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Anthony J. Masys
Editor

Applications of Systems Thinking and Soft Operations Research in Managing Complexity

From Problem Framing to Problem Solving

Springer

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Introduction

Anthony J. Masys

Abstract Today we find ourselves confronted with problems of dynamic complexity and interdependency. Such ‘wicked problems’ and messes are seemingly intractable and are characterized as value-laden, ambiguous, and unstable, that resist being tamed by classical problem solving. Actions and interventions associated with this complex problem space can have highly unpredictable and unintended consequences. Examples of such complex problems include health care reform, global climate change, transnational serious and organized crime, terrorism, homeland security, human security, disaster management, and humanitarian crisis management. Moving towards the development of solutions to these complex problem spaces depends on the lens we use to examine them and how we frame the problem. Systems Thinking and Soft Operations Research has had great success in contributing to the management of complexity. This book captures current trends and developments in the field of systems thinking and soft operations research to support problem framing.

Keywords Wicked problems · Soft operations research · Problem framing · Systems thinking

1 Problem Framing

The reductionist paradigm has dominated most of classical science based upon the worldview ‘…in which entities are generally treated as independent and systems are taken to be close to equilibrium…and assumed to be linear’ (Lyons 2004: 22). The emergence of systems thinking and complexity science has challenged the reductionist lens recognizing actors/agents as interdependent thereby giving rise to nonlinear dynamics.

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In today's complex environment 'Managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other (Rosenhead and Mingers 2001: 4–5).

Such problems as those associated with disaster risk reduction (Masys et al. 2014), climate change (Masys 2006), humanitarian relief (Masys et al. 2014), and non-traditional security (Masys 2015) can be viewed as "wicked problems" or "messes" (Rittel and Weber 1973). Soft Operations Research (OR) approaches have emerged to tackle such wicked and messy problem situations, characterized by conflicting perspectives and ambiguity. Rosenhead and Mingers (2001: 4–5) describe 'messy problems' as that which have inherent complex interdependencies and dynamic complexity. They argue that 'Individual problems may be solved. But if they are components of a mess, the solutions to individual problems cannot be added, since those solutions will interact'. New methods and methodologies have evolved to address such inherent complexity in problem spaces. As noted by Kogetsidis (2011: 283), 'soft systems approaches can be seen as a response to the inability of hard systems thinking to handle human and social aspects of problem situations (Jackson 2010)'. Soft approaches are said to be appropriate in messy problem situations, characterized by obscure objectives and multiple clashing viewpoints (Checkland and Holwell 2004: 45–46).

Heyer (2004: 4) argues that: 'Soft OR uses predominantly qualitative, rational, interpretative and structured techniques to interpret, define, and explore various perspectives of an organisation and the problems under scrutiny. They generate debate, learning, and understanding, and use this understanding to progress through complex problems'.

Soft OR is characterized by

- structuring the problem situation, rather than by problem solving;
- facilitating dialogue between the various stakeholders with the aim of achieving a greater degree of shared perceptions of the problem situation, rather than providing a decision aid to the decision maker;
- 'What' questions, more than by 'How' questions, i.e., 'what is the nature of the issue?'; 'what are appropriate objectives?' given the various world views of the stakeholders; 'what is the appropriate definition of the system for the issue considered?' 'which changes are systemically desirable and culturally feasible?' and only then 'how are these changes best brought about?'
- eliciting the resolution of the problem through debate and negotiation between the stakeholders, rather than from the analyst; and
- changing the role of the 'problem analyst' to one of becoming a facilitator and resource person who relies on the technical subject expertise of the stakeholders (Daellenbach 2002).

Our linear mindset and reductionist approach to understanding complex problems fails. Dealing with such inherent complexity such as that illustrated by wicked problems and messes, systems thinking emerges as a new paradigm. Jackson (2003: 65) defines systems thinking paradigm as'…a discipline for seeing the 'structures' that underlie complex situations, and for discerning high from low leverage change…Ultimately, it simplifies life by helping us to see the deeper patterns lying beneath the events and the details'.

In this complex problem landscape, systems thinking emerges as both a worldview and a process in the sense that it informs ones understanding regarding a system and can be used as an approach in problem solving (Edson 2008: 5). 'Systems thinking' as discussed in Senge (1990) emphasizes interconnectedness, causal complexity and the relation of parts to the whole (Ackoff 1994), thereby challenging traditional linear thinking and simple causal explanations. Senge (1990: 68) describes systems thinking as 'a discipline for seeing wholes…a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots'. As a worldview, systems thinking recognizes that systems cannot be addressed through a reductionist approach that reduces the systems to their components. The behaviour of the system is a result of the interaction and interrelationships that exists thereby acknowledging emergent behaviours and unintended consequences. Systems thinking purports that, although events and objects may appear distinct and separate in space and time, they are all interconnected. As a process, systems thinking recognizes the requirement to assess the system within its environment and context (Senge 2006). Senge (1990) remarks that, because the world exhibits qualities of wholeness, our investigation of it should stem from a paradigm of the whole.

As part of the Springer book series: Advanced Sciences and Technologies for Security Applications, this edited volume: **Applications of Systems Thinking and Soft Operations Research in managing complexity**, focuses on the contribution of Soft OR and systems thinking as it applies along three themes:

- Organizational theme
- Disaster Management theme
- Systems Thinking theme

This book comprises 13 chapters from leading researchers engaged in problem framing and systems thinking tackling wicked and messy problems. The chapters present state-of-the-art research on systems thinking tools, techniques and applications supported by case studies and computational simulation.

2 Content

2.1 Part 1: Organizational Theme

The first three chapters provide a powerful lens regarding the notion of organizational design and dynamics.

John Brocklesby in his chapter '**Using systems modeling to examine law enforcement collaboration in the response to serious crime**' looks at how systems modelling can contribute in helping collaborative law enforcement agencies think about how they might improve their capacity to deal with the rapidly escalating complexity that is associated with trans-national and/or organized crime. Some collaborative law enforcement arrangements have existed for many decades, however in recent years more have been established both within and across national jurisdictions. From a complexity-management perspective, such systems make a good deal of sense. However they are very often beset with a wide range of organisational problems which have to be carefully managed. Against this background, the chapter argues that there is a need for theory that can account for the complexity of the challenge and point towards more holistic and integrated solutions. Drawing upon examples representing three distinct levels of collaboration, i.e. the operational taskforce, the national multi-agency system, and the regional cooperation agency the chapter argues that systems-based modelling tools have much to offer.

Domenico Lepore, Angela Montgomery and Giovanni Siepe in their chapter '**Managing Complexity in Organizations through a Systemic Network of Projects**' describe how managing complexity has become one of the most important issues for economists and managers over the last twenty years. The reason for the increasing importance of this issue is related to the exponential growth of interconnections and interdependencies that has arisen in contemporary society and organizations. Organizations often struggle to adapt their management methods to the shift towards increased complexity.

They present a management methodology, 'The Decalogue', that is a systemic approach for managing complexity in organizations and supply chains through focusing on constraint management (Theory of Constraints) and the understanding and control of variation (Theory of Profound Knowledge). Through the application of this methodology, an organization can transform its operations from a traditional hierarchy (silo mentality) to an organizational model of a systemic network of projects that are appropriate for operating and adapting within a complex reality.

Blane Després in his chapter '**Family of Related Systemic Elements (FoRSE™) Matrix: Big(ger) Picture Thinking and Application for Business and Organizations**' argues that we can best pursue problem framing and solutions by understanding their relationship to the organization's purposes. Part of the process of problem framing involves distinguishing between problems and symptoms. In this chapter he presents big(ger) picture thinking as a best fitting framework via the FoRSE™ Matrix system, and clarifies big(ger) picture thinking and little window glimpses.

2.2 Part 2: Disaster Management Theme

Hanneke Duijnhoven and Martijn Neef in their chapter ‘**Disentangling wicked problems: a reflexive approach towards resilience governance**’ discuss the complex challenge of dealing with diverging threats in our contemporary hyper-connected society. In recent decades, resilience has become a key notion that has been adopted by policy-makers and academia to embrace the changing risk our society faces. Yet the traditional, modernist rational logic that dominates approaches to resilience management, does not fit with the problem at hand. In this chapter they argue that societal challenges in the current era require a paradigm shift: we need novel perspectives on how to approach the governance of risks and the societal implementation of resolutions. They argue that the recent focus shift from *risk assessment* to *resilience enhancement* in many disaster management communities is an important aspect of this paradigm shift, but that it is by itself not enough to deal with the ‘wickedness’ of today’s complexity.

Kristen MacAskill and Peter Guthrie in their chapter ‘**Post-disaster reconstruction—what does it mean to rebuild with resilience**’ provide a unique perspective on framing resilience. In recent years the concept of resilience—the ability to both withstand and recover from a “shock”—has become a core term in international, national and local policy for urban development. Because resilience has been adopted in a range of decision-making contexts, various interpretations of the concept are potentially confusing for those attempting to adopt it in their own decision making. To help provide clarity, this chapter presents a framework that captures different interpretations of resilience as a concept to frame decisions for disaster risk reduction in our communities and cities. This framework acknowledges that resilience is a trans-disciplinary concept; its purpose is to help create a coherent understanding of how sector-specific applications of resilience lie within a broader conception of resilience in disaster risk management. More specifically, the framework is used to examine how resilience is considered in the post-earthquake reconstruction of infrastructure networks in Christchurch, New Zealand. There is still much to learn from case studies of post-disaster recovery, where the recovery environment introduces different and perhaps unfamiliar levels of complexity in decision-making compared to business as usual planning and development.

