On Quality Standards for Demining

James Trevelyan
Department of mechanical and Materials Engineering,
The University of Western Australia, Nedlands 6907
E-mail: jamest@mech.uwa.edu.au

Summary

In the last two years several authors have commented critically on the 99.6% standard for humanitarian mine clearance which has been adopted by the United Nations and its agencies. At the time of writing these standards are being redrafted yet, from the literature and recent comments, it is clear that there is little intellectual foundation on which to build a new standard.

This paper is an attempt to make a contribution towards a better foundation.

There are three issues which need to be addressed. First, what is an acceptable quality standard for humanitarian demining? The second, how can one measure the quality levels actually achieved in humanitarian demining? Third, how can one implement a cost-effective training and monitoring process to ensure that the desired standard is achieved consistently?

This paper addresses the first two issues. The paper concludes that the acceptable quality for demining in Afghanistan is likely to be between 0.00001 and 0.0001 devices per sq. m. and then demonstrates the fundamental and practical aspects of a quality measurement method which can verify that this level of clearance has been achieved.

Acceptable Risk and Quality in Demining

The ultimate aim of demining activity is to reduce the risk of incidents causing death or injury to land users. Brown (1999) presents an interesting discussion of risk management in this context but did not have access to statistical data to fully develop his arguments.

Clearly, the risk of mine incidents depends on several factors.

One factor is the intended use of the land. A public footpath or marketplace carries a much greater risk that a single device will be inadvertently triggered by a land user than a comparable area of open grazing land.

Another factor is the number of people who are likely to use the land. This is clearly related to the level of surrounding population which can change dramatically after mine clearance. As people gain confidence and return to formerly mined areas, populations can build rapidly.

A third factor is the type of mine and UXO threat present in the ground. Certain kinds of mines (e.g. PMN 1) are more dangerous than other types.

A fourth factor is the local climate and environment. For example, in Cambodia there are many mined areas routinely used by civilians during the dry season when the ground sets hard and is reinforced by grassroots. Local families know, however, that they must keep their children and animals off the ground during the wet season when mines can be much more easily triggered. Casualties also rise dramatically in the wet season according to anecdotal evidence we have received.

It is highly desirable in any discussion of risk to attempt to obtain quantitative data. There are extensive sets of data available for such an analysis. Most mine-affected countries keep accurate records of civilian incidents in mined areas. Mine action agencies keep records of areas cleared and the mines removed from those areas. Therefore, in principle, useable data exists on which to base quantitative assessments of risk. So far, we are not aware of any attempt to analyse this data in order to assess actual risk levels.

Quite apart from the quantitative risk of mine incidents to civilians, the subjective perception of risk governs human behaviour to a much greater extent. It is the perceived risk which modifies the behaviour of people exposed to mine hazards, and in doing so, largely determines the socio-economic impact of mines on a population.

