

Chapter 6.

Mechanical cost-effectiveness

Summary

This chapter establishes a methodology for the calculation of the cost-effectiveness of mechanical demining equipment, in particular through the Cost-Effectiveness Model (CEMOD) software programme. This software can be used to assess past or projected costs or to evaluate past or projected plans.

Introduction

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

The apparently limited success in the use of mechanical clearance methods means that most demining organisations continue to rely heavily on manual clearance techniques. While manual techniques may be a reliable way of ensuring that acceptable clearance standards are met, they can be slow, expensive and dangerous.

The growing number of purpose-built mechanical mine clearance machines in use and under development and the increasing variety of ways in which machines are used to support mine clearance makes it an opportune time to assess the cost-effectiveness of mechanical mine clearance. This information can help to serve at least two purposes. First, a greater awareness of the cost-effectiveness of various methods of mine clearance may help demining agencies to use their existing resources more effectively. Second, more widely available and standardised data on the cost-effectiveness of mechanical equipment relative to other clearance methods could help planners and developers allocate support to the machines and techniques that offer the greatest promise.

The aim of this chapter then, is to establish a methodology as to how an organisation calculates the cost and the productivity of a machine working in a minefield, and

how its cost-effectiveness should be established, in comparison with equivalent clearance carried out by manual or MDD teams. The CEMOD cost-effectiveness software model is available from the GICHD on CD-ROM upon request. It allows a manager to decide whether machines or manual methods are more economically viable for certain clearance tasks.

For both mechanical and manual mine clearance methods, annual data is likely to provide a more accurate picture than weekly and monthly costs. A shorter reference period can be more easily distorted by atypical costs, so annual data on items like spare parts is likely to provide a more accurate picture. Similarly, a longer reference period may give a more accurate reflection of labour costs and productivity, because these can be affected if a significant component of the time period is devoted to training.

Moreover, in monsoonal environments, costs are likely to differ between wet and dry seasons. For example, in the wet season, soils may break up more easily, aiding the detection or disablement of mines. Offsetting this, some clearance methods may not be possible in the wet season due to the bogging of machines and the inundation of land preventing the use of mine detectors. Hence, both costs and productivity may differ across seasons and this can distort comparisons if data for different methods relates to different seasons. The use of an annual reference period can be thought of as averaging across the various seasons, and so allows greater consistency of comparisons.

In cost-benefit analysis the term “economic” is generally taken to include shadow pricing with the objective of assessing social¹ benefits and costs from a national perspective. The objective of this study is to improve the cost-effectiveness of mechanical demining by implementing agencies. As such, the emphasis should be on the actual costs they face (whether distorted or not). For this reason our analysis will be based on estimates of *financial* costs and benefits.

This report describes how the Cost-Effectiveness Model (CEMOD) should be used to analyse the effect of, for example, donated equipment on *financial*² viability — i.e. is it ultimately more cost-effective to purchase the desired machine rather than to “make do” with one donated. It allows calculation of performance indicators (e.g. cost per square metre) based on alternative assumptions to establish viability:

- actual costs faced by project managers, e.g. donated equipment at zero cost; and
- “real cost” to funders of demining activity.

The Cost-Effectiveness Model (CEMOD)

Model purpose and overview

Economics is the study of how society manages scarce resources. Each year resources available for mine action are sufficient to tackle only a small proportion of mine-affected areas worldwide. Mine action is an expensive activity that can often be undertaken using a number of different methods. Data already available suggests that there is a wide range in the unit cost of these methods, even after adjusting for quality and variation in other key variables. Clearly it is essential that scarce mine action resources be deployed in such a way as to achieve the best possible outcomes. Cost-effectiveness analysis has a key role to play in achieving this goal.

Cost-effectiveness analysis can be approached in two ways: a) to determine the least-cost method of achieving a known goal, or b) to find the policy alternative that will provide the largest benefits for a given level of expenditure (the *fixed budget approach*). This report is concerned with the fixed effectiveness approach.