Anthony J. Masys, Eugene Yee, and Andrew Vallerand in their chapter ‘**Black swans, dragon kings and beyond: towards predictability and suppression of extreme all-hazards events through modeling and simulation**’ contributes to the discourse on Dragon Kings arguing for continued and concerted efforts to explore this domain. A ‘Black Swan’ is described by Taleb (2007) as that which is an outlier, that which is outside the realm of regular expectations which carries with it an extreme impact such as natural disasters, market crashes, catastrophic failure of complex socio-technical systems and terrorist events such as 9/11. Sornette (2009) identifies a different class of extreme events (outliers) that he calls ‘Dragon Kings’. Sornette (2009) argues that Dragon Kings may have properties that make them not only identifiable in real time but also predictable. The evolving science on complexity (and, more specifically, on complex networks) and on resilience suggest that modeling and simulation of such extreme events can assist in the predictability and the suppression of low probability extremely high consequence events such as natural hazards (flood, earthquake, wildfire, tsunami, extreme weather), cyber-attacks, and financial events. Furthermore, the science of complex networks is developing rapidly and has fundamentally reshaped our understanding of complexity, potentially leading to innovative methods for the prediction of emergent behavior on natural and technological networks, as well as specific strategies for designing networks that are more resistant (resilient) to both failure and attack. Governments and owners of critical physical and digital infrastructure may benefit from analyses, advice and exercises that involve predictable and suppressible "Dragon-King" type of low probability extremely high consequence extreme events, as well as from the utilization of recent advances in complex network theory, to ultimately enhance resiliency.

Regan Potangaroa in his chapter "**Unproblemising the Technical Complexity of Shelter in Post Disaster Reconstruction**" describes Humanitarian Emergency Response and shelters in post disaster reconstruction in terms of a wicked problem. The intractable and 'wicked' nature means that donors and agencies involved in humanitarian aid see it as "easy to get into, but hard to get out of". There are seemingly no one-off, "silver bullet" solutions and where such "cookie cutter" solutions are applied, their weaknesses soon become apparent to all involved. While most lessons learnt and evaluations have pointed towards better coordination, stronger leadership, more innovation and integration of service delivery there remains little appreciation of the role of technical complexity in resolving the apparently 'intractable' problem of shelter provision. This chapter uses a case study approach to identify and propose an approach that is not evident in the current literature.

2.3 Part 3: Systems Thinking Theme

Steve Strang and Anthony Masys in their chapter '**Supporting Intelligence Analysis through visual thinking**' describe the current threat landscape as a complex problem space, value-laden, open-ended, multidimensional, ambiguous and unstable which can be labeled as 'wicked and messy'. Events such as 9/11 highlight "surprising events" that reflect an organizations inability to recognize evidence of new vulnerabilities or the existence of ineffective countermeasures (Woods 2006: 24). This necessitates the requirement to readjust to their existence and thereby the need to consider the extremes (Taleb 2007: xx), to challenge dominant mindsets and explore the space of possibilities. In Limits of Intelligence Analysis, Heuer (2005) argues how limitations in perception, perspective, and resistance to change, as well as understanding and communicating uncertainty all contribute to the complexity of intelligence analysis.

Addressing the unique challenges associated with transnational threats as terrorism and organized crime requires creative and collaborative efforts among key intelligence and security stakeholders that facilitate questioning judgments and underlying assumptions, and employing critical and creative thinking in order to explore the possibility space. This chapter explores the application of 'visual thinking' to deal with the complexity and challenges associated with intelligence analysis.

Simon A. Bennett in his chapter '**The Benefits of systems-thinking approach to accident investigation**' presents an argument that the origins of disaster are complex. Systems-thinking offers the best chance of identifying contributory factors. Two disasters are discussed with reference to actor-network theory (ANT) which, thanks to its 'principle of generalised symmetry', supports holistic, high-fidelity analysis. There are overheads associated with the methodology. Where safety is concerned, reductionist analyses come a poor second to high-fidelity, systems-thinking-informed analyses. As the saying goes, the Devil is in the detail. That said, the systems-thinking approach to accident investigation is not without its problems—like deciding the boundaries of the network space. Inevitably, an investigative methodology grounded in inclusivity (ANT, for example) produces long lists of contributory factors (actants)—from rules, regulations and cultural predispositions to physical objects like radar sets, missile launchers, warheads and shrapnel. The size of the network space considered by a systems investigation influences the direction the investigation takes and the conclusions reached—because size determines which factors are considered and which are not.

Polinpapilinho F. Katina in his chapter '**Systems Theory as a foundation for discovery of pathologies from complex system problem formulation**' articulates a set of systems theory-based pathologies that act to limit performance of complex systems. In response to the common mantra that problem formulation is the most important activity in successfully dealing with complex system problems, this research elaborates on the utility of systems theory as the basis for problem formulation through the discovery of system pathologies. Pathologies are taken as circumstances that act to limit system performance or lessen system viability (continued existence) and as such they reduce the likelihood of a system meeting performance expectations.

Leena Ilmola and Nikita Strelkovsky in their chapter '**Soft (?) social systems and shocks: an experiment with an agent based model**' describe how emerging uncertainties of global systems present a challenge to decision making. Plenty of studies have been conducted, and models have been built on operations research and economics in order to support decision making in complex environments. Models are frequently missing the main source of uncertainty; a reaction of a social system to a disruptive event or a shock. The feedback of the social system is often pushing our well planned operations out of their trajectories. This chapter presents a decision support application to meet the challenges associated with uncertainty and feedback loops.

Simon Levine in his chapter '**System Failure? Why humanitarian assistance can't meet its objective without systems thinking—and why it finds it so hard to use it**', describes the systems approach as it applies to humanitarian disaster planning and operations. This chapter describes a system (emergency response to droughts in the Horn of Africa) that was clearly not functioning well in the eyes of those who were working in it. It tells the tale of a diagnosis that did not start with system theory, but which found itself forced into understanding the problems in system terms, and which tried to find a system solution to avoid future repeated failures. It is presented here as a story of both hope and disappointment with lessons that are hopefully of wider applicability than just for the humanitarian system that it describes. There was, and remains, hope, because so many of the practitioners found the use of system thinking (without any system jargon or intellectualisation) to be a refreshing take on an old problem and they saw that it offered a different way to do something about long standing failures. It is also a tale of disappointment because ultimately the initiative did not succeed in establishing the processes that were needed.[1] And it is hopefully instructive because systems thinking itself reveals why the initiative was so likely to fail: it is a sad truth that institutional diagnosis tends to be reserved for problems and is rarely used *ex ante* in assessing the institutional (or system) feasibility of proffered solutions.

Ivan Taylor in his chapter '**Using First Nations Systems Thinking to Operationalize Sustainable Development**' present a systems thinking approach that reflects a Canadian First Nation's view of sustainable development. This approach is operationalized using a System Dynamics model, called Mini-World, developed by Harmut Bossel. The primary stocks in the Mini-World model were converted to represent the quality of The Land, The People and The Economy which is terminology to which the First Nation can relate. Bossel's concept of "orientors" is used to translate the stocks in the model into traditionally and culturally specific values in which the First Nation is particularly interested. It is hoped that this translation of the measures, from a classical System Dynamics model into concepts the First Nation can relate to, will lead to acceptance and use of this operationalization of their systems thinking.

3 Conclusion

Systems thinking and soft OR provide lenses and methodologies to examine wicked problems and messes. The traditional linear approach to problem solving tends to not capture the inherent complexity of wicked problems. Framing the problem thereby becomes essential.

We begin the chapters with this reflective quotation:

> *'The way we think is outdated. As a result, the way we act creates problems, and then we are ill-equipped to address them because of the way we think'* (Gharajedaghi 2004).

[1]The chapter draws on the experience of the Pastoral Areas Coordination, Analysis and Policy Support (PACAPS) initiative of the USAID programme, Regional Enhanced Livelihoods in Pastoral Areas (RELPA).

References

Ackoff R (1994) Systems thinking and thinking systems. System Dyn Rev 10(2–3):175–188

Checkland P, Holwell S (2004) Classic OR and sift OR- an asymmetric complementarity. In: Pidd M (ed) Systems modeling—Theory and Practice. Wiley, England

Daellenbach HG (2002) Hard OR, Soft OR, problem structuring methods, critical systems thinking: a primer. http://orsnz.org.nz/conf36/papers/Daellenbach.pdf

Edson R (2008) Systems thinking. applied: A Primer. ASysT Institute http://www.anser.org/docs/systems_thinking_applied.pdf

Gharajedaghi J (2004) Systems Methodology A Holistic Language of Interaction And Design Seeing Through Chaos and Understanding Complexities1http://www.acasa.upenn.edu/JGsystems.pdf

Heuer RJ (2005) Limits of intelligence analysis. Orbis 49(1):75–94. http://www.worldaffairsboard.com/attachments/staff-college/20727d1273228985-ebo-sod-limits-intelligence-analysis-fpri-winter-2005-heurer-.pdf

Heyer R (2004) Understanding soft operations research: the methods, their application and its future in the defence setting. Command and Control Division Information Sciences Laboratory: DSTO-GD-0411 http://dspace.dsto.defence.gov.au/dspace/bitstream/1947/3707/1/DSTO-GD-0411.pdf

Jackson MC (2003) Systems thinking: creative holism for managers. John Wiley & Sons Ltd, West Sussex

Jackson MC (2010) Reflections on the development and contribution of critical systems thinking and practice. Syst Res. Behav. Sci 27:133–9

Kogetsidis H (2011) Systems approaches for organizational analysis. International journal of organizational analysis 19(4):276–287

Lyons M (2004) Insights from complexity: organizational change and systems modeling. In: Pidd M (ed) Systems modeling—Theory and Practice. Wiley, England

Masys AJ. (2006) Understanding climate change through modelling and simulation: a case for verification, validation and accreditation. In: Published in the proceedings of the climate change technology conference, Ottawa, Canada, 9–12 May 2006

Masys AJ (ed) (2015) Exploring the security landscape—non-traditional security challenges. Springer Publishing (forthcoming)

