Living with UXO

Using Morphological Analysis for Decision Support in Phasing out Military Firing Ranges

Adapted from a Report to the Swedish Armed Forces UXO Program March 2004

Maria Stenström, Peter Westrin & Tom Ritchey

(Contact: ritchey@swemorph.com)

Introduction

In Sweden, the need for military firing ranges[*] is significantly less today then during the Cold War period. Many ranges are currently being phased out, and the official proprietor – the Swedish Fortifications Administration – plans to sell or lease phased-out ranges to civilian users.

However, UXO – UneXploded Ordinance – will always be present on firing ranges. For this reason, these areas cannot simply be turned over – "as is" – to civilian clients. The risk for injury or death due to exploding UXO must be assessed and weighed against the benefit of utilizing the land, and the cost of its clearance.

At the request of the Swedish Armed Forces, a multi-disciplinary group, under the leadership of the Swedish Defense Research Agency (FOI) in Stockholm, is currently developing a socio-technical modeling method, which will support the decision-making process for phasing out military ranges. This executive summary presents the method and the model, as far as it has been developed, up to December 2003.

UXO is the generic term for explosive ammunition or other armaments which, when used either in actual combat or in training, did not explode as intended. There are many reasons for UXO: for example, technical defects in weapon systems or in the ammunition itself, or impact on a surface that is too soft to detonate the fuse. It is difficult to estimate the total volume of UXO in Sweden today, but it is probably in the range of several million units.

Ironically, UXO is the price we pay for the *safety requirements* associated with handling ammunition, both in peacetime and wartime. The most important safety demand is that the firing system or fuse is not prematurely triggered. The warhead of an UXO is often undamaged, protected by its surrounding metal envelope. Since the explosive substances it contains (usually a TNT derivative) are usually chemically stable, it may take many decades before it decomposes into harmless substances.

[*] The term "firing range" will be used here to denote all forms of military training ranges involving UXO.

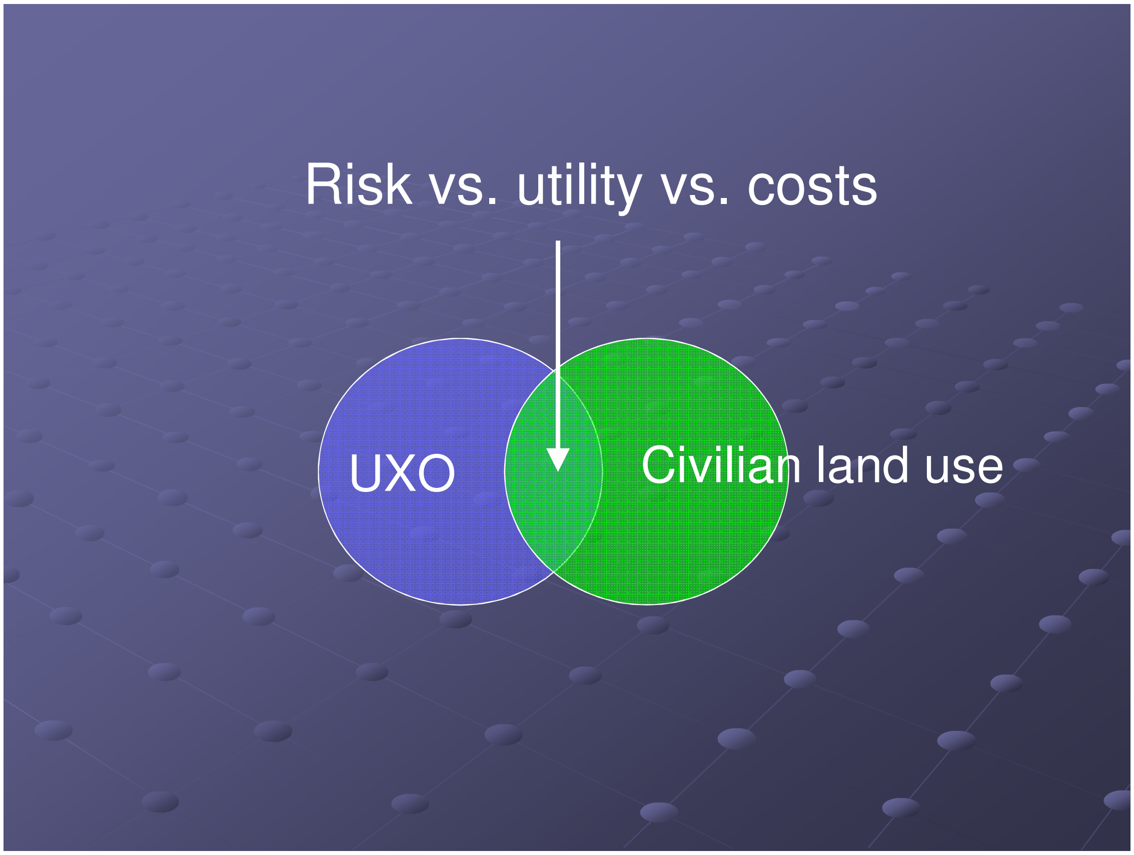

Figure 1. In phasing out military firing ranges, a balance must be found between the risk for injury, the benefit of its civilian utilization, and the cost of clearance.

