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Scenario Development and Force Requirements using Morphological Analysis

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SUMMARY

Morphological analysis (MA) is a non-quantified modelling method for structuring and analysing technical, organisational and social problem complexes. It is well suited for developing scenarios, and the method is highly appropriate for complex cases where expertise from several areas is required. It is also useful for developing and relating operational and tactical scenarios to force requirements. Using MA for problem solving or scenario generation typically involves workshop sessions supported by a computer tool. Casper (Computer Aided Scenario and Problem Evaluation Routine) was developed at the Swedish Defence Research Agency (FOI) by Dr. Tom Ritchey in order to support MA work.

An example of how MA is used for the development of a set of scenarios is given. These scenarios were developed for the Swedish Armed Forces' long-term planning and describe a number of long-term strategic situations, including peace support operations. The use of MA to define force requirements will be illustrated briefly by elements of an airborne capability study at the Swedish Army Command.

INTRODUCTION

Development of scenarios is a common task within military analysis, but one that is sometimes approached more as an art than as a science. It is not uncommon that scenarios are developed using the so-called "BOGSAT"[1] method, i.e. involving subject matter specialists but using a rather unstructured approach for developing the scenarios. It is not uncommon that older scenarios, generated with the "BOGSAT" method, are used as a starting point.

A more structured method, which we have found useful for scenario development, is **morphological analysis** (MA). It is also useful for several other applications, such as general problem structuring and force requirements studies. Compared to the development of force requirements in "Cold War" days, we usually need to use a larger number of tactical and operational scenarios to capture the relevant tasks and environments, and we also need to take a larger number of factors into account. Many of these factors involve "small scale contingencies" (e.g. the risk of collateral damage), and are often difficult to quantify and to capture using conventional computer models. MA, a structured approach using judgemental input, can be a useful tool to supplement quantitative data or to structure and parameterise various alternatives.

As some steps in MA benefit greatly from graphic presentation techniques, and other steps require much calculation, the method is considerably easier to apply when supported by a computer implementation. CASPER (Computer Aided Scenario and Problem Evaluation Routine) is such an implementation. MA and different versions of CASPER have been used successfully at FOI (previously FOA) for scenario generation and problem solving for a number of defence-related and other clients since the mid-90s. Dr. Tom Ritchey at FOI has been responsible for developing CASPER and the use of morphological analysis at FOI and in Sweden [Ritchey 1997, Ritchey 1998].

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[1] "Bunch Of Guys Sitting Around a Table"

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This paper is to a large extent based on a presentation given earlier at the Cornwallis VII conference on scenario development using MA [Eriksson 2002] and has been supplemented with some material on force requirements [Kaunitz, Ritchey & Stenström 2002].

WHAT IS MORPHOLOGICAL ANALYSIS?

Morphological analysis is a non-quantified modelling method for structuring and analysing technological, organisational and social problem complexes. It relies on the representation of a problem using a number of parameters (or variables), which are allowed to assume a number of conditions (or states). This is the analysis phase of MA. From these parameters, consistent configurations (alternatives) are derived by considering the consistency between conditions for different parameters in a pair-wise fashion. This is the synthesis phase.

The strength of the method lies in its ability to model problem complexes in a non-quantitative manner, and, using the terminology created by Ackoff, in assisting in transforming "messes"[2] into "problems" [Ackoff 1979, Pidd 1996]. Problem complexes where MA is useful typically contain non-resolvable uncertainties, cannot be causally modelled or simulated, and require a judgmental approach. For this reason, morphological analysis is used in workshop sessions with experts and problem-owners. These workshop sessions are facilitated by a person knowledgeable in the method.

Morphological analysis, or *Morphologie* in German, was pioneered by the Swiss-born astrophysics professor Fritz Zwicky (1898-1974), who was active at California Institute of Technology, and who made important discoveries in the field of supernovae [Zwicky 1966, Ritchey 1998]. Morphological analysis has also been applied to scenario development without the assistance of a computer tool. [Rhyne 1995, Coyle & Yong 1995, Johansen 1996]

THE MORPHOLOGICAL FIELD

In morphological analysis, a morphological field is used to represent the problem, its parameters and the conditions they can assume. The number of parameters is typically too large to represent the problem by using one spatial dimension for each parameter, as when a matrix is used to show alternatives for two parameters (e.g. four-fold tables). Therefore, each of the parameters is shown in a column, with the possible conditions as boxes in the column.

