in terms of time and cost, may completely eliminate the mine risk in a small area, or significantly reduce the risk in a much larger area.

Figure 1 illustrates the idea that greater reductions in risk come at ever-increasing costs. When the risk is very high, it is likely that a small investment will achieve rapid risk reduction. However, as the level of risk approaches lower levels, the investment required to reduce the risk further escalates. Thus, it might be relatively inexpensive to remove the majority of mines from an area, but locating and removing the last few mines might involve a much greater cost in terms of money and time. In order to optimise both the amount of risk reduction achieved, and the amount of investment devoted to the task, a threshold can be set (*vertical line — “Acceptable” Mitigative Threshold — in Figure 1*).

Figure 1: Cost as a function of degree of risk reduction



Box 2 illustrates the potential savings in resources that could be achieved if a risk management approach was adopted in the manual mine-clearance industry.

Box 2 also illustrates that risk management is an iterative process. A decision to clear an area should be continually reassessed, based on the acquisition of new information. In the case described in Box 2, the information obtained during clearance about the presence and pattern of mines should have informed a new risk management decision to cease clearance of that site, rather than to continue to allocate resources to clearing an area in which the risk is perceived to be extremely low.

Box 2. Lessons from a Cambodia site visit

During the course of the Study of Manual Mine Clearance, the GICHD team visited a clearance site on the edge of a main (sealed) road. The area marked out by a technical survey team as a suspected hazardous area (SHA) ran from the edge of the road to approximately 10 metres short of the railway line running parallel to the road. The SHA's width was an estimated 500 metres, and its length approximately 700 metres.

A team of 35 deminers had cleared 40 per cent of the site in six months of work. Thirty mines were found in a direct line perpendicular to the railway line. No other contamination had been found. Based on the Landmine Impact Survey (LIS) and local intelligence, there appeared to be no further contamination in the marked SHA. Clearance of the rest of the site was expected to take a further nine months.

An application of a risk-reduction policy may have resulted in a more effective use of resources and better value for money for the donor community and key stakeholders. Based on a situational analysis of a combination of factors including local intelligence, it was fairly clear that the likelihood of mines being located in the remaining area was minimal. A judgement to lay this land aside would appear to be the sensible option, yet it had not been considered by any of the managers of the programme. Nine further months of work in an area where there was a very low chance of locating mines is a poor application of resources.

Based on the results of risk assessment, i.e. the study of the hazards, their magnitude, probability, and the costs of consequences, practical risk management measures can be discussed and taken — for example, the installation of passive measures, such as fencing the land where mines are present and restricting use; or active ones, such as the removal of the hazard source to a given level of reliability.

Each measure will have some residual risk that should be carefully evaluated and entered into the financial side of the equation. Therefore, risk management is a decision-making science rather than another housekeeping tool.¹

The risk assessment process

Risk assessment can be conducted at different levels. At the strategic level, it can help to develop national mine action programmes that prioritise mine clearance tasks in relation to the end users' needs for economic, political and environmental recovery.

At the operational level, a risk assessment can help to plan a specific task.² It will help in selecting the tools to be used, the process to deploy, the protection that should be worn and sometimes the time of year when it would be most appropriate to work.

Through a risk management/risk assessment approach, it is possible to achieve many goals in the mine clearance field, such as:

- better programme governance and organisation protection;
- improved stakeholder confidence leading to enhanced fundraising;
- a more rigorous basis for planning as a result of a structured consideration of the key elements of risk;
- more effective allocation and use of resources resulting in a more “competitive” organisation;
- improved communication and consultation, both internally and externally;
- better identification of opportunities and threats associated with organisational initiatives;
- compliance with relevant legislation, capability to negotiate/discuss standards;
- greater openness and transparency in decision-making and ongoing management process;
- improved loss control, reduced loss/incident damage and cost of risk, including commercial insurance premiums;
- learning and promulgating lessons from both successes and failures; and
- no costly surprises because undesirable risks have been previously identified and managed.

The following is a step-by-step risk assessment approach as it might apply to the mine-clearance industry.

Step 1. Define the system

In order to prepare a Mine Clearance Risk Assessment (MCRA), the “system” has to be defined. The “system” could be an entire country, a province, group of provinces or a single minefield (for example, the K5 mine belt in Cambodia). Possible targets (deminers, general public during/after mine clearance, the mine clearance organisation itself, donor, government, etc.) should be listed.

1. HSE (2001).

2. Serco (2002), (2003).

Step 2. Identify the hazards

An effective MCRA requires identification of hazards or potential failure modes. Many of the hazards faced by the mine-clearing industry are unique to that industry. Further, the hazard presented by a particular mine type may be exacerbated by geographical or climatic features of the region. For example, a particular type of mine may present a greater hazard in areas of particularly hard soil, where excavation is more likely to cause the mine to detonate.

The Landmine Impact Survey (LIS) is an attempt to build a hazard-identification tool. The LIS has a strong “historical” weight, in that it is based on information at a community level about past mine incidents and their impact. The possibility of future accidents is not specifically evaluated. In a country with a highly mobile population and/or strong demographic pressure, using only “the past” for decision-making might limit the usefulness of the LIS. This in itself does not necessarily limit the usefulness of the LIS, but rather reflects limitations for planners and planning processes.

The way to more effective and efficient mine clearance is through acquiring more information about the hazards occupying an area rather than assuming a worst case scenario.³ This means, in risk management terms, performing a better hazard identification. In mine action, efforts are being developed in various directions to meet this goal. For example, maps are developed in Cambodia where accurate record-keeping of the direction of movement of victims, distance from the last safe position, location of the accident and other important topographic parameters are being recorded with the aim of “contouring” unsuspected minefields or checking residual risks. Special detectors and other analytical devices are being tested, together with remote sensing and other imagery techniques in various research centres all over the world. Unfortunately, none of these techniques seems to offer a reliable, sustainable alternative to using men, machines and dogs to find mines, especially when considering the incredible diversity of environmental conditions, and the wide range of ground conditions to be found in suspected minefields.

Step 3. Identify elemental failure modes

Failure modes which are attributable directly to single external causes are identified as “elemental failure modes”.⁴ Elemental failure modes cannot be subdivided further. Examples of elemental failure modes in the mine-clearing industry are:

- a mine detonation during prodding; or
- a mine detonation by an animal.

Step 4. Combine elemental failure modes into compound failure modes

Any one of several elemental failure modes can affect a given component of the system. By mathematically combining the probability of occurrence of each of the elemental failure modes, the compound failure modes can be assessed. An example of this might be the failure of a deminer to cover every square inch of the ground requiring clearance (a single elemental failure mode) followed by a failure of the internal quality control processes to pick up on this omission (a further single elemental failure mode).

Step 5. Assess the probability of occurrence

Likelihood of events may be estimated using statistical analysis and calculations. Where no reliable or relevant past data is available, subjective estimates may be made, reflecting an individual or a group’s belief that a particular event will occur. The probability of occurrence may be defined based on historical occurrence rates from reputable sources.

3. GICHD (2004a).

4. Oboni et al. (1997) and (1998).

If there are no records, techniques exist to interpolate between known similar cases. If necessary, probabilities inferred this way can be modified by expert judgement following interviews or meetings with key personnel, experts and staff.

To avoid subjective bias, the best information sources and techniques should be used when analysing probabilities of occurrence. Sources of information may include the following:

- past records;
- current practice and relevant experience;
- relevant published literature;
- public consultation;
- experiments and prototypes;
- economic, engineering, or other models; and
- specialist and expert judgements.

Techniques include:

- structured interviews with experts in the area of interest;
- use of multi-disciplinary groups of experts;
- individual evaluations using questionnaires; and
- use of models and simulations.

Wherever possible, the confidence placed on estimates of levels of risk should be included. Assumptions made in the analysis should always be clearly stated. The probability of occurrence of each of the elemental failure modes is assessed numerically and those numerical points combined using simplified event trees.

Step 6. Estimate the consequences

The same approach used for probabilities can be used for estimating consequences. Key personnel, experts and staff estimate the range of costs which might be associated with each of the identified events. The costs are generally assigned within a range. If there is cultural reluctance to use a cost for life, the consequences can be expressed in “number of casualties”, as is often done in this study. However, placing a value on the cost of life is common practice in the insurance industry and in many governments.

Step 7. Present the results

Once all the necessary evaluations have been performed, the results can be presented.

As described above, the technique is extremely versatile, but ideally requires numeric data. Without numeric data, evaluating hazards as different as vehicle accidents and anti-personnel mine detonations is not possible. Furthermore, using numeric values allows for easy updating of estimates as new experience and new data are made available.

Specific templates for various levels of risk assessment could be prepared in the future and specific data acquisition campaigns could greatly enhance the risk assessment process. And, as work progresses, new information may be acquired or a higher degree of confidence in some of the existing information may be reached. New information may require changes to the initial risk assessment that will affect the methods and resources that are appropriate for the task.

Having completed a risk assessment, decisions can be made about how best to mitigate the risk. Cost-benefit analysis (*discussed later*) can provide a way to evaluate the efficacy of available strategies. Cost-benefit analysis integrates factors such as the cost of a programme, the numbers of casualties resulting from different deployment strategies and the level of risk reduction achieved in order to optimise the use of available resources.

A worked example of how a risk assessment process can be undertaken is shown later in the section.

Risk during manual mine clearance

The risk to the manual deminer

Manual deminers face risk not only from explosions and accidents during the actual process of mine clearance, but in other aspects of their professional responsibilities and daily lives. As mine-clearance activities are usually undertaken in countries which tend to be politically unstable and less developed, deminers tend to be subject to high risk from disease, such as malaria and HIV/AIDS, motor vehicle accidents and terrorist acts, in addition to mine accidents.

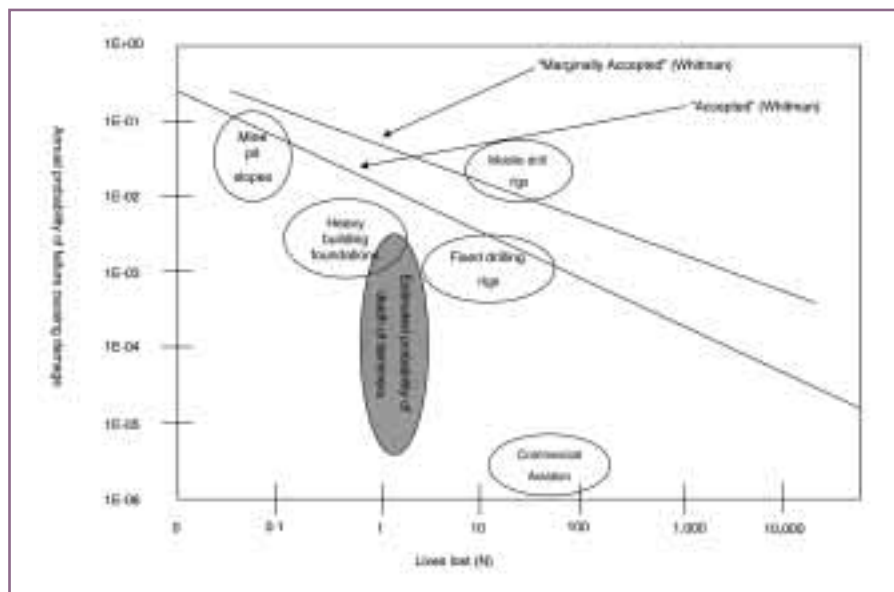
While local populations in industries other than mine clearance face similar risk from simply working within these hazardous countries, it may be that mine clearance exposes employees to a greater level of risk from non-mine-related incidents than local people in other occupations. For example, manual deminers are often required to spend long periods away from home, often in primitive living conditions. Such conditions put workers at higher risk of contagious, sexually-transmitted and other diseases. For example, living in a tent in the jungles of Angola may increase the risk of malaria, and poor hygiene and lack of access to health care may facilitate the spread of disease. Similarly, deminers working in some countries may become the target of terrorist attacks due to the fact that they are employed by international organisations.

How dangerous is it to be a deminer? Figure 2 shows the annual probability of an accident in relation to the number of lives lost per year for a number of industries typically regarded as dangerous. The y-axis (vertical) of Figure 2 shows the likelihood that an accident will occur in each industry. For example, accidents are more likely to occur on mine pit slopes than in the commercial aviation industry. The x-axis (horizontal) shows the severity of an accident when one does occur in terms of the number of lives lost. So, while accidents are more frequent in the mining industry, when an accident does occur in the commercial aviation industry, a greater number of people die.

The two solid lines in Figure 2 represent limits of acceptable risk as established by Whitman.¹ Thus, according to Whitman, accidents of greater severity are acceptable as long as the probability of their occurrence is very low.

The estimated range for deminers was obtained by adding estimated casualties from accidents as well as lethal diseases (malaria, AIDS) and road accidents, and dividing that number by the estimated number of deminers working in Cambodia in the years 2000–03. The probability and severity of accidents for deminers is shown as a grey area. Figure 2 shows that the mine clearance profession, despite the high rate of death due to disease, is not more hazardous than certain other professions such as working on mobile drill rigs, in open pit mining or on foundation works.

Figure 2: Annual probability of an accident as a function of the number of lives lost in several dangerous industries



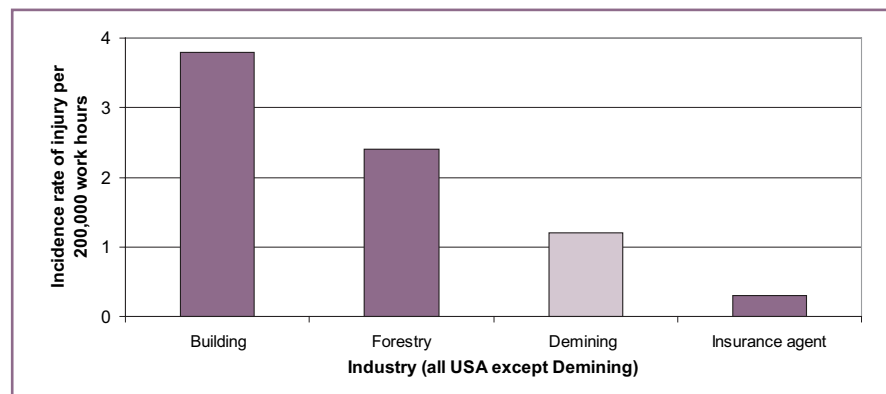
Source: Leroi E. et al. (2003). Ovals and areas represent ranges rather than precise numbers.

Figure 3 compares non-fatal injury rates for various US industries in 1998 with that of deminers in Afghanistan for the same year. All incidence rates are calculated based on the rate of illness or injury per 200,000 working hours, which equates to 100 employees working for a full calendar year. The incidence rate for mine clearance in Afghanistan in 1998 (roughly 1:200 deminers per year) fell between that of forestry workers and insurance agents. Thus, despite the perception that mine clearance is a dangerous occupation, and despite the fact that safety policies were likely to have been well below that expected in the US for the same period, mine clearance appears to be a relatively safe industry, at least in terms of injury that did not result in death.