UXO is the generic term for explosive ammunition or other armaments which, when used either in actual combat or in training, did not explode as intended. There are many reasons for UXO: for example, technical defects in weapon systems or in the ammunition itself, or impact on a surface that is too soft to detonate the fuse. It is difficult to estimate the total volume of UXO in Sweden today, but it is probably in the range of several million units.

Ironically, UXO is the price we pay for the *safety requirements* associated with handling ammunition, both in peacetime and wartime. The most important safety demand is that the firing system or fuse is not prematurely triggered. The warhead of an UXO is often undamaged, protected by its surrounding metal envelope. Since the explosive substances it contains (usually a TNT derivative) are usually chemically stable, it may take many decades before it decomposes into harmless substances.

When attempting to locate UXO on a firing range, one must begin by identifying the *target areas*. These are the areas that were *intended to be hit* by the artillery or other weaponry involved. The determination of the boundaries of these areas can be a difficult task, especially if the range has been in use for a longer time period, since particular target areas can have been abandoned and forgotten over the years.

Within a particular target area, there are often *hot spots* – areas with particularly high concentrations of UXO. In extreme cases, UXO density can reach a level of 10.000 units per hectare (c. 4000 per acre). Immediately surrounding a main target area is a *risk zone*, in which ammunition *may* have landed by mistake – either because of technical or human error (see Figure 2, below).

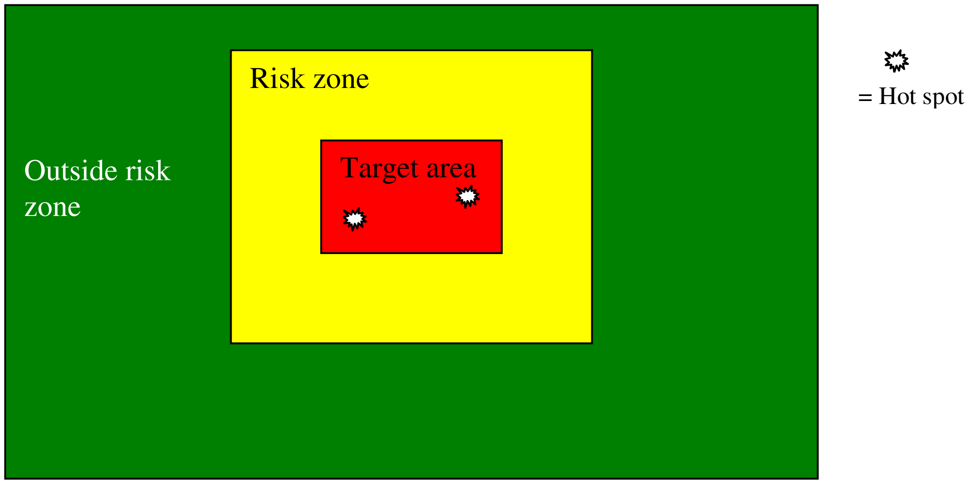

Figure 2. Within a firing range, there are four types of areas; target areas, hot spots within target areas, risk zone and remaining areas, with varying concentrations of UXO.

UXO can be found at different depths in the ground – from 0 to 10 meters – depending on surface conditions, type of ammunition and angle of impact. One rule of thumb is: the larger the caliber, the deeper the UXO. However, most UXO lie no deeper than 1 meter (c. 3.3 feet).

UXO does not necessarily keep still and remain at the same depth forever. One reason for this is so-called frost heave, in which hard objects like stones – or UXO – are gradually lifted by the seasonal action of freezing and thawing soil. In large portions of Sweden, frost heave can raise objects 0.5 to 2.5 centimeters (c. one inch) per year. This means that UXO, which lie at a depth of 20 centimeters today, can be transported to the surface with 10 to 20 years.

Localizing UXO is accomplished by surface prospecting and surface probing. Surface prospecting involves searching for UXO, which are visible to the unaided eye. Surface probing involves using *mine detectors* or *ammunition clearance detectors* (ACD). Mine detectors scan to a depth of c. 30 centimeters and detect all metallic objects larger than a given size.

