Modeling Alternative Futures with General Morphological Analysis

By Tom Ritchey

Abstract

General morphological analysis (GMA) is a method for systematically structuring and analyzing the total set of relationships contained in multi-dimensional, non-quantifiable problem complexes. During the past 15 years, GMA has been extended, computerized and applied to long-term strategy management and organizational structuring. It is especially useful for developing scenario models and mapping alternative futures. This article outlines the fundamentals of the morphological approach and describes its use in a number of case studies in scenario development and futures projections done for Swedish government authorities and NGOs.

1. Introduction and Methodological Background

Developing scenarios and modeling alternative futures ("future projections") presents us with a number of difficult methodological problems. Firstly, many of the factors involved are not meaningfully quantifiable, since they contain strong social, political, and cognitive dimensions. Secondly, the uncertainties inherent in such problem complexes are in principle non-reducible and often cannot be fully described or delineated. This includes both so-called agonistic uncertainty (conscious, reflective actions among competing actors) and non-specified uncertainty (for instance, uncertainties concerning what types of scientific and technological discoveries will be made in the future).

Finally, the very process by which such projections are developed is often difficult to trace —i.e., we seldom have an adequate "audit trail" describing how relevant parameters are identified and how these parameters are related to each another. Without some form of *traceability*, we have little possibility for scientific control over results. How, then, can the task of developing complex scenarios and future projections be put on a sound methodological basis?

With this question in mind, a research program was initiated at FOI (the Swedish Defence Research Agency) in the early 1990s that was aimed at developing a methodological framework for creating models of systems and processes that cannot be meaningfully quantified. We began by attempting to develop an extended form of what is called *typology analysis* (Bailey, 1969). Initially, we thought we were doing something new. However, we subsequently learned that extended typology analysis was invented as early as the 1940s by Professor Fritz Zwicky at the California Institute of Technology in Pasadena. He called it the *morphological approach*.

The term *morphology* derives from the ancient Greek word *morphe*, which means *shape* or *form*. The general definition of morphology is "the study of form or pattern," i.e., the shape and arrangement of parts of an object, and how these

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conform to create a *whole*, or Gestalt. The "objects" in question can be physical (e.g., an organism or an ecology), social/organizational (e.g., a corporation or a defense structure), or mental (e.g., linguistic forms or any system of ideas).

The first to use the term *morphology* as an explicitly defined scientific method would seem to be J.W. von Goethe (1749-1832), especially in his "comparative morphology" in botany. Today, morphology is associated with a number of scientific disciplines where formal structure, and not necessarily quantity, is a central issue, e.g., linguistics, geology, and zoology.

Zwicky proposed a generalized form of morphology, which today goes under the name of General Morphological Analysis (GMA):

> Attention has been called to the fact that the term morphology has long been used in many fields of science to designate research on structural interrelations—for instance in anatomy, geology, botany and biology. ... I have proposed to generalize and systematize the concept of morphological research and include not only the study of the shapes of geometrical, geological, biological, and generally material structures, but also to study the more abstract structural interrelations among phenomena, concepts, and ideas, whatever their character might be. (Zwicky, 1966, p. 34)

Zwicky developed GMA as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes (Zwicky 1966, 1969). He applied the method to such diverse fields as the classification of astrophysical objects, the development of jet and rocket propulsion systems, and the legal aspects of space travel and colonization. He founded the Society for Morphological Research and championed the "morphological approach" from the 1940s until his death in 1974.

More recently, morphological analysis has been applied by a number of researchers in the United States and Europe in the fields of policy analysis and futures studies (e.g., Rhyne 1981, 1995; Coyle 1995, 1996). In 1995, advanced computer support for GMA was developed at FOI (Ritchey, 2003a). This has made it possible to create non-quantified inference models, which significantly extend GMA's functionality and areas of application (Ritchey 1997–2011). Since then, more than 100 projects have been carried out using computer-aided GMA, for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analyzing organizational and stakeholder structures.

2. General Morphological Analysis

Essentially, GMA is a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex. This is accomplished by going through a number of iterative phases which represent cycles of analysis and synthesis—the basic method for developing (scientific) models (Ritchey, 1991).

