Chapter 2
General Morphological Analysis (GMA)

"... within the final and true world image everything is related to everything, and nothing can be discarded a priori as being unimportant." (Zwicky, 1969)

"Morphological analysis is simply an ordered way of looking at things." (Zwicky, 1948a)

2.1 What's the Problem?

Analyzing and modelling complex social, organisational and political (i.e. policy driven) systems 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, self-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 extreme non-linearity of social systems means that literally everything depends on everything else. What might seem to be the most marginal of factors can, under the right historical circumstances, become a dominating force of change. All of this means that traditional quantitative methods, mathematical (functional) modelling and simulation (in the sense of attempting to predict how things are *actually* going to "work out"), are relatively useless.

An alternative to formal (mathematical) methods and causal modelling is a form of non-quantified modelling relying on *judgmental processes* and *internal consistency*, rather than causality. Causal modelling, when applicable, can – and should – be used as an aid to judgement. However, at a certain level of *complexity*[1]

[1]See Chap. 10: complexity (self-referential systems).

This chapter is based on earlier articles published from 1998 and onwards, including Ritchey (1998, 2002, 2006a).

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(e.g. social, political and cognitive processes), judgement must often be used – and worked with – more or less directly. The question is: How can judgmental processes be put on a sound methodological basis?

Historically, scientific knowledge develops through cycles of analysis and synthesis: every synthesis is built upon the results of a proceeding analysis, and every analysis requires a subsequent synthesis in order to verify and correct its results (Ritchey, 1991). However, analysis and synthesis – as basic scientific methods – say nothing about a problem having to be quantifiable.

Complex social-political problem fields can be analysed into any number of non-quantified variables and ranges of conditions. Similarly, sets of non-quantified conditions can be synthesised into well-defined relationships or configurations, which represent "solution spaces". In this context, there is no fundamental difference between quantified and non-quantified modelling (see Chap. 6).

General Morphological analysis (GMA) is a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes. It was originally developed by Fritz Zwicky, the Swiss astrophysicist and aerospace scientist based at the California Institute of Technology (see Chap. 9).

Zwicky applied this 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 advanced the "morphological approach" for some 40 years, between the early 1930s until his death in 1974.

More recently, morphological analysis has been applied by a number of researchers in the USA and Europe in the fields of policy analysis and futures studies (see References). In 1995, advanced computer support for GMA was developed at the Swedish Defence Research Agency (for a description, see Ritchey, 2003b). This has made it possible to create non-quantified inference models, which significantly extends GMA's functionality and areas of application (see Ritchey, 1997–2009). Since then, more than 100 projects have been carried out using computer aided morphological analysis, for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analyzing organizational and stakeholder structures.

This Chapter will continue with a history of morphological methods, a description of the modelling processes itself, and an example concerning the modelling of an o*rganisational structure*.

2.2 Short History of Morphological Methods

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

Today, morphology is associated with a number of scientific disciplines in which formal structure is a central issue. In biology it is the study of the shape or form of organisms. In linguistics, it is the study of word formation. In geology it is associated with the characteristics, configuration and evolution of rocks and landforms.

The first to use the term *morphology* as an explicitly defined scientific method was J.W. von Goethe (1749–1832). Goethe introduced the term to denote the principles of formation and transformation of organic bodies. Concentrating on form and quality, rather than function and quantity, this approach produced generalizations about the combinatorial logic of biological structures. Of central importance was the idea of the *morphotype*; that is, a structural or organisational principle which can be identified and studied through comparative anatomy.

This early theoretical morphology was eventually eclipsed by Darwinian evolutionary theory in the late nineteenth century. With the exception of the works of William Bateson (1896) and D'Arcy Thompson (1917), it remained obscure until the Modern Synthesis in evolutionary biology began to treat Darwinian evolution from at the level of genes, phenotypes and populations. The present literature in theoretical morphology is now quite extensive (McGhee, 1999).