So, overall, it seems that mine clearance is safer than many industries which employ large numbers of people. Yet, if the risk to the manual deminer is to be minimised, an examination of the hazards faced by deminers is required.

1. Whitman (1984).

Figure 3: Incidence rates in various US industries compared to mine clearance in Afghanistan in 1998



Incidence rates are for non-fatal injuries resulting in at least one lost workday calculated per 200,000 work hours.

Source of data: Bureau of Labour Statistics (www.bls.gov) and UNMACA annual report 1998.

Risk from illness

Manual deminers face risk from illness due to the working and environmental conditions in countries affected by landmines. Deminers in north-west Cambodia are heavily exposed to malaria, dysentery and other tropical diseases, resulting in impaired conditions for whole teams and working-schedule disruptions. Mine clearance organisations can seek to minimise risk from disease by ensuring deminers in the field are equipped with mosquito nets, have access to clean water and hygienic food preparation, and have reasonable access to health care to both treat outbreaks of disease and prevent their spread.

AIDS is a disease that is becoming an increasing problem among deminers. Death rates as high as 10 per cent of the total workforce have been recorded among deminers in Mozambique, with similar stories emerging from such countries as Angola.² (Although it cannot be considered a workplace disease, long stays away from home and the relative affluence of the deminers are aggravating factors.) Some mine clearance organisations, such as Norwegian People's Aid (NPA), are providing HIV/AIDS awareness courses to their deminers to educate them about transmission prevention.

Risk from injury

From anecdotal and limited data gathered within the context of this study, it appears that the number of workplace accidents is relatively small. But it is very difficult to know with any degree of precision the number of working hours lost because of mine clearance accidents, mostly due to lack of thorough record-keeping of these events. In most cases, as soon as an accident occurs, the team on that site (between five and 30 people) stop work immediately while the casualty is dealt with. Depending on the organisation, the gravity of the accident and the organisation's philosophy, staff may be back to work within an hour, or they may take the rest of the day off and be back at work the following day.

2. Tim Lardner (personal communication, 2004).

In Mozambique in 2004, NPA had six operational teams of up to 35 deminers plus two survey teams. The Accelerated Demining Programme had nine operational teams of 20 deminers and two survey teams. Both programmes had one accident in the year 2003, bringing the annual ratios to within the order of 1:200 for non-fatal accidents for each of them. Fatal accidents are quite rare in the profession on a worldwide basis.

The UN has developed a unified humanitarian deminers' accident database (DDAS – Database of Demining Accidents), which displays more than 400 records. Despite these efforts, the UN database is somewhat limited due to the diverse nature of the raw material, the possible bias at source and the reticence of some operators to release data. In general, accidents appear to be most common during excavation, especially in hard terrain. Nevertheless, it seems that death rates for demining accident victims are less than 15 per cent of the overall accidents.

Supervisors seem to be prone to more accidents than deminers, possibly due to deployment in more unusual situations and a less stringent compliance with PPE-use regulations can compound injuries to result in more significant effects.

Given the limited amount of accident data and the lack of standardisation of this data, it is very difficult to draw firm conclusions about the link between error, fatigue and dehydration. Of the 268 (of 409) accidents in the DDAS that are linked to a time, there is a general trend for more accidents in the period between 09.30 and 12.30 (see Figure 4). Unfortunately, because of the variations in working routines and break times, we cannot draw conclusions other than to suggest that clearance between 09.30 and 12.30 appears to be more dangerous than at any other time — perhaps because most mine clearance is undertaken at this time.

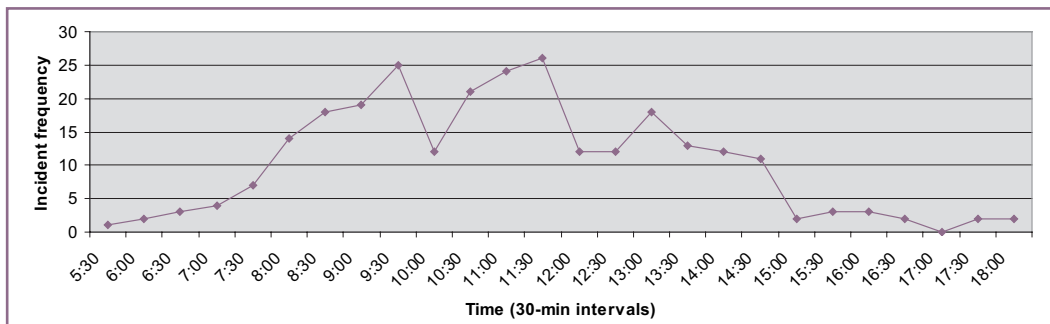


Figure 4: Occurrence of accidents throughout working day

A review of relevant literature³ and numerous accident reports,⁴ lead to a qualitative understanding that the main reasons for accidents are:

- boredom and/or lapses in concentration;
- long shifts, fatigue;
- excessive heat and humidity (these can affect the performance and hydration of deminers and may dictate a change to the working hours or the frequency of rest periods);
- poor on-site management;
- pressure to increase productivity;

3. For example, BARIC Consultants (1996).

4. By the Bosnia and Herzegovina Mine Action Centre.

- lack of authority of the mine action centre inspectors;
- high false alarm rate leading to complacency;⁵
- possible over-confidence in detector performance (the electromagnetic qualities of the ground can severely affect metal-detector performance; proximity to power lines, reinforced concrete, buildings, power lines and transformers can all affect the performance of metal detectors, and transformers may adversely affect field communication systems; finally, rain can soften the ground surface and make it easier to safely excavate, but rain may also change the electromagnetic properties of the ground and make devices harder to detect with a metal detector);⁶
- steep, irregular, or damp ground (these can also seriously affect the use of machines in ground preparation, the deployment of manual deminers and the performance of metal detectors, and extremes of wet and dry conditions can increase the hazard by changing the properties of the ground);
- lack of refresher courses in periods with few positive finds;
- inappropriate standing operating procedures (SOPs) (failure to adapt to specific environments: for example, mines placed in a steep area may move; they may also become deeply buried; deminers can slide — therefore SOPs should allow them to work from the bottom of the slope upwards);
- missed mines;
- booby-traps;
- urban detritus/destroyed environment, hard ground (hard ground can increase the risk of injury from an unintended detonation when excavating);
- the presence of obstructions — boulders, burnt-out vehicles, etc. — can hamper access, command and control lines, and the choice of resources to deploy; and
- difficulty of site because of overgrown vegetation (areas that are heavily overgrown present a greater hazard because the vegetation may hide an obstruction, trench or other hazard).

However, it is clear that more data needs to be collected in order to assess deminer safety during operations. It would be advisable to collect data related to “casualties per employee-hours worked” and/or “lost hours per employee-hour worked due to casualty”, as these measures would allow direct comparison with other industries around the world.

Risk management applied to process risk

This section will develop the risk management stages as detailed previously and use the example of personal protective equipment (PPE) requirement assessment.

In many instances, PPE appears to contribute to excessive fatigue, heat stress and inadvisable behaviour (such as lifting the visor when close inspection is needed). Indeed, military approaches⁷ seem to have led to PPE that is heavy and cumbersome and the necessity of body armour is not fully proven. Polycarbonate visors are heavy and hot to wear, they scratch easily and, as a result of heat and poor vision, deminers tend to lift them, especially when they need to see perfectly, i.e. during excavation.⁸

5. The presence of large quantities of scrap metal can also seriously affect metal-detector performance.

6. It seems that many demining groups are not using metal detectors properly, i.e. they are failing to ensure proper calibration techniques taking into account the moisture of soils and their metal content (laterites, etc). Toews (1997).

7. Angel and Tack (2001).

8. Trevelyan (1997).

Paradoxically, this is the most dangerous part of the work.

A risk management approach could be used to examine the effect that PPE has on risk during manual mine clearance using the steps identified previously.

Step 1. Define the system

In this case, the system is the SOPs of a demining agency. The potential risks to an individual deminer are to be assessed.

Step 2. Identify the hazards

Many “industrial” hazards can damage the chosen target (the individual deminer). These include vegetation, wildlife (snakes), disease, etc. However, for the sake of this example, we will limit ourselves to the most serious hazard faced by a manual deminer during operations (a mine detonation), in as far as it relates to PPE use, either because the PPE itself can increase the operational hazards, or because inappropriate or ill-fitting PPE can cause the deminer to violate the SOPs.

Step 3. Identify elemental failure modes

Elemental failure modes would be specific PPE problems that could lead to a hazardous event. They are each characterised by a probability of occurrence and a magnitude (for example, if a visor is scratched to a certain degree, it may reduce visibility by 10 per cent). Examples of elemental failure modes are, say, PPE being too heavy, visors that are easily scratched, etc. These lead to direct operational hazards and/or SOP violations. Other problems that may be caused by PPE use could be such things as exhaustion and heatstroke, again leading to operational health hazards and/or SOP violations.

Step 4. Combine elemental failure modes into compound failure modes

If several elemental failure modes were to occur simultaneously (for example, if a deminer was working in extreme heat with a heavily scratched visor), the probability of a mishap could be increased. For example, a deminer wearing heavy PPE might become hot and fatigued, lose concentration, and (with a scratched visor) may lead to a greater combined probability than if a clear visor were used under extreme heat conditions or a scratched visor under comfortable heat conditions. Each scenario might have different consequences. Indeed, injuries to the deminer in the event of a mine detonation would be very different.

Step 5. Assess the probability of occurrence

In order to complete this step for each elemental (Step 3) and compound (Step 4) scenario, data would need to be gathered on such things as the density of mines in a suspected area (greater number of mines leads to greater chance of detonation), the local weather and seasonal temperature variation (fatigue caused by PPE may be more likely in hot climates, or in hot seasons), the number of accidents suspected to have been caused by PPE, etc.

Step 6. Estimate the consequences

The consequences of various aspects of PPE use can be estimated (see Step 4 above). For example, mine accidents caused by PPE use have consequences in terms of death, injury, etc.

Step 7. Present the results

After completing the previous six steps, an assessment of the risk of PPE use can be presented. For example: “for deminers working in an area where the threat is limited to

small blast mines, only eye protection is needed.” In order to develop a comprehensive risk-management approach, risk assessments of alternative strategies would also need to be completed. For example, if deminers were no longer required to wear PPE, how would this affect the risk to the deminer? If visors were improved, would this lead to lower risk to the deminer?

The costs and benefits of alternative strategies can be included into a cost-benefit analysis to weigh the reduction in risks against the cost of different options.

Safety distances

The IMAS requirements on PPE for deminers operating in a hazardous area are clear. Annex C of IMAS 09.20 advises a default distance of 25 metres between deminers operating in an area with an anti-personnel blast mine threat — unless “*a detailed risk assessment*” has been undertaken.

What this risk assessment should consist of is not stated, but many mine clearance organisations have undertaken their own informal risk assessment and decided that when they are working in areas where the threat is from relatively small anti-personnel blast mines, the distance between lanes be reduced. This means that in some organisations, such as CMAC in Cambodia, manual mine clearance is being undertaken in lanes as close together as 10 metres. This is a pragmatic approach to a problem and one that should be considered more broadly.

Risk after mine clearance

The applicability of zero-risk approaches

Mine clearance is an activity leading to the removal — or neutralisation — of a specific type of hazard, i.e. anti-personnel and anti-tank landmines, as well as UXO.

The International Mine Action Standards (IMAS)¹ define residual risk as the risk remaining following the application of all reasonable efforts to remove and/or destroy all mines or UXO hazards from a specified area to a specified depth.² Notions of reasonable effort and depth seem to constitute a relaxation of the “abatement to zero” approach. Moreover, IMAS implicitly introduce the notion of tolerable risk, stating that cleared land can never be absolutely safe — it can only ever be relatively safe.

IMAS also state that national mine action authorities should determine the tolerable risk that they are prepared to accept in their particular environments.

Hazards to clients

Class actions

One possible implication of a policy which settles for a higher-than-zero risk after clearance is that of public class actions against mine clearance agencies in the event of mine accidents post clearance. Despite the fact that civilian mine clearance is mostly driven by donations there are no compelling reasons why public challenge and class actions should not target the mine clearance industry at large, i.e. any of its direct or indirect actors. This is particularly true in the case of residual risk.

There are several precedents that have been set in recent years that may guide the mine action industry. These are covered in much more detail in the recent GICHD study, *A Guide to Insurance for Mine Action Operators*.³

1. UNMAS (2003).

2. Modified from ISO Guide 51:1999.

3. GICHD (2004b).

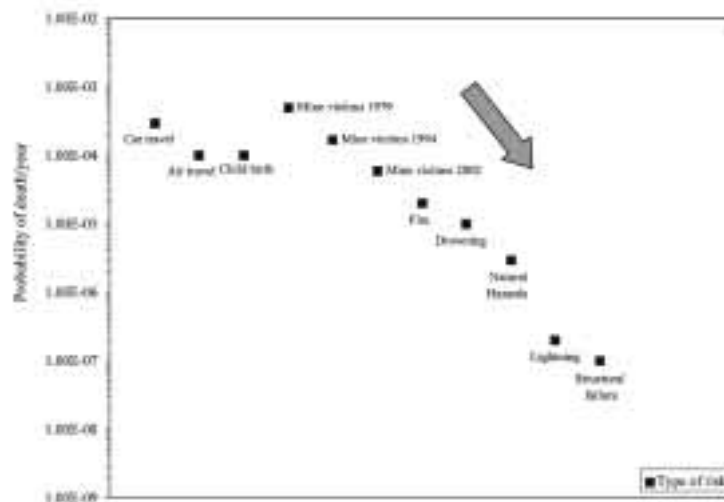
1. In Bosnia in 2003/2004, the director of the Federal Demining Centre in Bosnia and Herzegovina was taken to court and accused of bearing personal liability for the deaths of three children who strayed into an area that was alleged not to have been marked. On this occasion, the verdict was one of "not guilty", but it has no bearing on cases that might be brought under other legal jurisdictions.
2. In 2001, a class action was brought by 230 Kenyans alleging that the British Army was negligent with regards to clearing UXO on a military range in Kenya. The claim was eventually settled out of court for US\$8 million.
3. In 2003, a Kosovo-Albanian family brought a case to the European Court of Human Rights against the French contingent of the Kosovo Protection Force (KFOR) based on the allegation that the French KFOR knew of the locations of cluster bombs but failed to mark or clear them. This case is still *sub judice* in Strasbourg.

The legal issues and possible liabilities for mine action actors and donors are certainly not to be dismissed. However, their study is plagued by the complexity of multiple national legal systems and requires a detailed legal approach, which lies well beyond the scope of this study.

