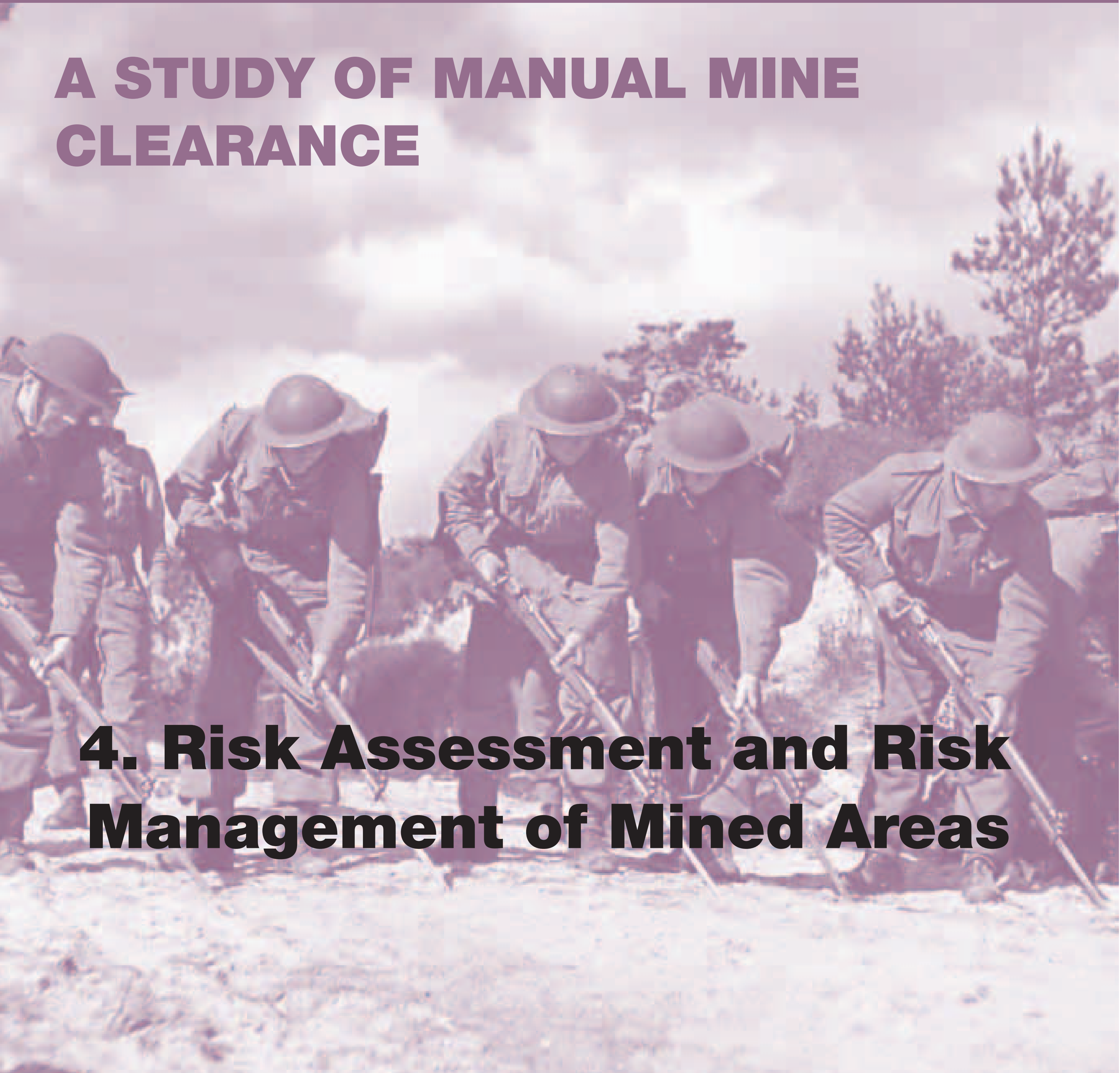

A STUDY OF MANUAL MINE CLEARANCE

4. Risk Assessment and Risk Management of Mined Areas

Geneva International Centre for Humanitarian Demining
Centre International de Déminage Humanitaire - Genève

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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

Photo credit:
Cover: British Army mine clearance of a road in 1945, "S*oldiers 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:

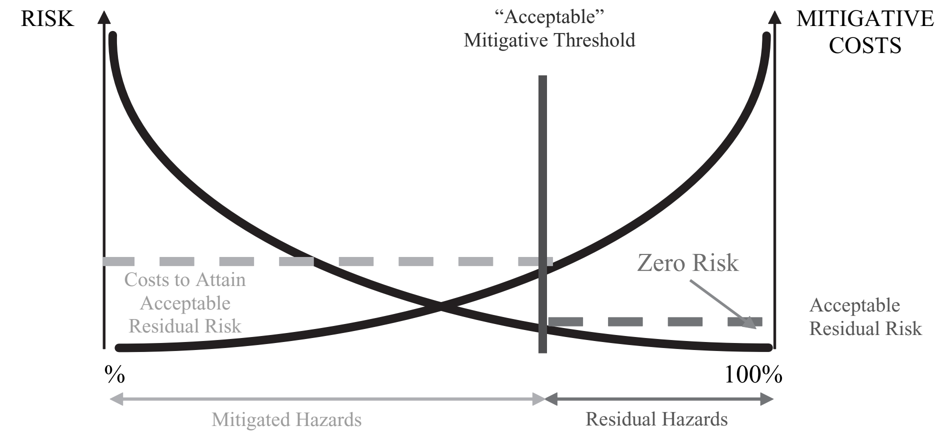
$$R_H = p_H \times C_H$$

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.