Masys AJ, Ray-Bennett N, Shiroshita H, Jackson P (2014) High Impact/ Low Frequency extreme events: enabling reflection and resilience in a hyper-connected world. 4th International Conference on Building Resilience, 8–11 September 2014, Salford Quays, United Kingdom. Procedia Economics and Finance 18 (2014): 772–779

Rittell HW, Weber MM (1973) Dilemmas in general theory of planning. Policy Sci 4:155–169

Rosenhead J, Mingers J (2001) Rational analysis for a problematic world revisited. Wiley, England

Senge P (1990) the fifth discipline: the art and practice of the learning organization. Doubleday Currency, New York

Senge P (2006) The fifth discipline: the art and practice of the learning organization. Doubleday Currency, New York

Sornette D (2009) Dragon-kings, black swans and the prediction of crises. Int J Terraspace Sci Eng 2(1): 1–18. (http://arXiv.org/abs/0907.4290)

Taleb NN (2007) The black swan: the impact of the highly improbable. Penguin Books Ltd, London

Woods DD (2006) Essential characteristics of resilience. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience engineering: concepts and precepts. Ashgate Publishing Ltd, Hampshire

Part I
Organizational Theme

Using Systems Modelling to Examine Law Enforcement Collaboration in the Response to Serious Crime

John Brocklesby

Abstract This contribution looks at how systems modelling can help collaborative law enforcement agencies think about how they might improve their capacity to deal with the rapidly escalating complexity that is associated with transnational and/or organized crime. Some collaborative law enforcement arrangements have existed for many decades, however in recent years more have been established both within and across national jurisdictions. From a complexity-management perspective, such systems make a good deal of sense. However they are very often beset with a wide range of organisational problems which have to be carefully managed. Against this background, the chapter argues that there is a need for theory that can account for the complexity of the challenge and point towards more holistic and integrated solutions. Drawing upon examples representing three distinct levels of collaboration, i.e. the operational taskforce, the national multi-agency system, and the regional cooperation agency, the paper argues that systems-based modelling tools have much to offer.

Keywords Law enforcement · Organised transnational crime · Collaboration · Systems thinking · Viable systems

1 Introduction

This chapter examines the role that systems theory and modelling might play in assisting collaborative law enforcement agencies make sense of, and deal with the myriad of organisational challenges that are involved in responding to the various complexities that are associated with modern criminality, particularly that which is organised and which operates across national and/or regional boundaries.

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Focussing on relatively new collaborative arrangements that are being introduced within and across national jurisdictions, and globally, the paper argues that there is an urgent need for better discussions about how, organisationally, this problem might best be tackled. In particular, there is a need for theory that can account for the plethora of organisational issues and tensions that are associated with collaborative systems and point towards more holistic and integrated solutions.

In looking at what role systemic thinking and modelling might play in this, the chapter specifically focuses on two key aspects; the first theoretical, the second epistemological. In relation to the former the proposition is that if new organisational systems including meta-systems are being mooted as the best way of responding to the undoubted complexity exhibited by transnational crime, then it logically follows that a complexity-based and systemic perspective is as good a place as any to start looking in the search for possible design solutions. In relation to the latter, although appropriate theory is a good starting point in formulating some general design principles it also seems axiomatic that successful collaboration hinges on finding appropriate mechanisms and processes that will allow key stakeholders to work out themselves the finer details of how this might translate in concrete settings. This strongly suggests the need for an appropriate organising framework to establish some order, to forewarn stakeholders, and assist them in making sense of the plethora of challenges that collaboration presents, and to assist them in coming up with workable solutions.

In what follows the chapter begins by providing some background information on both the nature of the problem as well as how it is being addressed organisationally. It then introduces relevant systems theory and modelling tools and demonstrates how these can be applied across various levels of collaboration including temporary operational task forces, national multi-agency systems, and finally cross-border regional cooperative agencies.

2 Background

Over the last decade or so, government bodies and law enforcement agencies have introduced a raft of new organisational arrangements to address the problem of escalating transnational organised crime. In many regions, what in the past may have been localized and hierarchically organised groups operating in particular areas of criminality, are now being transformed into, or superseded by, sophisticated, flexible network-based structures that can hide their leadership and financial assets in one place while moving quickly across regions and international borders in response to perceived new market opportunities and threats. For example, writing about his experiences with the Camorra crime syndicate in Naples and the surrounding towns, Saviano (2006) highlights key aspects of the changing nature of organized crime. Here the procurement and sale of drugs, people smuggling, counterfeit clothing and electronics is part of a global network of criminal activity that earn billions of dollars. As part of this network the Camorra no longer exhibit signs of a rigid hierarchical organisation, but loosely structured organization that is willing to engage in mutually beneficial deals with anyone in the world. With constantly evolving networks relationships are often transient and transactional. At the same time, established criminals are becoming smarter, many having acquired specialist skills such as cyber crime and money laundering through tertiary study and/or professional training. A similar picture to this is painted by a range of scholars and investigative journalists [see, for example, Saviano 2006; Glenny 2009; Moore 1996; Williams 2006; Wright 2006; Klerks 2003].

The challenges that such developments pose to government agencies and law enforcement agencies are manifold. Globally western government agencies have existed in vertical silos which tend to accentuate accountability, departmental efficiency and structural clarity at the expense of communication and collaboration. In policing, the dominant law enforcement paradigm has been based primarily on the hierarchically-organised local area command or state police force focussing mainly on domestic crime, while intelligence agencies would focus on foreign governments and international security threats. This creates difficulties in areas such as cyber-crime, human trafficking, and narcotics, where criminal activity occurs both inside and outside national boundaries.

With this apparent mismatch between organized criminal networks and traditional policing methods and structures, governments have begun to recognize that law enforcement needs to be more flexible and innovative, and that there must be more collaboration between and across law enforcement agencies and experts from different areas of the public sector. This has prompted governments around the world to establish new organisational structures that broaden policing capability and seek to transcend the normal bureaucratic way of doing business (Homel 2004; Jacobs and Hough 2010).

Typically these new law enforcement agencies work alongside rather than replace the traditional area or state police command; they also operate at numerous levels. At one extreme these can range from temporary 'operational taskforces' that might be charged with gathering intelligence on, and/or bringing to justice and prosecuting a particular criminal group, to permanently staffed national cross-jurisdiction agencies that seek to provide an integrated response by combining specialist input from areas such as law enforcement, coastguard, customs, cyber-crime, immigration, taxation, fraud. Beyond that, and at the other extreme, there are longer-established international cooperative agencies such as Europol that convene 'joint investigation teams' to coordinate law enforcement activity internationally, and provide analytical, technical and logistical support to national police bodies.

From a managing complexity perspective, creating collaborative systems such as these makes a good deal of sense. However the organisational challenges that they face are manifold. When independent agents or organisational units that have previously operated in a silo fashion are brought together, as they are for example when professional experts participate in an operational taskforce, or when national bodies engage in regional cooperation, it would be naive to assume that there will necessarily be a synergistic relationship. While annual reports, newspapers, websites and increasingly social media proudly highlight the many successes of such collaborations (see, for example, OCTA reports, Europol, OFCANZ, SOCA, ACC) wider testimony suggests that they can be beset with a range of problems including conflicting values, confused identities, difficulties in balancing cooperation and competition, local agendas undermining global agendas, and ambiguous participant 'rules of engagement' [see, for example, Kavanagh and Richards 2001; Ling 2002; Lowndes 1988; Ashby 1952]. Wherever the balance between positive and negative outcomes lies, it seems clear that the particular structures and processes that are put in place need to be carefully thought through, and the relationships between the participants and the new 'systemic whole' has to be carefully managed.

Amongst the range of potential systemic tools and methodologies that might assist in this project, the discipline of cybernetics, the derivative theory of viable systems and its associated analytical tool, the Viable System Model (VSM hereafter), stands out as being particularly useful. Cybernetics and the theory of viable systems propose solutions to the problem of dealing with complexity so it stands to reason that they are relevant to debates around how to best deal with what is perhaps one of the most complex problems facing society today; the VSM itself specifically addresses the question of how collaborating but otherwise autonomous groups need to be managed in order to generate synergistic outcomes for whatever 'system' they participate in. This is clearly relevant when the focus is on collaboration across organisational units. And finally, the VSM framework provides a way of identifying and representing issues diagrammatically in a manner that, in any particular concrete setting, can organise people's thinking about otherwise complex phenomena, thereby facilitating dialogue on how these structures might best be designed, issues addressed, and the system managed.

3 Theory

Much has been written about the theory and modelling tool used here (Beer 1972, 1979, 1985; Espejo 1989; Espejo and Schwaninger 1993; Espejo et al. 1996), so only a basic outline will be provided. The logical starting point, and one of the foundational concepts in cybernetics is W. Ross Ashby's so-called 'Law of Requisite Variety'. Here the term 'variety' is basically a proxy for complexity; it refers to the number of possible states exhibited by any 'environment' in which the system, including its various processes and the management of these, can be taken to be embedded. Such variety is relative to some defined purpose; it is not an absolute measure. Beyond that, the 'law' itself states that the environment can only be 'controlled' if the 'controller' can match its variety. This idea is captured in the maxim "*only variety can absorb variety*".