It is important to note, that Goethe developed morphology with the expressed purpose of methodologically distancing the life sciences from the then reining paradigm in *Naturwissenschaft*, i.e. classical (Newtonian) mechanics. However, this methodological shift was exactly what was needed in another area, which was even less disposed to such a paradigm: the emerging disciplines of sociology and psychology. Theoretical morphology was thus carried over into the *Geisteswissenschaft* of Classical German Sociology – represented by Wilhelm Dilthey (1833–1891) (Dilthey, 1989) and Max Weber (1864–1920) (Weber, 1949). More specifically, morphology and morphotypes became typology and ideal types.

A typology (the Greek word *typos* originally meant a hollow mould or matrix) is a very simple morphological model based on the possible combinations obtained between a few (often two) variables, each containing a range of discrete values or states. Each of the possible combinations of variable-values in the typological field is called a *constructed type*. Typologies abound, especially in the sociological literature, and typology analysis is virtually a discipline in itself (Bailey, 1994; Doty & Glick, 1994). The simplest and most common form of a typology is the ubiquitous *four-fold table* (or a so-called MBA 2×2), which pits two variables against each other, each variable containing two values or states.

The type-concept was not created by Weber. It was already well established methodologically by Goethe in his conception of morphotypes. However, by employing typologies as a method for formulating sociological and social philosophical categories, Weber simplified, generalised and popularised typology analysis as a simple *concept-structuring method* applicable to virtually any area of investigation.

Although typological fields are certainly not restricted to two dimensions or simple binary relations, there are severe limits to the complexity of the classical typological format. Visually, a typology utilizes the dimensions of physical space to represent its variables. Each of the constructed types lies at the intersection of two or more coordinates. However, the number of coordinates that can be represented in physical space ends at *three*. Typologies of greater dimensions – representing hyperspaces – usually get around this problem by embedding variables within each other. However, such formats quickly become difficult to interpret, if not hopelessly unintelligible. There are, however, other ways to represent hyperspaces.

In the late 1940s, Fritz Zwicky, the Swiss astrophysicist and aerospace scientist based at the California Institute of Technology (Caltech), proposed a generalized form of morphological analysis:

> "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, 1969, p 34)

In general morphology, the problem of representing – and visualising – more than three dimensions is overcome by placing the variables in columns beside each other, their value ranges listed below them. This is called a *morphological field*. A particular constructed morphotype (called a *field configuration*) is designated by selecting a single value from each variable (see Fig. 2.1).

Zwicky published a number of articles applying morphology to the classification of astrophysical objects (Zwicky, 1948a) and to the development of jet and rocket

Character of Chemical Reactions	Method of Thrust Augmentation 1	Method of Thrust Augmentation 2	Physical State of Propellants	Operating Mode of Propulsive Power Plant	Reactivity or Reaction Speed of the Propellants
Self-contained - carries all chemicals necessary for activation and operation.	No motion	No thrust augmentation	Gaseous state	Continuous operation	Propellants are self-igniting
If air-propelled, carries only fuel and uses atmospheric oxygen.	Translatory motion	Internal thrust augmentation	Liquid state	Intermittent (pulsating) operation	Artificial ignition is necessary
If propelled through or over water, uses water as propellant reacting with an on-board water-reactive chemical.	Rotary motion	External thrust augmentation	Solid state		
If propelled through or over the earth may use earth as propellant reacting with an on-board earth-reactive chemical.	Oscillatory motion				

Fig. 2.1 Zwicky's "propulsive system morphology" from 1947, containing six dimensions (parameters) and 576 ($4 \times 4 \times 3 \times 3 \times 2 \times 2$) formal configurations – one displayed

propulsion systems (Zwicky, 1947). He also published a more general article on the "morphological method of analysis and construction" (Zwicky, 1948b) and later wrote a book on the subject (Zwicky, 1969). His morphological astronomy lead to a number of hypotheses and later discoveries, but remained more or less specific to astrophysics. His work on jet propulsion systems, however, had a wider impact in the area of engineering design.