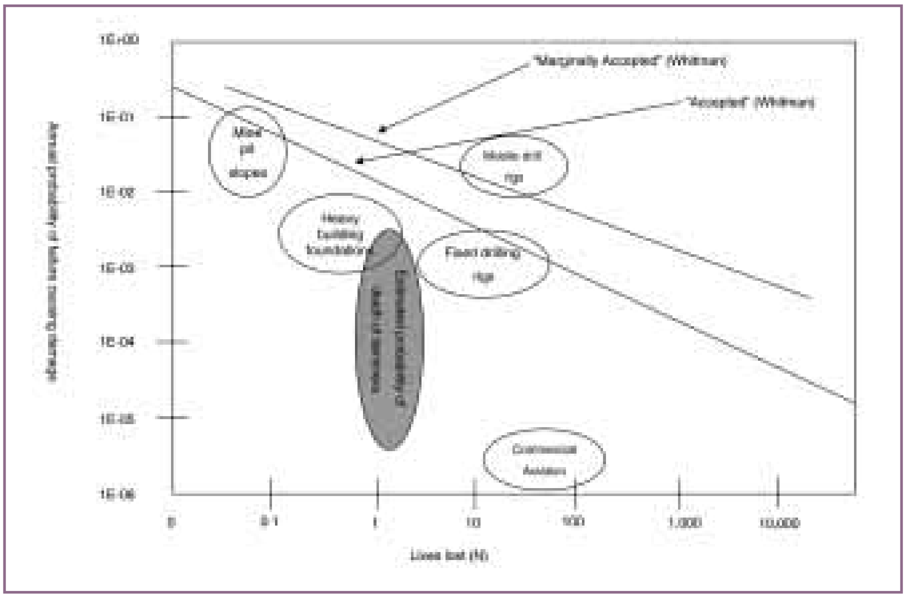
While local populations in industries other than mine clearance face similar risk from simply working within these hazardous countries, it may be that mine clearance exposes employees to a greater level of risk from non-mine-related incidents than local people in other occupations. For example, manual 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



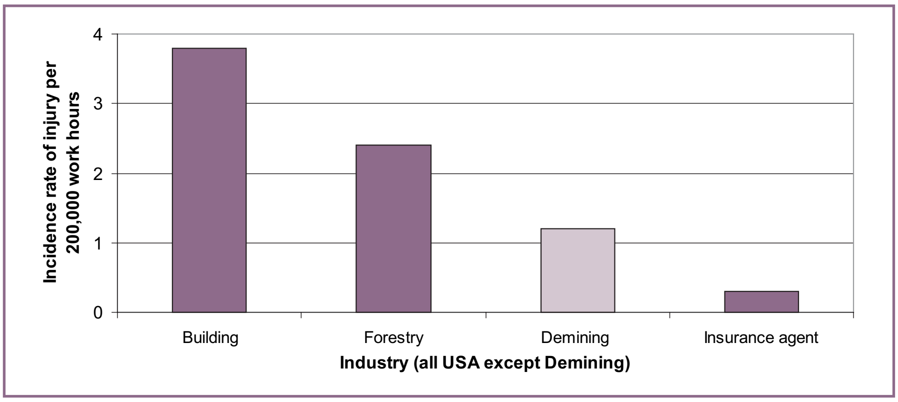
Source: Leroi E.et al.(2003). Ovals and areas represent ranges rather than precise numbers.

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.

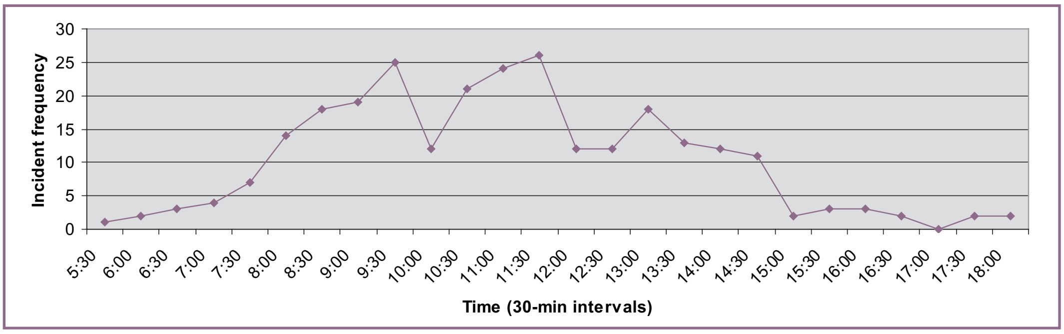


Figure 4: Occurrence of accidents throughout working day

A review of relevant literature[3] 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 approaches[7] 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.