There is an important distinction between cost-effectiveness analysis and cost-benefit analysis. Cost-benefit analysis can assess both a) whether any of the alternatives are worth doing (whether benefits to society exceed costs), and b) how alternatives should be ranked if more than one has benefits that exceed costs. On the other hand, cost-effectiveness analysis cannot tell the analyst whether a given alternative is worth doing (this requires a cost-benefit analysis), but if a decision is made to achieve a particular goal, it can help in deciding which policy alternative will do so most efficiently.³

The design of the CEMOD is based on the concept of the “mine clearance method” i.e. any method used to achieve the IMAS standard. There is little point in comparing different machines in isolation if they make different contributions to mine clearance. The only useful comparison is between alternative methods that achieve the same goal.⁴ For example a given piece of land might be cleared to the same standard by four alternative *methods*:

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

A vegetation cutter might have a lower cost per square metre than a flail, however the overall cost of method 2 might be lower than method 3 because manual mine clearance is faster after a flail.

The following sections of the report describe how the CEMOD can be used to estimate the cost-effectiveness of alternative mine action methods.

Analysis functions

The CEMOD may be used for four main types of analysis (see Table 1).

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

Table 1. Types of analysis performed using CEMOD

	Implementation function	Planning function
Past expenditure	Analyse the cost-effectiveness of alternative methods of mine clearance. <i>Based on "actuals".</i>	Analyse the cost-effectiveness of alternative methods of mine clearance. <i>Based on "actuals".</i>
Projected expenditure	Project the future cost-effectiveness of alternative methods of mine clearance <i>Based on expected costs faced by the implementation agency.</i>	<i>Adjust to create "level playing field".</i> Project the future cost-effectiveness of alternative methods of mine clearance <i>Based on "expected costs".</i> <i>Adjust to create "level playing field".</i>

How to determine costs

Allocation to cost categories and cost centres

All costs should be broken down into staff salaries, staff allowances, consumables and capital equipment and allocated to the available cost centres (management and administration, mine survey, medical, dog teams, manual mine clearance and mechanical mine clearance; separately for each machine type).

If the organisation operates more than one of a particular type of machine it will usually be appropriate to allocate costs to these machines as a group. However costs can be allocated to each machine separately where a separate analysis is desirable. In this case each machine should be given a separate name (e.g. Flail A, Flail B, etc.). Machines that use a variety of attachments can be analysed separately or as a group. If analysed separately then a proportion of the cost of the "base unit" must be allocated to each of the attachments.

Salaries and allowances

Staff salaries cover the employment costs of all personnel including senior management. Both local and expatriate staff should be included (except that implementing agencies should not include those expatriate staff costs which are donated). The staff allowances category should be used for items such as field allowance, travel allowance, etc. However agencies can choose, if they wish, to combine all such costs under the staff salaries subheading.

Consumables

This covers all items that are generally consumed within a year, e.g. petrol, stationery, machinery repair costs, dog food, rent for buildings, etc.

CEMOD is not designed to take account of changes in stock levels, so consumables cost data should reflect *use* during the reporting period rather than *change in stock levels*.

Capital equipment

This covers all items that usually have a working life of more than one year. It includes major items such as mine clearance machinery and vehicles. Also included are smaller items such as mine detectors and dog kennels. Buildings constructed (or purchased) by the project should also be included.

In each case effective working life should be estimated. This is used to estimate the annual cost of capital equipment (based on capital cost divided by working life). In some cases judgement may be required; some examples may prove useful:

Table 2.

Example	Working Life
<i>Based on past experience the average working life of a manual mine detector is estimated to be three years. Value of discarded equipment is negligible</i>	3 years
<i>Vehicles are kept for four years then sold. They usually realise around 33 per cent of their cost new. Add 33 per cent to working life to account for salvage value.</i>	4 years
<i>Project will last more than five years. Equipment is expected to last for five years and will then be donated to local mine clearance organisation.</i>	5 years

Management and administration costs: defining the unit of analysis

The unit of analysis should usually be the whole implementing agency that carries out mine clearance activities. In some cases it may be appropriate to include a particular *part* of an agency, e.g. in cases where separate divisions have quite separate activities that may be unrelated to mine clearance. In this situation management and administration costs should be entered for the *whole* organisation, and an estimate made of the percentage attributable to mine clearance activities. Management and administration costs for separate headquarters organisations should not be included. This should increase the comparability of data between organisations. So, for example, the home country or regional⁵ headquarters cost of an NGO involved in mine clearance activities would not be included.