Parameter X	Parameter Y	Parameter Z
X1	Y1	Z1
X2	Y2	Z2
X3	Y3	Z3
X4	Y4	
X5	Y5	

[2] Mess: a complex issue which does not yet have a form or recognisable set of dimensions.

A given configuration, where conditions are assigned to each parameter, is shown by highlighting the relevant conditions for each of the parameters. The configuration above is characterised by X3 – Y4 – Z1 and is one of 5 * 5 * 3 = 75 possible configurations for this morphological field.

ANALYSIS PHASE

In the analysis phase parameters (variables) are identified, followed by ranges of conditions for each parameter. Ideally, the conditions for each variable should be chosen in such a way that they are mutually exclusive. For example, in the morphological field above, X2 and X3 shouldn't be able to coexist. In short, the product of the analysis phase is a morphological field associated with the problem at hand. In the workshop setting, the process is iterative – the initial set of parameters and conditions are typically reworked many times. (Sample morphological fields from real-life applications can be found in the examples later in the paper.)

SYNTHESIS PHASE

Our initial morphological field has a large number of possible configurations. (E.g. 5 * 5 * 5 * 5 * 3 = 1875 in the "environment matrix" of the scenario example found later in the paper.) The synthesis phase allows us to eliminate a large number of these. We do this by judging the consistency between conditions for different parameters. We ask "is condition 1.1 for parameter 1 consistent with condition 2.1 for parameter 2?" and so on – a pair-wise comparison. The result is entered into the cross-consistency matrix. The scale used to judge consistency can vary. As a minimum, a "yes/no" scale can be used, but a scale of 3-4 steps is usually more useful, e.g. "yes – maybe – no". (CASPER allows different scales to be used.)

It is common to continue to modify the morphological field even during the synthesis phase. Once the workshop participants are forced to discuss the consistency of different conditions, it may turn out that they need to be formulated in a different manner, or that different parameters can be combined into one, or that one parameter needs to be split into two. It will also become obvious if different participants use terminology inconsistently when they are forced to discuss the coexistence or consistency of different conditions. Morphologists have experienced many animated discussions in this step! This step in the process also works as a kind of "garbage identifier" – poorly identified conditions can be found and eliminated.

Next, the internally consistent configurations are synthesised. Using a computer tool, it is just a matter of pressing a button. (CASPER performs this step). Behind the button, algorithmically speaking, a quadratic assignment problem is solved. Output is in the form of a list of surviving configurations.

Finally, one or several configurations are used by the working group for further discussion or for the solution of the problem. From this step, it is also possible to go back to a previous step and modify the morphological field or the cross-consistency matrix.

In some cases, more than one morphological field can be used to analyse a problem complex, which may be combined at a later stage. Reasons to do this may be that the number of relevant parameters is large, or that the problem complex consists of two or more aspects, with different parameters, that to some extent are separable.

In a typical application of the method, a two-day workshop would suffice for a relatively small problem area, especially if some of the participants are familiar with the modelling method. For analysing larger, more complex problem areas, 2-5 workshops would be required. It is advantageous to spread out the workshop sessions over time, to allow participants to digest the information between sessions.

A SCENARIO GENERATION EXAMPLE

As an example on how MA and CASPER can be used for scenario generation, we show the creation of a set of six "+20 year environments" and strategic level scenarios for the Swedish Armed Forces. These scenarios were developed for use in long-term planning (defining future force structures, capabilities and investments), and the work was done in 2000[3]. Three of these six scenarios were peace support operations. The reason why a set of several scenarios was used was that we really can't forecast in this time perspective, so we instead need several scenarios as a basis for war-gaming and discussions. It is therefore important to choose the scenarios in a reasonable way. Each of them needs to be consistent and plausible, and together they need to cover a reasonable variety of different developments, "to span the problem space". As a conflicting requirement, the scenarios shouldn't be too many, because then it will not be possible to treat all of them in the continuing analysis process. Furthermore, potential users of the scenarios may lose overview.

There is no golden rule that unequivocally gives the number of scenarios needed. The complexity of the problem, the resources available to analyse the consequences of the scenarios later in the process, and the level of detail desired in each scenarios, will all affect this number.

Morphological analysis can be of great assistance in this process, since
- the problem space is defined in creating the morphological field,
- the workshop method involved can provide a productive forum for structured discussions between subject matter specialists of different disciplines,
- inconsistent configurations are removed in the process,
- having an easily accessible list of surviving configurations assists in choosing configurations to be developed into scenarios, and
- the illustration of different configurations in a morphological field assists the working group in deciding how many, and which, scenarios are needed.