The method begins by identifying and defining the most important dimensions (or parameters) of the problem complex to be investigated, and assigning each dimension a range of relevant values or conditions. This is done mainly in natural language, although abstract labels and scales can be utilized to specify the set of elements defining the discrete value range of a parameter.

A morphological field is constructed by setting the parameters against each other in order to create an n-dimensional configuration space (Figure 1). A particular configuration (the darkened cells in the matrix) within this space contains one "value" from each of the parameters, and thus marks out a particular state of, or possible formal solution to, the problem complex.

The point is to examine all of the configurations in the field, in order to establish which of them are possible, viable, practical, interesting, etc., and which are not. In doing this, we mark out in the field a relevant solution space. The solution space of a Zwickian morphological field consists of the subset of all the configurations which satisfy certain criteria. The primary criterion is that of internal consistency.

Obviously, in fields containing more than a handful of variables, it would be time-consuming —if not impossible—to examine all of the configurations involved. For instance, a 6-parameter field with 6 conditions under each parameter contains more than 46,000 possible configurations. Even this is a relatively small field compared to some of the ones we have been studying. Thus the next step in the analysis-synthesis process is to examine the internal relationships between the field parameters and "reduce" the field by weeding out configurations which contain mutually contradictory conditions. In this way, we create a preliminary outcome or solution space within the morphological field without having first to consider all of the configurations as such.

This is achieved by a process of *cross-consistency assessment.* All of the parameter values in the morphological field are compared with one another, pair-wise, in the manner of a cross-impact matrix (Figure 2). As each pair of conditions is examined, a judgment is made as to whether—or to what extent—the pair can coexist, i.e., represent a consistent relationship. Note that there is no reference here to direction or causality, but only to mutual consistency. Using this technique, a typical morphological field can be reduced by 90% (or even 99%) depending on the problem structure.

There are two principal types of inconsistencies involved here: purely *logical* contradictions (i.e., those based on the nature of the concepts involved); and *empirical* constraints (i.e., relationships judged to be highly improbable or implausible on empirical grounds). *Normative* constraints can also be applied, although these must be used with great care, and clearly designated as such.

This technique of using pair-wise consistency assessments between conditions, in order to weed out inconsistent configurations, is made possible by a principle dimension inherent in morphological fields, or in any discrete configuration space. While the number of configurations in such a space grows exponentially with each new parameter, the number of pair-wise relationships between parameter conditions grows only in proportion to the triangular number series—a quadratic polynomial.

Naturally, there are also practical limits reached with quadratic growth. The point, however, is that a morphological field involving as

Figure 1: A 6-parameter morphological field. The darkened cells define one of 4800 possible (formal) configurations.

Parameter A	Parameter B	Parameter C	Parameter D	Parameter E	Parameter F
Condition A1	**Condition B1**	Condition C1	Condition D1	Condition E1	Condition F1
Condition A2	Condition B2	Condition C2	**Condition D2**	Condition E2	Condition F2
Condition A3	Condition B3	**Condition C3**		Condition E3	**Condition F3**
Condition A4	Condition B4	Condition C4		**Condition E4**	Condition F4
Condition A5		Condition C5		Condition E5	
				Condition E6	