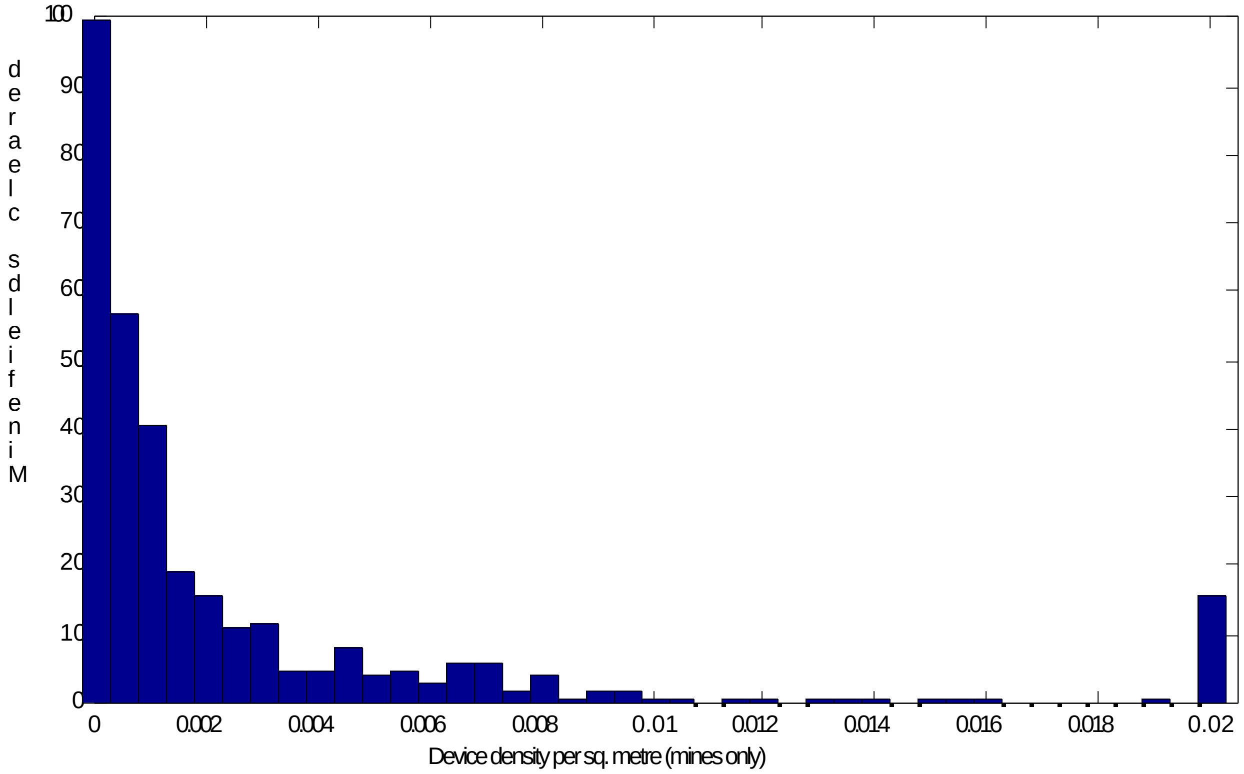

Figure 1 Data on mine density from 336 residential minefields cleared in Afghanistan between 1993 and 1997. Data from Mine Action Program for Afghanistan.

The socio-economic impact of mines in Afghanistan has been documented in a recent report (MAPA 1999) that provides many useful details of this. No one would seriously dispute the notion that the level of mine casualties has been, and continues to be unacceptable. The perceived risk of mine accidents significantly affects the habits of the civilian population and prevents many of them from leading a normal life. There are accurate statistics on the number of mines removed from areas already cleared and from these we can calculate the density of mines per sq m which has given rise to this unacceptable level of risk. Figure 1 presents this information graphically and the following table presents some numerical results. Interestingly there is little difference in device density between agricultural and residential areas. The agricultural data includes data for grazing areas.

336 residential minefields:

    70% minefields < 0.004

    32% minefields < 0.001

1174 agricultural minefields:

    81% minefields < 0.004

    55% minefields < 0.001

Table 1: Number of minefields with fewer than 0.001 or 0.004 devices (mines and UXO) which were cleared, per square metre. Source: Data supplied by Mine Action Program for Afghanistan.

In recent discussions on a new quality standard for demining (GICHD 2000) there was a proposal for a new approach to demining quality standards: an acceptable quality level (AQL) derived from international standards on quality control inspection (ISO 2859). It is presumed that this specification applies at a certain depth below the ground surface. According to informed sources, an acceptable quality level of about 0.3% (0.003, or 3 devices per 1000 square metres) was proposed. We can see from figure 1 that a majority of minefields in Afghanistan had lower device densities before mine clearance started!

It is not easy to decide what level of risk is acceptable. Further, it is difficult to assess the actual extent of mine clearance in terms of the percentage of devices removed. It is generally accepted that the level of risk on cleared land is acceptably low for the population to resume a normal life. Let us assume, as a reasonable estimate, that 99% of devices have been cleared. Using the data presented in figure 1 we can then make some estimates of an acceptable quality level for demining. Given that nearly all minefields have a contamination level of < 0.01 we can expect that the contamination level after clearance is less than 0.0001 because clearance removes (by our assumption) 99% of all devices. We know from field experience that current clearance levels being achieved by demining teams are acceptable. There is clearly a considerable degree of uncertainty: the data tells us that 0.001 is unacceptable since around half the minefields have a lower level of contamination before clearance. The few minefields which have higher mine densities than 0.01 are likely to attract more care in clearance which may result in clearance of greater than 99%. Given that most minefields will have less than 0.00001 after clearance, we can conclude that an acceptable quality level for Afghanistan lies somewhere between 0.00001 and 0.0001 devices per sq m.

The factor missing from this argument is the link between device depth and the risk of an accident. This is strongly dependent on the type of device and the ground conditions so there will be a large variation. Given that about 90% of mines cleared in Afghanistan are PMN-1 which are very sensitive compared with other common mine types, it is possible that clearance levels have to be better in Afghanistan than in other countries where less sensitive types of mines predominate.