This problem was modelled as two morphological fields:
- An environment matrix that covers the general political, strategic and economic developments judged to be the most relevant to the problem, and that could possibly exist in a given scenario. It consists of five parameters as shown below:

Sweden in Europe	**Russia**	**Relations Europe-USA (Geopolitical perspective)**	**Focus of European (EU) security interests**	**Development in poor countries**
Sweden a state within "US of Europe"	Central control, aggressive and strong	Antagonism	Global peace-keeping and humanitarian ops	Stability and some economic development
Part of regionalized EU	Central control, aggressive and weak	USA weak and isolationist	Strategic interests (resources)	Status quo
Nation-state within EU	Disintegration	USA strong with other focus than Europe	Regions bordering to Europe (PSO)	Crises and wars
Nation-state with bilateral relations	Cooperative and weak	Cooperation between equals	Fortress Europe	
Weak nation-state in weak Europe	Cooperative and strong	USA leading role	No common view/focus or weak ambition	

[3] What is shown here is the "raw" result from the original MA sessions. Since then, some of these scenarios have been slightly modified due to additional policy input and other factors. The raw data is still shown here, since the intention of this paper is to show an example of real-life utilisation of MA from a methodological point of view, rather than to report on current Swedish defence policy.

- A conflict matrix that covers the relevant characteristics of the conflict that the Swedish armed forces are called on to handle within a scenario. It consists of four parameters as shown below:

Location of operation	**Threatened Swedish objects**	**Means of violence**	**Antagonist type**
"At home"	Civilian targets in Sweden	WMD systems	Alliance/state with superpower capacity
Neighbouring region	Military targets in Sweden	Long range precision guided weapons	State/alliance
Europe and surrounding regions	Swedish operations abroad	Conventional joint forces (platforms)	Quasi-state/small state
Rest of world	Swedish interests abroad	Conventional army (platforms)	Paramilitary without territory
		Conventional army (no platforms)	International network
		Simple conventional weapons	Small group/individual
		Limited use of NRBC agents	
		IW only	

The two matrices were first processed separately, and then combined to obtain a combination of strategic environments and conflicts.

It is important to realise that these two matrices, and their cross-consistency matrices (not shown) represent the judgements of the people involved at the time the work was done, and nothing else. They are not shown here as a ”truth” or a scientific result, but as an illustration how MA can be applied to a problem complex of this type.

Finally, six configurations were selected and developed into scenarios under the headings:
- Arctic Region (a warfighting scenario)
- Baltic Link (a warfighting scenario)
- European Peace Enforcement (a peace support operations scenario)
- Disintegrating Russia (a peace support operations scenario)
- Global Peace Keeping (a peace support operations scenario)
- Emerging Threats (a more or less non-military scenario)

Each of these represents a consistent set of conditions for each of the parameters in the two matrices.

In order to produce the scenarios in their final form, text and maps were produced, which is work performed without immediate assistance from morphological analysis. Despite this, the previous discussions in the MA workshops provided focus also for this part of the work.

FORCE REQUIREMENTS

Within force requirement studies, scenario development using MA is also of great importance, although different types of scenarios (more low-level than long-term) are usually required. If the higher-level scenarios have been developed using MA, development of lower-level scenarios using MA may be easier, since material from earlier scenario generation can be used.

However, the use of MA for force requirement studies is not limited to scenario generation. MA can also be used for general problem structuring, e.g. in order to find the most relevant external factors to treat in the requirements process, and for parameterisation of alternatives. The ability of MA to treat several parameters and conditions, while keeping the number of feasible configurations (i.e., alternatives) at a manageable level, is valuable here.

In a recent Airborne Capability study at the Swedish Army Command, MA was used to parameterise the possible alternatives for the ground combat element (an airmobile battalion or elements thereof) and its associated transport helicopters. The resulting matrix is shown below:

Strike key function in urban environment	Troop & Weight	Protection	Transport & Distance	Helicopter alternatives
Combat system 2015-2020	750 st (battalion) 113 tons	Unit as a whole: personnel, equipmqnt, VMS	Equipment and personnel 20 km/h	100 km Maximum
Combat system 2010	600 st (battalion) 90 tons	Equipment: personnel, vehicles	All equipment 4 km/h	100 km Medium
Direct fire & light support	450 st (3 companies) 68 tons	Personal: personnel, equipment	Portion of equipment 2 km/h	100 km Minimum
Direct fire	300 st (2 companies) 45 tons		No vehicles 2 km/h	150 km Maximum
Only light armour piercing weapons	150 st (1 company) 22,5 tons			150 km Medium
				150 km Minimum
				20 km Maximum
				20 km Medium
				20 km Minimum