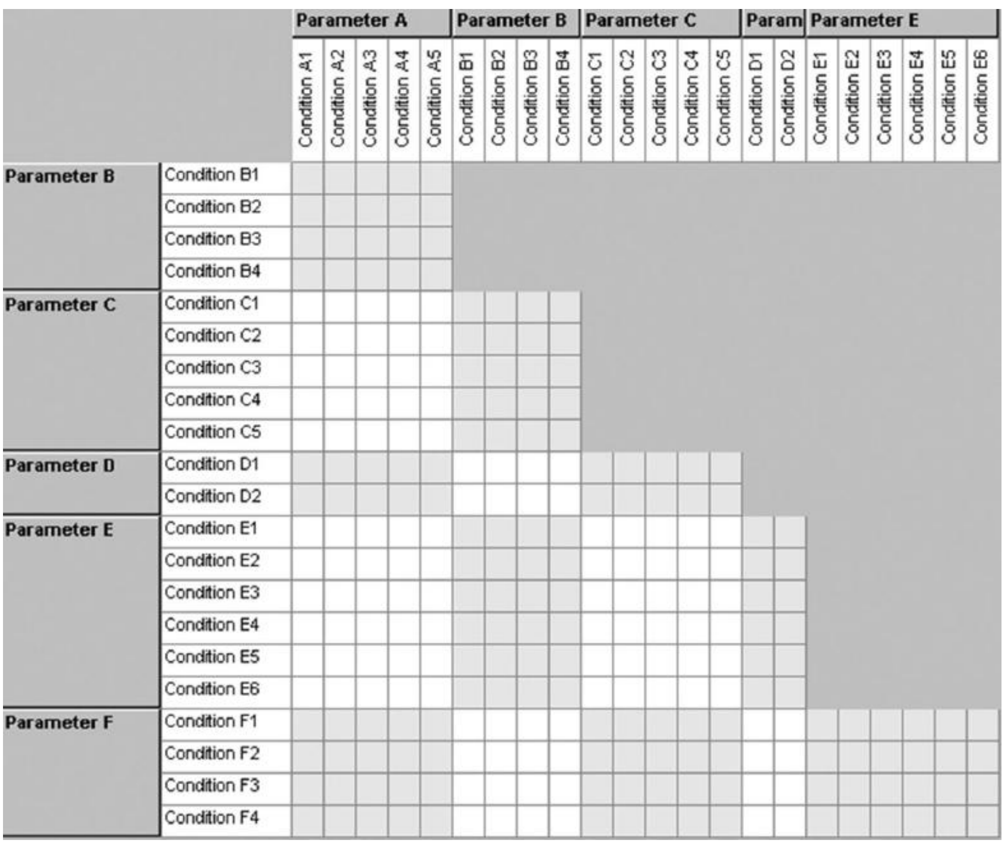
many as 100,000 formal configurations can require no more than few hundred pair-wise evaluations in order to create a solution space.

When this solution (or outcome) space is synthesized, the resultant morphological field becomes an inference model, in which any parameter (or multiple parameters) can be selected as "input," and any others as "output." Thus, with dedicated computer support, the field can be turned into a laboratory within which one can designate initial conditions and examine alternative solutions.

GMA seeks to be integrative and to help discover new relationships or configurations. Importantly, it encourages the identification and investigation of boundary conditions, i.e. the limits and extremes of different parameters within the problem space. The method also has definite advantages for scientific communication and—notably—for group work.

As a process, the method demands that parameters, conditions, and the issues underlying these be clearly defined. Poorly defined concepts become immediately evident when they are cross-referenced and assessed for internal consistency. Like most methods dealing with complex social and organizational systems, GMA requires strong, experienced facilitation, an engaged group of subject specialists and a good deal of patience.

Figure 2: The cross-consistency matrix for morphological field in Figure 1.



3. Scenario-Framework Models: Four Examples

The four future projection models presented here are:

- Scenarios and strategies for an extended-producer responsibility system
- Future human actions affecting long-term nuclear waste storage
- Nuclear sabotage threat scenarios
- Climate change scenarios

Please note: at the request of the clients involved, some of the models presented here have been truncated or generalized.

3.1 Scenarios and Strategies For an Extended Producer Responsibility System

Extended producer responsibility (EPR) imposes accountability over the entire life cycle of products and packaging introduced on the market. This means that firms which manufacture, import and/or sell products and packaging, are required to be financially or physically responsible for such products after their useful life.

They must either take back spent products and manage them through reuse, recycling, or using them in energy production, or they must delegate this responsibility to a third party, a so-called producer responsibility organization (PRO), which is paid by the producer for spent-product management. In this way, EPR shifts responsibility for waste from government to private industry, obliging producers, importers, and/or sellers to internalize waste management costs in their product prices (see Hanisch, 2000).