Types of analysis: Appropriate treatment of capital equipment, donations and overhead expenditure varies according the type of analysis performed. This is summarised in Table 3 and covered in more detail below:

Table 3. Treatment of capital equipment, donations and overhead expenditure

	Existing capital equipment	Possible new equipment	Donated equipment	Remarks
Implementation function				
Past costs	Depreciate over effective working life		Only include costs to the implementation organisation	<i>Market cost of donated items NOT included</i>
Projected costs	Depreciate current salvage value of existing equipment over remaining working life	Depreciate expected cost of new equipment over expected working life	Only include actual/expected costs to the implementation organisation	<i>Purchase price of existing equipment is treated as a sunk cost</i>
Planning function				
Past costs	Depreciate over effective working life		Include full cost (net of any donated element)	<i>Market cost of donated items INCLUDED</i>
Projected costs	Depreciate over effective working life	Depreciate over effective working life	Include full cost (net of any donated element)	

Past costs

This analysis function should be used to analyse the past cost-effectiveness of methods of mine clearance used by an implementation agency.

- Enter all costs faced by the implementing agency over a given reporting period (usually one year).
- All management and administration costs are entered, but only a percentage of these are allocated to mine clearance (this percentage is entered by the user).
- Enter all capital items used by the agency.⁶
- Only enter the cost of donated equipment that is actually paid by the implementing agency e.g. do not enter the capital cost of donated equipment, but enter “actual costs” e.g. running costs, cost of repairs, etc.

Projected costs

This analysis function should be used to analyse the projected (future) cost-effectiveness of methods of mine clearance that may be used by an implementation agency.

In most respects the method of determining costs is the same as for past costs. Projected costs should be based on past data (where available) or in the case of new equipment or new methods, on data from other agencies working under similar conditions.

When deciding whether or not to *replace* existing equipment, we need to compare the projected cost of existing equipment (treated as a sunk cost) against the projected cost of the new equipment (depreciated over its expected working life). In this case, enter the *salvage value*⁷ of the existing equipment and the *full expected cost* of the possible new equipment. In this case enter *remaining*⁸ working life for existing equipment.

If the new equipment will be used to *expand mine clearance activities* (not to replace existing equipment) enter the actual cost of existing equipment and the *full expected cost* of possible new equipment.

Planning (past and projected)

This analysis function is used to analyse the past/projected cost effectiveness of alternative methods of mine clearance. In order to increase comparability, donated cost items should be included at their real/market price.

All capital items should be entered at their actual or projected cost.

Allocation of costs

Cost-effectiveness analysis requires the development of an appropriate system to allocate all direct and indirect costs to each cost centre. The cost allocation system needs to be reasonably accurate, without being too onerous in its data requirements. CEMOD includes the following cost centres:

- management and administration costs,
- mine survey,
- medical support, and
- mine clearance “procedures” (e.g. manual, dog teams, machines).

The following notes summarise the way in which costs are allocated in the CEMOD software.

Management and administration costs (including mine survey)

- Calculate the total cost of management and administration for the implementing agency (excluding international and regional headquarters costs).
- Estimate the percentage of management and administration costs attributable to mine clearance activities.
- Estimate mine clearance management and administration cost (based on above).
- Add the cost of mine survey activities.
- Divide by total area cleared in last reporting period to arrive at management, administration and survey cost per square metre.

Medical support

- Calculate total medical costs (avoid double counting, e.g. inclusion of any of the management and administration costs included above).
- Estimate the percentage of medical costs attributable to:
 - manual mine clearance and clearance by dogs,
 - mechanical mine action.
- Estimate medical costs per deminer or dog handler day for manual mine clearance and clearance by dogs (it would not be appropriate to use a per square metre measure in this case since a deminer clearing a larger area/day should have a lower per square metre medical cost).
- Estimate medical cost per square metre for mechanical mine clearance (this should be a reasonable approximation, although medical cost per square metre will also vary with machine speed and crew size).