This matrix was developed for the analysis of a combat task in an urban setting (one of five similar matrices for various tasks). The first parameter describes which combat system is used to strike the intended target. The second parameter describes the troop strength and weight of the unit. The third parameter describes the unit's level of protection. The fourth parameter describes the tactical mobility of the unit without its helicopters, and the fifth parameter describes the tactical flight profile of the helicopters. MA was (as always) used to judge the consistency of the different conditions, e.g is "direct fire" consistent with "no vehicles", in order to arrive at a small number of configurations. In this case, MA was used together with war gaming.

A more full discussion of this case study can be found elsewhere [Kaunitz, Ritchey & Stenström 2002].

SOME ADDITIONAL COMMENTS CONCERNING MA/CASPER

It is important to realise that morphological analysis relies on judgmental input, and therefore is subject to the same limitations as all such methods. (For a presentation of various other such methods applied to non-military problems we recommend the book "Rational Analysis for a Problematic World" [Rosenhead & Mingers 2001].) For problems where a thorough qualitative evaluation is needed (e.g. for analysing logistical requirements of a military operation), or where detailed modelling of temporal and spatial relationships may be needed to fully grasp the problem (e.g. evaluating the outcome of combat), morphological analysis is less suited as a one-method approach to the problem. However, more often than not, a problem suitable for quantitative methods needs to be structured before it is amenable to detailed modelling, and the results of simulations may need to be put within a larger context to be of maximum use. In such cases, it may still be of value to use MA in a part of the analysis and problem-solving process.

CASPER supports the entire MA process and provides an easy-to-understand interface to the user. It is implemented as a PC/Windows programme written in C++ and Objective Grid. The MA modelling platform was designed and implemented by FOI, initially using specific funding from the Swedish Armed Forces, and is not marketed as a commercial product. Rather, FOI has used it for commissioned research, analysis and problem solving where FOI personnel work together with clients. The reason for this is that a successful application of morphological analysis to a "mess" requires strong facilitation by an analyst experienced in the method, and has therefore been judged to be less suitable as a "do-it-yourself" software implementation. In order for the client to be able to access the result after the problem modelling has been performed, they are provided with the simplified software MA/CASPER-Viewer. This program allows for viewing of the data and manipulating the configurations, but not for altering the matrices.

Both the method and the software have been proven in some 30 projects since the mid-90s, and the use of the method has been expanding at FOI [Ritchey 1997, Ritchey 1998, Almén et al. 2000, Stenström & Ritchey 2001, Kaunitz, Ritchey & Stenström 2002]. Many of these projects have been within military long-term planning and studies, or civil defence-related. Some applications have been for foreign or international customers.

In working with MA/CASPER, there are limitations in the size of the expert groups (usually not more than 7 persons per facilitated group) and the number of parameters (usually not more than 12) that are possible to handle in a single field. This usually does not prevent a skilled analyst from using the tool, but rather puts some restrictions on how the MA workshop sessions are organised and led.

CONCLUSION

Morphological Analysis supported by the CASPER software…

- handles multi-dimensional problems with non-quantitative factors,
- provides for a well-structured discussion about complex problems,
- is well suited for working with groups of experts that represent different areas of competence,
- produces an "audit trail" and documentation,
- can be used for structuring and evaluating multidimensional problem complexes with non-quantifiable parameters, and
- is well suited for scenario generation.

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Scenario Development and Force Requirements using Morphological Analysis

SWEDISH DEFENCE
RESEARCH AGENCY

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Division of Defence Analysis, Stockholm, Sweden

Specialist Meeting on Analysis of Smaller Scale Contingencies for
Long Term Defence Planning (SAS-037), Winchester, UK, October 2002

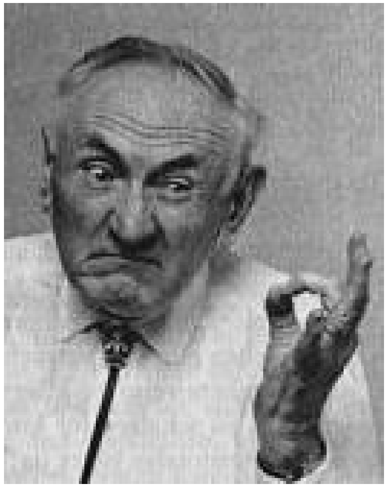
Scenario development

• Scenario development is important to many areas of defence analysis, including long-term planning and force requirement studies.
• Scenarios are often developed used the ”BOGSAT” method and possibly some old scenarios – more attention is often given to subject matter expertise than to a well-structured approach to the scenario development itself.
• Scenarios for SSC and planning for PSOs may need to take a broader range of variables into account, which may called for a wider variety of subject matter experts being used to develop them.
• A well-structured and transparent approach to scenario development is therefore even more important for SSC and planning PSOs.

