Experiencing GMA as a means of developing a conceptual model of the problem space involving understanding cascading effects in crises

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ABSTRACT

A complex challenge facing those involved in crisis management relates to how to manage cascading effects in crisis situations. This paper provides a practice-based insight into the use of General Morphological Analysis (GMA), a non-quantified modelling method that can enable a shared understanding of the various interdependencies involved in cascading crises, by creating a conceptual model of a problem space. This insight paper provides an understanding of the nature of the method, and to reveal the project-related experiences of the facilitator and researchers, thereby contributing to an understanding of the benefits and challenges associated with GMA. Authors find that GMA provided a useful means of a multidisciplinary group developing an initial conceptual model for a complex problem. Whilst a challenging experience, the method will be used for conducting gap analyses at a later stage in the project, thus providing benefits to understanding and managing cascading effects in crises.

Keywords

Cascading effects, general morphological analysis, problem space, crises.

INTRODUCTION

Managing cascading effects in a crisis is an important, yet profoundly complicated process. Cascading effects in crises refer to situations where a disruption of one element, such as infrastructure, causes a sequence of disruptive events, which can cause deleterious impacts far beyond the initial impacts of the crisis (Little, 2010). A prominent example of a crisis containing cascading effects is the sequence of events that took place at the Japanese Fukushima Daiichi Nuclear Power Plant following an earthquake and tsunami in 2011. The supply of power to the plant was cut off, and emergency generators were destroyed. Without power the cooling systems of the plant stopped working, resulting in the overheating of the fuel rods, leading to radioactive material being released into the air, and to contaminated water spilling from the plant's storage facilities for many months (BBC, 2013). Thus, in order to better manage cascading effects in a crisis, it is necessary to understand the dynamic web of interdependent infrastructures, systems, and stakeholders involved in responding to and managing a crisis.

Accordingly, the present paper provides a practice-based discussion on the use of General Morphological Analysis (GMA), a non-quantified modelling method that can enable a shared understanding of the various interdependencies involved in cascading crises, by creating a conceptual model of a problem space. Within this

insight paper, emphasis is placed on the experiences of those involved in participating in GMA workshops.

A conceptual model is a set of interconnected variables that is used to define a system or phenomenon, and examines its behavior in a way that allows for "thought experiments" to be conducted with it. This set of interconnected variables represents the problem space of the system to be studied – in this case an integrated technical/social/organisational system. This paper is based on preliminary work undertaken within the European Commission funded project FORTRESS (Foresight Tools for Responding to cascading effects in a crisis). FORTRESS aims to build a modeling platform for cascading effects in cross-border crises. Additionally, it strives to develop a corresponding decision support tool, in order to support crisis managers in preparing for and responding to cascading crises.

This insight paper will detail the methodological considerations related to the use of GMA in FORTRESS, as well as the views of participants and the facilitator based on their experiences of morphological workshops carried out, in order to provide the reader with an insight into the experiences of engaging with this method for bringing an interdisciplinary team together to work on a complex problem.

GMA: AN INTRODUCTION

GMA is a method for modelling complex social and organisational planning problems that are not amenable to quantification, and where the uncertainties involved are significant and cannot be reduced. It examines all the possible relationships between various social, political and organisational dimensions of a complex problem, and allows researchers to consider all potential outcomes. With computer support, GMA produces non-quantified, multidimensional inference models which can be used to test assumptions, theories and proposed solutions before further steps in a research project are taken (see Ritchey, 2006).

Computer-aided GMA was originally developed at FOI (the Swedish Defence Research Agency) in the 1990s, in order to better facilitate long-term defence and civil preparedness planning. It was specifically designed to deal with multi-stakeholder social and organisational policy problems and to facilitate collaboration between different disciplines and different societal sectors.

