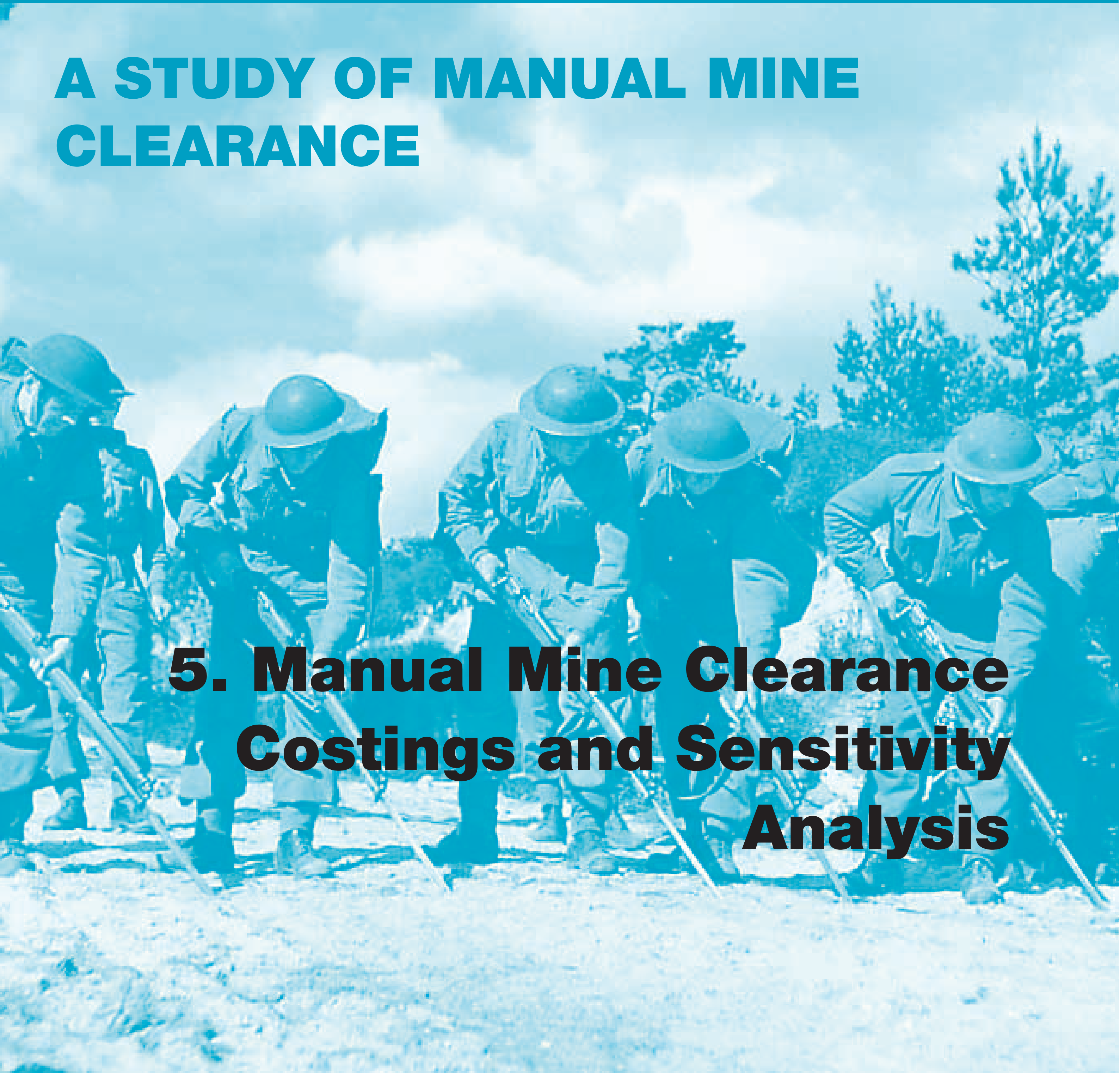
A STUDY OF MANUAL MINE CLEARANCE



5. Manual Mine Clearance Costings and Sensitivity Analysis

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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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

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 least[1] 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 necessary[3] 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 indirect[4] 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