In 1962, in a paper presented at a conference on engineering design methods in London, Norris (1963) proposed that the morphological approach should be turned into a full-fledged engineering design method utilising computers (!), in order to systematically separate and collate different design solutions. Some authors saw even wider applications. Ayres (1969) pointed out how morphological analysis could be employed to systematically generate scenarios. He cited the work on future, non-national nuclear threats by Theodore Taylor (1967) at the Stanford Research Institute.

In 1975, Müller-Merbach (1976) of the University of Darmstadt wrote an article for *Operational Research* titled "The Use of Morphological Techniques for OR-Approaches to Problems". There he pointed out that general morphology is especially suitable for operational research, not the least because of the growing need for operational analysts to be part of the *problem formulation process*, and not simply a "receiver" of pre-defined problems.

In a more specific context, Rhyne (1971, 1981) – also associated with the Stanford Research Institute – picked up on Taylor's earlier work and began to apply a somewhat restricted form of morphological analysis as a scenario development technique. (In order to generate new interest in the method, Rhyne packaged it under the esoteric name of "field anomaly relaxation" (FAR), a term borrowed from mechanical engineering [personal communication].) During the 1990s he continued to write about its potential as a systematic approach to futures projections (Rhyne, 1995a, 1995b).

Finally, in the early 1990s, Geoff Coyle, then working at the Royal Military Collage of Science in Swindon, discovered Rhyne's work and promoted morphological analysis as one of a number of structured techniques for scenario development (Coyle et al., 1995, 1996).

Unfortunately, GMA has been written about and discussed far more that it has actually been used in "real" client-based projects. One of the principle reasons for this, I believe, is that it has been mostly carried out by hand or with only rudimentary computer support. Employing GMA in this way is not only extremely difficult, time consuming and prone to errors; it severely limits the number and range of parameters that can be employed. Since the number of configurations (i.e. formal solutions) in a morphological field increases exponentially (or in a *factorial* manner) with the number of parameters applied to it, working with as few as six or seven variables becomes a considerable task. Thus, until recently, GMA has usually been carried out as a relatively simple form of attribute listing with internal consistency checks.

In 1995, my colleagues and I at the Department for Technology Foresight and Assessment at Totalförsvarets Forskningsinstitut (FOI – the Swedish Defence Research Agency in Stockholm) realized that general morphological analysis would never reach its full potential without *dedicated, highly flexible, workshop oriented* computer support. The system we began developing then, and which is presently in its fifth programming generation, fully supports the analysis-synthesis cycles inherent in GMA and makes it possible to create morphological ("what-if") inference models. During the past 15 years, GMA has been utilised in more than 100 client-based projects, for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analysing organisational and stakeholder structures.

2.3 Morphological Modelling

Since we will frequently be using the terms *model* and *modelling*, it is best to get these concepts defined at the outset. Although there is no concise, unanimously agreed upon *general definition* of a (scientific) model, for the purpose of this study, we posit the following three conditions as necessary and sufficient for a *minimal definition* of a (scientific) model[2]:

– A model must contain two or more constructs that can serve as variables, i.e. dimensions which can support a range of states or values. [In morphological modelling we call these the model's *parameters*. We define a *parameter* as being one of a set of measurable factors that define a system and determine its behaviour, and which can be varied in an experiment – including a *Gedanken experiment*.]
– One must be able to establish relationships (causal, statistical, logical, etc.) between the states or values of the different parameters. [In morphological modelling the relationships are predominantly "logical" in the sense that they concern consistency, coherence or co-existence.]
– Inputs can be given, and outputs obtained. [In morphological modelling, this is achieved by (temporarily) designating one or more parameters as independent variables (inputs) and realising the results on the remaining variables (outputs)].