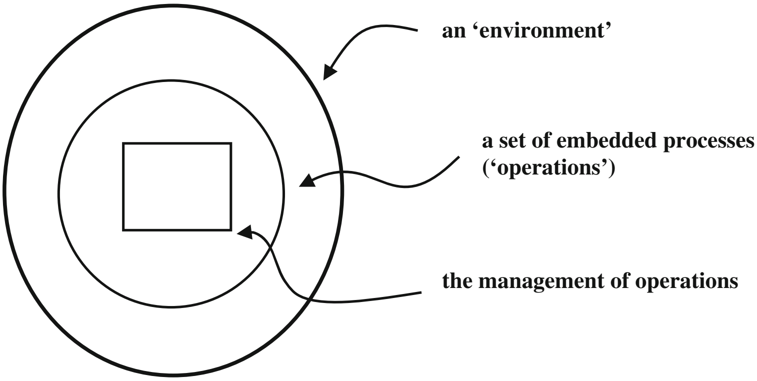

Fig. 1 A notional purposeful system showing embedded processes and their management in a defined environment

In the social world, 'environments' can exhibit extremely high variety. Hence the 'controllers' of systems operating in such a context have to strike a balance by simultaneously increasing the variety of their own system and reducing that of 'the environment' (see Figs. 1 and 2). Potentially, the transient, fleet-footed, technologically sophisticated and well-resourced criminal networks described earlier embody extremely high variety, and, as a result, they present major challenges to those who are looking to curtail their activities. In this sense, the enhanced and integrated capabilities of the new organizational and multi-agency arrangements just described, represent what cybernetician would refer to as an 'amplification' strategy. At the same time the targeting of particular types of criminal activity, or particular criminal groups, represents an 'attenuation' strategy.

What then might this theoretical way of thinking mean 'organisationally'? To all intents and purposes this is the question that the VSM seeks to address. The answer is presented in the form of a framework that is designed to assist those who are seeking to understand the necessary and sufficient activities that allow a system to survive in uncertain and complex circumstances.

On this account of viability, all such systems (see Fig. 3) include: autonomous '*operational elements*' that directly interface with the external environment, that enact the identity of the system ('System 1'); '*co-ordination*' functions, that ensure that the operational elements work harmoniously ('System 2'); '*control*' activities that manage the operational system and allocate resources to it ('System 3'); '*audit*' functions that monitor the performance of the operational elements ('System 3*'); '*intelligence*' functions, that consider the system as a whole—its strategic opportunities, threats, and future direction; and, finally, an '*identity*' function, that conceives of the purpose or raison d'être of the system, its 'soul', and place in-the-world.

Following the logic of the law of requisite variety, and relative to purposes worked out within the system and 'managed' through System '5', the level of autonomy ceded to 'System 1' and its various units is commensurate with the level of variety that is perceived to exist in the environment. Thereafter, the main

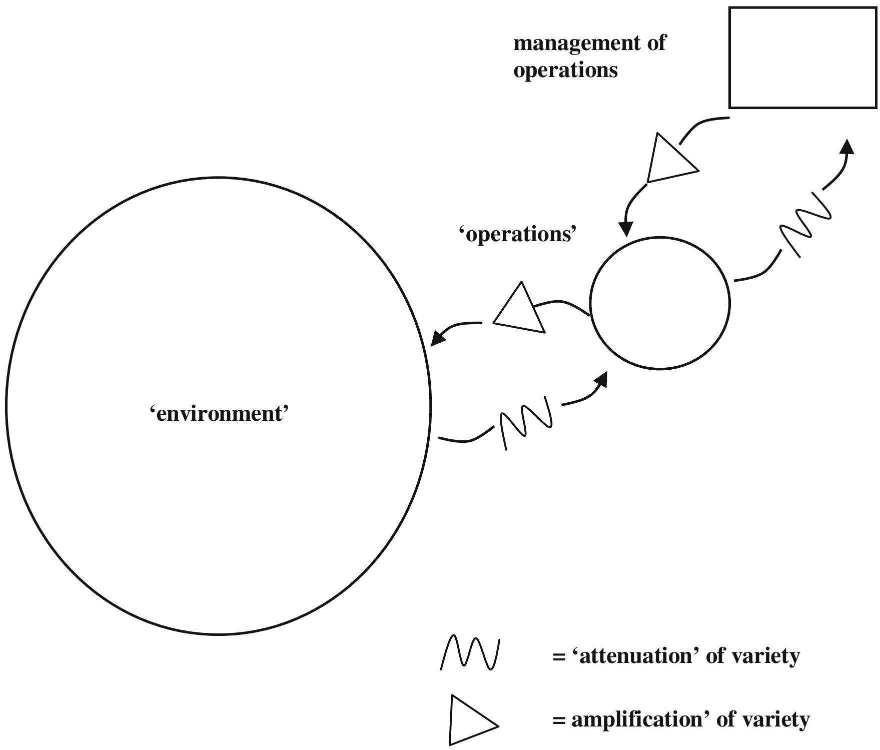

Fig. 2 Ashby's 'Law of Requisite Variety' ('*only variety can absorb variety*') applies at the interface of the relationship between 'operations' and 'the environment', as well as that between operations and its management

theoretical proposition is that the conditions outlined above: the various systemic elements and the communication channels running between them, and between them and the environment, must be present, working effectively and, importantly, 'in balance' through the whole system. If these conditions are not met, then viability is jeopardised.

An important feature of this model is its so-called '*recursivity*'. This refers to the containment of the 'whole system' within each of the operational elements. On that basis each System 1 unit can be conceptualised as a viable system in its own right. Equally, any particular system can be conceptualised as an operational component of a higher level system.

The law of requisite variety clearly bears directly on the proposition that policing and law enforcement agencies need, as far as is possible, to match the complexity and variety exhibited by criminal organisations. Of course this is much easier said than done. Considering the mobility and transient nature of many criminal groups, the 'invisibility' of their leadership, their inter-weaving of licit and illicit activity, their technological sophistication, and in many cases their massive resource base

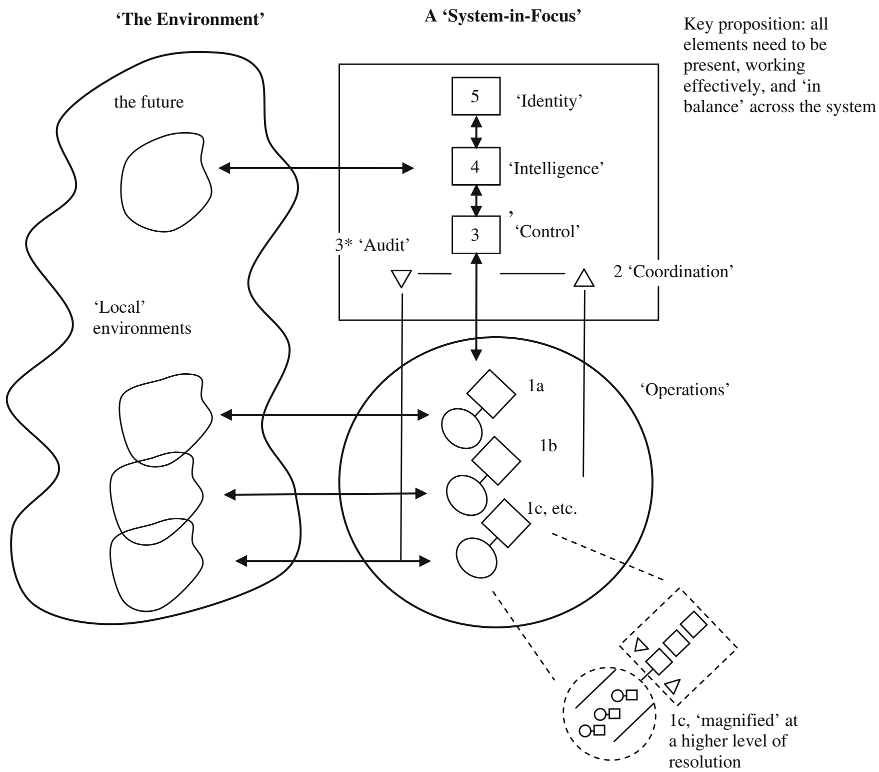

Fig. 3 The main elements of the viable system model showing key activities, information flow and relationships

and covert political influence, it is self-evident that this represents a significant 'variety' challenge to cash-strapped, highly bureaucratic, and regionally-focused law enforcement agencies.

Beyond that since there is a 'pooling' of law enforcement capabilities and knowledge at multiple levels, the 'nested' recursive nature of the VSM offers clear analytical advantages. The basic proposition, to be examined shortly, is that having a clear sense of identity, thinking strategically, planning, controlling and coordinating operations applies at all law enforcement levels irrespective of whether we are speaking of local and temporary taskforces, national agencies or global organisations. Shifting from theory to practice, this framework can be used to examine real collaborate structures to ensure that there are no missing components or 'missing links in the chain' that might undermine the ability of the system as a whole to work effectively. Importantly however, viability is not just about the parts of the system, it is also about the relationships between them. The parts need to be working 'in sync' and 'appropriately balanced'. As we shall see shortly some of the debate about the effectiveness of these new law enforcement collaborations can be interpreted as being about missing links, ambiguities or imbalances across the system.

4 Modelling Collaboration Systems

Before we look at specific examples of collaboration from this perspective, let us take a quick look at what has already been said about collaborative arrangements in general. The intent here is to develop some initial appreciation of how this particular model can help people think more systematically about the range of barriers that individually and in combination can frustrate or detract from purposeful collaboration.

Despite the advantages of currently popular concepts such as ‘joined-up government’, the ‘whole-of-government’ or ‘integrated government’ approach, these arrangements are clearly not infallible, and there is now a burgeoning literature covering some of main pitfalls (Kavanagh and Richards 2001; Ling 2002; Lowndes 1988; Ashby 1952). When interpreted within a VSM frame, these difficulties include defining, instigating and disseminating an overall defining sense of identity and core values for the integrated system (S5); ambiguity over accountability (who takes the lead with S3 or is it a shared arrangement?); difficulties in measuring the effectiveness and impact of performance (unclear and/or underdeveloped S3*); opportunity costs of management and staff time spend ensuring integration (resourcing the ‘meta-system’ i.e. S2–S5 and its associated information requirements); budget silos creating difficulties as agencies can fight over ‘who pays’? (how do contributions to S3 work?). In addition, in some areas, cooperation has proven to be difficult due to a lack of trust, or has fallen foul of the personal interests of bureaucrats, politicians and professionals who might be judged more on their individual role or that of their department and not necessarily outcomes-focused (S1 conflict). In some cases collaboration can turn out to be more costly than beneficial due to higher risks of failure as a result of disagreements, complexity and ambiguity over accountability. Given these kinds of difficulties, putting in place adequate S2 mechanisms is critical. Other problems with collaborative arrangements include allegations of empire-building, elitism, inter-agency rivalries, dumping of unqualified personnel, a lack of intelligence sharing between partners (sometimes due to lack of IT integration) and tensions surrounding conflicting objectives.