Risk to local populations from mines

Figure 5 shows the probability of individual death as a function of various human activities compared to present and past casualty probabilities from mines/UXO in Cambodia.

Figure 5: Probability of death of an individual for general risk and risk from mines/UXO in Cambodia.



Source: Morgan et al.(1992); Ale (1991); Handicap International & Cambodian Red Cross (2002).

A couple of interesting points can be gleaned from Figure 5. First, the number of mine victims in Cambodia seems to be decreasing. The cause of this decline is not evident from the figure, but may be due to mine action, or to avoidance of mined

areas by local populations or indeed a number of other factors. The second interesting point is that the probability of death from a mine in 2002 in Cambodia was similar to that of childbirth, or air or car travel.

The limitation of Figure 5 is that the calculations include regions of Cambodia in which the risk from mines is low. Therefore, the risk in mined and rural areas may be under-represented here. Additionally, risk from such events as air travel accidents may not apply to a Cambodian farmer living in a heavily-mined area, who may not have access to air travel. Figure 5 is also limited in that other effects of suspected mine and UXO presence are not shown. For example, suspected mine presence on roads may be restricting access for aid agencies attempted to rehabilitate the area, and local use of land may be restricted. However, depicting risk graphically, as in Figure 5, might help to put the mine risk in perspective. If a wider range of data were collected on the cause of death of individuals in various regions of Cambodia, this information could be used to inform donor agencies so that relief work and resources could be targeted to the areas where it is most needed.

Residual (post-clearance/post-treatment) risks

The aim of donors, national authorities and operators is to deliver land back to the end user that is completely clear from mines. This may lead to a perception that the residual risk level should then be zero. However achieving zero risk in any large scale endeavour like mine clearance is not always possible, given the constraints on available resources, the need for cost effectiveness and the limitations of technology. In Western Europe the residual risk in areas contaminated by mines and UXO and subsequently released for public use after the 1914–18 and 1939–45 wars persists today. The reality is that mine-affected countries will always remain mine affected to some degree and they must continue to take measures to deal with that threat.

In the health, safety and environmental fields, regulators identify three criteria:

1. **An equity-based criterion:** all individuals have an unconditional right to a certain level of protection (this means that “averaging” over a whole country may not be the right methodology when considering options).
2. **A utility-based criterion:** comparing the incremental benefits of the measures used to prevent the risk of injury and the cost of these measures (cost-benefit analysis).
3. **A technology-based criterion:** this is satisfied when state-of-the-art control measures are applied, whatever the circumstances.

Mine clearance organisations and authorities tend to take a technology-based approach and ignore equity-based and utility-driven solutions. Thus manual clearance is preferred, as it generates more confidence because human operators are used rather than dogs or machines. (This could be a perception bias. Indeed, the DDAS shows that about one in four of manual mine clearance accidents were due to missed mines.)

Future reviews and preparedness

Each function of mine action and each process within those functions should include risk assessment and its own risk management process. Risk management is a continuous process, subject to review and alteration as the situation changes, more information becomes available and lessons are learned.

Preparing future data gathering

On several occasions throughout this whole study, the need for better data has been highlighted. After pointing out that mine clearance is an industry with striking similarities to other industries, that its operators do not seem to be exposed to critically higher levels of hazard, and that legal attacks may be lurking in the future, it becomes evident that the industry needs to start collecting meaningful data.

This requires meaningful data for risks, i.e. data to help formulate proper policies, risk treatments and SOPs, as well as data to communicate with all the stakeholders, to negotiate residual risk levels and to prove compliance with codes and internal policies.

Perhaps the most important data missing today is the “hours lost per 200,000 hours worked” rate. This would be the key to effective comparisons of the mine clearance industry with any other industry worldwide. This would allow meaningful negotiations with the insurance industry, together with a precise record of the severity of accidents and their post-traumatic evolution over a given time.

Other critical data missing is “mine depth” (i.e. the depth at which the mine is located), that appears to have never been regularly recorded thus far, yet which may be vital for the defence of an organisation facing legal action, as well as being useful for equipment developers and accident investigators. IMAS default to a clearance depth of 13 centimetres and, although a number of countries have made some changes to this measure, it is the norm.

Finally, proper record-keeping and data recording should continue to be improved as vital instruments for future risk and crisis management of any organisation, donor or government.

A view on crisis management and expectation management

Communication and consultation, currently among the most neglected aspects by mine-clearance organisations, are important considerations at each step of the risk management process. It is important to develop a communication plan for both internal and external stakeholders at the earliest stage of the process. This plan should address issues relating to both the risks and how to manage them.

Effective internal and external communication is important to ensure that those responsible for implementing risk management, and those with a vested interest, understand the basis on which decisions are made and why particular actions are required. This is particularly critical considering the fact that risk management incorporating cost-benefit approaches may lead to a relaxation of reliability in favour of speed.

Perceptions of risk can vary due to the difference in values, needs, assumptions, concepts and concerns of stakeholders as they relate to the risk or the issues under discussion (for example, witnesses have stated that people in highly mine-contaminated areas of Cambodia were more concerned by ghosts and bad luck than mines).

A consultative/team approach is useful for defining the context appropriately, for ensuring risks are identified effectively, for bringing different areas of expertise together in analysing risks, for ensuring different views are appropriately considered in evaluating risks, and for appropriate change management during risk treatment. Involvement also allows the “ownership” of risk by managers and the engagement of stakeholders. It allows them to appreciate the benefits of particular controls and the need to endorse and support a treatment plan.

Stakeholders are likely to make judgments about risk based on their own perception of risk. Since the views of stakeholders can have a significant impact on the decisions made, it is important that their perceptions of risk be identified, recorded and integrated into the decision-making process.

Conclusions and recommendations

Conclusion 1.

Manual mine clearance may not be as dangerous a profession as it is often perceived to be.

Findings

Since the first “serious” manual mine clearance operations were undertaken towards the end of the 1939–45 war, significant improvements have been made in the safety of the mine clearance profession. From the early days, where mine clearance was an extremely high risk occupation, the industry today has developed into one where it appears, given the limited amount of data available to analyse, to be as safe, or safer, than many other comparable industries. If data were to be collected more rigorously, this could well be used to further improve safety for workers. Small policy changes can have significant impacts on the risk workers are exposed to. For example, if malaria is prevalent, a realistic risk reduction measure would be to provide nets for all workers.

Recommendation 1.

a. Data should be collected in a more standard, thorough and rigorous manner in order to undertake a more effective risk reduction analysis. This data should include working hours, and open and honest accident reporting from all organisations.

b. Detailed discussions should be held with insurers to explain the relative risks of mine clearance activities to attempt to reduce premiums.

c. Managers should consider the inclusion of a risk management policy as an integral part of their management tools and processes.

Conclusion 2.

Cost-benefit analysis as part of the risk management process may provide a useful tool for making the best use of limited resources.

Findings

This section of the study has sought to demonstrate that there may be merit in considering a “less than perfect” clearance option. The model proposed in the Annex is just that — a model — but the concept needs to be carefully considered by the community and a clearer model for “tolerable risk” needs to be defined. Data collection is key to allow informed decisions to be made about where and how to approach mine clearance tasks.

Recommendation 2.

- a. Data collection be standardised and improved to allow clearer oversight of cost-benefit issues related to mine clearance. This data should enable detailed analysis of the costs of the land cleared to be drawn (see further in Section 5).*
- b. A discussion be initiated in the mine action community about a more realistic approach, in terms of the moral acceptance of land that may not be completely “cleared” of mines and UXO.*
- c. Terms such as “cleared land”, “released land”, “mine-free” and “impact-free” need to be more clearly defined.*
- d. The depth at which mines are located should be recorded systematically. This has never been done methodically but would provide valuable information in order to development a professional risk management approach.*

Conclusion 3.

Most land cleared contains no explosive ordnance. The current “all-or-nothing” approach to manual mine clearance is inappropriate and unsustainable.

Findings

Mine clearance is still largely “input driven” rather than “output driven”, i.e. it is based on the money available, rather than an assessment of how much is needed to reduce risk in a given area to an “acceptable” level. However, it needs to be recognised that there are practical difficulties in establishing a contractual mechanism that allows an organisation to clear to lower standards without allowing less scrupulous organisations to take advantage of the situation.

The aim of manual mine clearance is the clearance of every mine and every item of unexploded or abandoned explosive ordnance from a given area. So, if a given area of land is declared to have been cleared, then it should, to the best available knowledge, be clear of all explosive ordnance. In this respect, IMAS 09.20 should remain fixed. Indeed, there are many situations in which such a level of clearance is necessary or is demanded.

But this full clearance standard is not necessarily universally applicable, nor is it by any means universally achieved. For this reason, the mine action community and its stakeholders need to urgently consider moving to a more explicit risk management approach. Moreover, spending months clearing an area and finding no mines — but a lot of pieces of miscellaneous and harmless metal — is a waste of resources, as well as

being unsatisfactory for those engaged in it. Yet, this is exactly what the mine clearance community still does far too often.

Area reduction may well form the key to this process, yet is typically misunderstood. Area reduction is defined within the IMAS but there is no agreement on how it is best conducted. There is an urgent need to identify appropriate methodologies for quickly and efficiently focusing the scarce manual mine clearance resources on those areas where they are truly needed. Technical survey is not well defined.

Recommendation 3.

- a. The mine clearance community should move explicitly towards a risk-management approach to addressing explosive ordnance contamination and impact. In doing so, a new standard for the treatment of land contaminated by explosive ordnance should be considered – “released land”. The type of approach to such “area risk reduction” will depend on the context, including the views of the different stakeholders.*
- b. Further research should be undertaken into appropriate methodologies for conducting area reduction and technical survey.*

Annex

A model cost-benefit analysis

Using a cost-benefit analysis to reduce risk

A cost-benefit analysis can help to show how clearance reliability, costs and performances of clearance programmes, and the cost of consequences to victims (even entire countries), for a given territory can be compared with a given growing population over a certain duration.

To illustrate this concept, an example of simplified cost-benefit analysis has been developed and is illustrated below.

Simplified cost-benefit analysis

A cost-benefit analysis was used to compare two different techniques; manual-ground processing (Technique A) and machine-ground processing (Technique B). The analysis compares the area of land that each technique can clear in a year (A) at a certain cost (C) and reliability (Rel) (i.e. percentage of mines cleared).

The following assumptions were made:

- there is no awareness programme changing the behaviour of potential victims;
- people do not learn from their mistakes;
- the population in the area increases at a rate of R per cent per annum;
- there is no migration of population within a province to avoid hazardous areas; and
- there is no degradation of the effectiveness of mines.

The basic data for the simplified model, considering a starting period in 2002 are:

- the area potentially affected by mines = 4,466 square kilometres;¹
- the number of civilian deaths and severe injuries per year = 850; and
- present population = 14 million.

Technique 1 (Manual-ground processing, General Case)

A typical manual ground-processing programme could clear $A_a = 20 \text{ km}^2$ each year at a cost of $C_a = \text{US\$}20$ million per year at a national clearance standard of $\text{Rel}_a = 99.6$ per cent.²

Technique 2 (Machine-ground processing, General Case)

Conservative assumptions estimate that mechanical-ground processing can clear three times the annual surface of manual-ground processing, at half the cost.³ This

1. Cambodia Strategy Document for the First Review Conference of the APMBC, November 2004.

2. Brown (1999).

3. *Ibid.*

estimate allows for a multiple-pass or multiple-machine operation supported by conventional quality control using dogs and/or manual teams to give a clearance standard of $Rel_b = 95$ per cent. This leads to a yearly cleared area of $A_b = 60$ square kilometres at a cost of $C_b = \text{US\$}10$ million.

For both techniques we can calculate:

- the theoretical number of yearly victims avoided in a cleared area for a clearing reliability of 100 per cent; and
- the number of victims avoided by an imperfect ($Rel < 100$ per cent) programme.

The simplified model calculates — for each year and for up to 40 years from the start of the programme, for both techniques and the “do nothing” option — the following:

- cost in US\$ billion (the cost of a victim is considered to be on average US\$1 million, a value lower than most large-scale risk assessments);
- the number of casualties (victims);
- the probability of casualties; and
- the cumulative cleared area.

Based on data gathered from CMAC, Halo Trust, MAG and the RCAF⁴ (Royal Cambodian Armed Forces), about 42 square kilometres were cleared in Cambodia in 2003 at a total cost of US\$20 million. While these data may be imprecise for a number of reasons, for the purposes of an example, the principles still apply. This data is incorporated in the cost-benefit model to compare Techniques 1 and 2 for specific provinces.

Working example:

Battambang province is in western Cambodia along the Thai border. This province had 186 mine victims in 2002. Its total area is about 12,800 square kilometres and the mined area was assumed, for the sake of this example, to be 1,500 square kilometres. This province has an estimated mined area corresponding to a third of the whole mined area of Cambodia. Let us assume, for the sake of this example, that 14 square kilometres are cleared yearly in this province. It is also assumed that the population growth is 3 per cent.

Table 1 provides different costs according to various possible population growth-rates and three considered mine clearance scenarios (doing nothing, and Techniques A and B).

Table 1 shows that the cost of doing nothing (taking into account US\$1 million per casualty⁵), could be lower than a slow manual-clearing technique (Technique A).

4. RCAF meeting in Phnom Penh, 23 February 2004.

5. Whitman (1984).

Technique B is the most economical and efficient, provided a certain level of residual risk is tolerated.

Table 1: Estimated cost in terms of US\$ and number of casualties for three different rates of population increase when there is no clearance (“do nothing”) and when Techniques 1 and 2 are used in Battambang province over the next 40 years

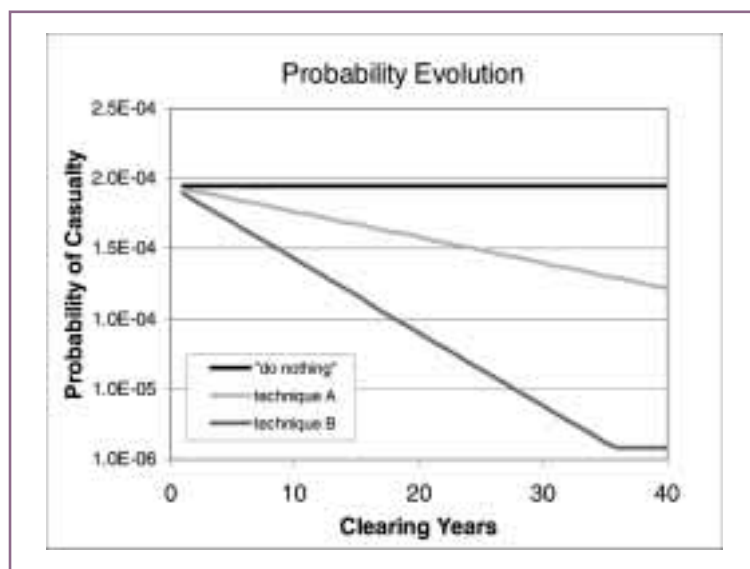
| | Population increase = 0.03 | | Population increase = 0.04 | | Population increase = 0.05 | |
|-------------|----------------------------|--------------|----------------------------|--------------|----------------------------|--------------|
| | Casualties | Cost (US\$B) | Casualties | Cost (US\$B) | Casualties | Cost (US\$B) |
| Do nothing | 14,025 | 14.02 | 17,675 | 17.67 | 22,469 | 22.47 |
| Technique A | 10,850 | 16.75 | 13,481 | 19.39 | 16,908 | 22.81 |
| Technique B | 5,114 | 8.07 | 5,925 | 8.88 | 6,917 | 9.87 |

N.B. The cost encompasses the cost of casualties at US\$1million/individual and the cost of the clearance programme.