ACDs detect only ferromagnetic objects and can localize larger objects – such as bombs – up to a depth of 5 meters (c. 16 feet). With a positive reading, clearance personnel must carefully excavate the object and – if it is, in fact, an UXO – disarm it, often on the spot. It should be noted, however, that there are often a great number "false alarms" associated with surface probing.

A complex socio-technical problem

UXO clearance is both expensive and time consuming. Furthermore, competence in this area is in short supply. It is therefore important to focus resources where they are most needed and where they give the most effective results. Some areas within a range can be relatively simple to restore for recreational use. Other areas can be so difficult to clear that the costs do not motivate the utility. Still other areas may require a detailed analysis in order to determine the balance between the risks involved and the utility of land use. It is this trade-off which must be considered before an UXO area can be returned to civilian use.

The total UXO issue is a complex one. It involves military technology, economics, geology, botany, ethics, community planning, and human behavior – as well as physics and the operational analysis of search and probe techniques. The problem complex also involves considerable uncertainty as to the how much UXO actually exists in any given range, what types of UXO are present and how sensitive these are to physical impacts or heat.

This means that the entire UXO problem must often be dealt with on the basis of judgments and estimations, rather than on "objective facts", which can be exceedingly difficult to establish with any certainly. One method, which has been developed to treat complex problems of this type, is *general morphological analysis* (GMA – see summary at the end of this report).

A cross-disciplinary working group, established by FOI, has worked with the UXO-problem since the Spring of 2002. Its aim – with the aid of morphological analysis – has been to structure the problem complex and to develop a model and a process for UXO risk assessment, in connection with the phasing out of military firing ranges. The process involved is primarily designed for use on ranges that have not been earlier mapped and risk assessed.

One might be tempted to regard the UXO issue as a purely technical one. However, the decision to phase out a firing range is a far more complex issue, involving both technical and social-political aspects. This means that one must consider the organizational, political and legal constraints surrounding the technical issues, as well as public health concerns. The structure of the problem complex has resulted in overall model which is divided into three fairly distinct steps (Figure 3, below).

1. The known facts about an UXO field – which is mainly concerned with technical and geological issues.
2. Risk and uncertainly analysis (technical, organizational and behaviorist issues).
3. Measures to be taken (technical, economic and legal issues).

In each step, we have developed a number of morphological fields, which support the gathering and compilation of the known "facts", their documentation and evaluation. Based on this, we have further developed a total evaluation process, which provides step-by-step support for decision making in connection with the phasing out of firing ranges.

The evaluation process

The evaluation process for a specific range should be carried out by a locally (municipal) based working group, combining civilian and military competence with knowledge of local conditions and local municipal planning. The working group is supported in the evaluation process by persons well versed in UXO issues and by experienced process facilitators.

Since much of the UXO-issue concerns genuine uncertainty – and not detailed quantitative risk –, an open and well-documented dialogue within the group is necessary, in order that the evaluation lead to well-grounded decisions. The overall goal is to develop a process, along with supporting tools and resources, in such a way as to facilitate such a dialogue.

The evaluation process is built on the three-tiered process consisting of the following steps.

Step 1. Compilation of UXO facts
Step 2. Uncertainty analysis
Step 3. Risk evaluation and selection of measures to be taken