GMA has been utilised in a number projects, including projects on crisis management (e.g., Ritchey, 2006; Ritchey, Lövkvist-Andersen, Olsson and Stenström, 2004). GMA is usually carried out in professionally facilitated modelling workshops consisting of six to eight subject specialists in the area of study. The method involves a number of iterative steps corresponding to cycles of analysis and synthesis: the basic process for developing all scientific models. The initial workshops are primarily intended to allow project participants from diverse backgrounds to freely discuss and consolidate their different perspectives and knowledge bases concerning the project's problem space, goals and means. This process is necessary in order to develop a common project problem space, terminology and modelling framework. New knowledge and insights generated in the development of the morphological models is also one of the important results of such GMA work-sessions. The iterative steps commonly employed when using GMA in a project are:

Analysis phase

1) *Identify relevant parameters*: Identify and define the main parameters that need to be considered within the complex problem or scenario (in FORTRESS these are the column headings in Figure 1).

2) *Identify/define value ranges*: Each parameter is assigned a range of relevant alternative values that it can assume (the column entries under each heading in Figure 1).

Synthesis phase

3) *Relate all variable values to each other* and assess their mutual consistency. This is called a "Cross-Consistency Assessment" (CCA) and allows for the group's appraisal of which relationships in the problem space are possible and plausible, and which are not. This is invaluable for fostering structured discussion and collective creativity.

4) *Synthesise mutually consistent configurations*. A "configuration" consists of one or more states in each of the variables (e.g., the blue cells in Figure 1). The total sum of all internally consistent configurations makes up the solution *space* of the morphological model. The model allows the group to identify and compare different "cases" within the modelling space.

5) *Use the model interactively* to investigate and group all mutually consistent configurations in order to identify alternative scenarios and/or policy solutions.

By conducting a GMA, participating organisations should then develop a common terminology and conceptual framework for the problem complex. This common framework is a living model that serves as a transparent reference to what one is doing, and can be up-dated if and when new discoveries are made about the problem area. At the end of the project, and for the dissemination phase, the morphological models can be used to present the project's results in a graphical, interactive form. These models are computer-based, and the recipients of the project's results receive software in order to run them.

Ritchey (2011) identifies several limitations to conducting a successful GMA. There is the need for a strong and experienced facilitator, otherwise there is the possibility of the quality of morphological models being undermined. Furthermore, as the next section will illustrate, it is crucial that adequate time is allocated to enable the GMA to take place in a collaborative setting; a successful GMA usually takes between two and six days, but can, depending on the scale of the study, take longer. Regarding the participants, it is crucial to ensure that they have sufficient expertise in their area, as this is key to safeguarding validity within the development of the problem space. Another point concerns the requirement of appropriate computer support, due to the complexity of mapping the group work undertaken during a GMA. Crucially, as with all modelling methods, the outcome of a morphological analysis is no better than the quality of its input. It is the responsibility of the facilitator – in collaboration with the client – to make sure that a competent group is formed, and that the GMA modelling process is carried out properly.

GMA IN FORTRESS

GMA was introduced in the FORTRESS project to assist in getting thirteen project partners from different backgrounds and disciplines on the same page. Three GMA workshops were organised early on in the project. The general purpose of these workshops was to engage participants in structured discussions aimed at generating a common understanding of important elements to be considered in the analysis of cascading effects in crises. Two representatives from five organisations attended the initial two-day workshop in London. The list of participants included crisis management practitioners, independent researchers and academics from various disciplines who conduct research in crisis management. Following the first workshop, whilst an additional two day workshop with all participants would have been beneficial, due to lack of time and availability, two one-day meetings were held with a selection of the participants in London and Vienna.

In the workshops, GMA was used to construct the project's problem space. It was included in the initial design of the project to assist the partners in identifying and agreeing upon a framework, in this case the spectrum of aspects to consider in the examination of cascading effects. Discussions facilitating the creation of the problem space were centred on the following question: *What are the most important/relevant parameters concerning cascading effects of disruptive events on critical infrastructure, and how do these parameters relate to one another?* Such parameters included the nature and onset of the crisis, the geographical scale of impact, the sectors directly and indirectly impacted by the crisis, and authorities involved in crisis management.