The long-term purpose of EPR is to encourage more environmentally friendly product development—e.g., products that require fewer resources, are easier to reuse/recycle, and which contain fewer environmentally dangerous substances. The problem, then, is to develop flexible EPR strategies for a future in which there is a good deal of uncertainty concerning, for instance, national and international directives, technological developments, shifting political ideologies, market forces, and ethical concerns.

The purpose of the EPR study was to systematically formulate a range of future contextual environments by which to test alternative EPR strategies. Two working groups of seven persons each—a "strategic environment group" and a "strategy development group"—performed the modeling together with two morphologists. The groups were composed of researchers from the Swedish EPA and other relevant government authorities, from two NGOs and from two private companies involved in waste management and recycling. Each group worked two days on their respective fields, with a final one-day joint session during which the strategic environment model was merged with the strategy model.

Figure 3 is an EPR future projection field consisting of eight parameters which represent "external" factors that can influence or constraina Swedish EPR system. The eight parameters generate 20,736 formal configurations. In contrast to strategy fields, or fields representing system solutions, scenario or future projection fields are often difficult to assess internally and reduce. This is because it is risky to exclude relationships which may seem improbable today, but which might very well be the case in five, ten, or twenty years.

In such cases, it is better to work backwards, so to speak: Select one or more parameters as drivers, choose a number of configurations based on varying these drivers, and then assess the chosen configurations for internal consistency afterwards. Repeat this process until the desired number of projections is achieved.

For the study in question, eight specific configurations were chosen. Together, these covered all of the parameter states in the scenario field ("full field coverage"), and represented a broad range of future EPR environments. The configurations were then named and linked to the column at the far left—a scenario-name "place-

Figure 3: An eight-parameter scenario field with a scenario "placeholder" parameter (at far left) showing list of scenario configurations defined in the study. One configuration—Current Policies (Negative trend)—is selected (grey).

SCENARIO	Buyer behaviour	Consumption patterns Total: Private import:	Consumer sorting behaviour (trends)	National environmental policy	Price of new raw material vs reclaimed material	Production technology: volume of materials	Technology development: reclaiming technology	EU-directives for import and export of waste
Global Crisis (Production gone wild)	Willing to pay more for green products	Total: Up Private import: Up	Voluntary (ideologically driven)	At the forefront: Holistic approach (legal & econ.)	New: High Reclaimed: High	Much less than today	Very rapid increases	Less restricted than today
Raw Material Depletion	Will to buy green, but will not pay more	Total: Status Quo Private import: Up	Will sort for compensation/ reward	At forefront, but no holistic approach (legal only)	New: High Reclaimed: Low	Somewhat less than today	Substantial increases	Same as today
Current policies (Negative trend)	No interest in buying green products	Total: Up Private import: SQ	Will sort if facing sanctions	Ideological, based on voluntary acceptance	New: Low Reclaimed: High	Same as today	Only marginal increases	More restrictive than today
Current policies (Positive trend)		Total: SQ Private import: SQ	Will resist sorting	Least possible adaptation	New: Low Reclaimed: Low			
Green-house effect (Stop emissions)								
Batman: High-tech solutions								
Dematerialised production (New materials)								
Green market (ideological paradise)								

holder." This is done for practical reasons, in order to keep track of specific configurations of interest. (When such a placeholder is employed to define specific configurations, we call the field specified. When no such placeholder is present, then the field is open.)

(Note: On the computer, morphological field configurations are color-coded. For instance, selected input conditions are rendered in red, and output conditions in blue. In the figures below, red is represented by grey, and blue is represented by black.)

The eight alternative future EPR environments were later linked onto a strategy space, in order to establish which what types of strategy alternatives would be most effective and/or flexible for different ranges of alternative futures (Figure 4).

The project was reported in the official Swedish Government Report: SOU 2001:102 *Resurs i retur* (*Resources in return*), 2001.

3.2 Future Human Actions Affecting Long-Term Nuclear Waste Storage

As with many other countries that utilize nuclear power, Sweden has a program for maintaining a long-term nuclear waste repository. Future human actions (FHA) that can affect the safety of such repositories need to be understood in order to develop adequate strategies for their construction and future regulation—including knowledge management. All of this involves questions concerning the long-term evolution of society and human behaviour.