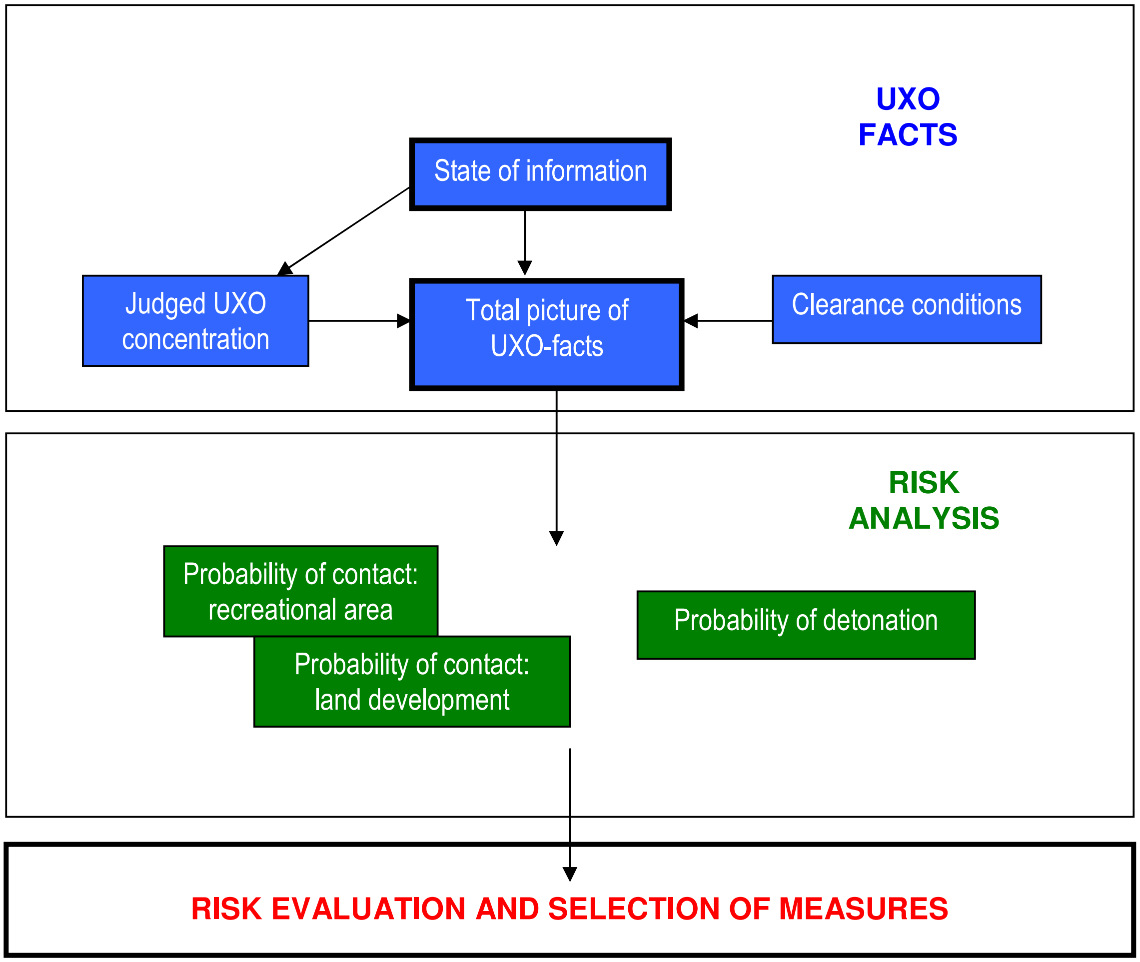

Figure 3. The UXO- problem complex structured in three steps.

Step 1. Compilation of UXO facts.

A. Selection of "sub-areas"

Here, the morphological field *Information status* is constructed to give a first sub-division of the firing range into sub-areas. These should be documented and designated on a map. The sub-divisions include: hot spots, target areas, risk zones, outside risk zones. A sub-area should be as homogenous as possible as concerns geology, vegetation, types and frequency of UXO, and other clearance conditions. Each sub-area and time period is associated with the particular military activity, which was carried out in the area, as well as the type of information sources on UXO. Finally, an overall judgment about the sub-area's condition is given. The morphological field thus summarizes the information status of the area (see example in Figure 4, below).

Estimating UXO-densities

UXO density is a key issue in the evaluation process. Ideally, one would like to base decisions on detailed UXO reconnaissance. However, this is not always possible, and – at least initially – one often has to be content with theoretical estimations. In order to support such estimations, we have developed a morphological field concerning *Estimated UXO-density* (Figure 5, below).

Sub-area (in given field)	Type of area	Period of activity	Type of military activity	Source of information	Area properties
1	Hot spot in target area	Since end of Cold War 1990-	Air Force target	Reconnaissance (statistically secure)	Less complex Good knowledge
2	Target area (not hot spot)	During Cold War 1970-1989	Infantry and armoured vehicle target	Written reports (known to be trustworthy)	Complex Good knowledge
3	Risk area	During Cold War 1945-1969	Artillery fire	First hand oral reports	Less complex Poor knowledge
4	Outside risk area	During WW2 1939-1945	Anti-aircraft	Sampling with instruments	Complex Poor knowledge
5		Between wars 1919-1938		Military analysis 1 In situ	
		Before and during WW1 1880 - 1918		Latest surface prospecting	
				Military analysis 2 By map	
				Second hand reports	

Figure 4. Information status. In the example, a sub-area is judged to be a target area, which was used during World War II and the Cold War period for infantry and artillery. The source of information is "military experience". The area is judged as being complex, with a poorly developed information base.

Sub-area	Type of ammunition	UXO generation	Impact angel	Proportion UXO of fired ammunition	How much ammunition fired?	Estimated UXO density	Median UXO depth
1	Type 20 mm High explosive shell ca 0.12 kg	Soft impact	Bombing trajectory	30%	100 000 rounds/ha or more	1 000/ha or more	0 - 0,3 m
2	Type 30 mm High explosive shell ca 0.22 kg	Impact in dense forest	Flat trajectory Direct fire	10%	30 000 rounds/ha	100/ha	0.3 - 0,5 m
3	Type 40 mm High explosive shell ca 0.9 kg	Hard impact		3%	10 000 rounds/ha	10/ha	0,5 - 1 m
4	Type 57 mm High explosive shell 2.4 kg			1 %	3 000 rounds/ha	1/ha or less	Deeper than 1 m
5	Type 80 mm Mortar 3.4 kg			0,1 %	1 000 rounds/ha or less		
	Type 12 cm Mortar alt 10.5 cm high explosive shell 13 kg						
	Type 15.5 cm High explosive shell 50 Kg						
	Bomb 120 kg						

Figure 5. Estimated UXO-density. The input data concern the known facts and judgments about what type and how much ammunition has been expended during the range's entire period of activity.