The depth of clearance will be strongly dependent on the detectability of the mine. Minimum metal mines pose well known problems in this respect. Later sections of this paper treat the issue of clearance depth in more detail.

This method of calculating acceptable quality level is relatively simple but does not take into account regional variations in land use, nor the higher risk of incidents which may occur once a large population returns to use the land. The statistical data has been analysed for one country but similar data is readily available in most other countries with mine clearance programs. There is also an in-built assumption of clearance effectiveness (99%). However, using techniques described later in this paper, it is possible to measure the clearance effectiveness being achieved by deminers and hence replace this assumption with real data.

Inspection Requirements

How can we prove that this level of quality has been achieved? Standard formulae for quality control inspection can be applied in this instance such as those provided in ISO2859. However, the probability of finding any mines is very small, especially after clearance. Given an acceptable quality level of 0.0001, the standards tell us that we have to inspect almost the entire minefield area to be confident of clearance. Clearly, the 5 percent or 10 percent inspection typically carried out is not adequate to prove clearance at this level of quality.

There is a further difficulty with this approach. In many instances the technique used for quality control is the same, or is a minor variation on the manual demining method used for clearance. Therefore, a target missed in the original clearance may well be missed again in the quality control check.

We can conclude from this that quality control inspections alone cannot reliably confirm that deminers have achieved quality levels which would probably be considered acceptable in Afghanistan. It would be useful to analyse quality inspection reports from Afghanistan to model the statistics of quality control inspections which have been done.

Measuring Quality Levels During Demining

The reason why normal quality inspections cannot reliably confirm clearance quality is that the probability of finding a missed mine is likely to be very low. If the original number of mines were larger and the demining quality level was numerically larger (ie more mines remaining per sq metre), then the probability of finding a missed mine would higher. The area of ground which needs to be inspected would therefore be smaller and the inspection would be less expensive.

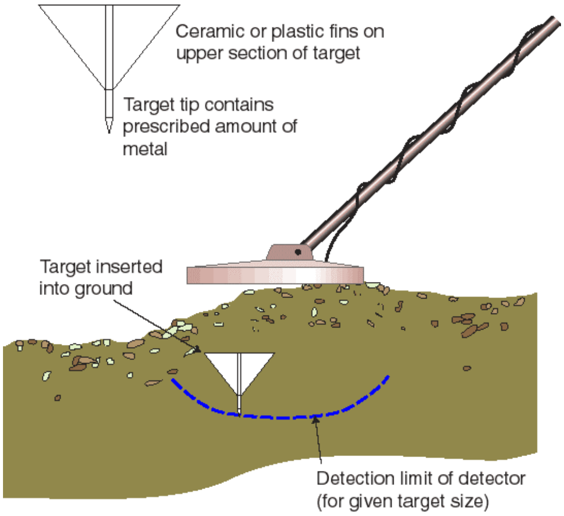

Figure 2: Target for measuring detection probability. Target can be detected by probing or metal detector (from Trevelyan 1999).

We can overcome this problem by inserting a reasonable number of known targets into the minefield before or during clearance. Targets can be placed randomly in an area to be cleared. Given an appropriate number of targets, we can calculate the quality level of demining achieved by the deminers by measuring the proportion of targets they recover. Trevelyan (1999) presents detailed aspects of this method, including statistical modelling calculations.

There are two groups of targets required. One group of targets is inserted into the ground at varying depths up to the limit of detection for the particular metal detector being used. The proportion of these targets recovered will reveal the effective detection depth of the demining process.

The second group of targets is placed on or near the surface so they are easily detectable. The proportion of these targets recovered by deminers will reveal the proportion of the minefield area has been missed by the deminers. For example, it can be shown that if deminers find all of the 200 targets distributed randomly across an area, we can be 90% sure that the deminers have covered 99% of the area. We suggested above that this level of clearance will nearly always be sufficient to achieve the acceptable quality level calculated for Afghanistan in this paper. The number of targets is very small compared to the number of fragments typically removed from minefields.

Practical Issues

For this method to be effective it is important that the targets are randomly placed and that the deminers have no way of telling where the next target is likely to be or how many targets have been placed. A computer program is a convenient way to generate target positions and depths to meet this requirement.

There are however a number of practical issues to be resolved. Perhaps the most obvious is the difficulty of inserting targets into uncleared minefields. Fortunately, there are a number of feasible approaches to solve this problem.