Morphological modelling is simply a non-quantified, discrete-variable application of these requirements. As discussed above, the process goes through cycles of analysis and synthesis – the basic procedure for developing all (scientific) models (Ritchey, 1991).

The analysis phase begins by identifying and defining the most important dimensions of the problem complex to be investigated. Each of these dimensions is then given a range of relevant values or conditions. Together, these make up the variables or parameters of the problem to be structured. A morphological field is

[2]Some might object that this definition excludes the classical "influence diagram" as a *scientific* model. But I think it significant that influence diagrams are called *diagrams*, and not *models*. These diagrams represent nodes as black boxes with "arrows" of influences depicted between the nodes. They allow for no variability or inference. However, what is, and what is not, to be considered a *scientific model* is a matter of convention, as long as our definitions are clear and we apply them consistently.

constructed by setting the parameters against each other, in parallel columns, representing an n-dimensional configuration space. A particular constructed "field configuration" (morphotype) is designated by selecting a single value from each of the variables. This marks out a particular state or (formal) solution within the problem complex (as in Fig. 2.1).

Ideally, one would examine all of the configurations in the field, in order to establish which of them are possible, viable, practical, interesting and so forth, and which are not. In doing so, we mark out in the field a relevant "solution space". The solution space of a Zwickian morphological field consists of the subset of configurations which satisfy some set of criteria – one of which is *internal consistency*.

However, typical morphological fields of six to ten variables can contain between 50,000 and 5,000,000 formal configurations, far too many to inspect by hand. Thus, the next step in the analysis-synthesis process is to examine the internal relationships between the field parameters and *reduce* the field by identifying, and weeding out, all mutually contradictory conditions.

This is achieved by a process of *cross-consistency assessment* (CCA). All of the parameter values in the morphological field are compared with one another, pair-wise, in the manner of a cross-impact matrix (Fig. 2.2). 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 up to 90 or even 99%, depending on the problem structure. (Certain types of *scenario fields* are an exception, as will be discussed below.)

		Character of				Method of Th				Method of			State of P			Opera	
		Self-contained	If air-propelled	Water propelled	Earth propelled	No motion	Translatory motion	Rotary motion	Oscillatory motion	No augmentation	Internal augmentation	External augmentation	Gaseous state	Liquid state	Solid state	Continuous	Intermittent
Method of Thrust 1	No motion																
	Translatory motion																
	Rotary motion																
	Oscillatory motion																
Method of Thrust 2	No augmentation																
	Internal augmentation																
	External augmentation																
State of Propellants	Gaseous state																
	Liquid state																
	Solid state																
Operating Mode	Continuous																
	Intermittent																
Reactivity	Self-igniting																
	Artificial ignition																

Fig. 2.2 The cross-consistency matrix (CCM) for the field in Fig. 2.1

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 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. In general, we first want to distinguish between what is *possible* and *not possible* (or not plausible), before going on to consider normative issues. (Although, as we shall see, some models are *predominately normative* in character.)

This technique of using pair-wise consistency relationships between conditions, in order to weed out internally inconsistent configurations, is made possible by the principle of dimensionally inherent in the morphological approach. While the number of configurations in a morphological field grows exponentially with each new parameter, the number of *pair-wise relationships between conditions* grows only as a quadratic polynomial – more specifically, in proportion to the triangular number series (see Chap. 6). Naturally, there are practical limits reached even with quadratic growth. However, a morphological field involving as many as 100,000 formal configurations can require no more than few hundred pair-wise consistency assessments in order to create a solution space.

When this solution space is synthesized, the resultant morphological field becomes an interactive inference model, in which any parameter (or multiple parameters) can be selected as "input", and any others as "output". Thus, with proper computer support, the field becomes a *conceptual laboratory* for exploring knowledge bases and solution requirements, testing assumptions and interventions, and spotting potential *unintended consequences* – which are one of the main outcomes of intervening into *wicked problems*.