Manual demining

- Calculate total cost of manual demining operations (e.g. salaries/pay, staff allowances, equipment, transport, etc.).
- Estimate deminer days (no. of deminers x no. of demining days) by activity. This should be available from standard log books used by most demining organisations e.g.:
 - manual only,
 - manual after flail,
 - manual in support of dog teams,
 - others,
 - total deminer days.
- Assign cost of manual demining operations to each activity based on average cost per deminer day x no of days engaged in each activity.
- Estimate per square metre costs based on logbook records of area demined using each method.
- In the case of manual in support of dog teams the actual area manually demined should be recorded (e.g. the clear lanes required by the dog teams), not the total area cleared using dog teams and manual combined.

Dog teams

- Calculate total cost of dog team operations (e.g. salaries/pay, staff allowances, equipment, transport, dog training, international technical assistance, kennels etc.).
- Estimate dog handler days (no. of dog handlers x no. of operating days) by activity (this should be available from standard log books used by most demining organisations):
 - dog teams only,
 - dog teams after flail,
 - dog teams after vegetation cutter,
 - total dog team days.
- Assign cost of dog team operations to each activity based on average cost per dog handler day x no of days engaged in each activity.
- Estimate per square metre costs based on log book records of area demined using each method (the net area cleared by dogs excluding the lanes cleared using manual mine clearance).

In some contexts (e.g. Bosnia) each unit of land is cleared by two independent dog/handler teams. In this case the actual daily output per dog handler/day is double that entered in the spreadsheet. An example may make this clearer:

The demining organisation enters:

- Area cleared by dog teams 320,000 square metres
- Dog handler days to clear this area 1,600 days
- This implies area cleared per DH day 200 square metres

However to clear 200 square metres requires coverage by two separate dog teams e.g. 400 square metres per day.

Mechanical mine clearance

- Calculate total cost of mechanical operations for each machine (e.g. capital equipment, salaries/pay, staff allowances, equipment, running costs, transport, international TA, etc.).
- Capital costs have been annualised using straight line depreciation, assuming no salvage value.
- Calculate machine costs per square metre.

Model output and interpretation

Model output includes cost-effectiveness, cost saving and machine costs per year.

Key indicators include:

- Annual cost and cost per square metre for each mine clearance method;
- Annual cost saving from use of mechanical support;
- Cost saving from use of mechanical support per square metre;
- Cost ratio mechanical support: manual mine clearance; and
- Time for machine to pay for itself.

Model output is demonstrated in Table 4.

Table 4. Model output

Variable	Item in ToR	Remarks
Cost per m ² (actual and "real") Cost per unit	Cost effectiveness	Cost effectiveness is estimated by comparing cost per unit cleared with base case (manual clearance or another chosen method). In the Past Cost and Projected Cost functions, cost effectiveness is based on costs "actually" faced by project managers. In the Planning function, cost effectiveness takes account of the "real" cost of donated demining equipment.
Total cost saved compared to manual (or other method)	Cost saving ⁹	Cost saving is be calculated relative to manual clearance or another selected method.
Cost per time period	Define weekly or monthly manual and machine costs	Annual data on running costs, spare parts, etc. provides a more accurate picture. Some staff may be salaried but cannot work in some months of the year.
Sensitivity Analysis or Switching Values	Highlight variables relating to cost effectiveness	Effect of change in assumptions on cost per m ² , total cost saved, etc. – highlighting variables with greatest effect on cost effectiveness (see above).

How to calculate cost per square metre

The CEMOD system calculates mine clearance costs per square metre for each method of mine clearance. CEMOD allocates management, administration, survey and medical costs in a standard way that will facilitate comparison between different mechanical clearance systems, and between mechanical and manual or manual/dog systems.

This report includes guidelines for the treatment of donated items and headquarters administration/supervision costs. Four analysis functions are described, since the "real" cost of mine action depends on the perspective of the decision maker — whether they are an implementing or planning agency and whether the analysis covers past or projected costs.

Cost per square metre should only be compared "where all other factors are equal", i.e. for clearance of mined land of similar characteristics. Differences in cost per square metre between minefields may be a reflection of changes in mine field characteristics — rather than the cost-effectiveness of alternative mine clearance procedures.

How to determine the cost-effectiveness of alternative methods of mine clearance

Analysis of the cost-effectiveness or productive value of mine action machines is integrated into the comparison of alternative methods of achieving the same goal

(mine clearance to a given standard). This allows direct comparison of alternative combinations of procedures including area reduction, area preparation and combination machines with multiple tool attachments.