Figure 6 shows that the probability of casualties in Battambang province would decline more rapidly, and reach a much lower level, if Technique B were used instead of either Technique A or doing nothing.

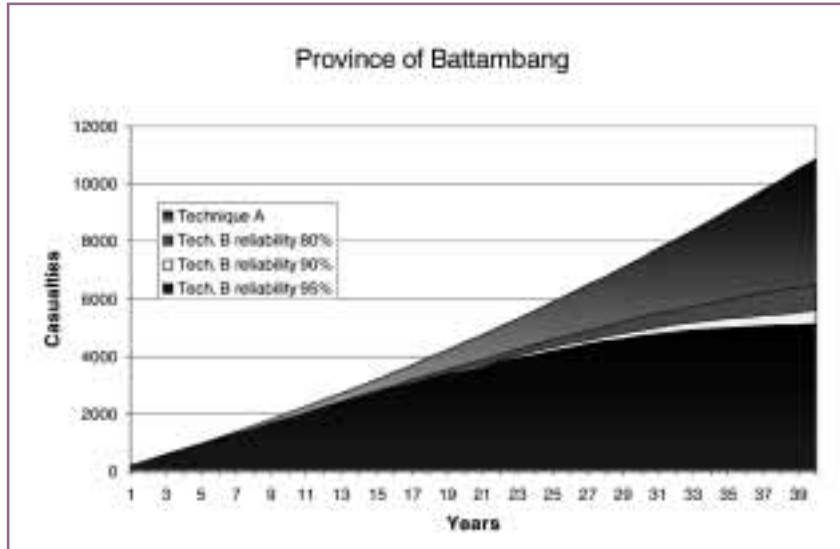
Figure 6: Diminishing probability of casualty using different techniques in Battambang province

(Assuming population growth rate 3 per cent and reliability of 95 per cent for Technique B)



Even if a lower reliability (down to 80 per cent) was assumed for Technique B, the use of this faster, cheaper mechanical technique is better than a manual technique in the mid to long term, in terms of cumulative numbers of casualties, as shown in Figure 7.

Figure 7. Cumulative casualties for Techniques A and B
 (Using the data described in the worked example
 and a population growth rate of 3 per cent)



This cost-benefit and risk analysis shows how an increase in the mine clearance rate, even when that increase is associated with a reduction in reliability, results in accelerated socio-economic benefits. In the short term (a few years instead of the 40 years displayed in the figures), the “slow” Technique A produces only a small reduction of casualties relative to the “do nothing” approach.

It is evident that in a country such as Cambodia, with strong demographic pressure, slow methods may lead to excessive casualties over time, whereas a faster method, perhaps with less stringent clearance criteria, may represent a more suitable solution.

The techniques used, and data assumed, are illustrative only. In other words, any mine clearance technique which clears at a rate faster than manual mine clearance, and which is able to remove more than 80 per cent of the mines, will show a clear advantage. The important point is the utility offered by the cost-benefit analysis in that, providing accurate data are available, it allows mine clearance agencies to unambiguously compare clearance options.

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Glossary of acronyms

| | |
|-------|--------------------------------------------|
| APMBC | Anti-Personnel Mine Ban Convention |
| AXO | abandoned explosive ordnance |
| CCW | Convention on Certain Conventional Weapons |
| CMAC | Cambodian Mine Action Centre |
| DDAS | Database of Demining Accidents |
| IMAS | International Mine Action Standards |
| KFOR | Kosovo Protection Force |
| LIS | Landmine Impact Survey |
| MAG | Mines Advisory Group |
| MCRA | mine clearance risk assessment |
| NGO | non-governmental organisation |
| NPA | Norwegian People's Aid |
| PPE | personal protective equipment |
| RCAF | Royal Cambodian Armed Forces |
| SHA | suspected hazardous area |
| SOP | standing operating procedure |



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A STUDY OF MANUAL MINE CLEARANCE

5. Manual Mine Clearance Costings and Sensitivity Analysis



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The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

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Contents

| | |
|-----------------------------------------|----|
| Summary | 1 |
| Introduction | 3 |
| General cost estimation | 3 |
| What costs should be included? | 4 |
| Combining direct and indirect costs | 6 |
| Basic analysis of costs | 8 |
| Worked example | 8 |
| The "model" mine action centre | 13 |
| Measurement of costs | 14 |
| Sensitivity analysis using the MMAC | 14 |
| The use of the model in the GICHD Study | 20 |
| Practical applications of theory | 24 |
| Concluding remarks | 27 |
| Conclusions and recommendations | 29 |
| Bibliography | 31 |
| Glossary of acronyms | 33 |

Photo credit:

Cover: British Army mine clearance of a road in 1945, "Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared"; photograph courtesy of the Imperial War Museum, London ©Crown Copyright, negative number H 29725.

Summary

Different programmes appear to use different methodologies to cost mine clearance operations and reported costs often provide a very incomplete account of the full costs. This section outlines the principles of cost accounting and gives a worked example of costing a small programme. It goes on to outline and use a model developed to depict the results of a sensitivity analysis of the costs against output (in terms of cost per square metre) of a notional manual mine clearance programme.

Introduction

General cost estimation

The development of standard cost models for manual mine clearance programmes is far from straightforward because of the lack of financial skills on the part of managers. While many organisations have come to believe that the simple division of total programme costs by the number of square metres of land cleared will provide a satisfactory solution, the reality is somewhat more clouded than that.

Programmes currently measure inputs and outputs using different indicators. As seen in Section 2 of this study (*The Management of Manual Mine Clearance Programmes*), rates of clearance are seldom standardised and there is often wide variation in the defined and the perceived rates of clearance for deminers in different conditions. In a meeting for the United Nations Office for Project Services (UNOPS) in Beirut in 2003, UN programme managers and UN Chief Technical Advisers of 12 national programmes were asked for figures on the productivity of their manual mine clearance teams in various conditions. The results, shown in Table 1, were surprising insofar as there was such a wide variation of estimates of productivity between programmes.

Table 1. Quoted rates from clearance programmes

| Type of clearance | Lowest rate quoted (square metres per deminer per day) | Highest rate quoted (square metres per deminer per day) | Proportional difference between lowest and highest quoted rates |
|----------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------------------|
| Manual mine clearance (with ground preparation) | 12.5 | 125 | 10x |
| Manual mine clearance (without ground preparation) | 8.3 | 75 | 9x |
| Battle area clearance | 38.0 | 1,029 | 26x |

Different programmes may define these tasks in different ways. There is often confusion between what programmes view as manual mine clearance: at times, survey, technical survey, area reduction, and myriad other locally developed terms to attempt to define areas of land have, in one way or another, been recategorised either as part of clearance or as part of broader “demining”.

In addition to the “output” figures that programmes quote, the “input” figures — i.e. the financial resources required to run the programme — are also seldom clearly defined and often confusing. Programmes receive donations in-kind, “free” explosives, and other supplies; they may also have bilaterally funded advisers whose costs do not show on the bottom line of any accounting sheet.

This situation is often compounded by donors who have different reporting requirements and little consistency in what they require *vis-à-vis* cost and effectiveness analyses.

What costs should be included?

When asked about their clearance costs, many organisations tout figures that would quickly drive them to bankruptcy because they are too low — the full cost is at least¹ the sum that allows an organisation to continue operating at the same level for an indefinite period. A complete accounting of full costs would include:

1. All expenditures for demining made by the implementing organisation, including:
 - costs of demining personnel and the supervisors, managers, advisers, and support staff who spend all or virtually all of their work time on demining activities;
 - insurance and financing costs (e.g. interest on loans used to pay for operations until funds are received from the donor, government, etc., that asked for the demining to be done);
 - costs of offices and other facilities used by deminers and other staff who spend all or virtually all of their work time on activities related to demining;
 - costs of materials and supplies which are consumed fairly quickly when used; and
 - costs of equipment which typically last more than a year or are over a certain value (often termed capital equipment).

These are termed direct costs, as they relate directly to the demining operations.

2. A reasonable share (discussed later) of expenses made by the implementing organisation to support a demining operation along with other activities, such as:
 - managers or advisers in charge of a broader mine action programme which includes demining and other mine action activities, along with their support staff, office rental and equipment, vehicle expenses, etc.
 - managers at the organisation’s main headquarters, along with their support staff, office rental and equipment, vehicle expenses, etc.;
 - the costs of preparing proposals (including those which are not successful) for future demining contracts or grants;
 - insurance and financing costs covering the organisation’s overall operations; and,

1. True costs might also be higher. For example, for a new demining programme, the current level of performance may have to be increased through training and better equipment to reach an acceptable or required level.

- the costs of audits and evaluations commissioned by the headquarters of the implementing organisation.²

These are termed indirect costs. They are necessary for the organisation (and therefore its demining activities) to operate and survive, but it is hard to be precise about their direct impacts on the demining activities, at least at any one point in time.

3. The actual costs paid by other organisations (if any) to provide necessary³ support to the demining operations, including:
 - the cost of donated supplies and equipment for demining;
 - the cost of technical advisers (including their benefits and the costs of training the advisers); and
 - the costs of audits and evaluations of the demining activities commissioned by these other organisations.

So, the full range of costs of a demining operation includes both direct and indirect⁴ costs (*see Box 1*) paid by the implementing organisation, and may include costs borne by other organisations. Ideally, it is this figure that should be used when comparing costs across demining operations, for two reasons. First, from the outside perspective, it is the only figure we can use with full confidence for cost comparisons across demining operations. Second, from the inside perspective, it represents the full “cost of doing business”. Organisations that do not have a reasonably clear understanding of the full cost of doing business tend to go out of business.

That being said, there are normally practical difficulties in obtaining a complete picture of the full costs. Often the implementing organisation will not know (and often has little incentive to ask about) the true costs of items purchased on its behalf. In a few cases, the donor providing the donated equipment, supplies or advisers will have difficulty coming up with a reasonable figure because its accounting system is not designed to isolate such figures. Today, with low cost information and communication technology so readily available, this is not a technical problem; rather, it reflects the fact that donors have little interest in such figures for their own purposes. Indeed, many donors seem to have little interest in knowing the relative cost-effectiveness of different ways of delivering assistance to recipient countries, because cost-effectiveness appears not to be an important factor in many of their decisions.⁵

So in practice, we often cannot come up with the “full costs of doing business” (FCDB) for demining operations. What is to be done? In the short term, we should compile as complete a picture as possible *and* clearly identify what data we are missing from the FCDB costs.

2. For profit-seeking firms, necessary costs include a reasonably healthy profit. Otherwise, owners would shift their investments of time and money to something else, and the demining would stop.

3. Of course, there may be cases in which, say, donors provide equipment or advisers which are not necessary, or should not cost as much as the donor pays for them. We shall ignore this complication for now.

4. For very simple demining organisations, which only do demining and only in one country, all costs could be treated as direct costs.

5. This is clear from the fact that donors often use their militaries to deliver humanitarian assistance and for things such as demining. Many studies have shown that militaries are many times more expensive than alternatives such as NGOs or commercial firms. But it does “show the flag” and providing opportunities to serve in interesting places helps motivate military personnel and affords them some useful training.

Box 1. Dividing the costs: where to draw the lines? And how long a line?

A reasonable argument can be made that the full accounting of the costs of demining should include the entire “supply chain” for demining, including all survey (general, technical, post-clearance), marking, clearance and quality assurance (QA) costs — in short, from the time a piece of land “becomes our problem” to the point at which it is “not our problem” (i.e. declared safe for civilian use), although there is still the question of residual liability, which is discussed below. In some part, this is because the allocation of responsibilities among different types of demining organisations is somewhat arbitrary at any point in time.

For example, we might well see in the same country:

- (i) some operators conducting their own survey and QA activities;
- (ii) the mine action centre (MAC) providing these services to (or imposing them on) some other operators;
- (iii) some donors hiring separate contractors for QA tasks they are paying for; and
- (iv) civil engineering contractors requiring demining firms to engage specialist QA firms to oversee demining operations around, say, a road being reconstructed.

Over time, the typical division of responsibilities along this demining supply chain could change more fundamentally. Such changes have often happened in other industries when buyers push the costs of maintaining high quality onto suppliers, say, by buying only from suppliers that are compliant with the relevant ISO standards. Similar changes are quite possible in the demining industry, in which case operators who are ill-prepared to obtain ISO accreditation might well go bankrupt before they put the necessary quality management systems in place. In other industries, purchasers have pushed residual liabilities for quality onto suppliers, which then need to establish enhanced warranty schemes and, perhaps, obtain residual liability insurance.

In the case of demining, if insurance firms agreed to provide such residual liability insurance policies, they would start taking a very close look at the QA systems of demining operators. Operators without sound QA processes would only obtain such insurance at very high cost, if at all, and would likely go bankrupt as a result. Using this supply chain logic, the full cost of a demining operation should also include a share of the costs of “services” provided by the national authority and the MAC to the demining operators. These would include the costs of accreditation and quality assurance, entering data received from the operators, etc. When comparing two demining operations within the same country, these might safely be ignored *if* the MAC was providing similar services to each, but including such costs would allow better comparisons across countries.

Combining direct and indirect costs

Clearly, all direct demining costs should be included when calculating total demining costs. But how to deal with indirect costs — typically, costs incurred at a higher level in the implementing organisation’s management chain (e.g. national and international headquarters) for services in support of, say, demining operations in a number of countries and of non-demining programmes (mine risk education (MRE), refugee assistance, consulting services, etc.).

Generally, indirect costs are treated as *overheads* and *apportioned* among the various programmes that are supported in some way by these costs according to some reasonable and well-defined basis. For a simple example, take an organisation with a country mine action programme comprising mine clearance and MRE operations, with US\$900,000 in direct expenditures per year on clearance plus US\$100,000 on MRE, and with US\$100,000 in costs borne by the national programme management office. Reasonably, the overhead expenses (i.e. the national office) might be allocated to clearance and MRE operations in the same ratio as their direct costs, or 9-to-1.