GMA employs *facilitated group interaction* as a central feature of the modelling process, since we are not only structuring a complex problem, but creating among the participants shared concepts and a common modelling framework. What is essentially a process of collective creativity is best facilitated in dialogue between participants, rather than each participant addressing an "assembly". For this reason, we have found it best to work with subject specialist groups of no more than six to seven persons. If a wider knowledge base is required, one can either bring specialized competence into specific group sessions, or work in parallel groups (see Chap. 7).

Depending on the level of ambition (e.g. how many different models a client wishes to develop; the complexity of the models; and the number of groups involved) a modelling job can take between two and ten workshops days. We utilize two facilitators per workshop group. These alternate between, on the one hand, facilitating the group process as such and, on the other hand, tending the computer, recording and reflecting. Virtually all of the work is done in the workshop setting, with little back-office or software preparation time required.

Also, the software is designed to facilitate project documentation during the workshop sessions themselves. The models that are generated during these sessions belong to the client, who is provided with software and documentation to run and maintain them.

2.4 Example: Organisational Structure

A simple example of a morphological model may suffice to illustrate the principles of the method. It is drawn from a project done in the late 1990s for the Swedish National Defence Research Agency (FOI) concerning future *Organisational structure*. In fact three models were developed for the project: *Organisational structure*, *Markets and clients* (see Case Studies) and *Security and legal issues*. (*Note*: the model shown here is a truncated version of the original model. It is employed here only as a pedagogical example.)

With the end of the Cold War, Swedish defence research (as in many other countries) began to develop into broader areas of interest than simply territorial or invasion defence. Also, with changing threat perceptions, there were clear budgetary issues afoot (i.e. budgets were going to be cut!). How could a predominately national defence oriented organisation like FOI reform or re-invent itself to cope with new post-Cold War developments.

The first problem is to identify and properly define the dimensions of the problem – that is to say, the relevant *issues* or parameters involved. These included organisational and leadership types, client sectors, products and employee profiles – all at a relevant level of abstraction. One of the advantages of GMA is that there are no formal constraints to mixing and comparing such different types of issues. On the contrary, if we are really to get to the bottom of an organisational or policy problem, we must treat all relevant issues *together*.

Secondly, for each issue (parameter), a spectrum of "values" must be defined. These values represent the possible, relevant states or conditions that each issue can assume, for the particular study at hand.

The process embodied in these two "steps" is an iterative one, much like the iterative ups-and-downs illustrated in Conklin's diagram describing the time line of structuring "wicked problems" (see Chap. 3).

The morphological field for the organisational structure model is shown in Fig. 2.3. It contains 186, 624 possible configurations – which is simply the product of the number of values under each parameter.

The next (iterative) step in the analysis-synthesis process is to reduce the total set of (formally) possible configurations in the morphological field to a smaller set of internally consistent configurations representing a "solution space". (This is what Zwicky called the *principle of contradiction and reduction*, and what we call a "Cross-Consistency Assessment" (CCA).)

This reduction allows us to concentrate on a manageable number of internally consistent configurations. With dedicated software, we can designate inputs, define drivers and examined resultant output configurations as elements of scenarios or specific strategies in a complex policy space. Figure 2.5 shows the model designated with three inputs (grey).

Organisation TYPE	Leadership culture	Dominant buyer structure	Dominate product/ service	Co-operation strategies	Principle Employee profile	Main employee incentive
Official state agency	Bureaucratic hierarchy	Ministry dominated	Process + method support	Outside help when needed	Life-long service	Money
Government owned enterprise	Strong scientific leadership	Military and material dominated	Soft studies	Joint ventures	Career researcher	Managerial career
Academy	Marketing division leadership	Defence Industry	Hard studies	Consultant purchasing	Development engineer	Pleasure in one's work
Trade institute	Umbrella management	Civilian agencies	Basic research	Mediator only	"Consultant"	Educational motivation
Consultant firm	"Gatekeeper"	Private markets (national)	Testing, construction		Entrepreneur	Titles, specialist career
"Learning organisation"	Skunk-works	International markets	Second opinion		Elite troops	Organisation gives status