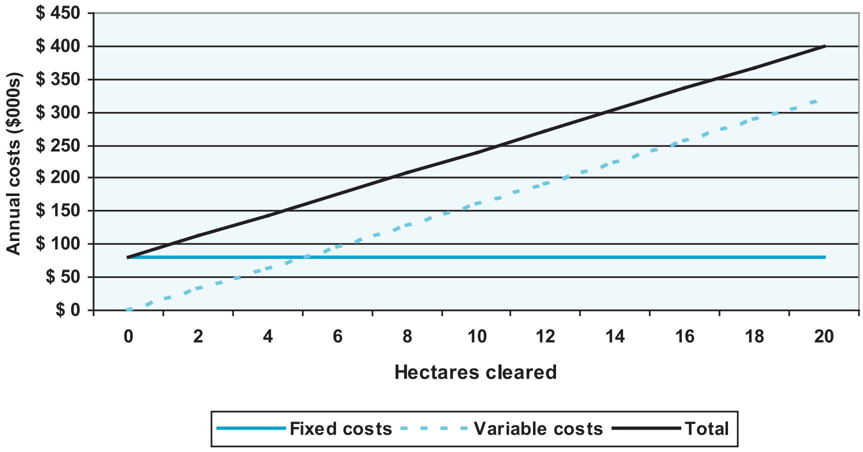
7 .This would cover salaries and benefits, fuel and supplies, equipment maintenance, insurance, etc.

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]

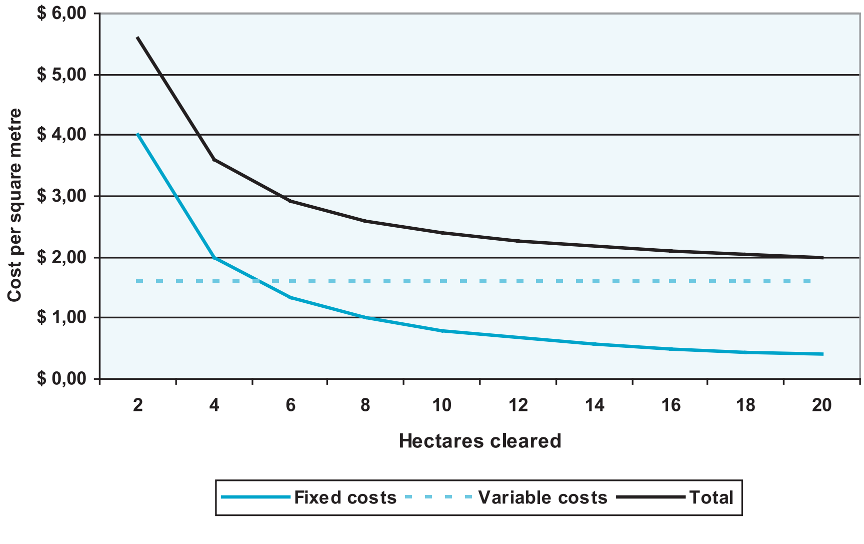
So in this case our fixed costs are $80,000 per year. With this information, we can depict how our costs behave as we increase the amounts we clear in a year (*Figure 1*).

Figure 1: Fixed, variable and total costs



Dividing the costs as depicted above by the hectares cleared in the year gives us unit costs[10] 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