For this reason, the Swedish Nuclear Fuel and Waste Management Company commissioned a study to develop an initial conceptual framework (1) to consider what factors to take into account

Figure 4: Linked fields. The scenario placeholder parameter is imposed on the strategy field. One scenario is selected (grey), with one of its possible strategy configurations shown (black).

SCENARIO	EPR rules and regulations	Environmental adaptation of products	Required range of information about products	Waste sorting system	Collection system	Recycling system	Dominant EPR market for waste products	Instruments for deposition and burning
Global Crisis (Production gone wild)	Voluntary, branch regulated	Focus on clean materials	Chemicals Material Energy	> 15 commodity groups	Very near premises	Mechanical recycling	International	Recycling: Up Energy: Down
Raw Material Depletion	General legislation toward individual. No monopoly.	Same mix as today	Chemicals Material	> 15 material groups	High density "bring system"	Thermal recycling	National and close international	Recycling: Up Energy: Up
Current policies (Negative trend)	General legislation toward collective Partial monopoly.	Focus on dematerialisation	Chemicals Energy	Same as today	Low density "bring system"	Chemical recycling	Local/regional	Recycling: Down Energy: Up
Current policies (Positive trend)	Finely detailed legislation (who, how & what)		Chemicals only	< 5 commodity groups		Biological recycling		Relative increase of deposition
Green-house effect (Stop emissions)				< 5 material groups				
Batman: High-tech solutions								
Dematerialised production (New materials)								
Green market (ideological paradise)								

concerning long-term nuclear waste storage, and (2) to develop a selection of representative scenarios for illustrative consequence analysis. The work began with a series of GMA workshops in which experts representing a wide range of technical, historical, social, and information-based competencies took part.

These workshops had the dual purpose of identifying framework conditions that describe feasible societal contexts for future human actions, and also providing a forum for structured discussions among various competencies needed to create "smart teams." The initial discussions at the workshop concerned factors that can influence future human actions directed towards the repository site (consciously or unconsciously) and what might trigger an action that affects repository safety.

Factors of widely differing natures, from human anxiety to technology, were judged to be important: e.g., values, mood, social wealth/stratification, knowledge, intent, motive, geographic conditions and technology. One of the central questions posed was under what circumstances knowledge of the repository could be lost by society, and what the possible consequences of this would be.

Figures 5 and 6 show two configurations obtained from one of the models developed. This model concerned societal knowledge of and reasons for intruding into the repositories.

3.3 Nuclear Sabotage Threat Scenarios

The Swedish Nuclear Power Inspectorate (SKI) is the regulatory authority for nuclear activities in Sweden. Its responsibilities include nuclear safety and security issues, including physical protection against theft of nuclear material and

Figure 5: Example of positive long-term social development resulting in deposits being retrieved as resources.

Main form of human settlements	Level of scientific knowledge	Transportation system	Information system	Knowledge of repository	Form of society (legitimacy & governability)	Purpose of intervention/ disruption
Megalopolis	Significantly higher among elite	Increased capacity	Increased capacity	Generally known	Legitimate Ungovernable	Retrieve deposits as resource
X-city (rank order)	Significantly higher in general than today	As today	As today	Known only to elite	Legitimate Governable	Inspecting repository
Sparse	As today	Reduced capacity	Reduced capacity	Known locally only	Illegitimate Governable	Mining for other resources/building
	Significantly lower than today generally	Decay	Decay	Lost	Illegitimate Ungovernable	Mapping/ geological investigation
						Sabotage

sabotage of nuclear facilities. Since the middle of the 1970s, SKI has applied the concept of Design Basis Threat (DBT), i.e., a profile of the type, composition, and capabilities of an adversary.

The DBT has repeatedly been reviewed and revised over the years. However, in light of the terrorist attacks in New York City and Washington, D.C., in September 2001, the DBT needed to

Figure 6: Example of positive long-term social stagnation and lost knowledge of repository.