There are two main complications that arise in practice. First, there may be multiple layers of overheads. For example, there might be a national office with some staff working only on mine action activities (say, manual clearance, mine detection dogs (MDD), and MRE) but others working on mine action plus additional programmes (say, construction of housing for returning refugees). There would also be overhead costs incurred at the international headquarters, but there might also be regional offices covering a number of countries plus special programmes supporting the organisation's MDDs on a global basis. This raises some complications,⁶ but these need not concern us here.

Box 2. Perfection is not required

Cost accountants generally seek reasonable rather than perfect solutions when, for example, devising ways to calculate overheads or determining what should be considered a direct rather than an indirect cost. Many items that organisations lump into indirect costs could, in principle, be treated as direct costs. For example, a firm could require headquarters staff to record how many minutes they work on something directly associated with a distinct programme. So a secretary typing a letter to a donor concerning landmine clearance in Mozambique would charge that time directly against the Mozambique clearance programme. Similarly, staff could be asked to record each piece of paper against a specific programme. But collecting and processing all these records costs time and money, and it would be difficult to ensure such records were even accurate.

Thus, two tests of reasonableness are: (i) do the benefits exceed the costs of keeping the records? and (ii) can we rely on the accuracy of the records?

A third common test of reasonableness is materiality — does it make any real difference? For example, when international telephone calls were still expensive, many organisations required employees to type in a valid project code before any international call would be put through. Once such a system was put in place, these project codes would be stored automatically, so there was little cost in forcing staff to use the codes. However, international telephone costs have fallen dramatically in much of the world, and some organisations are shifting to internet phone systems in which individual calls are essentially free. Eventually as costs fall, the difference between a perfect allocation of long-distance telephone charges among programmes compared to the simpler system of treating these charges as an overhead will become immaterial — why bother making staff go through the effort of punching in the extra code?

Another complication that commonly arises in mine action is that the implementing organisation may not know the total direct costs for some of its programmes because

6. Often, it also leads to heated debates among an organisation's programme managers, who typically dislike having to get their clients or donors to pay for costs incurred at higher levels and over which they have little control, and for corporate "services" that they feel provide little benefit to their programmes.

expensive equipment and advisers have been donated. Leaving out equipment costs will often mean a clearance programme's direct costs are significantly understated while, at the same time, the MRE programme receives no donated equipment. In such a case, total direct personnel costs might be a better basis for allocating overheads than total direct costs; but what if the MRE programme benefits by in-kind technical advisers provided and paid for by a donor?

Because of such complications, the proper allocation of overheads may not be a straightforward exercise. However, perfection is not required (*see Box 2*).

Basic analysis of costs

The most fundamental reason why, in most industries, we see that organisations have reasonable systems to properly account for and allocate costs (i.e. cost accounting systems) is because, at any one time in a well-established industry, most of the organisations we can observe have survived for some years. These survivors have reasonably sound cost-accounting systems, while organisations which lacked them have largely disappeared. The same is likely to hold true in mine action as the industry matures.

The reason why cost accounting is important to the survival of organisations is that it facilitates analysis, so managers understand how their costs are made up, how they are likely to change as the operations change, and what efforts on their part are most likely to result in cost savings.

Worked example

Consider the following example of a clearance operation with US\$400,000 in capital (or non-expendable) equipment (vehicles, mine detectors, vegetation cutters, etc.) to support its manual deminers. Neglecting the purchase cost of capital equipment for now, the deminers can, on average, clear one hectare for US\$16,000,⁷ assuming Standing Operating Procedures (SOPs) are followed and no overtime is worked. What are the total direct costs (i.e. before indirect costs are added as overheads) per hectare?

It should be clear that it depends on how many hectares are cleared. This is because the purchase cost of the capital equipment is the same regardless of how many hectares are cleared — this is a *fixed cost* — at least until the point where the rate of clearance will require the purchase of more equipment. The other costs (US\$16,000 per hectare) vary with the amount of work done and are termed *variable costs*.

The importance of distinguishing between fixed and variable costs can easily be illustrated in a couple of simple graphs (*Figures 1 and 2*). But first, we need to discuss fixed costs. In this simple case, all the fixed costs are for equipment.⁸ But properly maintained equipment lasts for more than one year. If we are trying to calculate our costs for a period of one year (or less), it would be incorrect to include the total purchase price for equipment that lasts for many years; instead, if on average the equipment

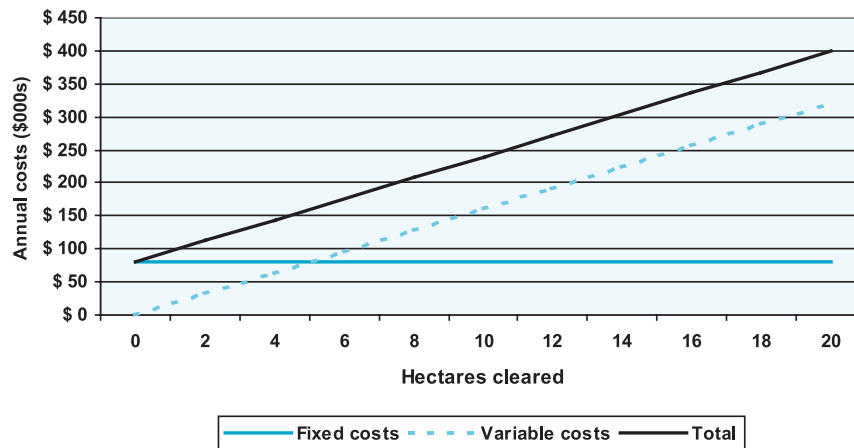
7. This would cover salaries and benefits, fuel and supplies, equipment maintenance, insurance, etc.

8. Other fixed costs for demining organisations might be (i) an annual licence fee allowing the organisation to operate after it is accredited, or (ii) an annual registration fee charged to foreign NGOs or commercial companies operating in a country. Neither of these would vary according to how many hectares were cleared in a year.

will last for five years, we should only include one-fifth of the purchase price as costs in a single year.⁹

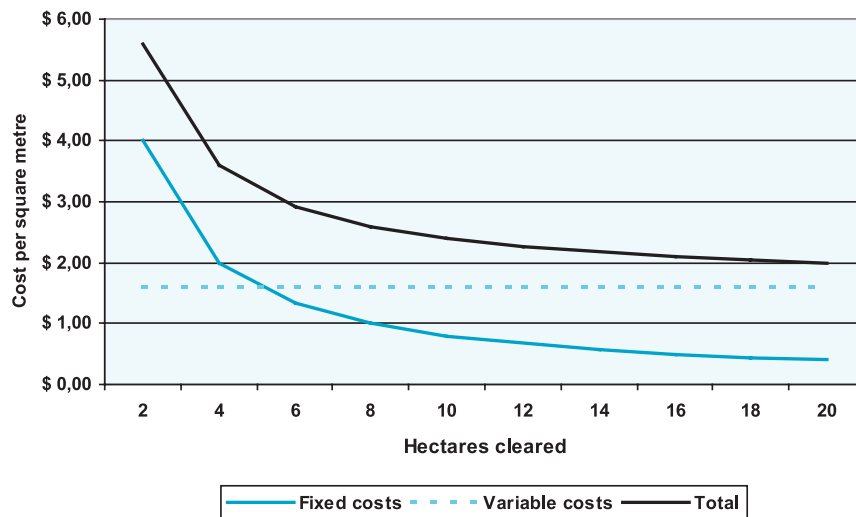
So in this case our fixed costs are \$80,000 per year. With this information, we can depict how our costs behave as we increase the amounts we clear in a year (*Figure 1*).

Figure 1: Fixed, variable and total costs



Dividing the costs as depicted above by the hectares cleared in the year gives us unit costs¹⁰ as depicted in Figure 2.

Figure 2: Unit costs



9. This is the simplest way of apportioning the costs of equipment and other “capital assets” (e.g. buildings that we own) over their useful working life. There are other approaches to calculating the costs of “depreciation” in the value of a capital asset, but we will not address these.

10. In this case, costs per hectare. To get costs per square metre, divide by 10,000.

Thus, the unit clearance costs decline in a curve as the annual productivity increases. This decline reflects the fact that the average fixed cost per hectare decreases as more hectares are cleared. This is often termed “economies of scale” and is the source of a large portion of productivity benefits.¹¹

At some point, however, increasing the area cleared would result in an increase in unit costs. For example, the vegetation-cutting machines might only be able to manage 20 hectares in a year; clearing more would require time-consuming vegetation cutting by hand. Even if the organisation could train more deminers, it would eventually run out of experienced supervisors who could maintain productivity levels.

Such problems would cause variable costs to rise faster than before, as depicted in the Figures 3 and 4 (as production exceeds 20 hectares).

Figure 3. Approaching and exceeding normal capacity

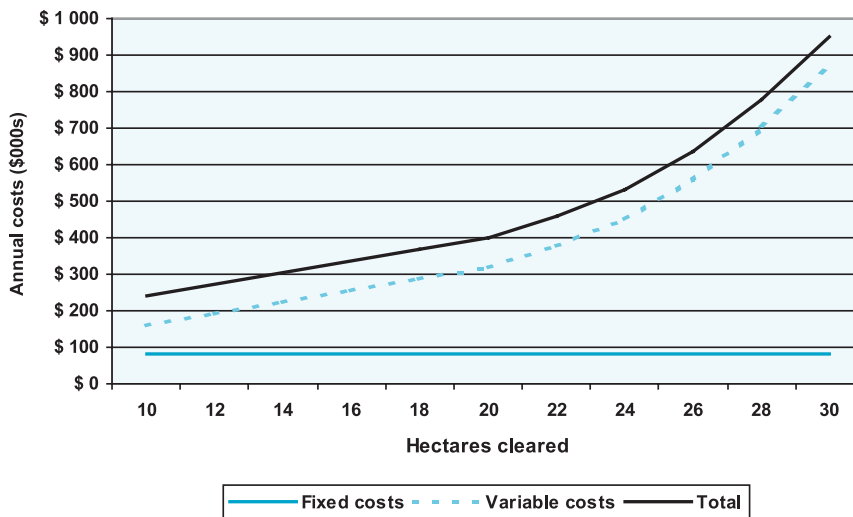
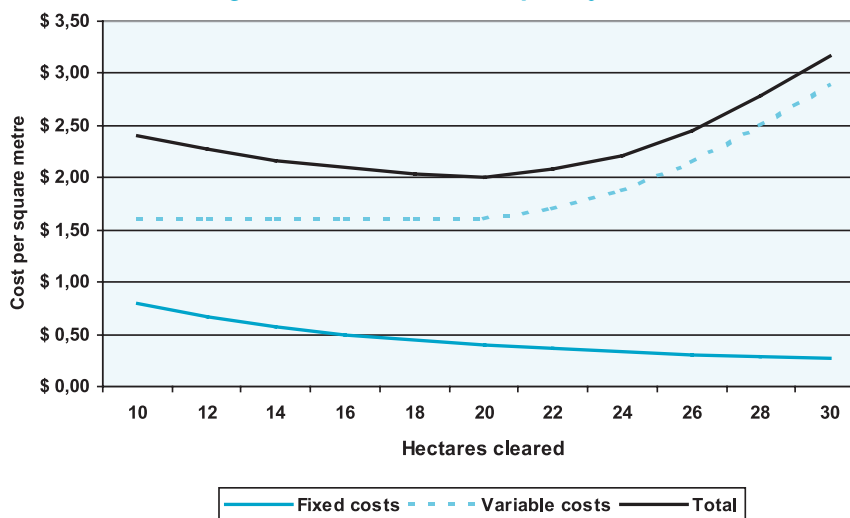


Figure 4. Unit costs as capacity exceeded

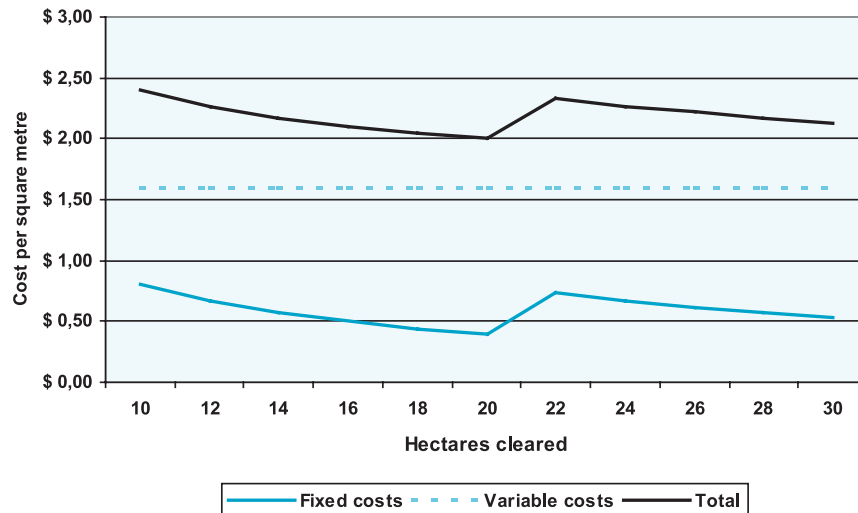


11. Unsurprisingly, the other big source of productivity increases stem from efforts to reduce variable costs per unit, usually by getting more productivity out of each deminer in the standard work day. This may entail simple measures like ensuring work starts on time, reducing the amount of sick leave that staff take, and regular maintenance of equipment. More ambitious measures would include better integration of existing assets (e.g. having manual clearance start shortly after vegetation is cut by machines).

In this simple example, the cost-minimising point of production is 20 hectares a year (when total costs fall to US\$2 a square metre).

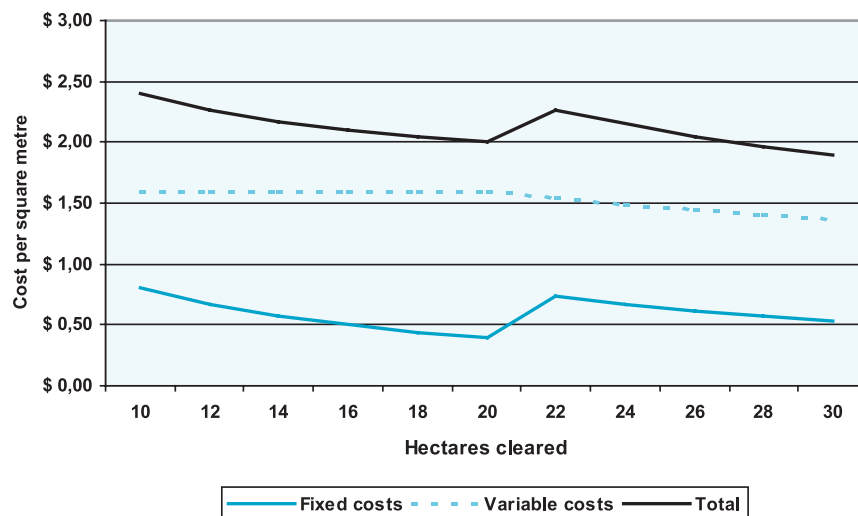
An alternative solution to increasing production beyond 20 hectares per year is to invest in greater capacities, say by purchasing more vegetation cutters, vehicles, mine detectors, etc., and by paying for courses to train more deminers, team leaders and site supervisors. Figure 5 depicts the effect of investing a further US\$400,000 in this manner.