Morphological analysis is one method that has proven itself useful for this purpose.

What is Morphological Analysis?

• A non-quantified modelling method for structuring and analysing technological, organisational and social problem complexes.
• Typically used for problems that are inherently non-quantifiable, contain non-resolvable uncertainties, are difficult to causally model or simulate, and require a judgmental approach.
• Therefore very suitable for scenario development
• Relies on problem representation using a number of parameters (***analysis phase***), followed by the creation of consistent configurations from these parameters (***synthesis phase***).
• Pioneered by Fritz Zwicky (1898-1974), Professor of Astrophysics at Caltech



1. Simple, general example of morphological analysis

2. Scenario development example

3. Applications in force requirement studies

A Morphological Field – Simple Example

- The morphological field, with one column for each parameter, is a suitable representation for any number of parameters/variables
- Let's analyse the following problem "how to match clothes with weather and occasion" using morphological analysis!

Parameters →

Conditions →

A configuration

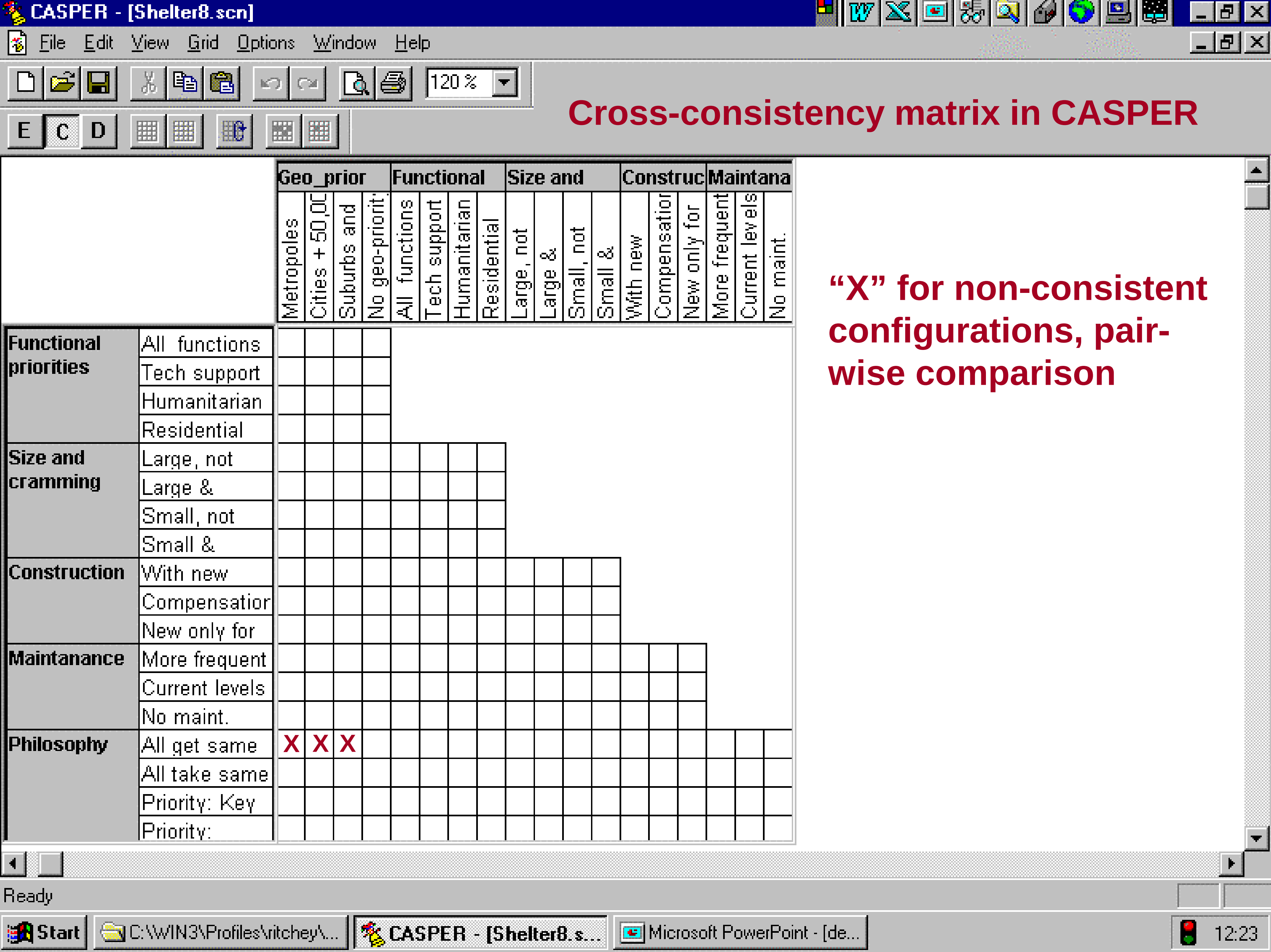
Cross-consistency check

Clothing	Weather: Temperature	Weather: Precipitation	Occasion
Shorts	Freezing	None	Going to work
Pants & Shirt	Mild	Rain	Going to the beach
Suit	Very hot	Snow	Going to the movies
Jacket & Umbrella			

108 configurations

9 configurations less!

Cross-consistency matrix in CASPER



"X" for non-consistent configurations, pair-wise comparison

CASPER - [Shelter8.scn]

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List of consistent configurations