The problem space consisted of a visual overview in table form, in which all the parameters of relevance, as identified by workshop participants, were listed in the top row, along with their value range. For example, values such as global and national were listed under the parameter 'scope of impact' (see Figure 1). A total of twenty parameters were identified in the first workshop. These parameters and their value ranges were adjusted and refined in two subsequent workshops.

The problem space was subsequently used in the analysis of case studies of past crises. All the relevant parameters and their values were included to visually represent each case study, with the aim of scrutinising and comparing them at a

later stage in the project. The same use of the GMA will take place later in the project when engaging with crisis scenarios, which will be used to run a systems and behavioural analysis to further understand the complex nature of cascading effects in crises.

Within the social sciences, qualitative methodologies such as focus groups also provide an opportunity for discussion of key questions and areas of consideration by a group of experts. However, these groups are often larger (10-15), as opposed to GMA where group sizes are more adequate to 6-8 participants (Ritchey 2011). Whilst a focus group enables participants to discuss matters as a group, the output is more likely to be data that is of value for textual analysis by the researcher, rather than a computerised model based on a process of agreeing upon and formulating an actionable set of interdependencies (as can be produced with GMA).

Case	Types of hazard	Principal nature(s) of impact	Scope of impact	Onset of crisis
Tsunami-Fukushima, Japan, 2011	Natural	Physical	Global	Sudden
Firework factory explosion (2000) - Netherlands	Social	Social / Psychological	International & cross border	Rapid (Hours/days)
London attacks (2005)	Technological	Economic	National	Slow (Weeks)
Heat wave 2003 (France)	Antagonistic	Political	Regional	Creeping (months/years)
Malaysia MH17 plane crash (2014)			Local	

Figure 1. Part of the problem space created for the Fukushima nuclear disaster

Furthermore, a first iteration of the modelling process of interdependencies and relationships between critical infrastructures was developed in the initial workshop. This was done by the means of a Weighted Influence Diagram (WID). This diagram (see Figure 2) listed twelve sectors that could be affected by crises. Subsequently the workshop participants discussed which of these sectors would likely influence another sector if affected (e.g., if ground transportation was affected, could this affect the emergency services?). Additionally, the sectors not strongly influencing but likely to be strongly influenced were identified. This process of analysing cross-impacts or cross-influence relationships between sectors was based on empirical case studies and informed judgments of the workshop participants. The WIDs was developed with the purpose of enabling an initial identification of relevant interdependencies between systems and sectors, which could be of importance in the analysis of cascading effects in crises.

Wirkung VON / AUF	1	2	3	4	5	6	7	8	9	10	11	12	Su.E
1. Transportation (ground)		2	2	1	1	1	2	3	2	2	2	3	21
2. Transportation (air-water)	2		2				3	1	2				10
3. Energy production	3	3		3	3	3	3	3	2	3	2	2	30
4. Energy transmission and distribution	3	3	3		3	3	3	3	2	3	2	2	30
5. Water provision			2				2	3	1	1	1	2	12
6. Public Communication	2	3	1	2	1		1	3	2	1	2	2	20
7. Waste _biochem			1	1	2			2		1	1	2	10
8. Healthcare (hospitals..)		1							2			2	5
9. Emergency services/ homeland sec.	2	3					1	2		1	1	2	12
10. Economic/financial services	1	1	2	1		1		1			1	1	9
11. Government (decision/continuity)						1			2			1	4
12. Social infrastructure						1		1	1		1		4
Summe Beeinflussung	13	16	13	8	10	10	15	22	16	12	13	19	

Figure 2. Cross-impact matrix for the Weighted Influence Diagram

The knowledge on aspects of the problem space and interdependencies between different elements will be refined and expanded throughout the project. An example includes the use of case study profiles as empirical examples in a gap-analysis model to identify the disparities between vulnerability and resilience factors, in order to determine whether particular systems related to crisis and disaster response are vulnerable to cascading or cross-border effects in crisis situations. This model will also be developed with GMA.