Fig. 2.3 One of the organisational development models produced for the Swedish Defence Research Agency in the late 1990s

		Organisation						Leadership						Dominant						Dominate						Co-operatio				Principle					
		Official state agency	Governmentowned	Academy	Trade institute	Consultant firm	earning organisation"	ureaucratic hierarchy	Strong scientific	Marketing division	mbrella management	"Gatekeeper"	Skunk-works	Ministry dominated	Military and material	Defence industry	Civilian agencies	Private markets	Internationalmarkets	Process + method	Soft studies	Hard studies	Basic research	Testing, construction	Second opinion	Outside help	Joint ventures	onsultant purchasing	Mediator only	Life-long	Career researcher	evelopment engineer	"Consultant"	Entrepreneur	Elite troops
Leadership culture	Bureaucratic	F	-	X	F	X	X																												
	Strong	X	X	F	X	X	-																												
	Marketing	K	F	X	F	F	-																												
	Umbrella	X	-	-	X	F	F																												
	"Gatekeeper"	F	K	-	K	X	X																												
	Skunk-works	X	X	-	X	-	F																												
Dominant buyer structure	Ministry	F	K	-	F	K	K	F	X	K	-	-	-																						
	Military and	F	-	-	F	-	K	F	X	K	K	-	-																						
	Defence	K	-	-	-	-	-	K	-	F	-	-	-																						
	Civilian	-	-	K	K	-	-	-	K	-	F	-	-																						
	Private markets	X	-	X	X	-	F	X	-	F	F	-	-																						
	International	X	-	-	X	-	F	X	-	F	F	-	-																						
Dominate product/ service	Process + method	F	-	K	F	F	F	-	-	-	-	-	K	-	F	X	-	-	-																
	Soft studies	F	-	F	F	K	F	-	-	-	-	-	-	F	-	K	F	-	-																
	Hard studies	-	-	F	F	F	F	-	-	-	-	-	-	-	-	F	-	-	-																
	Basic research	K	X	F	K	X	F	K	F	K	-	F	-	X	X	X	X	X	-																
	Testing, construction	-	-	-	K	-	F	-	K	-	-	-	-	X	-	-	-	-	-																
	Second opinion	F	K	K	F	-	F	-	-	K	-	-	K	F	X	X	-	X	-																
Co-operation strategies	Outside help	-	-	-	-	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
	Joint	-	-	-	-	K	F	K	-	-	K	-	X	K	K	-	-	-	-	K	-	-	-	-	-										
	Consultant	-	-	X	X	K	X	-	K	-	K	-	-	K	K	-	-	-	-	X	-	-	-	K	X										
	Mediator only	-	X	X	X	-	-	K	X	-	X	K	X	X	K	-	-	-	-	X	-	-	X	X	X										
Principle Employee profile	Life-long	F	-	F	F	X	X	F	-	X	X	F	X	-	-	K	K	K	X	-	-	-	-	-	-	-	-	-	-						
	Career researcher	-	K	F	-	K	-	-	F	X	-	F	F	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	X						
	Development engineer	K	-	-	K	-	-	-	-	F	-	-	F	K	-	-	-	-	-	K	X	-	X	-	X	-	-	-	X						
	"Consultant"	F	-	K	X	F	K	-	K	F	F	K	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-						
	Entrepreneur	-	-	F	K	-	F	X	X	F	F	X	F	-	-	F	F	F	F	-	-	-	-	-	-	-	-	-	-						
	Elite troops	K	K	F	K	-	F	X	F	-	-	-	F	-	-	-	-	F	F	-	-	-	-	-	-	-	-	-	-						
Main employee incentive	Money	K	F	X	K	F	-	K	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K	K	F	F	-	F
	Managerial career	F	-	F	-	K	K	F	K	-	-	-	K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	F	-	-	K	K	-	-
	Pleasure	-	-	F	-	-	F	-	-	-	F	-	F	-	-	-	-	-	-	-	-	-	F		-	-	-	-	-	-	F	F	-	F	F
	Educational motivation	-	-	-	F	F	-	K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
	Titles, specialist	X	K	F	K	-	-	K	-	-	K	-	K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K	X	F	-	F	-	-
	Organisation status	F	-	F	X	K	F	-	-	-	F	-	F	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	-	-	F	-	-	F	F