Main form of human settlements	Level of scientific knowledge	Transportation system	Information system	Knowledge of repository	Form of society (legitimacy & governability)	Purpose of intervention/ disruption
Megalopolis	Significantly higher among elite	Increased capacity	Increased capacity	Generally known	Legitimate Ungovernable	Retrieve deposits as resource
X-city (rank order)	Significantly higher in general than today	As today	As today	Known only to elite	Legitimate Governable	Inspecting repository
Sparse	As today	Reduced capacity	Reduced capacity	Known locally only	Illegitimate Governable	Mining for other resources/building
	Significantly lower than today generally	Decay	Decay	Lost	Illegitimate Ungovernable	Mapping/ geological investigation
						Sabotage

be revised once again, to properly take into account the experience gained from 9/11. For this purpose, SKI decided to employ GMA as a well-structured method within which both the process and the results would be transparent, traceable, and clearly documented.

The task was to develop a series of morphological models that described the total problem complex within which alternative scenarios could be formulated, developed, tested, and evaluated. The work was carried out in four two-day workshops during the first half of 2002.

Figure 7 shows one of the threat scenario models developed in the study, containing seven parameters. Originally generating over one million formal configurations, it was reduced to slightly more than 40,000. Note, that for reasons of confidentiality, some of the variable conditions have been modified or truncated in this example.

The highlighted configuration shows a threat scenario which describes a small group of aggressors without the support of an insider. The group has a high level of knowledge both about the targeted facility and the weapons and explosives it employs. The purpose of the attack is to sabotage equipment in vital areas and/or to compromise reactor safety systems and possibly cause radiological releases. Depending on the effectiveness of safety systems and physical protection measures, the potential consequence would either be no radiological consequences or limited emissions.

3.4 Climate-Change Conflict Scenarios

The series of climate change conflict models were developed for an EU-financed project called Climate Tools, carried out by the Swedish Defence Research Agency (FOI). The study was directed

Figure 7: A nuclear sabotage scenario-framework model developed for the Swedish Nuclear Power Inspectorate.

Aggressor's group size	Purpose/ goal	Level of knowledge concerning: W=weapons S=systems	Method	Equipment	Part of facility targeted	Consequences
One person No insider	Map/survey	W: high S: high	Reconnaissance	Hand tools	Perimeter	No radiological consequences
One person Insider	Influence opinions	W: high S: low	Illegal trespassing	Information technology (IT)	Protected areas	Loss of fissionable material
Group (< 7 pers.) No insider	Steal fissionable material	W: low S: high	Unauthorized access to computer systems	Handheld fire arms	Surveillance systems	Loss of secret information
Group (< 7 pers.) Insider	Disturb operations	W: low S: low	Threat to disturb the facility	HPM	Nuclear material storage	Limited emission
Group (7-20 pers.) No insider	Stop operations		Blackmail against employee	Explosives	Vital facility areas	Large emission
Group 7-20 pers. Insider	Take control of the facility		Infiltration	Car bomb	Reactor safety systems	Massive emissions
Group (> 20 pers.) No insider	Destroy and cause emissions		Sabotage from within	Short-range missile		
Group (> 20 pers.) Insider	Maximum destruction		Sabotage from outside	B-weapons		
			Massive armed attack a	Chemicals & C-weapons		
				Radiological substances		
				Aircraft		
				Middle/Long-range missiles		
				Nuclear weapons/ EMP		

at hypothesizing how different climate change scenarios, involving both temperature and sea-level increases, might affect different areas of the world, and in which ways. The inputs for the model are a set of futures projections involving given temperature and sea level increases and specific geo-political areas influenced. The outputs concern possible physical consequences, what main sectors of society would be most affected, subsequent societal consequences, and possible types of conflict that could arise out of this.

In Figures 8 and 9, a worst-case example was selected involving a mean global temperature rise of 6-8 degrees and a sea level rise of 70-80 centimeters. The time perspective was 50 years. Note that in this model, the Baltic area manages fairly well compared, for example, to southern Europe. While the principal types of conflict that might result are the same, their details differ in the different geo-political contexts.

Figure 8: Climate change conflict scenario model with worst case scenario selected for Baltic Sea area.