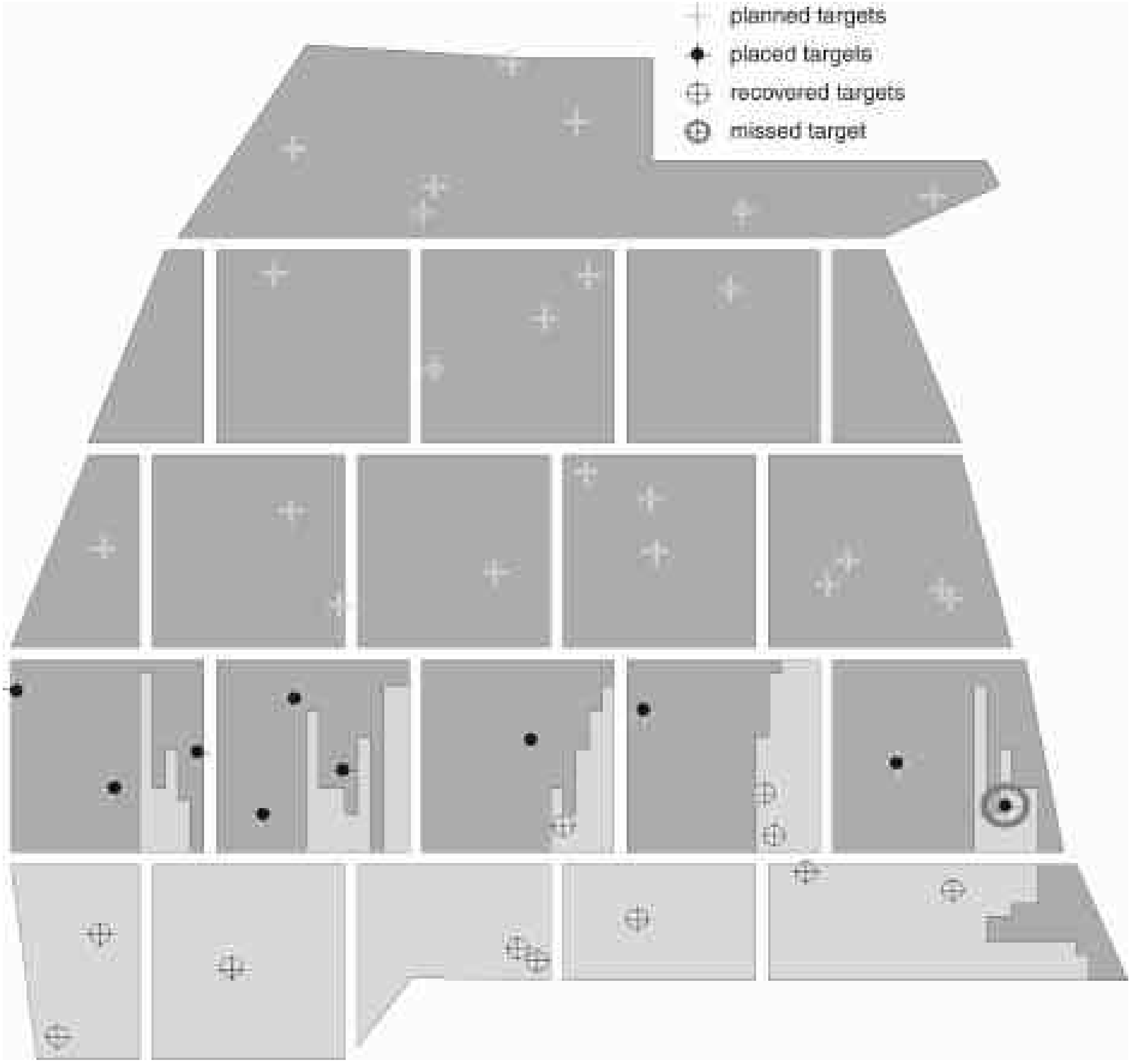

Figure 3: Progressive insertion of targets in a minefield clearance operation. The diagram shows clearance proceeding from the bottom upwards. Safe lanes have been cleared manuually to subdivide the minefield into manageable blocks (or boxes). Targets have only been inserted close to the current area of clearance activity. One target is marked as "missed", but this could be due to minor errors. The adjacent area is still to be cleared and the target may be found there.

There is no need to distribute all the targets in one operation. The targets can be placed everyday or two, given a typical rate of manual demining. Manually cleared access lanes provide more than sufficient access to any area likely to be cleared the following day or even week. Figure 3 illustrates this progressive method of distributing targets.

Remember that there are two kinds of targets: shallow targets to check area coverage and deeper targets to measure detection depth.