Fig. 2.4 Cross-consistency matrix (CCM) for the organisational development model in Fig. 2.3

Organisation TYPE	Leadership culture	Dominant buyer structure	Dominate product/ service	Co-operation strategies	Principle Employee profile	Main employee incentive
Official state agency	Bureaucratic hierarchy	Ministry dominated	Process + method support	Outside help when needed	Life-long service	Money
Government owned enterprise	Strong scientific leadership	Military and material dominated	Soft studies	Joint ventures	Career researcher	Managerial career
Academy	Marketing division leadership	Defence Industry	Hard studies	Consultant purchasing	Development engineer	Pleasure in one's work
Trade institute	Umbrella management	Civilian agencies	Basic research	Mediator only	"Consultant"	Educational motivation
Consultant firm	"Gatekeeper"	Private markets (national)	Testing, construction		Entrepreneur	Titles, specialist career
"Learning organisation"	Skunk-works	International markets	Second opinion		Elite troops	Organisation gives status

Fig. 2.5 Organisational structure model with three inputs (*grey*) and resultant output cluster (*black*)

2.5 Conclusions

General Morphological Analysis, including the process of "Cross-Consistency Assessment" (CCA), is based on the fundamental scientific method of alternating between analysis and synthesis. For this reason, it can be trusted as a useful, non-quantified method for investigating problem complexes, which cannot be meaningfully treated by formal mathematical methods, causal modelling and simulation.

However, as a non-quantified modelling method, GMA has several advantages over less structured approaches. Zwicky called it "totality research" which, in an "unbiased way attempts to derive all the solutions of any given problem". It may help us to discover new relationships or configurations which might be overlooked by other – less structured – methods. Importantly, it encourages the identification and investigation of *boundary conditions*, i.e. the limits and extremes of different contexts and factors.

It 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 parameters become immediately (and embarrassingly) evident when they are cross-referenced and assessed for internal consistency. This provides for a good deal of in-built "garbage detection", since these assessments simply cannot be made until the morphological field is well defined and the working group is in agreement about these definitions.

This type of *garbage detection* is something that policy analyses and futures studies certainly need more of.

Also, both the *formulation* of the morphological field itself, and the assessments put into the cross-consistency matrix, represent a fairly clear "audit trail", which makes the judgmental processes inherent in GMA relatively traceable, and – in a certain sense – even reproducible. We have run trials in which identical morphological fields were presented to different groups for cross-consistency assessment. Comparing the results, and bringing the groups together to discuss diverging assessments, helps us to better understand the nature of the policy issues involved, and also tells us something about the effects of group composition on the assessments.

One final note on morphological modelling: GMA is a fundamental method and very general procedure. It leaves open a number of questions about dependencies, independent variables, what is "input" vs. "output", what different types of consistencies are employed, etc. To attempt to impose one or another of these issues *beforehand* on the modelling process, or in the software applications, would be a huge mistake. It is the very *open nature* of these questions that allows for the creative exploration of the modelling space. Not "fixing" these issues beforehand gives us the possibility of free but disciplined creativity – what Bernhard Reimann called the *poetry of hypothesis*.

Before going on to a more detailed description of the GMA procedure (Chap. 4), we can first take a look at the main type of problem complex for which GMA was initially developed – i.e. *wicked problems* and *social messes*.

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