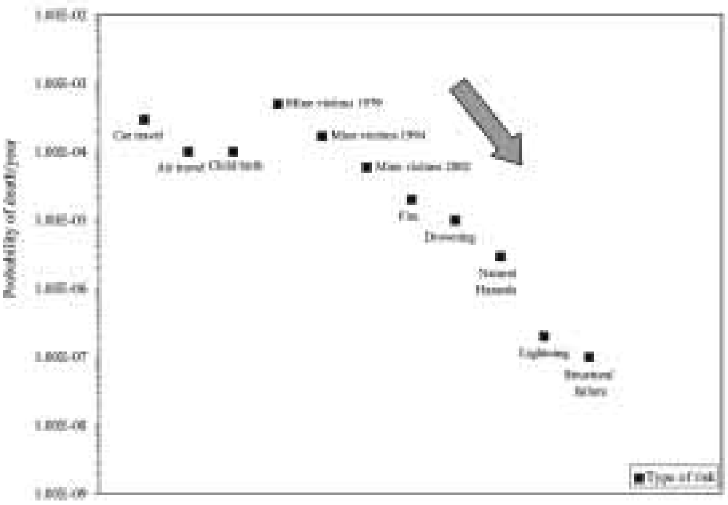
3. In 2003, a Kosovo-Albanian family brought a case to the European Court of Human Rights against the French contingent of the Kosovo Protection Force (KFOR) based on the allegation that the French KFOR knew of the locations of cluster bombs but failed to mark or clear them. This case is still *sub judice* 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 km^2 each year at a cost of C_a = US$20 million per year at a national clearance standard of 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 = 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 RCAF[4] (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 casualty[5]), 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.

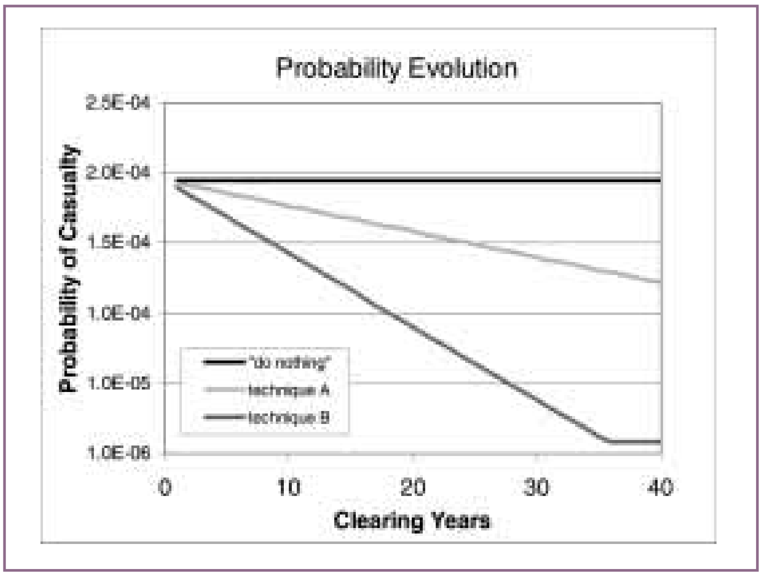
Table 1: Estimated cost in terms of US$ and number of casualties for three different rates of population increase when there is no clearance ("do nothing") and when Techniques 1 and 2 are used in Battambang province over the next 40 years

	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.

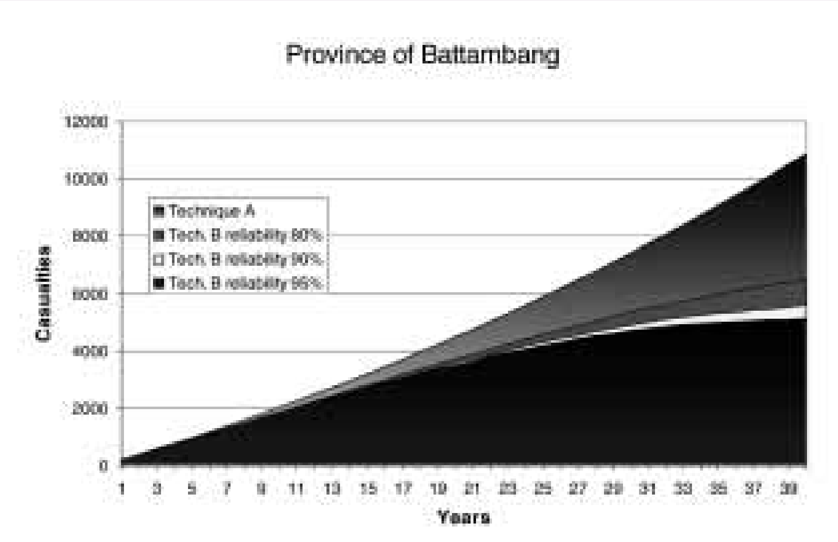
Figure 6 shows that the probability of casualties in Battambang province would decline more rapidly, and reach a much lower level, if Technique B were used instead of either Technique A or doing nothing.

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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