Figure 5. An additional US\$400,000 invested at the 20 hectare point



Note that this type of investment is in more of the same capacity — the manual clearance operations remain at the same level of productivity (i.e. the variable cost-line remains level in the unit costs diagram). A third approach would be to make “productivity-enhancing investments”, such as better equipment,¹² or training the existing deminers, team leaders, and site supervisors to higher levels so they work more productively. In our diagrams, this would have the effect of reducing variable costs once the new investments are made.¹³

Figure 6. Unit costs with productivity enhancing investment



12. For example, by retrofitting magnets behind the machines to pick-up metal fragments and reduce the number of metal fragment readings with the mine detectors.

13. For these diagrams, we assume the same US\$400,000 is invested and the costs are spread over five years.

Here we assume the need for greater production is known at the beginning of the year but that it takes time to make the productivity enhancing investments and for these to take effect, shown by the decline in the variable cost line after the investments are made.¹⁴

Which of these different strategies should a mine clearance manager adopt? It depends to some degree on whether the demand for additional clearance is likely to be sustained over time. If not, it would not make sense to make significant investments in more of the same capacities. However, even if the increased demand for clearance will be temporary, it may still be warranted to make productivity enhancing investments so that unit costs are reduced in future years.¹⁵

Box 3. Staff costs — fixed or variable?

The duration of time covered by the analysis also raises some broader questions. For example, should labour costs be treated as a variable or a fixed cost? If there will be no clearance for the foreseeable future, or if the long-term demand for clearance is expected to drop from the current level, operators would have to lay-off staff or face bankruptcy. In this sense, staff costs are variable.

On the other hand, most demining operators would rather keep their trained and experienced personnel on staff during short periods of inactivity, for fear of losing them to a competitor. Therefore, their salary costs would not decline even though no further clearance was being done, and over the short-term salary costs would be fixed. In Bosnia and Herzegovina, however, where uncoordinated training programmes by a number of donors resulted in a huge surplus in the numbers of trained deminers, firms can readily hire experienced deminers on short notice for individual contracts. For them, personnel costs are variable even in the short-run.*

* Also, in Bosnia and some other countries, many demining firms operate other lines of business such as security services. When there is no clearance work, they assign their demining personnel to work in these other activities. For such firms, personnel costs are variable even in the short-run, but they retain the capacity to start clearance operations at short notice. These competitive advantages are termed “economies of scope”.

The most basic output is that of safe land and reduced casualties. Safe land can be perceived as many things however — it can be land that has been physically cleared, it can be land that has been re-categorised after map survey, technical survey or other processes, but has been released to civilian use. It was clear, however, through the course of this study, that there is no consistency in reporting output with programmes reporting area cleared in the same category as area freed by technical survey or other processes. In addition, it was apparent that there was systematic over-reporting in most programmes.

Effective managers generally undertake this type of cost analysis regularly and develop systems that allow such processes to be undertaken without excessive additional workload, yet this does not yet seem to be commonplace in the mine action industry.

14. For illustration purposes, the diagram depicts a sudden productivity increase of 80 per cent. The sudden change in productivity is unrealistic, but a total increase of 80 per cent over time might be feasible with a package of productivity enhancing investments (particularly better equipment and better trained supervisors).

15. This also takes us into questions about whether the demining organisation has a strong incentive to reduce costs, which depends to a great degree on the nature of their contract or grant agreement. Such issues are beyond the scope of this report.

The “model” mine action centre

In order to look at costs in more detail, this study developed a model to allow detailed analysis of cost allocation and the impact of this on output costs. This process could be done for any mine action programme, but as all programmes are different it is equally valid to use the generic model mine action centre (MMAC) referred to below. The use of a simple survey of mine action implementing organisations and a process of sensitivity analysis (as also described elsewhere in this section) provided confirmation that the costs in the MMAC model are reasonable to the levels of accuracy necessary for a general model.

The MMAC model is useful in that it allows measurement of the factors that control costs, and facilitates the conduct of sensitivity analysis that enables managers to concentrate on those factors that “make a difference” to the costs of mine clearance.

The generic MMAC model tests the common hypothesis that manual mine clearance costs “US\$1 per square metre”. The model, including as it does all of the contributing factors (including a means of attributing overheads), suggests that a typical organisation conducting manual mine clearance compatible with the International Mine Action Standards (IMAS) is unlikely to achieve such a price even in countries that have comparatively low salary scales for deminers.

Among other assumptions (all set out in the model) the MMAC assumes that a typical demining platoon can clear an average of 1.5 hectares per month, a figure that is well within the *stated* clearance rates of several organisations. However, as revealed in Section 3 (*Operational Systems in Manual Mine Clearance*), which was conducted independently of the work in this section, it is entirely possible that organisations often achieve clearance rates far lower than the MMAC generic assumption of 1.5 hectares. These two statements are not contradictory; indeed the findings of Section 3 reinforce the conclusion that “US\$1 per square metre” is a target that is unlikely to be reached by a typically organised, IMAS-compliant mine action programme using only manual clearance. Furthermore, the structure of the MMAC model easily facilitates the analysis of a real programme with its own costs and productivity rates.

Measurement of costs

During the course of the study, various different costings for clearance were quoted by organisations giving figures from between US\$0.60 to US\$8.73 a square metre.¹ While the study was not able to verify these figures, the figures produced from the MMAC give costs of purely manual mine clearance techniques at between US\$1.42 and US\$1.72 a square metre.

Surveys have shown the factor costs included in the MMAC to be broadly accurate (i.e. within the range reported by real programmes), although sensitivity analysis shows that the final price will vary with a number of factors, including the price of explosives and the salaries of the deminers. However, the MMAC reveals that the most significant factor is the productivity of the individual deminer, which, as other Sections of this study illustrate, can vary greatly with geographical and, significantly, organisational factors. In short, a slight improvement in the productivity of manual deminers can make a significant difference to the price of cleared land even before new technologies are introduced. By extension, it would be possible to use the same analytical techniques to predict the effect on price of such new technologies; this is, however, outside the scope of this study.

Sensitivity analysis using the MMAC

To try to determine which elements of the demining process really make a difference to overall costs, the most appropriate economic technique to use was deemed to be sensitivity analysis. Sensitivity analysis can be defined as: *“The study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation.”*² This general definition can be amended to the specific context of demining: *“The measurement of the variation in output of demining processes as a result of variation(s) in the cost of inputs, particularly in terms of cost.”*

The technique of sensitivity analysis focuses on those variations that “make a difference” to demining programmes. It may also have wider applications for demining programme managers as a decision analysis tool.

How does sensitivity analysis work?

Sensitivity analysis simply analyses the impact that changes on inputs to a situation have on the outputs. From undertaking such an analysis, it is possible to see which changes in inputs or processes are likely to lead to the biggest changes in outputs, thereby providing an extremely useful analytical tool for the manager.

Incorporating sensitivity analysis into a model of a demining programme

It goes without saying that every demining programme is different, and the application of sensitivity analysis will therefore produce different results when applied to each

1. Figures from the Mine Action Programme for Afghanistan (1997) and Operation Emirates Solidarity in Lebanon (2003).

2. A full definition of sensitivity analysis can be found at the EU Institution for Informatics and Safety (ISIS) website sensitivity-analysis.jrc.cec.eu.int.

case. However, this paper will use the MMAC developed as a baseline in order to demonstrate how sensitivity analysis can be applied. The MMAC structure is set out in Box 4 below.

Box 4. The MMAC model organisation.

MMAC — a fictional body — consists of 850 personnel, with:

- 52 employed in HQ offices
- 72 employed in four regional offices
- 34 employed at a training centre
- 20 trainees
- 12 employed in four QA teams
- 600 employed in demining teams, divided into 25 teams
- 30 employed in 10 EOD teams
- 30 employed in MRE

MMAC has an annual budget of approximately US\$7 million, divided as follows:

| | |
|-----------------------------------------|-------------------------|
| Demining cost (not including overheads) | = US\$ 4,580,000 |
| EOD cost | = US\$ 350,000 |
| MRE cost | = US\$ 530,000 |
| <u>Overheads</u> | <u>= US\$ 1,540,000</u> |
| Total | = US\$ 7,000,000 |

Productivity = 1.5 hectares per platoon month; undiscounted price for demining = US\$1.42 a square metre.

The MMAC is built on a Microsoft Excel workbook and is available on request from the GICHD; more detail is in Annex 1.

Definition of output

Before this analysis is taken any further it is important to determine the definition and measurement of output. In this case the analysis takes the narrow, technical definition³ of output as square metres of cleared land and this analysis will measure the effect of changes in inputs in terms of the changes in price per square metre.

Sensitivity analysis methodology in the MMAC

The design of the MMAC facilitates the use of sensitivity analysis so the methodology is very simple. The steps are set out below.

Step 1. Identify the areas to be analysed.

In this example, this has been done in column (b) in Table 2.

Step 2. Identify where the target areas appear in the spreadsheet.

Step 3. Select sensitivity technique.

There are two main techniques that may be used in sensitivity analysis. First, one can choose to examine the sensitivity threshold, i.e. the point at which changes in input begin to cause a noticeable⁴ change in output. Second, one can choose a particular percentage change in the input and measure how much effect that particular change

3. www.hcr.hr/index.php?link=simpozij&lang=en.

4. In the example here, “noticeable” or “significant” is defined as a change of at least one cent in the result.

Table 2: Items for inclusion in Sensitivity Analysis

| Number (a) | Item (b) | Reason for inclusion (c) | Sensitivity Threshold (d) | Effect on price (e) | Remarks (f) |
|------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1 | Vehicles | Vehicles are an expensive item and take up a large proportion of the initial equipment buy | — | US\$0.02 reduction resulting from a 75% reduction in cost, i.e from US\$1.42 to US\$1.40. | Models result of purchasing second hand vehicles instead of new vehicles. |
| 2 | PPE | Some demining organisations are reported to have resisted the purchase of PPE because of the expense | — | No reduction in price from 100% reduction in cost | Models result of not providing PPE |
| 3 | Marking tape | Marking tape is of low unit cost but large amounts are used in demining | >180% | — | Output price only increases when a unit of tape increases from US\$4 to US\$7.56 |
| 4 | Batteries | As for number 3 | — | A 50% reduction in battery requirement reduces the output price by US\$0.02 to US\$1.40 | Also of interest in consideration of battery charging alternatives |
| 5 | Explosives | As for number 3, although explosives has additional problems of importing and storing hazardous goods | — | A 100% reduction in explosive costs reduces output price from US\$1.42 to US\$1.22 | Models the implications of donors supplying explosives free of charge |
| 6 | Medics in demining platoons | As for number 2, especially in the early days of humanitarian mine action | — | Removal of medics from the organisation chart reduces price from US\$1.42 to US\$1.40 | — |
| 7 | QA teams | The additional expense is reported as being a problem | — | Inclusion of QA teams in the MIMAC organisation chart results in a \$0.02 increase in output price. | — |
| 8 | Local staff salaries | A large proportion of annual budgets | 2% change | Reducing deminer salary by US\$5 per month reduces output cost by US\$0.01 | Only deminer salary measured here |
| 9 | Deminer productivity | A major element of the GICHD study | Less than 0.5% | 5% increase results in 5% decrease in price | — |
| 10 | Discount rate | Cost-Benefit Analysis (CBA) calculations suggest that demining programmes are very sensitive to changes in the discount rate. | Insensitive up to discount rate of 4.1% | Doubling the discount rate from 3.5% to 7% leads to an increase in the discounted price from US\$1.72 to US\$1.76 | — |
| 11 | Overheads | Previous work suggests that appropriate overhead attribution has implications for demining prices | Sensitive at 2.4% | 10% reduction leads to reduction in price from US\$1.42 to US\$1.39 | — |

would have on the output. One can select simple across-the-board changes, such as +/- 5 per cent, but the technique can be more subtly applied if one has an idea of the likely changes that might occur.

Step 3a. Establish sensitivity threshold by “halving and bracketing”.

This is a simple method to establish sensitivity threshold. Firstly, one selects a percentage change in a particular cost and enters it into the spreadsheet; the effect is then observed. If there has been no significant change, the process is repeated until an effect is noted. Once there has been a change, the (last) change is halved, and halved again if necessary, until the point where it just begins to have an effect is noted. This is the sensitivity threshold: the programme is insensitive to all changes in input price until that point.

OR

Step 3b. Examine effect of likely change.

The second technique involves the insertion of a likely change in input parameter.⁵ For example, if the cost of a particular input might rise by 10 per cent (due to a change in import taxes, for example) then the effect of this likely change can be measured by simply inserting that change into the spreadsheet and observing the effect.

Analysing the results

The results of a sensitivity analysis test are set out in columns at Table 2. The items tested are in column (b), with the threshold sensitivity at column (d) and the effect of change at column (e). The first observation that can be made is that some of the results are counter-intuitive.

Vehicles

Many programmes use new four-wheel-drive vehicles, even though there is a large market for used vehicles. However, the sensitivity analysis calculations show that a 75 per cent reduction in vehicle purchase price (i.e. a reduction from a new price of US\$20,000 to a used price of US\$5,000) only leads to a US\$0.02 reduction in the undiscounted price,⁶ even though there is a huge reduction in initial costs. This suggests:

- output costs appear to be comparatively insensitive to “one-off” costs when compared to repeat costs, especially if the programme is allowed to calculate costs over the effective life of the equipment (five years in the MMAC model); and
- programmes may benefit from purchasing new vehicles with the benefits of warranty cover and reduced maintenance costs.

However, this does not recognise the implications of cash-flow issues: programmes simply may not be able to afford the cost of new vehicles when starting up.

Personal Protective Equipment (PPE)

The sensitivity analysis of PPE was calculated by simply reducing the cost of the equipment to zero, i.e. modelling the effect of not having any PPE. Interestingly, the MMAC is insensitive to reductions in prices of PPE, which suggests that there is, in

5. It does not have to be an input cost that changes: the effect of a change in productivity rate or usage rate could also be measured.