Conditions for clearance

In the matrix *Conditions for clearance (Figure 6)*, one describes the conditions for surface probing. This matrix will also be used in step 3, *choice of measures*.

Sub-area	Vegetation conditions (at present)	Interference: Occurrence of fragments	General interference level	Excavation conditions	Conditions for surface probing
1	Brushwood	> 10 fragments /m2	High	Loose collapsing/ sliding earth	Easy
2	Forest with undergrowth	2 - 10 fragments /m2	Middle	Roots	Middle
3	Low vegetation	1 fragment /m2 or less	Low	Firm Stratified	Difficult
4	Forest without undergrowth	Fragment free	Discriminative	Loose Stratified	
5	Meadow Grass		None	Stony	
	Bare ground			Quarry Pitted	

Figure 6. Clearance conditions. The conditions in the example above indicate that it will be difficult to carry out a surface probe of the area in question.

Sub-area	Judged type of area	Sub-area's characteristics	Type of ammunition	Estimated OXA density	Median depth	Type of detonator and measure of sensitivity	Conditions for surface probe	"Initial decision"
1	Hotspot	Not complex Good knowledge	Type 20 mm high explosive shell	1 000/hectare or more	0 - 0,3 meters	Copper acidic formation	Easy	Status quo -- retain area as is
2	Target area exclusive hotspots	Complex Good knowledge	Type 30 mm high explosive shell	100/hectare	0.3 - 0,5 meters	AD mechanical	Middle	Collect additional UXO facts
3	Risk zone	Not complex Poor knowledge	Type 40 mm high explosive shell	10/hectare	0,5 - 1 meters	Mechanical detonator	Difficult	Continue with evaluation process
4	Outside risk zone	Complex Poor knowledge	Type 57 mm high explosive shell	1/hectare or less	Deeper 1 meter	Electrical detonator		Class area as safe for all activities
5			Type 80 mm mortar 3.4 kg			Electrical detonator with drained battery		
			Type 12 cm mortar alt. 10.5 cm high explosive shell 13 kg			Pyrotechnic detonator		
			Type 15.5 cm high explosive shell 50 kg			AD electric		
			High explosive bomb 120 kg					

Figure 7. Synthesis of UXO-facts. The judgment in this example is that more information should be acquired before the study of this area can continue.

Synthesis of "UXO-facts"

The matrix "*Synthesis of UXO-facts*" is used to summarize the most important empirical technical and geological conditions concerning a range. It supports classifying the UXO-sub-area into such categories as: a) should not be transferred to civilian sector at present time, b) further study required for decision to be made, c) can be transferred and utilized for restricted (specified) types of activities, but the evaluation process should continue, or d) can be transferred and utilized for all type of activities. Figure 7 (above) is an example of the description of such a sub-area.

Step 2: Risk and uncertainty analysis

We do not employ the term "risk" (R) here in its purely technical meaning: i.e. the (quantitative) *probability* (x) that something with measurable negative *consequences* (k) will occur.

- $R = xk$.

In the case of UXO, we use another approach. We deem the *consequences* of UXO-related injury or death as (socially and politically) unacceptable. We therefore wish to estimate the "risk" of such an (unacceptable) occurrence by estimating the likelihood of people coming into contact with UXO and the likelihood of UXO actually detonating because of such contact. Thus:

- Risk of an UXO-occurrence = *likelihood of contact with UXO* x *likelihood of detonation on contact*.

It is the two "likelihoods" on the right-hand side of the "equation" which must be estimated and reduced below some (politically) acceptable level.

The choice of sub-areas from the perspective of "land use"

We base our (primarily qualitative) risk analysis on the *likelihood* of contact with UXO, and the *likelihood* of it detonating on contact. These two "likelihoods" both depend on the types of activities being carried out in an UXO-area. In the first phase of the analysis, therefore, we divide areas into sub-areas based on the possible or desired *forms of activities* that may be carried out there. (The two major forms of activities we are concerned with are land excavation or recreational activities.)

At suitable point of departure for this subdivision is a municipality's land use plans. In the same way that we worked in defining the UXO-areas themselves ("UXO-Facts"), we use the UXO-area map and transparent plastic overlays. The area's subdivision according to *land use* may differ considerably from the subdivision according to "UXO-Facts". However, these two aspects of the problem will be overlaid and adjusted in phase 3 of the analysis.