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
Metropoles	All socio-tech. functions	Large, not crammed	**With new construction**	More frequent maintanance	**All get same shelter quality**
Cities + 50,000	Tech support systems	Large & crammed	Compensation	**Current levels**	All take same risk
Suburbs and countryside	**Humanitarian aims**	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	**Small & crammed**			Priority: Needy

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Morphological Analysis and the CASPER software

- Developed at FOI (formerly FOA) by Tom Ritchey.
- Both the method and the software are proven in some 20 projects since the mid-90s.
- It is a tool that uses judgmental input, so it can’t solve the problem on its own and it is no substitute for problem knowledge.
- Provides for a well-structured discussion. The structured analysis works as a “garbage detector” and can help pinpoint areas of disagreement between experts.
- It is well suited for working with groups of experts that represent different areas, and provides an arena for exploring the interrelationship between different parameters.
- Produces an “audit trail” and documentation

A Scenario Development Example

• This example describes how MA/CASPER was used to create **a set** of ”+20 year environments” and strategic level scenarios for the Swedish Armed Forces long-term planning.

Philosophy: we can’t really forecast, so we need several scenarios.

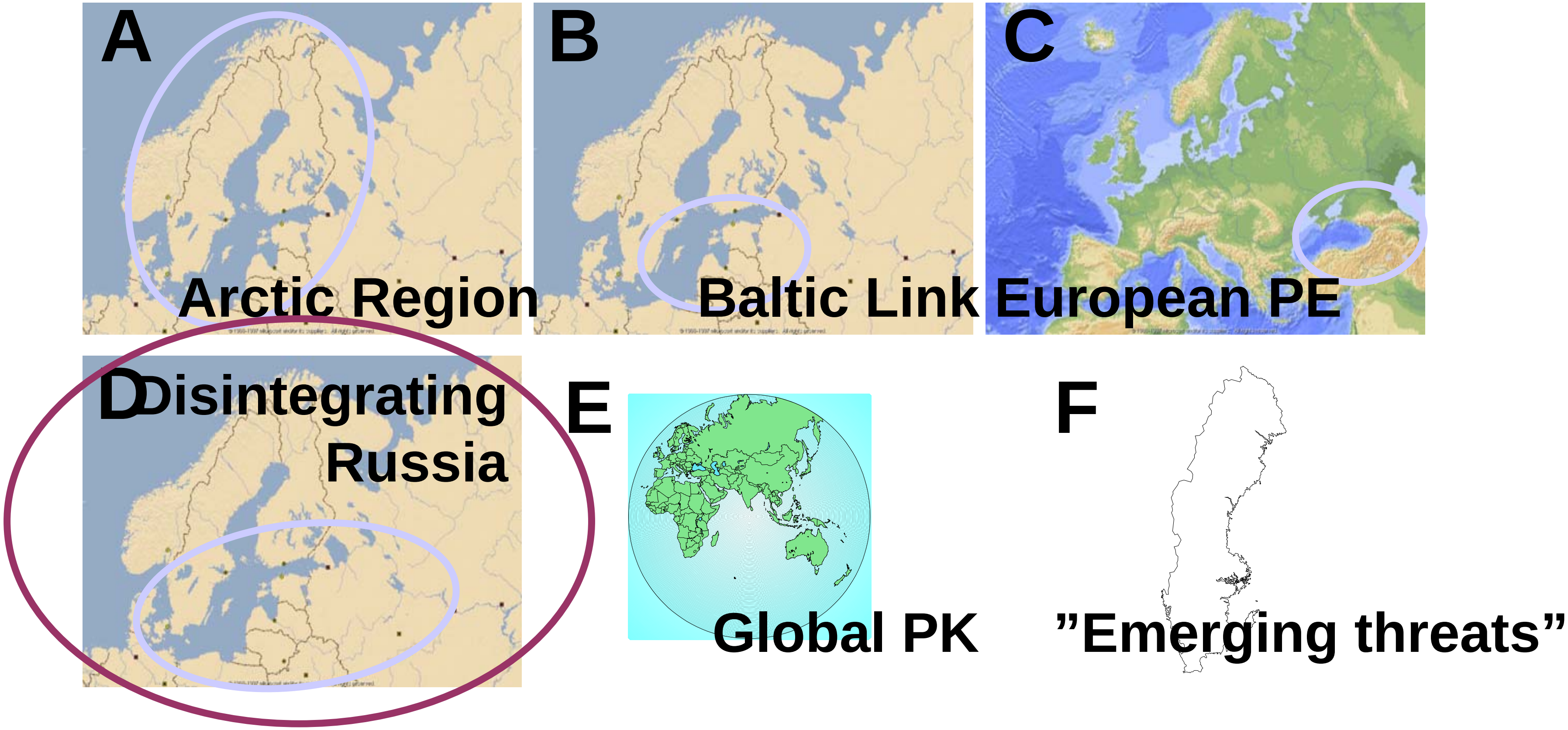
• In the MA/CASPER workshops to create these scenarios typical participation was 2-3 officers, 2 OR analysts, and 2-3 other FOI personnel (MA method specialists and a ”futurist scenario expert”).