Experiencing GMA

Considering the use of GMA in FORTRESS, different accounts of the GMA process can be presented. Here, two accounts are presented the perspectives of the facilitator and researchers involved in conducting GMA in FORTRESS.

Perspective of the facilitator

As is usual in multi-national, multi-disciplinary projects, the workshop participants, while all formally working within the crisis management field came from different backgrounds: both practitioners and academics were represented, as were several different academic disciplines, and nationalities. Under such circumstances, it is advisable to complete two, two-day GMA workshops in order to produce a common project problem space and to give participants enough time for reflection. The benefit of two GMA workshops is also to iron out differences in perspectives, terminology and methodologies for attaining the ultimate goals of the project.

The philosophy behind such a group facilitated GMA is that the "process" of exploring and creating the initial (first iteration) problem field is 90% of the initial "product" – which is to get an unstructured set of participants into a rational dialogue, and a group working more like a team, smoothing out pecking-orders and discussing what the project is "really" about and what level of abstraction we should be working with. Then, for the second two-day workshop, participants are in a much better place for the development of a second-iteration (and much better) problem space. However, due to practical factors beyond the projects' control (predominantly relating to time and the availability of resources), we found that only one two-day workshop would be possible. In this situation, the facilitator was forced to concentrate the initial problem structuring and team building process. We were therefore able to complete the formal requirement of the workshop (i.e., the GMA) with regard to constructing the project's main problems space, but the process of (further) clarifying concepts and building a single team approach was not complete *to the extent* that the facilitator had hoped. This "adjustment" period has thus carried over into the next project phase.

Perspective of the researcher

The authors of the present paper took part in two of the three initial workshops on GMA. One of the researchers has a background in the sociology of disaster, with particular expertise in public response and crisis communication. The other has a background in disaster management from a geographical perspective, specialising in community response and recovery. The following text is based on our experiences with GMA within FORTRESS. It is important to note that one of the researchers had experienced GMA in a previous project, and was thus somewhat familiar with the process.

Prior to the start of the initial workshop, all participants had been presented with limited information on GMA. Apart from an introduction to GMA the facilitator had instructed us "not to prepare anything; just come with an open mind". Such an approach was for us, frustrating. This is somewhat different to the nature of preparation that stems from preparing as a participant for a focus group or semi-structured interview, where participants might be presented with a list of questions prior to discussion, enabling to think about and consider their responses. In hindsight, this absence of information made sense. As participants came from different backgrounds, preparation and acquired knowledge by some might have created an imbalance in the ways all partners contributed to the process.

During the workshop it was important that all participants were able to contribute their ideas and thoughts, and felt comfortable with doing so. Coming from a research organisation where your role is to seek to understand processes such as organisational dynamics in a crisis, it can be difficult to manage the balance between theory and reality (i.e., the experience of the practitioner). An important part of this balance is for participants to feel as though they have an opportunity to present their own perspectives. In this sense GMA bears a strong resemblance to interdisciplinary research; the success of the GMA workshops depended on smooth communication and crucially, negotiation; both are key elements identified by Oughton and Bracken's (2009) in their account of interdisciplinary research. Additionally, the openness to be questioned by and discuss with others outside of one's field of expertise was of considerable importance. Just as crises are not restricted to one segment of society, the discussions on crisis should not be limited by traditional ways of thinking of one discipline or subject area.

A considerable challenge during this process of negotiation was the physical set-up of the workshop. As previously identified, as with other qualitative discussion methodologies (e.g., focus groups) a key component to a successful GMA is a small group. At times, heated discussions took place among participants resulting in some tension. For some, these discussions may have resulted in a sense of frustration and a feeling that little was being accomplished, however, the value of this process of discussion should not be overlooked. The process of going over components such as what do we agree stages of a crisis to be, is key to a clear guiding model for a project such as FORTRESS. An important component of managing the tension at times present in the room, that could be useful to other collaborative research methodologies was the time taken to have breaks. Although a seemingly practical solution, such an activity helped to build relationships and enable the group to proceed that may not always be considered a viable option due to time constraints.