CEMOD also produces data on annual machine costs and cost per operating day. Comparisons based on machine cost per square metre will be valuable where different machines perform similar tasks. Data on cost per operating day highlight the importance of maximising the effective operating hours of expensive pieces of capital equipment.

Manual mine clearance provides a useful benchmark (base case); against which alternative mine clearance procedures can be assessed. Alternatively, a mechanical method may be entered as the base case. CEMOD compares the cost of alternative methods of mine clearance with the base case (it provides cost per square metre and the cost per square metre of each method as a percentage of the base case). Data is also provided on potential annual cost savings relative to the base case if each method had been used over the entire area cleared. Some judgement is required in using these figures appropriately, since in many cases use of a single method over the entire area would not be feasible.

Sensitivity analysis

Sensitivity analysis tests how changes in key assumptions affect the key output from the model (e.g. cost per square metre). The analyst concentrates on the changes which, based on past experience, are most likely to occur. For example how would the key indicators change if:

1. area cleared per machine per year was 30 per cent less or more?
2. area cleared manually per day was 30 per cent more or less?
3. area cleared manually (or by dogs) after a machine was 30 per cent more or less?
4. management and administration costs per square metre were 30 per cent more or less?

To carry out sensitivity analysis using CEMOD:

- Enter data into CEMOD using actual past data (or your best estimate of what will happen in the future). Print Standard Reports. Save to an appropriate name e.g. CEMOD Base Case;
- Change a key assumption e.g. decrease area cleared per machine per year. Print Standard Reports. Save to an appropriate name e.g. CEMOD Scenario 1;
- Continue for as many alternative scenarios as appropriate; and
- Review results.

Discussion of CEMOD results should be backed up by a discussion of the how sensitive key indicators are to changes in key assumptions. For example:

“Mine clearance using method 1 (Mine Shredder followed by manual clearance) had the lowest overall cost per m². However achievement of this cost level requires annual clearance by Mine Shredder of 500ha. Based on past experience of ... there is a significant risk that this will not be possible, in which case method 2 would have the lowest cost per square metre.”

Factors affecting cost-effectiveness

The cost-effectiveness model is designed to provide standardised calculations of the cost of mine clearance using actual or projected data. Many factors are likely to influence the cost-effectiveness of particular methods of mine clearance in particular settings (see Table 4). Foremost among these will be labour and machine costs, and the comparative productivity levels of manual clearance teams, dog teams and mechanical clearance machines (whether in a support or leading role). However, other idiosyncratic factors are also likely to be important and these are not incorporated into CEMOD even though they are likely to be relevant to the decisions that agencies make about the most effective way to clear a given area.

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

Table 5. Key variables affecting cost-effectiveness

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

A similar complication comes from the type of mine that is expected in a given field. Mechanical procedures that are feasible when working with anti-personnel mines may not be feasible when working on anti-tank mines and the use of suitably armoured machinery is likely to affect the cost comparisons. Hence, the information provided by CEMOD cannot replace the detailed knowledge of project managers,

instead it is designed to provide additional information so that they can make better informed decisions about mine clearance.

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

Endnotes

1. i.e. from the point of view of, for example, Bosnian society as a whole. Such economic calculations might for example be adjusted for taxes, tariffs and other price distortions. They might include a shadow cost of labour lower than actual rates paid to those working on demining — to reflecting the high local rate of unemployment.
2. See note 1.
3. This paragraph is summarised from D.L. Weimer and A.R. Vining (1999), *Policy Analysis: Concepts and Practice*.
4. Subject to differences in conditions and other variables (discussed below). There is no explicit consideration of the time taken to achieve the goal because the value of timeliness may differ greatly between projects. However, timeliness is one of many factors that users of the model must bear in mind when interpreting the results.
5. Regional in the sense of covering a group of countries.
6. The present model does not account for inflation. This should not normally significantly affect results since most capital items have a fairly short life and many agencies will enter costs in US\$ terms (and the U.S. inflation rate is at low levels). This could be a problem if cost data is entered based on a currency with a high inflation rate.
7. The money that could realistically be obtained if the equipment was sold.
8. Number of years you expect existing equipment to remain in service from the analysis date.
9. It is assumed that the term productive value in the TOR (item 1) is the same as cost saving.