How then do these kinds of issues play out in the law enforcement context? In this next section some of the commentary is reproduced diagrammatically. This approach makes sense for a number of reasons. Firstly drawings are a good way of presenting complex ideas and data; they are a useful organizing device for helping people reflect on organizational structures and processes, especially when just enough detail is presented to allow people to grasp the key issues (see Checkland 1981; Mintzberg and van der Heyden 1999 for supporting arguments). The VSM, in particular lends itself to this approach. Using the model in this way, and in the organisational context, marks a major shift away from thinking about organisations in hierarchical and boxes/lines organisation chart terms, and towards a more organic approach that shows how an organisation or organisational system interacts with its environment, and how it actually works, instead of how it is supposed to work.

The VSM diagrams reproduced below are in a similar vein. The approach has been to take an example from each of the main multi-agency law enforcement levels that are involved in dealing with transnational crime. Section 4.1 begins with the temporary operational taskforce which is very much at the problem's 'coalface'; Sect. 4.2 then considers the permanent national multi-agency law enforcement body; and finally Sect. 4.3 looks at international cooperative arrangements. Since there is a limit as to what level of detail can be included in a single paper, and in particular shown in a diagrammatic model, the paper focuses on some of the more interesting aspects that arise out of this particular theoretical lens. The annotations are only illustrative; just enough information is presented to highlight the potential value and flexibility of the VSM modelling technique, and show how it might be used in this context.

4.1 The Operational Taskforce

The 'operational taskforce' concept refers to various forms of temporary collaboration involving specialists from different areas of government and law enforcement. These operate primarily within particular jurisdictions, but can and do operate internationally as well. These taskforces have recently been established in many parts of the world, in particular where permanent inter-agency organisations such as the FBI, the Australian Crime Commission, the UK's Serious Organised Crime Agency have provided a supporting organisational infrastructure. This is discussed in the next section. The illustration used here is taken from one such organisation, the Organised and Financial Crime Agency of New Zealand ('OFCANZ' hereafter) (Fig. 4).

Established in 2008, and housed within the New Zealand Police Force, OFCANZ aims to coordinate the various criminal enforcement units in New Zealand. It works across area command boundaries and partners with New Zealand's law enforcement, border and regulatory agencies, and financial authorities. OFCANZ also works closely with overseas criminal intelligence and law enforcement agencies.

Despite being housed within, and administered by, the NZ police force, OFCANZ has its own strong S5 identity and branding. Organisationally it operates through permanent, standing and directed taskforces. These taskforces include personnel from OFCANZ, personnel seconded to OFCANZ and personnel from partner agencies including the Inland Revenue Department, the Securities Commission, the National Enforcement Unit, and Customs and Immigration. During its first year of operation OFCANZ taskforces targeted Asian organised crime, 'outlaw' motor-cycle gangs, and serious and complex fraud that is associated with organised crime. Since then its' biggest operational taskforce success to date involved the arrest of members of the internationally-aligned Tribesmen Motorcycle Gang. Members of this gang were subsequently convicted of manufacturing, supplying, and selling and large quantities of methamphetamine.

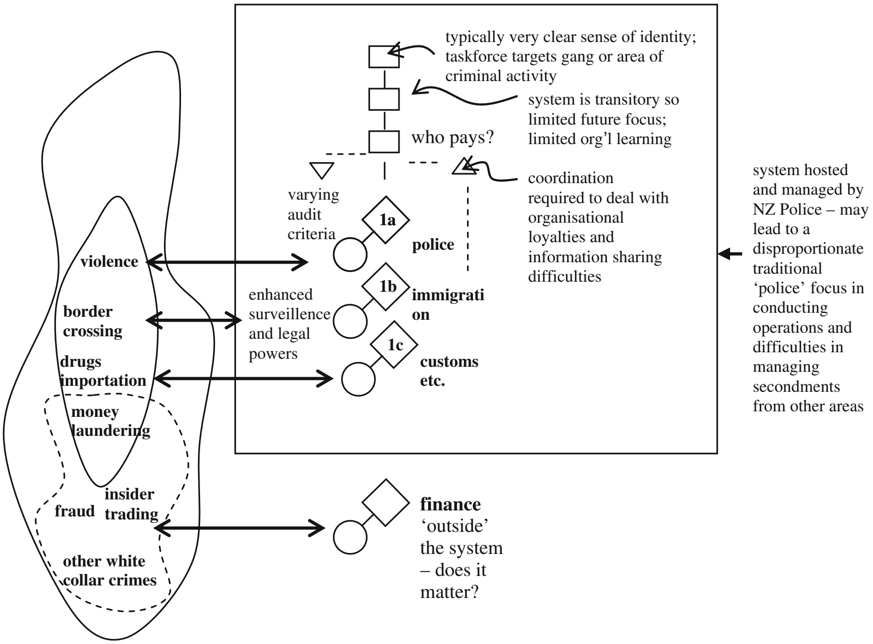

Fig. 4 The 'operational taskforce' (OFCANZ example)

Looking at the OFCANZ operational taskforces through a VSM lens raises a number of important questions. First and foremost it is hard to quibble with the idea that dedicated multi-capability taskforces (S1a, S1b, S1c etc.) will, in principle at least, provide much greater variety in dealing with complex criminal networks than is the case with the stand-alone area command. S1 taskforces have a broader knowledge base and their capability is enhanced through legislative and technological provisions that allow them to have enhanced surveillance and legal powers. In cybernetic terms this represents significant 'amplification' of S1 variety. Equally, taskforces are explicitly required to narrow their focus on a specific criminal activity or group in a manner that cannot be replicated within the area command structure, since the latter has little choice but to respond to serious crime committed 'on its patch' whenever this occurs. Theoretically this combination of amplification of capability and attenuation of focus provides a much better chance of obtaining positive outcomes. Having said that, there are some interesting systemic issues that are worth raising and these are discussed next.

One interesting feature of this system is that initially it was intended to merge the NZ Serious Fraud Office with OFCANZ. However the former agency strongly resisted and the merger did not proceed. Anecdotal evidence suggests that working relations between the two organizations has not been seriously compromised, and certainly being 'part of the system' (through membership of taskforces) but not 'part of the organisation', is not in itself a major impediment to success. However it does raise questions about the appropriateness of the S5 'financial crime' branding of OFCANZ and could lead to concerns over whether the primary responsibility for dealing with crime in this area rests with OFCANZ or the Serious Fraud Office.

Turning now to the operational taskforce ‘meta-system’, Systems 2–5 raise some interesting questions. Since taskforce members are drawn from different organizations and professions, each with their own traditions, cultures and ways of doing things, S2 coordination has been a major organisational challenge. Generally careful management has mitigated potential damage caused through inter-agency rivalries and expressed concerns over information-sharing. However dealing with these kinds of issues, and organisational loyalties more generally, places much responsibility on the shoulders of NZ Police, the host organisation. Pre-existing or latent tensions in these areas are potentially compounded if non-police taskforce members are subject to any excesses in traditional policing approaches to the conduct of operations, its working language and norms of behaviour, ethics and ‘command and control’ leadership styles. Moreover genuine collaboration might be difficult if non-police members come to think that their role is, or might be somehow be seen to be relatively less important. Managing secondments from other areas then arises as a major challenge.

System 3 (‘control’) raises the question of the day to day leadership of taskforces and the allocation of resources to it. In the NZ context the question of ‘who pays?’ is still being worked through. Understandably, on the question of leadership, recent operational taskforces in areas such as gang crime and drugs have been led by the police. However the situation is somewhat less clear cut in areas such as human trafficking, cyber-crime and corporate fraud where the main expertise often resides with other agencies. Here there is a clear dilemma to be grappled with: when there is an insistence on police leadership this can create tensions with non-police members who see themselves as being better informed and better equipped to guide the inquiry. The opposite scenario where someone from a different organization and professional group takes a leadership role within what is essentially a police organization and police culture generates a very different set of challenges.

System 3* (‘audit’) raises a related question. How are the taskforces and taskforce members to be judged? Since the taskforce itself is always set up with a particular set of objectives in mind performance is almost always judged on the ability of the team to obtain tangible results. Anecdotal evidence suggests that this had had a significant impact on the choice of OFCANZ’s early projects, with suggestions that the aforementioned ‘Tribesmen’ operation might have reflected a political imperative to quickly ‘get runs on the board’. In VSM terms since operational taskforces will usually have a very clear sense of identity (S5), i.e. to target a particular area of criminal activity or develop a case for the arrest and prosecution of a particular criminal group, the situation at the higher systemic level is somewhat different. At this level there is clear potential for tension between the longer term focus of OFCANZ’s S5 and the more immediate demands of the taskforce S3*. On the one hand OFCANZ admits that its brief is to minimize the long-term damage and harm caused by organised crime and to make NZ a less attractive destination for international criminal groups. On the other hand, in a country that is under severe pressure to cut costs, and has a relatively short 3 year electoral cycle, there is a view within the organisation that 'going for the low hanging fruit' is necessary in order to deliver quick results thereby demonstrating organisational worth to both political masters and the general public.

Judging the performance of individual taskforce members presents another set of challenges. Most members are seconded either from the police or from other organizations, and both therefore are subject to different and sometimes competing performance criteria. The greatest difficulty here is faced by non-police members. Taskforces, by their very nature, are highly focused and are under pressure to 'get things done' quickly. This does not always sit well with members from other government agencies who are used to being evaluated on the basis of 'doing things properly'. One could extrapolate from this the need to select very carefully task-force members who have the ability to bridge cultural, organisational and professional differences, and, importantly, share a common interest in delivering results in the area of investigation.