The likelihood of contact

Two morphological fields, *Contact: Recreation* (Figure 8) and *Contact: Land Excavation* (e.g. for building purposes, Figure 9), are employed to facilitate the judgments concerning the likelihood of contact with UXO for different types of activities. The judgments are based on earlier compiled facts concerning UXO types and densities, and by statistical estimates.

Recreational use and land excavation are quite different activities from the point of view of UXO-contact. While recreational activities most often involve only the surface use of land, it is not easy to control what people are will actually do. This means that the likelihood for contact must be estimated from purely theoretical models and the types of activities involved.

Land excavation, on the other hand, involves the possibility of coming into contact with all existing UXO, at least down to depth that is being excavated. However, excavation is usually a one-time activity, requires a building permit and can be more effectively controlled.

Dominant type of activity	Ground conditions (attenuation)	Means of potential contact	Maximum contact depth (down to ...)	Hours of activity per year and area	UXO-density units/ha) down to max. contact depth	k (contact-coefficient)	Number of contacts per year
Lighting fires	Sand	Heating of ground	5 cm	100 000	1 000	1	>= 100
Motor vehicle	Loose stratified	Hard impact causing structural dislocation	15 cm	10 000	100	0,1	10
Riding	Hard stratified	Hard impact	30 cm	1 000	10	0,01	1
Area for recreational walks		Soft impact causing structural dislocation	100 cm	100	<=1	E-4	0,1
Sandy beach recreation		Soft impact		10		E-6	<= 0,01
Golf		Structural dislocation without impact				E-8	

*Figure 8. Likelihood of contact for recreational activities. (k – the contact coefficient – is defined such that, N = k * hours of activity/yr-area * UXO-density down to maximum contact depth. This gives the estimated number of contacts per year and area.)*

Area	Type of activity	Area to be worked	UXO-density (units/ha) within excavation depth	Number of UXO contacted within area
A	Vehicle and equipment transport with area	100 ha	10 000	>=10 000
B	Felling and logging - down to 30 cm	10 ha	1000	1 000
C	Ploughing - down to 40 cm	1 ha	100	100
D	Machine excavating at point - down to 1 meter	1 000 m2	10	10
E	Machine excavating for fencing or pipe laying - down to 1 meter	100 m2	1	1
	Machine excavating large surface - down to 1 meter	10 m2		0,1
	Pile-driving down to 10 meters			Close to zero

Figure 9. Likelihood of contact for land excavation.

Likelihood of detonation

The morphological field *Likelihood of Detonation* is used to facilitate an estimation of this factor. Different "means of contact" are taken from the *Likelihood of Contact* matrices for different activities (e.g. hard impact on surface). Existing UXO-types and detonation sensitivities are taken from *UXO-Facts*. Figure 10 (below) is an example.

Presence of UXO of type:	Type of detonator and measure of sensitivity	Type contact: Hard impact (machine metal on metall)	Type contact: Medium impact	Type contact: Light impact	Type contact: Change of position	Type contact: Heat	Type contact: Spark/ EM-pulse
Bomb	Copper acidic formation	Very high probability (Close to 100%)	Very high probability (Close to 100%)	Very high probability (Close to 100%)	Very high probability (Close to 100%)	Very high probability (Close to 100%)	Very high probability (Close to 100%)
Missile	AD mechanical	Neither very high nor very low probability	Neither very high nor very low probability	Neither very high nor very low probability	Neither very high nor very low probability	Neither very high nor very low probability	Neither very high nor very low probability
Rocket	Mechanical detonator	Very low probability (Close to 0%)	Very low probability (Close to 0%)	Very low probability (Close to 0%)	Very low probability (Close to 0%)	Very low probability (Close to 0%)	Very low probability (Close to 0%)
Shell	Electrical detonator						
Warhead segment	Electrical detonator with drained battery						
Hand grenade	Pyrotechnic detonator						
Signal, smoke and gas ammunition	AD electric						

Figure 10. Likelihood of detonation. Example: a common type of high explosive shell with a mechanical fuse.

Phase 3: Risk assessment and selection of methods

Risk assessment

The first step is to compare and adjust the two, defined types of geographical sub-divisions, which were traced onto the plastic overlays: *UXO-type* areas and *Land use* areas. This is a simple matter of placing both of the overlays over the UXO-field map, and seeing how their respective divisions differ. Risk for each area is then evaluated according to the following classifications:

A. The sub-area contains UXO of such high density, or involves such great difficulties for clearance, that the cost of surface clearance far outweighs its social utility. The area should – for the time being – remain in the custody of the armed forces. (Employ *UXO-fact* matrix and *Cost key* matrix.)