• The work was done as two morphological fields in CASPER, an ”environment matrix” and a ”conflict matrix”, which separately went through the steps just shown. They were then connected to each other. For simplicity, just the first one is shown.

Environment Matrix
(one out of two morphological fields for this problem)

Sweden in Europe	Russia	Relations Europe-USA (Geopolitical perspective)	Focus of European (EU) security interests	Development in poor countries
Sweden a state within "US of Europe"	Central control, aggressive and strong	Antagonism	Global peace-keeping and humanitarian ops	Stability and some economic development
Part of regionalized EU	Central control, aggressive and weak	USA weak and isolationist	Strategic interests (resources)	Status quo
Nation-state within EU	Disintegration	USA strong with other focus than Europe	Regions bordering to Europe (PSO)	Crises and wars
Nation-state with bilateral relations	Cooperative and weak	Cooperation between equals	Fortress Europe	
Weak nation-state in weak Europe	Cooperative and strong	USA leading role	No common view/focus or weak ambition	

Thumbnail Images of the Resulting Set of Scenarios



• Each of them represent a consistent set of conditions, and together they span the problem space (both matrices) in the desired manner.

Tomas Eriksson
Division of Defence Analysis

Environment Matrix Configuration for ”Disintegrating Russia”

Sweden in Europe	Russia	Relations Europe-USA (Geopolitical perspective)	Focus of European (EU) security interests	Development in poor countries
Sweden a state within "US of Europe"	Central control, aggressive and strong	Antagonism	Global peace-keeping and humanitarian ops	Stability and some economic development
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Two overlapping configurations gave the same result in the conflict matrix

Morphological analysis in force requirement studies

• These studies also benefit from a structured approach to scenario generation, which will make it simpler to develop subordinate scenarios to allow for more detailed studies.

• MA is useful for general problem structuring, and in finding the factors that are most relevant to a problem. The increasing importance of SSC operations has made additional factors, e.g. collateral damage, relevant and complicated the picture.

• An additional use for is parameterisation of alternatives. The elimination of non-consistent configurations makes it possible to handle more parameters while keeping the number of configurations (alternatives) reasonable.