In the common case of a standing operating procedure (SOP) which requires deminers to find and remove all metal fragments using metal detectors and prodding, the standard targets can be made as small pieces of metal stamped with a unique identification number. The shallow targets can simply be thrown to their locations by hand. Given that the maximum throwing distance is likely to be only 5 – 7 metres (the distance from the nearest safe lane as shown in figure 3), reasonable accuracy can be achieved this way. In most terrain it will not be possible to find the targets except with a metal detector: they will simply disappear into the vegetation and ground cover. It would be advisable to ensure that the targets are a similar colour to the ground cover: encasing the targets with moulded plastic would be a cheap and durable solution.

The next issue is avoiding errors in recording which targets are found and their locations. The target numbers need to be designed with check digits[1] to detect transcription errors. Deminers will need a special procedure for marking target positions. For example, deminers could mark the position of each target located using a small green flag containing a pocket in which the target itself is placed. A few minutes later, the section leader or team leader collects the target and marks the position of the flag on the minefield map. This is essential to check that the targets were found in the correct sequence and locations. Finally, any targets which have been missed must be located. The original plan will show where the target was supposed to have been placed so the effort required to locate it should not be great provided the initial placement was reasonably accurate. There is also the chance that the target will be discarded as a metal fragment: some care is required by the deminer but this is not unreasonable given the aim of mine clearance.

The deeper targets required to check the depth of detection can be placed in the cleared areas of the minefield which are then checked again by deminers using metal detectors. Fewer targets are required for this: Trevelyan (1999) suggests that 40 to 50 targets should be sufficient.

In situations where probing is used to avoid the need to remove all metal fragments, a target detectable by metal detector and probing would be desirable, as shown in figure 2. This kind of target requires deliberate insertion and cannot be placed by throwing. One method of inserting this kind of target would be for a team leader (or QA inspector) to use a metal detector to work his way into an uncleared area to find a suitable (safe) location to insert a target with a simple hand tool.

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[1] Check digits are commonly used to control transcription errors and there are several well-known techniques used for bar codes, credit card numbers, book reference numbers and so on. See for example: http://www.augustana.ab.ca/~mohrj/algorithms/checkdigit.html

Figure 4: Concept drawing of target insertion tool. The tool is inserted through scrub and vegetation from a safe area up to 6 metres away. On remote activation, the target insertion "gun" rotates to a vertical position (shown) and injects a target into the ground beneath it, to a prescribed depth.

There are alternatives of course. We have commenced a designed study for a remote target insertion tool illustrated in figure 4. This is designed to be used from a nearby access lane. The target insertion tool operates like a builder's nail gun but is triggered remotely when the deminer has retreated the safe distance.

Mechanical Support

If machinery is being used in a minefield to support manual deminers, the machine itself can be used as a protected platform for target insertion. A simple manually operated device would be feasible, though the concept illustrated in figure 4 would may be a useful improvement.

The only satisfactory way to resolve practical problems and to test the validity of this method of measuring demining quality is carefully controlled field trials with several different demining organisations. This work has not yet been started.

Why is quality measurement important?

Measurement of achieved quality lies at the heart of all quality management programs. Texts on quality management assume the ability to measure quality. In typical industrial situations quality can be measured using standard instruments or inspection techniques -- the process of obtaining measurements is usually taken for granted. In service industries quality is usually measured through questionnaires or simple time measurements such as the time a customer waits to be serviced in a queue.

Quality improvement processes rely on measurement for evaluation. One cannot claim to have improved quality without being able to measure it with an accuracy considerably smaller than the degree of improvement.

Without quality measurement it is difficult to compare the quality level from different sources of supply. This lies at the heart of demining debates in several countries: are the commercial operators cutting corners by working too fast? Are the non-government organisations wasting donor funds by working too slowly and cautiously? How much does demining quality depend on the degree of supervision? What is the quality variation between different demining teams? How much does demining quality suffer if teams are given incentives to work faster?

In most industries commercial competition has yielded significant price reductions and performance improvements. Yet commercial competition in demining is seen by many as a retrograde step: commercial competition and the profit motive are seen by these people as having no place in humanitarian demining. They arguments have some validity while there is no effective means of monitoring quality. However, with an effective quality measurement system in place commercial competition is probably one of the best means of improving performance.

Deminers will make fewer mistakes if they receive immediate feedback. The quality measurement process introduced in this paper provides an effective way of doing this. The more traditional approach which uses quality control inspections weeks or months after the original clearance operation is much less likely to be able to do this.

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