6. When one recalculates this measurement with discounted prices, the discounted price of US\$1.72 can be reduced to US\$1.71, which is a similar absolute reduction (though a slightly smaller percentage reduction).

effect, no significant cost involved in providing PPE. This undermines the cost argument sometimes invoked as a reason for non-compliance with IMAS PPE requirements.⁷

Marking tape

Marking tape is included here as an example of a low-priced, but constant use item. In the MMAC it appears that demining is insensitive to all but very high increases in price (or usage) of marking tape, even though this is an item that is being consumed constantly. This might suggest that, in most cases, it is the “big ticket” items that have more effect (though see notes on batteries below).

Batteries

Batteries are similar to marking tape in that they are high-use, consumable items. They have also generated considerable interest over the years in the potential for replacing standard alkaline batteries with rechargeable ones.⁸ A 50 per cent reduction in usage rate reduces the undiscounted output price by US\$0.02. While this appears low it is still broadly similar to the effect of replacing new vehicles by second-hand ones.

This suggests that there is a case for encouraging the adoption of either cost-effective battery charging systems or reducing the battery consumption of mine detectors. It may even be appropriate to research the effect of deminers turning off detectors when they are not being used in the demining cycle, though there may be diminishing returns from establishment of more rigorous supervision regimes.

Explosives

Explosives are also consumables but are interesting because some programmes have them supplied free by donors. Sensitivity analysis of explosives shows that the provision of free explosives has a very significant effect on price, reducing the undiscounted price from US\$1.42 to US\$1.22.⁹ This suggests that significant benefits accrue from researching alternative explosive supply methods or other, non-explosive destruction techniques. The effect might be even greater when using non-explosive techniques as it would also then be possible to reduce storage cost overheads.

Provision of medics in deminer platoons

Medics (if employed solely as such) can be regarded as “overheads” in demining, and, like the provision of PPE, are a fixed cost of meeting safety regulations. In this sensitivity analysis the provision of medics is measured by removing the medic from the platoon organisation chart. The result was a noticeable (though not extreme) reduction in price, from US\$1.42 to US\$1.40. This reduction is mainly due to the fact that the medic salary is a repeat cost.

The implications are that savings can be made by an unscrupulous agency by cutting corners in terms of IMAS, especially as demining accidents are comparatively rare,¹⁰

7. This result is robust even when the cost of a visor is increased from US\$50 to US\$250, to model the cost of annual replacement of visors.

8. For an example, see the technology competition organised by Mines Action Canada and Engineers without Borders at www.minesactioncanada.com/competition/home/index.cfm?lang=e.

9. Even the discounted price, which has been set out separately as the “true” price of demining, reduces from US\$1.72 to US\$1.52, taking account of the impact of repeat purchases.

10. See the Database of Demining Accidents (DDAS) maintained by GICHD on behalf of UNMAS.

and, by extension, there is perhaps a role for external quality assurance bodies to monitor the actual provision of medical resources. There is a broader issue, however, as this demonstrates some possible benefits of multi-skilling the workforce.

Provision of internal QA/QC teams

It is reported that the IMAS governing QA/QC activities are poorly respected;¹¹ this is often attributed to the cost of establishing a QA/QC regime. Interestingly, sensitivity analysis suggests that the provision of four, fully-equipped QA/QC teams (each team equivalent to a three-person mobile EOD team) would only add US\$0.02 to the output price for the MMAC model.

This implies that, for an IMAS-compliant organisation, the provision of QA/QC capability is a comparatively small cost. However, for non-compliant organisations with questionable product quality the potential cost would be much higher — if the teams were to reject 10 per cent of cleared land, this would have the same effect as a 10 per cent reduction in productivity, which is measured below.

Local staff/deminer salary

The model appears very sensitive to changes in deminer salaries. The sensitivity threshold is around 2 per cent, and a US\$5 reduction in deminer monthly salaries from an assumed starting point of US\$150/month alone reduces the output price by US\$0.01. This suggests that, all other things being equal, prices in countries with higher average salaries should have a higher output price. It also may have implications for the sustainability of demining programmes at their current structures without international funding. A more significant result is seen when deminer salaries are reduced to US\$75 per month (similar to locality demining projects being piloted by MAG in Cambodia): with no other changes the cost per square metre is reduced to US\$1.25 from US\$1.42.

Deminer productivity

The model is also *extremely* sensitive to changes in productivity: this is because the MMAC is designed to isolate costs accruing to particular activities, and can isolate the effect on the cost of demining of a change in productivity. If productivity increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month) there is a 5 per cent decrease in price. Of course, this is only specific for the benchmark specifications for the MMAC, although the model can be easily adapted to fit specific programmes.

Discount rate

Other calculations¹² have investigated the effect of economic discount rates on demining, particularly by the use of cost-benefit analysis. The MMAC is set up to show the effect on demining prices if discounting is applied over the effective life of equipment (benchmarked at an average of five years).

As stated above, the benchmark MMAC, using a discount rate of 3.5 per cent reveals that demining programmes should increase the price of demining from US\$1.42 to US\$1.72 per square metre to allow for the effect of discounting and ramping up (when

11 Interview with Phil Bean, GICHD, March 2004.

12. See Keeley (2003b) at www.eudem.vub.ac.be/eudem2-scot/.

starting a new programme). The model is insensitive to any change in the discount rate from 3.5 per cent up to 4.1 per cent.¹³ However, doubling this discount rate (from 3.5 to 7 per cent) results in an increase in the discounted price to US\$1.76 a square metre, while a commercial discount rate of 10 per cent would increase the price to US\$1.79 a square metre.

Overheads

The model includes an attribution of overheads resulting from the provision of administration, logistics and training components in the organisation. The model uses the principles of activity-based costing to attribute overhead costs between the three activities of demining, EOD and MRE.¹⁴ The MMAC shows that a 10 per cent reduction in programme overheads would reduce the price from US\$1.42 to US\$1.39 per square metre.

The use of the model in the GICHD study

Sensitivity analysis provides a means to decide (or at least to confirm) the value of different lines of research undertaken by the GICHD study. Some general ideas for prioritisation of research effort are suggested by the sensitivity analysis carried out above. These are divided into technical, managerial and financial issues below.

Significant technical issues

- Investigate means by which productivity may safely be increased;
- consider potential for research into battery chargers or other means to reduce battery consumption;
- investigate means by which explosive consumption may be reduced, including:
 - relative cost of disarming and neutralisation;
 - destruction by burning (e.g. by pyrotechnic torch);
 - low order or other sophisticated explosive techniques; and
- examine stated reasons for non-compliance with IMAS PPE, safety and quality requirements.¹⁵

Significant managerial issues

- Investigate salary scales and comparison with local conditions;
- investigate potential for reducing overheads; and
- investigate improvements to productivity through better management (identified in Conclusion 1, Section 2).

13. This result may be surprising when compared to the results of a full cost-benefit analysis (CBA) of an entire program, which can appear to be very sensitive to changes in discount rate. However, the difference can be explained as follows: the sensitivity of the CBA is measured in terms of the customer demand, i.e. the beneficiaries of the clearance. Most of the benefit from clearance is gained in the future (and is thus heavily weighted against by conventional discounting techniques). On the other hand, the MMAC model calculates the effect of discounting on supply prices, and only over the life span of a five-year budget period, based on the average life expectancy of a single tranche of equipment. This implies that demand for demining services could be very elastic, i.e. responsive to a small change in price.

14. R. Keeley (2003a) at maic.jmu.edu/journal/7.3/notes/keeley/keeley.htm.

15. So, for IMAS-compliant demining organisations, provision of safety and quality mechanisms imposes a 10 per cent increase in cost. However, for a non-compliant demining organisation, cost could be significantly higher, as not only would there be a 10 per cent cost addition, but one would expect the QA team to reject some of the ground produced by the organisation. As sensitivity analysis shows, the price is very sensitive to small changes in productivity.

Significant financial issue

- Investigate appropriate discount rate and discounting policy for mine action programmes.

Potential use of sensitivity analysis by programme managers

A key assumption when considering sensitivity analysis is that managers have authority to adjust expenditure between different budget lines. Some organisations might only allow such flexibility if there is sufficient transparency in the funding structures.

Sensitivity analysis would be useful for programme managers when considering “alternative assumptions” for budgeting, especially when seeking to make cuts in overall budgets. When faced with a choice, the findings of this paper suggest that the programme manager should concentrate on:

- “big ticket” items; and
- items that are purchased repeatedly throughout the programme.

Risk analysis, contingency planning and analysis of alternatives

Sensitivity analysis is also a useful technique in risk analysis. Where the programme manager is unsure about the provision of a particular line item, application of sensitivity analysis allows the manager to model the likely effect of a given percentage change in price of that item on the overall price of the output. In the MMAC, 2.5 per cent of the programme cost is included as a contingency fund. This has the effect of adding US\$0.03 on to the price of each square metre of cleared land (i.e. raising the unit price from US\$1.39 to US\$1.42).

Possible use of sensitivity analysis in the development of a technical assistance policy

Overview of technical assistance

The sensitivity analysis carried out in the main body of this paper is based on a MMAC model that does not include any technical advisers (TAs) in its organisation. This omission is deliberate, as there is a huge variation in TA provision to different demining programmes, and one can expect to see TA numbers decrease as capacity development transfers skills from expatriate to local staff. Therefore, given the long-term nature of landmine/UXO contamination, one can expect that, over most of its life, a demining programme will have fewer (or even no) TAs compared to a new programme that is in a start-up phase.

There is a second reason for separating technical assistance from the main body of the sensitivity analysis paper. Unlike all of the other factors listed in Table 2 above, TAs carry out two main functions. Although they commonly provide training skills, and as such may be considered a short-term cost to the programme, they may also be used by donors to monitor the activities of the mine action organisation, a role which may continue as long as the donor provides funds. Furthermore, in other sectors the provision of TAs is often considered a “transaction cost”,¹⁶ which is traditionally borne by the donor rather than being attributed to the recipient programme.

16. “...a cost incurred in making an economic exchange.”

Defining the TA structure

In order to carry out a generic sensitivity analysis of the technical assistance element of a mine action programme, it is first necessary to define the structure of the provision of that technical assistance. This paper will assume that the MMAC mine action programme used in the main text of this paper will be complemented by the following TAs:

- chief technical adviser (mine action);
- planning adviser;
- adviser for operations and technical standards;
- logistics adviser;
- administration and human resources adviser;
- finance adviser;
- database adviser;
- programme officer;
- training adviser; and
- four regional advisers.

This gives a total of 13 expatriate TAs. This may seem like a large number, but in fact does not include TAs for QA, MRE, transport, MDD or machine operator training.

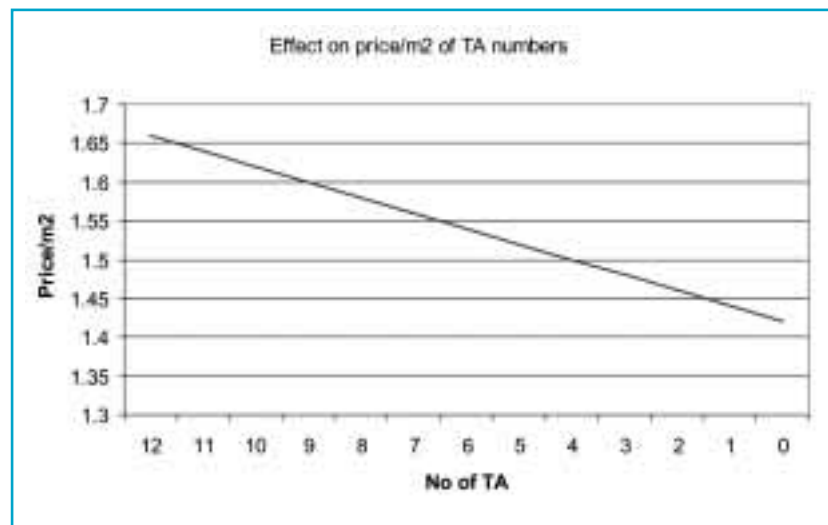
It is assumed that one of these expatriates is accepted by donors as a transaction cost for monitoring of the programme (and not charged to the programme in accordance with convention in general development programmes); in which case the remaining 12 TAs (whether they are involved in training or direct management) would be charged to the programme. The particular TA structure here may be considered a headquarters overhead but it would be possible to divide costs between programme components (for example, an MRE adviser could be charged directly to the MRE component). Assuming an all-inclusive-cost rate of US\$100,000 per expatriate¹⁷, the cost of providing TA for one year is therefore US\$1.2 million, approximately 18 per cent of the MMAC total budget.

Using the model, the effect on price can be shown to be significant. When the cost of including this TA team into the monthly staff costs is added to the MMAC, the undiscounted output price rises more than 18 per cent, from US\$1.42 to US\$1.66. When the effect of discounting and ramping up is included, the price increases to US\$2.00 per square metre. Clearly, a larger (or more expensive) TA structure would cause even more significant increases in the price of demining, especially where other TAs (such as machine-operator trainers) would be directly attributed to the demining component. The effect on price of reducing the number of expatriate advisers by one, as calculated by the model, is \$0.02/m². This is shown graphically at Figure 7.¹⁸

17. This is a conservative estimate based on the charge-out rates of one commercial demining organisation. It was suggested by members of the Study Advisory Group for this study that in many cases the cost could be double this. However, data available from UNOPS showed that UN-provided technical advisers (not considered the cheapest source of TAs) cost between US\$120,000 –US\$140,000.

18. Notwithstanding the financial implications of the rapid reduction in the number of TAs, there have been instances where a too-rapid reduction has had a significant negative impact on programme performance. Some of these are issues are addressed in Section 2 of this Study.

Figure 7: Effect on demining price of varying the number of expatriate technical advisers (based on a cost of US\$100,000 per adviser)



Dealing with the financial implications of cost attribution of technical assistance

Assuming that the skills provided by the TA are necessary, there appear to be four main strategies for acting to reduce cost implications. These are:

1. Accept the cost of expatriate technical assistance — as currently provided — as unavoidable. However, once the real costs are recognised and attributed to the programme, it will inevitably mean recognition that more land would be uneconomic to clear when its costs are compared with the downstream benefits of clearance.
2. “Nationalise” the programme (i.e. train local replacements for the expatriates) as soon as possible. This may be easier for more readily available skills such as (perhaps) information technology. However, a drive towards nationalisation must recognise the dual role of expatriates as monitors as well as advisers. Furthermore, some local staff salaries will need to be higher than others. Anecdotal evidence suggests the tendency is to compare demining programme staff costs with other local salaries, whereas this sensitivity analysis shows that the proper comparison should be an opportunity cost of an expatriate TA. This in turn implies need for recognition of investment in “human capital” once the local capacity has been developed.
3. Using fewer, but higher-skilled expatriates. Rapid nationalisation may deal with “civilian” skills but is less likely to provide access to advanced technical skills in the short term. One way to reduce expatriate cost may be the use of “multi-skilled” technical advisers. Most multi-skilled expatriates tend to collect such additional skills through their own “on-the-job” training and further work would be needed to compare the costs of training expatriates with the costs of training local staff.
4. Savings may be made through seeking alternative sources of technical assistance. TAs provided direct by the UN (for example) can be particularly expensive. Short- to mid-term consulting (one month up to one year) may in the long run be more expensive on a cost per day, but may be more cost-effective. This is particularly the case in skill transfer provided in modular programme training rather than through the common “counterpart” mechanism. However, TA teams can also be provided on contract. Here the supervising organisation (such as the UN) lets

a contract to provide all TAs connected with capacity development and skills transfer. Using the MMAC model, a saving of 20 per cent of the all-inclusive-cost for all 12 TAs translates to a US\$0.05 reduction in undiscounted price per square metre.