Moving on to System 4 raises the question of the need for there being an appropriate balance between the immediate priorities of a taskforce and carrying the learning and experience gained from a particular operation forward to assist in future enquiries. To date the main mechanisms used for this purpose have been a careful recording of and reporting on activities, along with some continuity of membership from one operation to the next.

4.2 *The National Multi-agency Law Enforcement System*

The example used here is the United Kingdom's 'Serious and Organised Crime Agency' ('SOCA') hereafter (Fig. 5). SOCA, which in 2014 was superceded by the larger 'National Crime Agency', is one of a number of national multi-agency law enforcement groups that exist around the world; other examples include the FBI, the Australian Crime Commission, Italy's 'Direzione Investigitiva Antimafia', and the previously discussed OFCANZ.

Prior to 2006, organised crime in the UK was being fought mainly by local area commands and various national intelligence agencies and regional crime squads. At that time there was growing recognition that the traditional local area command was becoming ill-equipped to deal with criminal activity conducted in its region but planned and managed elsewhere; that inadequate intelligence was flowing from higher sources; that it was ill-equipped in terms of surveillance and bugging technology; had limited expertise in fraud, customs and immigration, and ultimately had limited powers in working with criminals. In law of requisite variety terms, this represents a massive variety deficiency relative to that possessed by its criminal adversaries. Other systemic deficiencies included poor communication; inadequate coordination, and even competition across area commands (S2); inadequate resourcing through S3; and a traditionally strong S5 that puts heavy emphasis on maintaining the peace, promoting safety, and dealing with criminals in the local area.

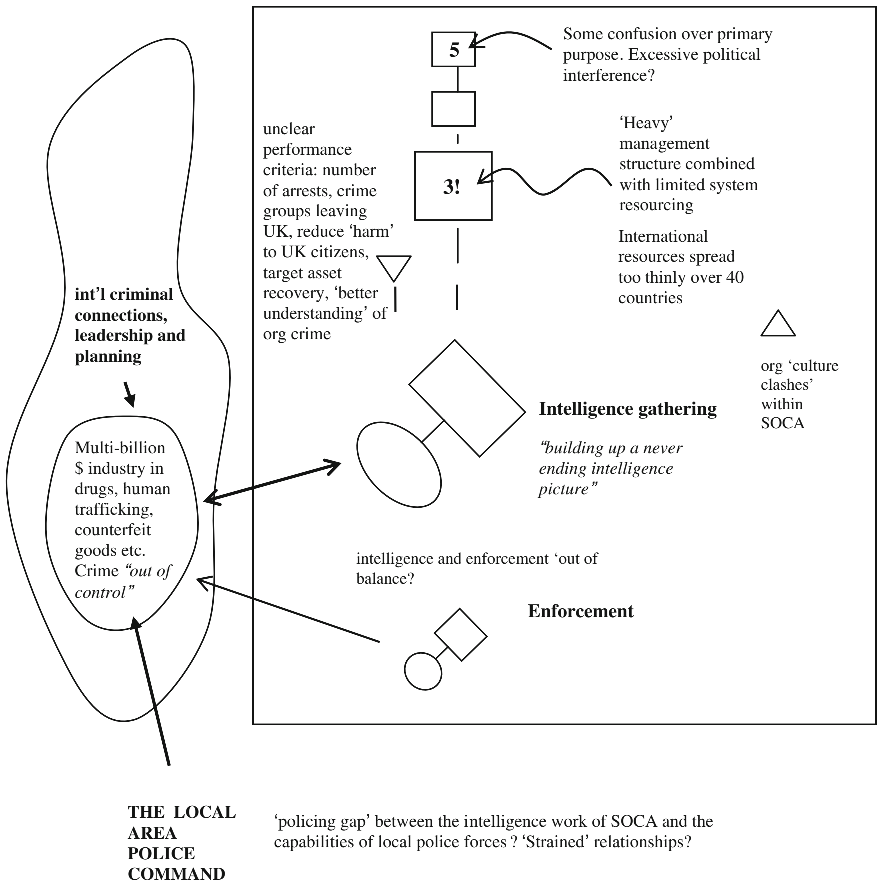

Fig. 5 A National multi-agency system: 'SOCA' example

In addition to this, and at the higher systemic level, national law enforcement agencies such as the National Criminal Intelligence Service, the National Crime Squad, and the National Hi-Tech Crime Unit were restricted in their actions due to bureaucratic struggles between them, difficulties in the sharing of information and intelligence and the large amounts of time taken to implement any actions or changes. There was also a perceived duplication of work across these agencies (Harfield 2006; Segell 2007; The Strategy Unit 2009).

In recognition of these sorts of issues, it was decided that there was a need to replace these individual agencies with a single body focusing its combined resources on a single strategy designed to operate more effectively in a less organisationally fragmented manner and to better equip it in dealing with an increasingly borderless criminal world. SOCA was established in 2006 for that purpose.

Organisationally, SOCA is divided into four specific groups each specialising in a separate area. In VSM terms, three of these directly enact the purpose of the organisation and are therefore part of the SOCA S1. These are ‘Intelligence’ which is responsible for gathering and analysing information and building alliances with other agencies; ‘Enforcement’ which provides an operational response to identified threats and builds cases against targets; and ‘Intervention’, which focuses on asset recovery and international work. The other key organisational unit, ‘Corporate Services’ is responsible for resourcing and capability-building (S3). In aggregate, these groups contribute to the S5 Mission of SOCA which is to: “reduce the opportunities for organised criminals to make money, disrupt and dismantle their enterprises, and raise the risks they run by more successful and targeted prosecutions of the major figures”.

In theoretical terms, the consolidation of previously fragmented activities in the new organisation represents a signification increase or amplification of S1 operational variety. This is further enhanced since SOCA’s law enforcement officers are now endowed with increased authority and have the powers of a police constable, a customs officer and an immigration officer. These powers are in addition to new prosecution structures, which include being able to offer criminals reduced sentences in return for cooperating with the investigation and testifying against fellow criminals, and compelling witnesses to answer questions valuable to an investigation[1].

In dealing with sophisticated criminal groups, the enhancement of S1 operational variety is clearly critical. However, as was said earlier, the balance of activities across this subsystem is equally important. Here criticisms of SOCA have not been in short supply. It seems that many within the organisation, as well as some outside of it, have accused SOCA of focussing too much on the gathering and processing of intelligence, building up a “never-ending criminal intelligence picture” and, in spite of its stated priority, failing to “stem the flow of drugs into the country” through a lack of operational activity (Laville 2009). In response, SOCA’s (Serious Organised Crime Agency 2009) claimed that its’ operation led to drugs shortages in some parts of the UK, and that it would be unreasonable to expect a major turnaround in criminal activity during the first few years of its operation.

SOCA’s S3 has also come under attack, critics accusing it of being a “top-heavy” organisation in terms of management with many complaints having emerged from those within the organisation that it has been wasting money on top management. It is portrayed as an organisation which is “cautious and bureaucratic, overburdened with managers and inexperienced at the sharp end” (Laville 2009). Moreover there are questions about the balance between S3 and S4. An external review of SOCA arose out of claims that there is too much forward thinking, too much strategising and planning (S4), and not enough activity to support current operations (S3). Aside

[1] http://news.bbc.co.uk/2/hi/uk_news/4163871.stm.

from this systemic imbalance between ‘the future’ and what might be described as ‘the here and now’, others (see, for example, Edwards 2008)[2] draw attention to the overall lack of resources allocated to SOCA, and point to the relative funding allocated to fighting organised crime and terrorism (in 2008 £457 m and £2500 m respectively), as an indication that the fight against organised crime “remains subordinate to the effort to combat global terrorism” (Williams 2006, 203). The argument seems to be that because terrorism is a “highly-visible threat” it tends to receive a well-resourced response. Meanwhile, organised crime operates in an ‘under the radar’ fashion and therefore acquires less attention. But as Edwards rightly states, “out of sight should not mean out of mind” (Edwards 2008).

Turning now to S3*, evaluating the performance and success of SOCA is a difficult task. SOCA itself claims that this is particularly challenging in key, but often ill-defined performance areas such as the quality of the intelligence it is collecting, and evidence of changes occurring in criminal markets that might indicate that criminals are finding the United Kingdom a more hostile environment in which to operate (Serious Organised Crime Agency 2009). Moreover, the aim of reducing harm is a difficult concept to measure compared to the usual means of measuring crime figures to judge the effectiveness of certain crime fighting initiatives. It must also be noted that many of SOCA’s successes will not have been able to be revealed to the public for reasons of confidentiality.

Questions are also being asked about which body should be given responsibility for SOCA’s S3*. To date the organisation itself has been responsible for its own assessment, and in the operational areas of law enforcement this was always going to present challenges. As Eades (2007, 11) notes, “Public confidence was expected to be difficult to capture (due to the) weak mechanisms of accountability and oversight, far-reaching powers, and politically appointed leadership of this criminal justice organisation”. The British Government is now saying that due to its low public profile and perceived lack of results it is necessary for SOCA to be policed by a body other than itself. It is also concerned that SOCA is not as accountable in day-to-day situations as are other law enforcement agencies, especially the Police.

4.3 The Regional Cooperative Agency

Moving up another organisational and systemic level, our third illustrative agency is Europol, colloquially known as ‘The European Police Force’ (Fig. 6). Since Europol has been widely discussed elsewhere, (see, for example, Brady 2008; van Duyne 2007; van Duyne and Vander Beken 2009), the level of background detail provided here is kept to a bare minimum.

Although first established through the Maastricht Treaty in 1992, the current Europol regime began in 2005. At that time, 27 Ministers of the European

[2] http://news.bbc.co.uk/2/hi/uk_news/scotland/8078381.stm.