B. The sub-area has the density, depth and UXO-type characteristics such that the stipulated land use allows for acceptable (low) risk without any special measures being taken. (Employ *Contact-likelihood* matrixes.)

C. The sub-area can be utilized for the stipulated activities after suitable (cost acceptable) measure have been taken. (Employ *Contact-likelihood* matrix, *Cost-key* matrix and *Measures list*.)

D. Knowledge about the sub-area is too sparse to allow the area to be classed according categories A to C. *This should come to light as early as possible in the evaluation process.*

Risk estimates can, and should, be made during the entire range-evaluation process. The earlier one can establish, *with reasonable assurance*, that a sub-area belongs to one of the categories A, B or C, the easier the entire range-evaluation will become. For instance, it may be that UXO densities are judged – early on – to be so low in a specific area, that any type of activity could be allowed. Conversely, an area may be established to have such high densities of UXO that no reasonable amount of clearance – at least at any reasonable price – would suffice to motivate turning it over for civilian use.

It is also important to determine – as early as possible – when sufficient knowledge is lacking, so as not to waste time and effort on especially difficult or uncertain areas. On top of this, all information, decisions and motivations should be carefully documented, in order to have the empirical data for future "experienced base" modeling[*].

The sub-areas, which belong to Category C (above), are those which will be further analyzed. Here we must pit the costs of clearance against the utility of land use.

Selection of UXO contact reduction methods

The principal ambition is to reduce potential contact with UXO to an acceptable level. Examples of methods for doing this include:

- Concentrated clearance in connection with building construction (including installation of underground pipes and cables)
- Periodic surface probing in case of frost heave
- Restrictions, e.g. prohibiting fires, camping or horse riding, and directing such activities to fully cleared areas
- Instead of excavating, covering areas with adequate layers of protective earth, e.g. for golf ranges, parks or gardens.

Costs of physical clearance depend upon the *clearance conditions* (figure 6). We have developed preliminary cost indicators, which translate into labor-time and material costs. Clearly, the choice of clearance as the primary method for reducing potential contact with UXO will depend on the estimated market value of the land (based on the utility of the planed land-use). This value must exceed, or be roughly equivalent to, the cost of clearance. This means that the clearance of very large areas is not practical at the present time, both due to the costs involved, and due to the fact that requisite civilian competence in clearing large areas has not yet been developed.

Conclusions

Learning to live with UXO means being able to balance the utility of land-use against costs and risks. In this case, the risks involve physical injury to the civilian population and the associated social and political consequences of this. Since this whole issue is often based on incomplete and highly uncertain data, it is important that the decision process be transparent and well documented. The ultimate goal is to make sure that those resources, which are

[*] One possibility is Bayesian Network modeling.

directed towards phasing out military training and firing ranges, are used in the most effective possible way, to the greatest benefit to society.