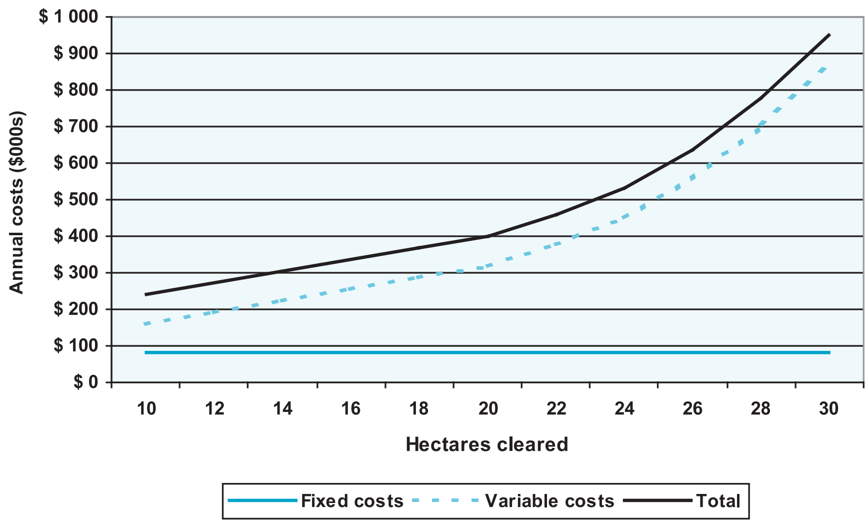
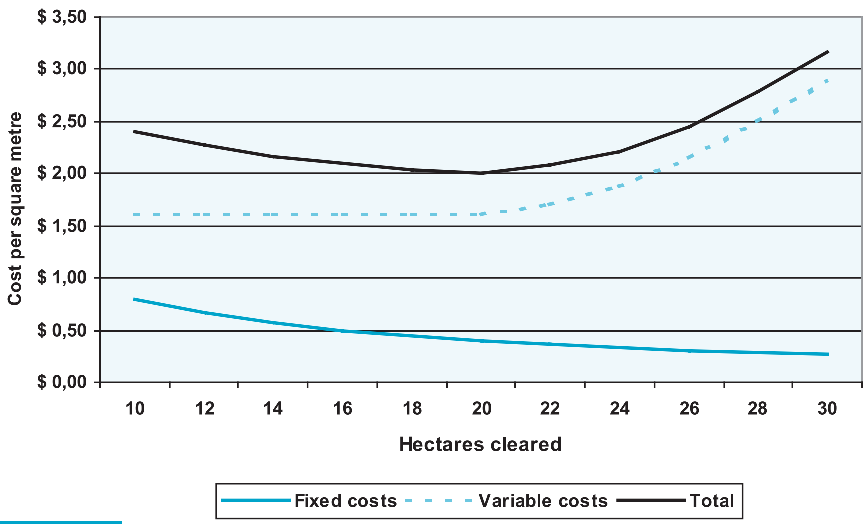


Figure 4. Unit costs as capacity exceeded

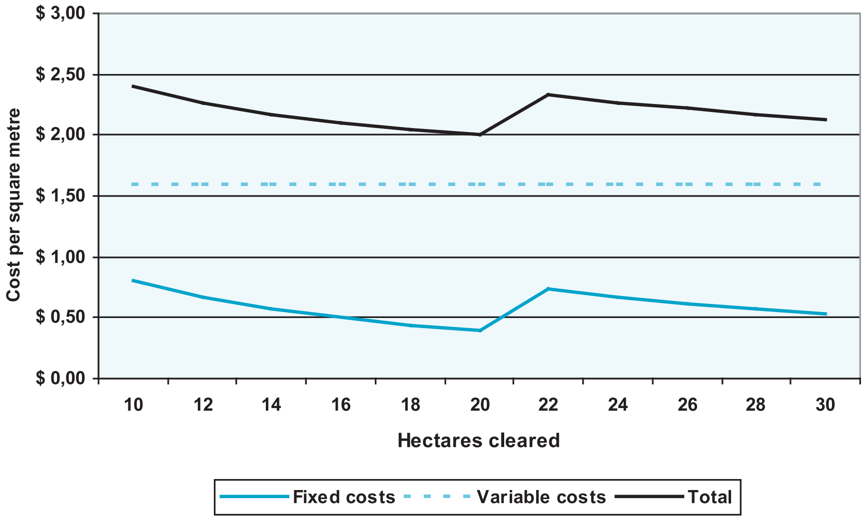


11. Unsurprisingly, the other big source of productivity increases stem from efforts to reduce variable costs per unit, usually by getting more productivity out of each deminer in the standard work day. This may entail simple measures like ensuring work starts on time, reducing the amount of sick leave 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).