Morphological field from "airborne capability study"

Strike key function in urban environment	Troop & Weight	Protection	Transport & Distance	Helicopter alternatives
Combat system 2015-2020	750 st (battalion) 113 tons	Unit as a whole: personnel, equipmqnt, VMS	Equipment and personnel 20 km/h	100 km Maximum
Combat system 2010	600 st (battalion) 90 tons	Equipment: personnel, vehicles	All equipment 4 km/h	100 km Medium
Direct fire & light support	450 st (3 companies) 68 tons	Personal: personnel, equipment	Portion of equipment 2 km/h	100 km Minimum
Direct fire	300 st (2 companies) 45 tons		No vehicles 2 km/h	150 km Maximum
Only light armour piercing weapons	150 st (1 company) 22,5 tons			150 km Medium
				150 km Minimum
				20 km Maximum
				20 km Medium
				20 km Minimum

Conclusion

• FOI's experience with Morphological Analysis and CASPER has been very positive, and so has the reaction from clients.

• Morphological analysis is highly useful for scenario generation.

• Morphological analysis is also useful for force requirement studies and problem structuring in many complex cases.

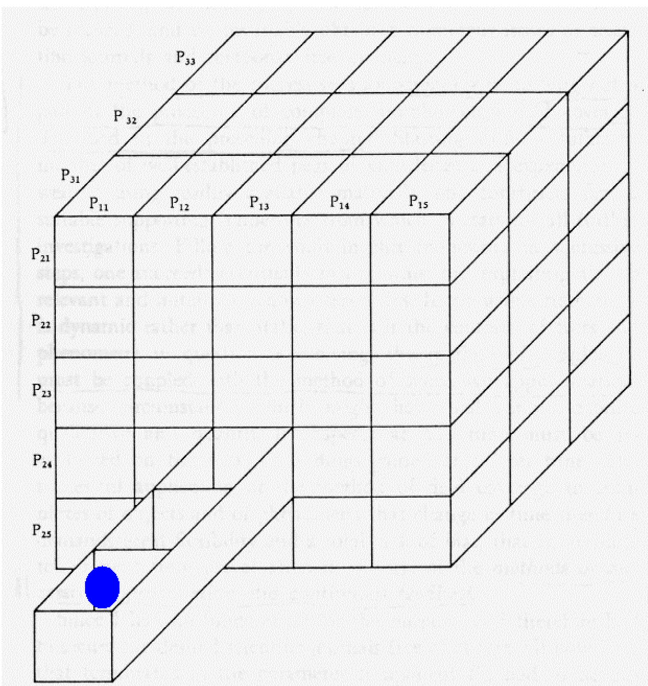
• The best results are achieved with strong facilitation, it's not a "do-it-yourself" software.

Questions?

Location of operation	Threatened Swedish objects	Means of violence	Antagonist type
"At home"	Civilian targets in Sweden	WMD systems	Alliance/state with superpower capacity
Neighbouring region	Military targets in Sweden	Long range precision guided weapons	State/alliance
Europe and surrounding regions	Swedish operations abroad	Conventional joint forces (platforms)	Quasi-state/small state
Rest of world	Swedish interests abroad	Conventional army (platforms)	Paramilitary without territory
		Conventional army (no platforms)	International network
		Simple conventional weapons	Small group/individual
		Limited use of NRBC agents	
		IW only	

The Morphological Field

Representing > 2 parameters/ variables graphically is somewhat problematic.
A box can be used for 3 variables:



The morphological field, with one column for each variable, is a suitable representation for any number of parameters

Parameter X	Parameter Y	Parameter Z
X1	Y1	Z1
X2	Y2	Z2
X3	Y3	Z3
X4	Y4	
X5	Y5	

CASPER - [Shelter8.scn]

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Define parameters of problem complex

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy

Ready

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CASPER - [Shelter8.scn]

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Define range of conditions for each parameter

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
Metropoles	All socio-tech. functions	Large, not crammed	With new construction	More frequent maintanance	All get same shelter quality
Cities + 50,000	Tech support systems	Large & crammed	Compensation	Current levels	All take same risk
Suburbs and countryside	Humanitarian aims	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	Small & crammed			Priority: Needy

Ready

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One field configuration (out of 2304)

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
Metropoles	All socio-tech. functions	Large, not crammed	With new construction	More frequent maintanance	All get same shelter quality
Cities + 50,000	Tech support systems	Large & crammed	Compensation	Current levels	All take same risk
Suburbs and countryside	Humanitarian aims	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	Small & crammed			Priority: Needy

Ready

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Identify contradictory conditions

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
~~Metropoles~~	All socio-tech. functions	Large, not crammed	With new construction	More frequent maintanance	All get same shelter quality
~~Cities + 50,000~~	Tech support systems	Large & crammed	Compensation	Current levels	All take same risk
~~Suburbs and countryside~~	Humanitarian aims	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	Small & crammed			Priority: Needy

We get rid of 432 configurations!

Ready

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