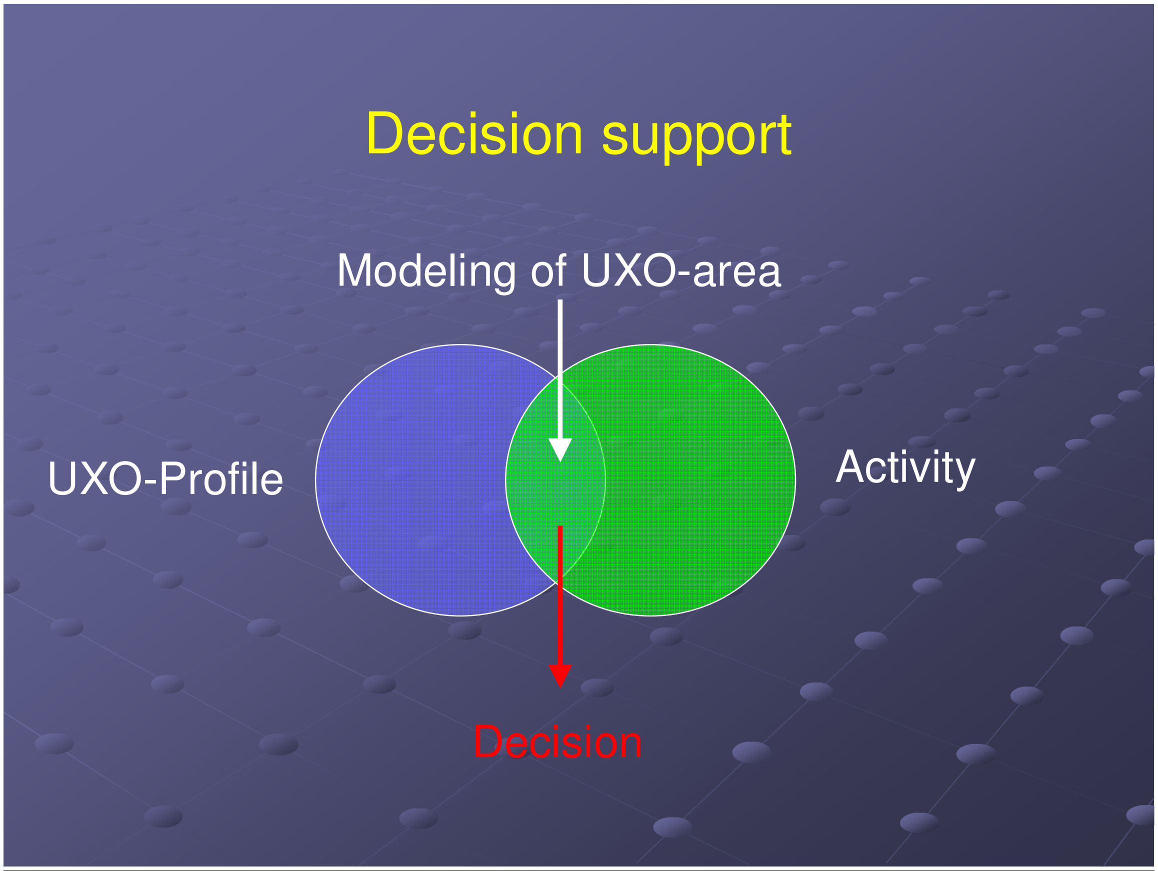

Figure 11. The evaluation process itself furnishes decision support for the phasing out process. The goal is to identify land areas in which the UXO-profile and the desired land use harmonize in an acceptable level of risk – with or without specific measures being taken – at as low a price as possible.

It has not been the ambition of the working group to propose *norms* for classifying levels of risk. The balance between risk and utility must be decided upon at the national political level. This is well in line with other areas of societal risk, for instance policy concerning traffic safety and smoking regulations. FOI's ambition is "simply" to develop a modeling procedure by which *decision alternatives can be clearly formulated*, so that various forms of land development can be compared to estimated risk levels and risk-reducing costs.

The Swedish Armed Forces should be able to reduce costs by phasing out firing ranges. This means that there should be some economic capacity for range clearance. However, the *total* clearance of large UXO infested areas – of which there are several in Sweden – is far beyond current economic possibilities. During our model development, we have assumed that society will be able to accept a certain (although very low) probability of UXO accidents. The notion of "zero tolerance" for such accidents, however, would mean the total suspension of any phasing out of military ranges. Such restrictions on land development would, in turn, result in considerable loss to society.

Appendix:

Computer Aided Morphological Analysis

The term **morphology** comes from classical Greek (*morphe*) and means the study of **shape** or **form**. It is concerned with the structure and arrangement of parts of an object, and how these "conform" to create a whole or Gestalt. The "objects" in question can be physical objects (e.g. an organism, an anatomy or an ecology) or mental objects (e.g. linguistic forms, concepts or systems of ideas).

Morphology – or morphological analysis – is associated with a number of scientific disciplines in which formal structure, and not necessarily quantity, is a central issue. In linguistics, it is the study of word formation. In biology, it deals with the form and structure of organisms, and in geology with the characteristics, configuration and evolution of rocks and landforms.

Morphological analysis is a general method for structuring, analyzing and inter-relating complex systems of variables, which are not meaningfully quantifiable. The method – which was originally developed by Fritz Zwicky, Professor of Astrophysics at the California Institute of Technology in the 1940's and 50's – was expanded and computerized by FOI in 1995. Since then, it has been employed in some 40 projects as a general method for non-quantified modeling for policy and strategy studies.

Computer aided morphological analysis is carried out in groups of subject specialists facilitated by experienced morphologists. The analysis is based primarily on a judgmental approach, since it concerns problems, which cannot simply be treated computationally. However, this judgmental approach is carried out within a solid methodological framework. The process is dialogue intensive and the results are traceable – i.e. the method leaves an "audit trail". In this way, the *process* of building a morphological model is as important as the result.

The *visible* result or output of a morphological analysis is one or more *morphological fields*. A morphological field is a parameter space describing the most important variables of the problem area, along with their internal connections. With computer support, a morphological field becomes a flexible an input-output (or "if-then") model, where any number of variables can be designated as inputs (or drivers), and the rest as outputs.

Computer aided morphological analysis can be employed to systematically develop scenarios, strategies, force requirements and policy alternatives, based on *linked morphological fields* which we call *virtual laboratories*. With the help of such laboratories, hypotheses can be generated and tested.

For more information on morphological analysis, visit: the Swedish Morphological Society at www.swemorph.com.