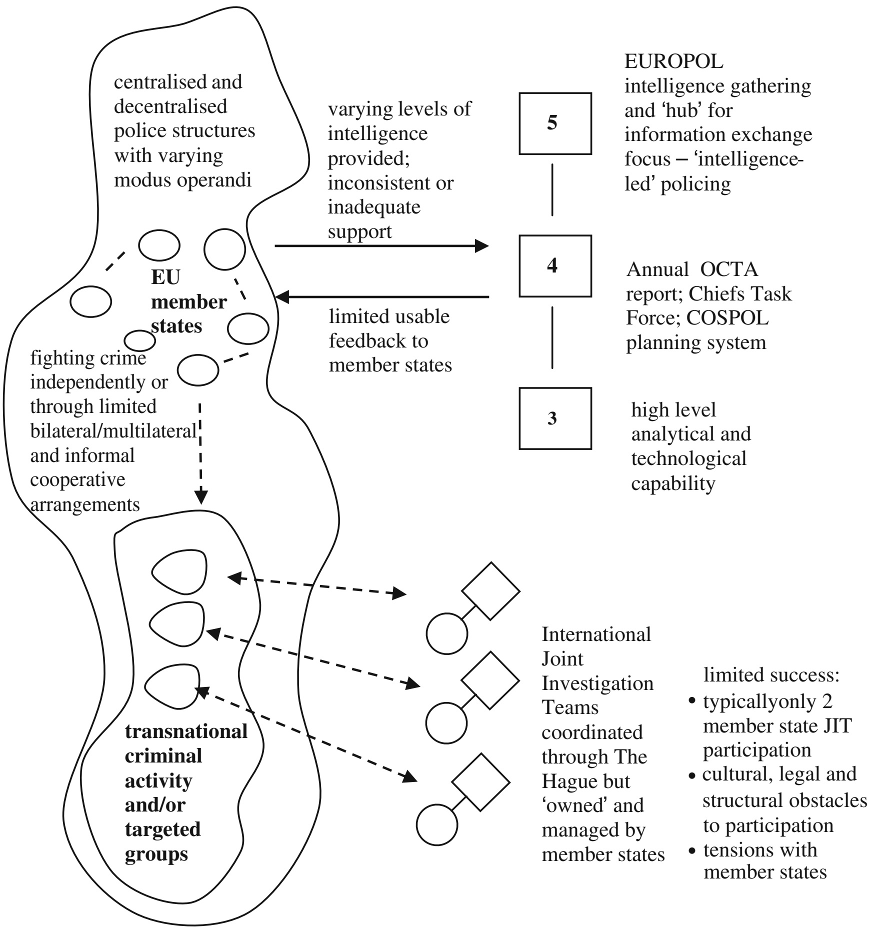

Fig. 6 International cooperative agency: Europol example

Community agreed on a 'European Criminal Intelligence Model' for coordinating investigations using 'unique information capabilities' and the expertise of permanent staff as well as police officers seconded from member states. Their role is to identify and track the most dangerous criminal networks in Europe. This 'intelligence-led' policing stresses the collaborative targeting of member state police resources on particular criminal groups. To that end, Europol is involved in thousands of cross-border investigations each year. It claims to have disrupted many criminal networks, contributed to the arrest of thousands of dangerous criminals, and the recovery of millions of Euro in criminal proceeds.

In addition to the high variety that is vested in its analytical and technological capabilities, there are two systemic features of the Europol approach that are particularly worth highlighting here. The first is the idea of the 'Joint Investigation Team' ('JIT'); the second, what is arguably Europol's seminal product for policy–

makers and police chiefs, the annual Organised Crime Threat Assessment (‘OCTA’).

JIT’s were first set up in 2000. Prior to their establishment, all cross-border investigations required a ‘Mutual Legal Assistance’ request between Member States which, in many cases, was a slow, bureaucratic and in systems terms ‘low variety’ process. In addition to harnessing Europol’s enhanced analytical and technological capabilities, JIT’s seek to amplify variety by better coordinating international investigations, improving the exchange of information across Member States, speeding up investigations, and allowing Member States to share ‘best practice’ and enhance trust. They also avoid inefficient and costly ‘double’ investigations. From a ‘variety-engineering’ perspective, all of this makes good theoretical sense. Despite this, and on Europol’s own admission, the take-up of JIT’s has not been as great as expected. There are some interesting systemic issues that might explain this.

Looking first at the VSM’s System 5, de Buck (2007) has noted that there has always been some ambiguity within Europol concerning the content and scope of a JIT. Specifically doubts have surrounded whether the whole JIT system within Europol is to support national police organisations, or, engage in operations, or do both. Over time Europol’s role in a JIT has erred towards providing analytical, technical and logistical support and to be facilitation-focused; however its own documentation shows that there is still scope for operational involvement (Europol 2009). This seems to have created tensions between it and Member States. Another interesting systemic feature is that although the JIT’s are very much part of the Europol system, they are not ‘owned’ by it. Indeed Europol itself can only recommend the establishment of a JIT; their actual establishment, operation, and leadership is entirely at the discretion of individual Member States. This is a very interesting systemic feature that potentially has both positive and negative consequences. On the positive side this organisational arrangement ought to nullify the impact of what Beer (1972) refers to as ‘pathological autopoiesis’, i.e. a situation, common in many large organisations, where the S2–S5 ‘meta-system’ becomes bureaucratically self-serving, seeing itself as a viable system in its own right, instead of a set of processes that are designed to support operations. In Europol’s case, this might apply had the experience of JIT’s been particularly successful. On its own admission though, this has not been the case. Currently around 40 JIT’s are in operation; however the take up has been very slow.

In terms of the meta-system (S2–S4) ‘management’ of the JITs, the organisational/professional impediments to collaboration that exist within a single jurisdiction are potentially many times magnified when this is expected to occur internationally. Coordination issues associated with perceived threats to sovereignty, different languages, and cultures, arise as potential pitfalls. Even mundane logistical problems such as members travelling and living away from home can be problematic. The day-to-day S3 resourcing and control of JIT’s has also created difficulties. For example, executive action can only take place on foreign soil when it is conducted according to the law of that particular land. This creates difficulties in defining the applicable law for a JIT that is working across Member States and for individual members who may be required to carry out investigative measures in accordance with unfamiliar law. S3 also raises questions about the leadership of JIT's. Under the current arrangements, leadership is ceded, not to Europol, but to a member from one of the participating Member States. Again this is not an insurmountable difficulty, however it does suggest that Europol needs to carefully manage the process since nationalistic tensions, cultural and language difficulties, and traditional rivalries almost inevitably will arise. In particular much responsibility rests on the shoulders of the JIT leader who must manage the possible tension that is created in the trade off between sharing and protecting country-specific knowledge while maintaining a careful balance between competition and cooperation (Parkhe 1993). In policing this becomes a very difficult issue since much of the most useful intelligence on criminal groups comes from 'unofficial' sources such as informants and undercover agents. Sharing such information even with trusted and close colleagues carries significant risk.

Another issue concerns the use and disposal of information obtained through a JIT. Currently national laws and law enforcement conventions impose limitations on the use of information obtained by Europol officials while taking part in a JIT; in particular the inclusion of information obtained into Europol databases is subject to the approval of the participating Member States. From a systemic perspective (S4) this might make it difficult to carry forward learning from one JIT to another.

Given these systemic difficulties, it is perhaps unsurprising that where JIT's have worked particularly well, this has typically involved a small number of Member States (usually 2) which have been able to build and capitalise upon pre-existing mechanisms for coordination, communication and control, and have not had to develop these from scratch. Block (2008, 80), for example, cites the case of a successful joint UK/Netherlands drug trafficking JIT which was initiated through a 'bottom-up' initiative of well-connected police commanders in the two countries and where considerable effort was required in putting in place housing, finance, and training and regulations for the seconded British officers. At the end of this assignment, and in the words of one of the involved police commanders: 'we proved that a JIT can work however I can't say that a JIT provides a bigger chance of getting results than a parallel investigation (in the two countries)' (Block 2008, 80). Elsewhere JIT's have worked well in cases of geographically and/or culturally closely aligned countries. For example, recent successes have included French-Spanish JIT's targeting Basque terrorism, Belgium-Netherlands JIT's targeting drugs and UK-Netherlands JIT's targeting drugs and human trafficking.

Similar systemic issues to those just discussed arise in relation to the 'Organised Crime Threat Assessment' ('OCTA' hereafter), which we have already said is Europol's core product of the intelligence-led policing concept for policy makers and police chiefs. OCTA was introduced in 2004 in order to provide for a more future-focused and pro-active assessment of organised crime. The key OCTA instrument is three detailed questionnaires that are completed by Member States on an annual basis. One questionnaire focuses on criminal groups, the second on general criminal activities, the third on a specific criminal activity such as money laundering or, in 2014, cyber-crime.

Since OCTA is undoubtedly the key formal mechanism within the Europol system that facilitates plugging the gap between projected futures (S4) and day-to-day operations (S1), it plays a pivotal role. However, as with the JIT's, experience to date has been mixed, with varying levels of support being provided by Member States. By most accounts, some Member States have taken the project seriously while others have paid lip service to it, preferring instead to fight trans-national criminal activity independently or through limited bilateral and often informal cooperative arrangement with close neighbours. Other criticisms have centred on the methodological limitations of the OCTA instrument. Thus, in a scathing attack, van Duyne (2007) raises questions about the reliability of the data, its processing, the reliability of the findings, and validity of the conclusions about the stated threats. Van Duyne further claims that the questionnaire is unwieldy, impractical, user-unfriendly, and frequently ambiguous in its wording. To cap it off, he submits that most of the threat observations could just as well have been made 15 years ago. It is difficult to assess these claims; however, it is worth noting that Europol has recently taken steps to improve the instrument.