Having everyone participate in the workshop with an open mind enabled the discussions to resemble that of an efficient brainstorm around a topic. As with focus groups, the presence of a strong and experienced facilitator, provided structure to the discussion. It enabled the GMA workshops to kick-start the project with common visual overviews of the key concepts and associated variables that are used in various ways and forms as the project progresses. Moreover, although weaknesses were present, the added value of GMA presented itself in the structured face-to-face group interactions that are key to building strong relationships. From a project perspective, greater allowance of time to enable a full GMA in the first instance would have yielded a more valid output.

CONCLUSION

The present paper serves as an insight paper into the use of GMA for developing a conceptual model in order to create a shared understanding, within a multidisciplinary team, of the various interdependencies involved in cascading crises. The paper began with an overview of the process of GMA, followed by how it is used in the FORTRESS project, as well as some of the outputs it was able to produce.

The paper continued by detailing the perspectives of some of those participating in the GMA workshops, thereby providing a first-hand account of the challenges and benefits that stemmed from the use of GMA in a multidisciplinary project. Benefits gained from the use of GMA in FORTRESS include: 1) gaining a comprehensive overview of the concepts and associated variables requiring our attention within the analysis of historical case studies of cascading effects in the project, and 2) helping to build relationships and a shared understanding of concepts among a multidisciplinary team, which is commonly an obstacle in multidisciplinary research. However, there was a crucial practical obstacle to gaining absolute value from the method: time. For those participating in GMA in FORTRESS a key lesson learnt was the need for adequate time to fully explore and develop the problem space in the first workshop. More time could have enhanced efficiency and saved time in later stages of the project.

Going forward, GMA will also be employed to develop a gap-analysis instrument in order to identify the discrepancies between pathogenic and resilient (systemic, organisational and human factors) factors. The aim is to identify where such pathogenic factors exist, without compensating resilient factors that can leave a system vulnerable to cascading or cross-border effects in crisis situations. The model will use the projects' nine case studies as empirical inputs and tests.

ACKNOWLEDGEMENTS

This paper is based on research emanating from the European Commission-funded FORTRESS project (Foresight tools for responding to cascading effects in a crisis) under grant agreement number 607579. The views in this paper are those of the authors and are in no way intended to reflect those of the European Commission.

REFERENCES

1. BBC (2013). Fukushima nuclear plant: Radioactive water leak found: 20 August. *BBC News Online*, 2013. http://www.bbc.co.uk/news/world-asia-23764382 (Accessed August 8 2014).

2. Little, R. (2010) Managing the Risk of Cascading Failure in Complex Urban

Infrastructures, in Graham, S. (ed.) *Disrupted cities: when infrastructure fails*, Routledge, New York.

3. Oughton, E. and Bracken, L. (2009) Interdisciplinary research: framing and reframing, *Area*, 41, 385-394.
4. Ritchey, T. (2006) "Modeling Multi-Hazard Disaster Reduction Strategies with Computer-Aided Morphological Analysis". Proceedings of the 3rd International ISCRAM Conference, Newark, 2006. http://www.swemorph.com/pdf/multi.pdf (Accessed March 5 2015)
5. Ritchey, T., Lövkvist-Andersen, A., Olsson, R. & Stenström, M. (2004) "Modelling Society's Capacity to Manage Extraordinary Events. Developing a Generic Design Basis (GDB) Model for Extraordinary Societal Events using Computer-Aided Morphological Analysis". Adapted from a paper presented at the SRA (Society for Risk Analysis) Conference in Paris 15-17 November, 2004. http://www.swemorph.com/pdf/chem2.pdf (Accessed March 5 2015)
6. Ritchey, T. (2006) "Problem Structuring using Computer-Aided Morphological Analysis". *Journal of the Operational Research Society*, 57, 792-801. http://www.swemorph.com/pdf/psm-gma.pdf (Accessed March 5 2015)
7. Ritchey, T. (2011) *Wicked Problems – Social Messes*. Springer, Berlin.