Scenario	Global mean temp change (C) Sea level rise (cm)	Area influenced (examples)	Consequences for area influenced	Main sectors influenced	Possible societal consequences for affected area	Conflicts that can befall influenced areas
Extreme Case (A1F1)	Mean temp increase: 6-8 C Sea level rise: 70-80 cm	Baltic Sea area	Heavy drought	Agriculture	Structural changes in international competition	Civil war, internal conflicts
High temp renewable energy (B1)	Mean temp increase: 5-6 C Sea level rise: 50-60 cm	Middle Europe	Desert spreading	Forestry	Increased regional divergence	Regional war/ conflicts over land and water areas
Mild rise renewable energy (B2)	Mean temp increase: 3-4 C Sea level rise: 20-40 cm	Southern Europe	Flooding	Energy production	Mass immigration ("climate refugees")	Economic resource conflicts (including fresh water)
Kyoto +	Mean temp increase: 1-2 C Sea level rise: 10-20 cm	North Africa / Sahel	Greatly increased precipitation	Transport	Mass emmigration ("climate refugees")	Closed borders
		Tropical Africa	Decreased water supplies	Living environment (housing)	Brain drain	Warlordism
		Southeast China	Increased heat waves	Fishery	Increased spread of contagions (infection)	Increased international terrorism
		Northeast China	Warmer and shorter winters	Industrial production	Increased poverty	Nothing
		Arctic Region		Tourism	Extreme protectionism	
		Russia		Water supplies	Financial crises	
		USA		Infrastructure	"Failed state"	

Figure 9: Climate change conflict scenario model with worst case scenario selected for Southern Europe.

Scenario	Global mean temp change (C) Sea level rise (cm)	Area influenced (examples)	Consequences for area influenced	Main sectors influenced	Possible societal consequences for affected area	Conflicts that can befall influenced areas
Extreme Case (A1F1)	Mean temp increase: 6-8 C Sea level rise: 70-80 cm	Baltic Sea area	Heavy drought	Agriculture	Structural changes in international competition	Civil war, internal conflicts
High temp renewable energy (B1)	Mean temp increase: 5-6 C Sea level rise: 50-60 cm	Middle Europe	Desert spreading	Forestry	Increased regional divergence	Regional war/ conflicts over land and water areas
Mild rise renewable energy (B2)	Mean temp increase: 3-4 C Sea level rise: 20-40 cm	Southern Europe	Flooding	Energy production	Mass immigration ("climate refugees")	Economic resource conflicts (including fresh water)
Kyoto +	Mean temp increase: 1-2 C Sea level rise: 10-20 cm	North Africa / Sahel	Greatly increased precipitation	Transport	Mass emmigration ("climate refugees")	Closed borders
		Tropical Africa	Decreased water supplies	Living environment (housing)	Brain drain	Warlordism
		Southeast China	Increased heat waves	Fishery	Increased spread of contagions (infection)	Increased international terrorism
		Northeast China	Warmer and shorter winters	Industrial production	Increased poverty	Nothing
		Arctic Region		Tourism	Extreme protectionism	
		Russia		Water supplies	Financial crises	
		USA		Infrastructure	"Failed state"	

4. Conclusions

General Morphological Analysis is based on the fundamental scientific method of cycling between analysis and synthesis. For this reason, it can be trusted as a useful, conceptual modeling method for investigating problem complexes which are not meaningfully quantifiable and which cannot be treated by formal mathematical methods and causal modeling.

Morphological Analysis, with dedicated computer support systematically deals with multi-dimensional problems that include non-quantified dimensions, provides for a well-structured discussion concerning such complex problems, is well suited for working with groups of subject matter specialists that represent different areas of competence, produces an "audit trail" and documentation, and is well suited for developing scenario and strategy laboratories.

As is the case with all modeling methods, the output of a morphological analysis is no better than the quality of its inputs. However, even here the morphological approach has some advantages. It expressly provides for a good deal of in-built "garbage detection," since poorly defined parameters and incomplete ranges of conditions are immediately revealed when one begins the task of cross-consistency assessment. These assessments simply cannot be made until the morphological field is well defined and the working group agrees on what these definitions mean.

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