In sum, sensitivity analysis demonstrates that the cost of expatriate technical assistance is a significant cost driver within mine action programmes, and can also be used to demonstrate the financial implications of alternative methods for provision of technical assistance.

Practical applications of theory

Case study 1

Revalidating the MMAC model from an African perspective

During a meeting of the Manual Mine Clearance Study Advisory Group in April 2005, the study team was asked to revalidate the MMAC model using other regional data (as the original model was based on South-East Asian information). It was also suggested that UNOPS would be a convenient source of such data.

The results are shown in Table 3. Using similar criteria for the sensitivity analysis conducted previously, some values for up to five national programmes were extracted from UNOPS files. The items chosen were selected from those already shown to be significant by the first sensitivity analysis shown above in Table 2. In order to protect the confidential nature of some of the UNOPS contracting processes, the countries are referred to as countries "A-E".

The results are illuminating. Firstly, the generic figures used to populate the MMAC model appear to be reasonably realistic, though it is worth restating that the design of the MMAC model is intended to accept specific data from particular programmes rather than act as a way to establish a global "standard" price. Secondly, the various data were then subjected to a sensitivity analysis to determine what effect they have on the MMAC model. The matrix at Table 3 shows how the incremental effect of each single individual change while the cumulative changes by programme are shown at the bottom of each column. The numbers in column **h** reflect the "Africa average" for all data. Thirdly, it would appear that explosives and local staff salaries remain sensitive to change, while vehicle costs are still *comparatively* insensitive. The data made available by UNOPS about an innovation to use binary explosives with reduced storage requirement show that, at least from a financial point of view, the savings from the cheaper storage are certainly worthwhile if the programme has to bear the costs of purchasing conventional explosive.

At the request of UNOPS, insurance was also subjected to sensitivity analysis: all other things being equal, insurance appears to have more effect on price than any of the other parameters modelled here. These results suggest that there may be value (in terms of increased cost-effectiveness) of UNOPS re-examining the insurance burden for its contracts. The feedback on this issue alone demonstrates an immediate practical gain from adopting the costing analysis processes set out in this section.

Table 3: Detailed Sensitivity Analysis using UNOPS data from African Projects

| Number | Item | Country | | | | | MMAC default | | Remarks |
|--------------------------|---------------------------------|-------------|-------------|-------------|-------------|-------------|----------------|-------------|-----------------------------------|
| | | A (c) | B (d) | C (e) | D (f) | E (g) | Average (h) | (i) | |
| Actual costs | | | | | | | | | |
| 1 | Vehicle | \$35,600.00 | \$39,800.00 | \$36,000.00 | \$31,000.00 | \$32,000.00 | \$34,083.33 | \$20,000.00 | See note 1 |
| 2 | Explosives | \$10.85 | — | — | — | — | \$10.85 | \$10.00 | See note 2 |
| 3 | Deminer | \$200.00 | \$250.00 | \$290.00 | \$450.00 | — | \$238.00 | \$186.00 | See note 3 |
| 4 | Insurance | \$170.00 | \$27.00 | \$80.00 | \$147.77 | \$150.00 | \$ 95.79 | \$15.00 | |
| | | | | | | | | | |
| Costs per m ² | | | | | | | | | |
| 5 | Vehicle | \$1.44 | \$1.45 | \$1.44 | \$1.44 | \$1.44 | \$1.44 | — | — |
| 6 | Explosives | \$1.41 | — | — | — | — | — | — | — |
| 7 | Deminer | \$1.44 | \$1.52 | \$1.58 | \$1.83 | — | \$1.59 | — | — |
| 8 | Insurance | \$1.78 | \$1.45 | \$1.57 | \$1.73 | \$1.73 | \$1.65 | — | — |
| 9 | Cumulative effect ⁴⁾ | \$1.82 | \$1.57 | \$1.75 | \$2.14 | \$1.75 | \$1.84 | \$1.42 | — |
| 10 | Cumulative effect | \$1.81 | — | — | — | — | — | — | Including explosives in Country A |

Notes:

1. In some programmes prices quoted are for Landcruiser rather than pickup; so actual change may be lower.
2. Binary explosive has additional benefit of reduced storage cost
3. Salaries may be charge-out rates and may be higher than actual salary paid.
4. This does not reflect the actual cost of demining in these countries; rather it reflects the changes in the MMAC model resulting from changing these particular parameters to values extracted from these country programmes. However, the actual cost of demining in these countries could of course be determined by loading all programme costs into the MMAC model.

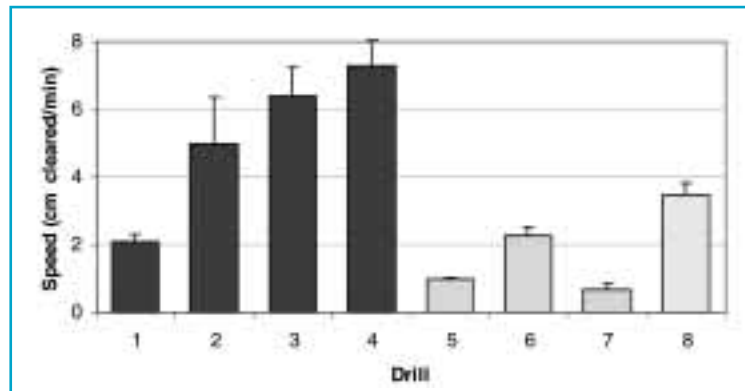
Source: Data is based on contracts issued by UNOPS in the period 2003-2005. Where different contracts have been issued in the same country and this fact results in different values for each item, a representative figure is used to give indicative costs for that country.

Case study 2

Cost implications of the manual mine clearance trials carried out in Section 3 (Operational Systems in Manual Mine Clearance).

Section 3 of this study sets out the results of manual mine clearance trials carried out in Mozambique using eight different one-man drills in land with no vegetation, four of which involve use of a metal detector. The graph at Figure 8 (taken from Section 3) shows the rate of advance in centimetres a minute per deminer along a lane frontage of one metre. The bars show the variation in each drill.

Figure 8: Clearance speed of different manual mine clearance drills.
(Drills 1-4 used metal detectors. Drills 5-8 did not.)



The median rates for each drill have been converted into platoon hectare/month rates and inserted into the MMAC model to see the implications on cost. The result is shown below in Table 4.

The results are very interesting: the first thing that can be seen is that none of these extrapolated rates matches the MMAC generic default rate of 1.5 hectare per platoon month. All other things being equal (i.e. no change in costs, work hours and overheads) this means that manual demining is in fact more expensive than the \$1.42 per square metre shown in the default settings in the MMAC model.

Given the sensitivity of the MMAC model to changes in rates of productivity, this is quite significant, as it shows (and indeed confirms the observations made in Section 2 of this study) that there appears to be a discrepancy between the average rates *reported* to the study team members (wherein a individual rate of 40 square metres/day is apparently unremarkable) and the clearance rates achieved during operational observations study (where the *maximum* individual rate is around 27 square metres/day) which are also similar to those *observed* by other members of the study team.

Although they would not have been equally familiar with each technique, the time and motion study used experienced deminers, one-man drills and ground without vegetation, so it would appear that there is little to be gained from incremental improvements in such factors (i.e. they do not explain the difference between observed

and reported rates¹⁹). Indeed, it could be imagined that the progress rates were actually faster than might be expected, given that they were aware that there were no live mines in the test lanes. The economic implications of this suggest the need for users of the MMAC model to be sure that they have accurate performance data if they want to get accurate assessments of true costs²⁰.

Table 4: Manual mine clearance trials – cost-effectiveness analysis

| Technique | Average rate | | | | | Cost/m2 |
|-----------------|--------------|--------|----------|---------------------|---------------------|--------------|
| | m2/hr | m2/day | m2/month | Platoon m2/month | Platoon ha/month | |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) |
| 1 ^{a)} | 1.26 | 7.56 | 158.76 | 2857.68 | 0.29 | 7.35 |
| 2 | 3.42 | 20.52 | 430.92 | 7756.56 | 0.78 | 2.73 |
| 3 | 4.44 | 26.64 | 559.44 | 10069.92 | 1.01 | 2.11 |
| 4 | 4.56 | 27.36 | 574.56 | 10342.08 | 1.03 | 2.07 |
| 5 | 0.6 | 3.6 | 75.6 | 1360.8 | 0.14 | 14.67 |
| 6 | 1.38 | 8.28 | 173.88 | 3129.84 | 0.31 | 6.62 |
| 7 | 0.48 | 2.88 | 60.48 | 1088.64 | 0.11 | 18.67 |
| 8 | 1.56 | 9.36 | 196.56 | 3538.08 | 0.35 | 5.87 |

a) Cost range for 7 hour day.

Secondly, it appears that the savings made in techniques 5-8 from abandoning metal detectors do not equal the opportunity cost of the foregone benefits from using them:²¹ in other words it is worth (at least in the MMAC structure) the extra initial investment to purchase metal detectors, even those these are a significant cost in the first year of any programme. Although this is shown to be the case in the trials in Mozambique, it may not be the case in situations with different ambient conditions.

Even if one sets aside the difference between the reported and the observed rates of progress, the large variance between the progress rates of the different techniques confirms the findings from the sensitivity analysis, i.e. that improved productivity is of key significance in bringing down the cost of mine clearance. For example, a change of working time by 1 hour in both the fastest and slowest of these drills has a significant effect on the price (from US\$2.07 to US\$1.77 a square metre in the fastest, and from US\$18.67 to US\$15.8 a square metre in the slowest). This suggests that it would be of significant benefit for programme managers to invest time to identify the most cost-effective manual techniques that are feasible in the conditions they face.

Concluding remarks

Demining is expensive, and costs clearly need to be controlled. Currently few programmes appear to be fully aware of their costs and as such, the price of cleared

19. Changes in terrain would also act to further reduce the results in terms of productivity. This could be measured by using the reduction factors included in the GICHD Study of Operational Needs (SON) study.

20. There are other, managerial implications that may be drawn from these discrepancies but these are outside the scope of this Section.

21. Even in the MMAC default settings, removal of mine detectors makes no difference to output cost per square metre; the removal of batteries does however drop the price from US\$1.42 a square metre to US\$1.40 a square metre.

land is extremely difficult to quantify. Sensitivity analysis is an economic technique that allows programme managers and other analysts to measure the potential effect of change. It allows users to focus on those items that are likely to make a difference, even when this is not immediately apparent.

Conclusions and recommendations

Conclusion 1.

Manual mine clearance is the most prevalent — and costly — component of mine action. There is a considerable problem within the demining industry in reporting on areas cleared.

Findings

Demining is expensive and initial cost-benefit studies suggest it may only be of marginal net benefit unless costs are controlled. This means that the demining industry should develop a clear benchmark of what a deminer should be expected to achieve given a set of criteria, and at what cost. Yet, some reports of performance may be significantly overestimated and confusion abounds between area cleared, reduced and cancelled.

Multi-skilled deminers who are on site appear to be a more practical and time-efficient approach. Incentives, such as pay increases and bonuses for conducting successful EOD tasks, may be a useful means of persuading deminers to become multi-skilled.

Sensitivity analysis on the impact of various costs and overheads on the price of clearance per square metre of land found that:

- A 75 per cent reduction in **vehicle** purchase price (i.e. a reduction from a new price of US\$20,000 to a used price of US\$5,000) only leads to a US\$0.02 reduction in the undiscounted price of clearance per square metre, even though there is a huge reduction in initial costs.
- A 50 per cent reduction in **battery** usage rate reduces the undiscounted output price by US\$0.02 per square metre. This suggests that there is a case for encouraging the adoption of either cost-effective battery charging systems or reducing the battery consumption of mine detectors.
- **Medics** (if employed solely as such) can be regarded as “overheads” in demining, and, like the provision of PPE, are a fixed cost of meeting safety regulations. Removing the medic from the platoon organisation chart and the first aid kit from the platoon equipment list results in a measurable reduction in price, from US\$1.42 to US\$1.40. Some organisations are attempting to overcome this problem by adding “dual-role” medics: individuals who operate normally as deminers,

but in the event of an accident, step in as a medic. With enough of these dual-role medics, an IMAS-compliant operation can still be undertaken and cost-effectiveness will be significantly increased.

- If **deminer productivity** increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month), there is a 5 per cent decrease in output price.

Recommendation 1.

a. If mine clearance is to prove cost-effective, costs need to be carefully controlled. The use of sensitivity analysis can be an important element in efforts to control operational costs.

b. Performance must be reported accurately and honestly, if confidence in the demining industry is to be maintained: exaggerated clearance statistics are wholly unacceptable.

Conclusion 2.

Modelling the costings of mine action programmes can provide managers with guidance on where expenditure is best used within a programme.

Findings

The link between expenditure in a programme and cost per square metre of cleared land might be expected to be directly linked, but in many circumstances, this is not the case. For example, a manager would probably assume that increasing productivity will decrease the cost of the output per square metre (i.e. of cleared land). However, the implications of purchasing more expensive equipment—for example PPE—may well not result in a proportionate decrease in the output costs. If the programme manager takes the time and effort to understand the relationship between the inputs and outputs, it may well provide a clearer indication of the benefits that may be obtained from more efficient expenditure.

Recommendation 2.

Programme managers should attempt to understand in more detail the relationship between inputs and outputs into their programmes.

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Glossary of acronyms

| | |
|-------|------------------------------------------------|
| CBA | cost-benefit analysis |
| DDAS | Database of Demining Accidents |
| FCDB | full costs of doing business |
| IMAS | International Mine Action Standards |
| ISO | International Organization for Standardization |
| MAC | mine action centre |
| MDD | mine detection dog |
| MMAC | model mine action centre |
| MRE | mine risk education |
| NGO | non-governmental organisation |
| PPE | personal protective equipment |
| QA | quality assurance |
| QC | quality control |
| SON | Study of Operational Needs |
| SOP | standing operating procedure |
| TA | technical adviser |
| UNMAS | United Nations Mine Action Service |
| UNOPS | United Nations Office for Project Services |
| UXO | unexploded ordnance |



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