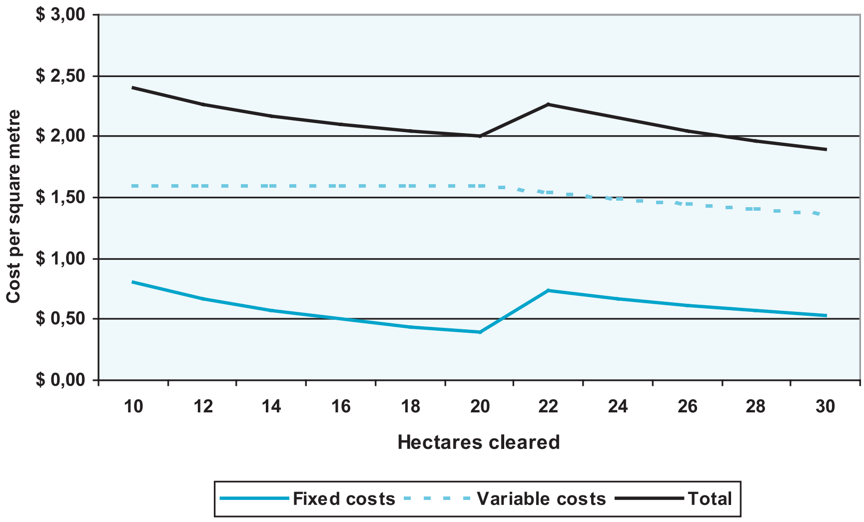
An alternative solution to increasing production beyond 20 hectares per year is to invest in greater capacities, say by purchasing more vegetation cutters, vehicles, mine detectors, etc., and by paying for courses to train more deminers, team leaders and site supervisors. Figure 5 depicts the effect 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
Overheads	= US$ 1,540,000
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 definition[3] 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 noticeable[4] 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 US1.42 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 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 MMAC 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 calculations[12] 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.

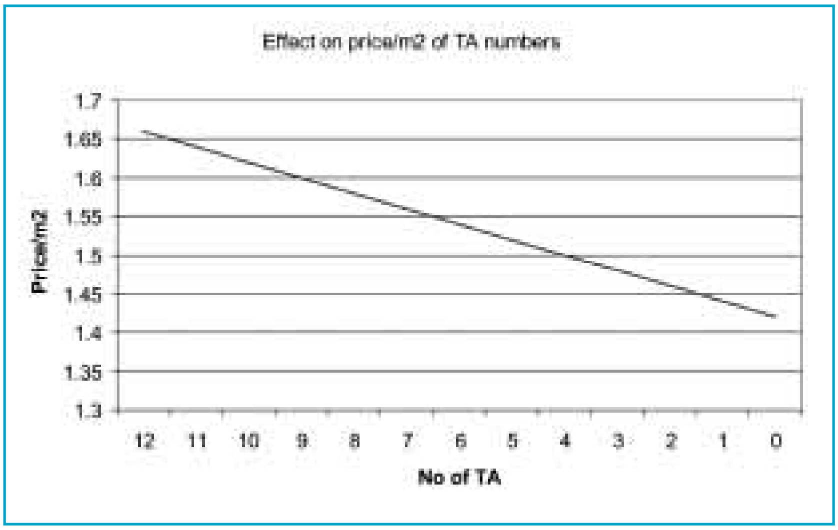
It is assumed that one of these expatriates is accepted by donors as a transaction cost for monitoring of the programme (and not charged to the programme in accordance with convention in general development programmes); in which case the remaining 12 TAs (whether they are involved in training or direct 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 expatriate[17], 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/m^2. 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	*B*	*C*	*D*	*E*	*Average*		
(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	*(h)*	*(i)*	*(j)*
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 particualr 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.

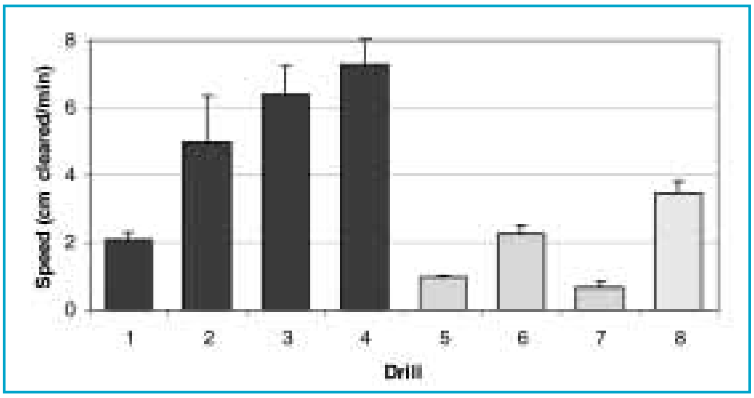
Source: Data is based on contracts issued by UNOPS in the period 2003-2005. Where different contracts have been issued in the same country and this fact results in different values for each item, a representative figure is used to give indicative costs for that country.

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 rates[19]). 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 costs[20].

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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