By necessity, methodological limitations and varying levels of OCTA support from Member States impacts on the quality of feedback provided back to national police organisations. Hence, any lapses or omissions has the potential to seriously undermine the viability of the whole system. That being the case, even if Europol as a whole could be shown to be viable in all other respects, any S4 deficiency needs to be taken seriously. Typically problems occurring at this level show up at some point in the future when unforeshadowed changes in external circumstances leave the organisation ill-equipped to cope. In the fast-changing world of trans-national crime this remains a distinct possibility.

5 Conclusion

At any point in time, it is self-evident that the level of transnational organised crime is the result of a complex combination of social, cultural, political and economic circumstances, the complete eradication of which is beyond the capacity of even the most generously resourced collaborative law enforcement agencies. Notwithstanding this, the level of public expectation and financial resources that are vested in them dictates that the agencies that have been charged with this responsibility operate as efficiently and effectively as possible.

To this end, the paper has argued that the debate about the functioning of these systems can benefit through being more theoretically informed than seems to have been the case hitherto. Overwhelmingly, discussions about operational taskforces, multi-capability national and regional agencies have either been exclusively descriptive, or they have tended to focus on some organisational aspect without placing it in the wider context. It is all very well, for example, pointing the finger at the lack of trust across collaborating partners or inadequate resourcing, on the assumption that addressing these issues will deal with the problem. Systemic thinking suggests the need for more integrated and holistic strategies. The point is well captured in Schwaninger's (2001, 138) claim that 'the result of a management process cannot be better than the model on which it is based, except by accident'. If then, there is any truth to the claim that the architects and managers of these new collaborative structures are fragmented in their thinking about the problem, then the 'solutions' are likely to be equally fragmented.

Against that background, the argument is that there is an urgent need for better theory to be injected into discussions about how, organisationally, this problem should be managed. In particular there is a need for theory that can account for the complexity of the challenge and point towards more holistic and integrated solutions. The law of requisite variety and the theory of viable systems are particularly well-suited to this task. More generally, systems thinking and problem structuring methods and tools have much to offer in dealing with the complexity faced by crime-fighting law enforcement agencies. System Dynamics and causal loop modelling, (for example Senge 1990; Vennix 1996), is potentially useful in examining non-linear and time-lag effects in criminal policy analysis and design; the conceptual modelling tools used in Soft Systems Methodology (Checkland 1981; Checkland and Scholes 1990) can assist in modelling the complex inter-related activities that occur on both the supply and demand sides of crime, this being a necessary precursor for the kind of interference, intelligence-gathering and prevention strategies that the aforementioned collaborative agencies are involved in; cognitive mapping or strategy 'journey-making' (Eden and Ackermann 1998) is useful for developing more holistic crime-fighting or prevention strategies that can foreshadow the unintended consequences of what ostensibly are sensible crime fighting or prevention strategies.

In terms of the specifics of inter-agency collaborative law enforcement the paper has identified a range of real or potential 'systemic deficiencies', all of which translate into questions that the various stakeholders need to think very carefully about.

Mapped out in the text and in diagrammatic form, some of the more important questions about these collaborative arrangements include the following. Most obviously there is the question of whether people will want to work together. We cannot assume this to be the case, no matter how compelling is the argument for collaboration. Will long-standing historic, cultural and operational tensions stifle cooperation? Will politics compromise results? Will governments dedicate sufficient, long term funding if results are not instant? While the positive implications for such collaborative projects are enormous the enthusiasm around it may be constrained by these cultural, political and resource issues. Moreover successful implementation would appear to depend on a number of things including developing clarity over identity and purposes, knowing who and/or what is responsible for coordination, knowing how leadership should work, knowing what each individual and group's role is, who they report to, how performance is assessed, how resources are managed, and, perhaps above all else, how these various groups 'fit together' both horizontally and vertically as part of a synergistic and coherent whole.

References

Ashby WR (1952) Design for a brain. Chapman and Hall, London
Beer S (1972) Brain of the firm. Allen Lane, London
Beer S (1979) Heart of enterprise. Wiley, Chichester
Beer S (1985) Diagnosing the system for organization. Wiley, New York
Block L (2008) Combating organized crime in europe: practicalities of police cooperation. Policing 2(1):74–81
Brady H (2008) Europol and the European criminal intelligence model: a non-state response to organized crime. Policing 2(1):103–109
Checkland P (1981) Systems thinking, systems practice. Wiley, Chichester
Checkland Peter, Scholes Jim (1990) Soft systems methodology in action. Wiley, Chichester
de Buck B (2007) Joint investigation teams. ERA Forum 8:253–264
Eades C (2007) Serious organised crime: a new approach. Kings College, Centre for Crime and Criminal Justice Studies, London, pp 1–11
Eden C, Ackermann F (1998) Making strategy: the journey of strategic management. Sage, London
Edwards ALM (2008) Criminology and criminal justice. 8:363–388
Espejo R, Harnden R (eds) (1989) The VSM: interpretations and applications of S Beer's VSM. Wiley, Winchester
Espejo R, Schwaninger M (1993) Organizational fitness: corporate effectiveness through management cybernetics. Frankfurt, Campus
Espejo R, Schuhmann W et al (1996) Organisational transformation and learning: a cybernetic approach to management. Wiley, Chichester
Europol (2009). EU organised crime threat assessment, European Police Office (Europol), pp 1–64 (39)
Glenny M (2009) McMafia: seriously organised crime. Vintage Books, London
Harfield C (2006) SOCA-a paradigm shift in british policing. Br J Criminol 46:743–761
Homel P (2004) Trends and issues in crime and criminal justice: the whole of government approach to crime prevention. Australian Institute of Criminology, Australian Government, Australia, pp 1–6
Jacobs P, Hough M (2010) Intelligence cooperation to combat terrorism and serious organised crime: the United Kingdom model. Acta Criminologica 23:94–108
Kavanagh D, Richards D (2001) Departmentalism and joined-up government: back to the future? Parliamentary Aff 54:1–18
Klerks P (2003) The network paradigm applied to criminal organisations: theoretical nitpicking or a relevant doctrine for investigators? recent developments in the Netherlands. In: Edwards AG (ed) Transnational organised crime: perspectives on global security. Routledge, London
Laville S (2009) Government's organsied crime strategy has echoes of the past. http://www.guardian.co.uk/uk/2009/jul/13/organised-crime-government-analysis
Ling T (2002) Delivering joined-up government in the UK: dimensions, issues and problems. Public Adm 80(4):615–642
Lowndes VSC (1988) The dynamics of multi-organisational partnerships: an analysis of changing modes of governance. Publ Adm 76:313–333
Mintzberg H, van der Heyden L (1999) Organigraphs: drawing how organizations really work. Harvard Bus Rev 77(5): 87–95
Moore RH (1996) Twenty first century law to meet the challenge of twenty first century organised crime. Technol Forecast Soc Change 52(2):185–197
Parkhe A (1993) Strategic alliance structuring: a game theoretic and transaction cost examination of inter-firm cooperation. Acad Manag J 36:794–829
Saviano R (2006) Gomorrah. Picador, New York
Schwaninger M (2001) Intelligent organizations: an integrative framework. Syst Res Behav Sci 18:137–158

Segell GM (2007) Reform and transformation: the UK's serious organized crime agency. Int J Intell Counter Intell 20(2):217–239

Senge PM (1990) The fifth discipline. Doubleday/Currency, New York

Serious Organised Crime Agency (2009) Annual plan and report. T. H. Office, The Stationery Office, London

The Strategy Unit (2009) Extending our reach: A comprehensive approach to tackling serious organised crime. The Home Office, The Stationary Office, UK, pp 1–81

van Duyne PC (2007) OCTA 2006: the unfulfilled promise. Trends Organ Crim 10:120–128

van Duyne PC, Vander Beken T (2009) The incantations of the EU organised crime policy making. Crime Law Soc Change 51:261–281

Vennix JAM (1996) Group model building: facilitating team learning using system dynamics. Wiley, Chichester

Williams P (2006) Transnational criminal networks. In: Arquilla J, Ronfeldt D (eds) Networks and netwars. Santa Monica, Rand, pp 61–97

Wright A (2006) Organised crime. Willan Publishing, UK

Managing Complexity in Organizations Through a Systemic Network of Projects

Domenico Lepore, Angela Montgomery and Giovanni Siepe

Abstract **Managing complexity** has become one of the most important issues for economists and managers over the last twenty years. The reason for the increasing importance of this issue is related to the exponential growth of interconnections and interdependencies that has arisen in contemporary society and organizations. Organizations often struggle to adapt their management methods to the shift towards increased complexity. We present a management methodology, 'The Decalogue', that is a systemic approach for managing complexity in organizations and supply chains through focusing on **constraint management** (Theory of Constraints) and the understanding and **control of variation** (Theory of Profound Knowledge). Through the application of this methodology, an organization can transform its operations from a traditional hierarchy (silo mentality) to an organizational model of a systemic network of projects that is appropriate for operating and adapting within a complex reality. We conclude that the approach we present, specifically applied to organizations with a well defined goal, is a "systemic" approach focussing on constraint management and control of variation. This systemic approach leverages the intrinsic process and project-based nature of the work of organizations. Traditional hierarchy is replaced by a different kind of hierarchy, driven by the goal of the system and governed by a new design of the organization as a "Network of Projects". The Network of Projects requires a cognitive shift and provides a robust and sustainable model for organizations to adapt and develop within a complex environment.

Keywords Complexity · System · Deming · Constraints · Decalogue

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1 Introduction

Addressing complexity is probably one the greatest challenges of our times. The reason for the increasing importance of this issue is related to the exponential growth of interconnections and interdependencies that has arisen in contemporary society and organizations.

Science is unveiling the patterns of connections that exist at every level of our existence and technology provides us with unprecedented possibilities for integration and cooperation. However, the inherent non-linearity that governs the emergence of all the phenomena that we label as "complex" is still largely addressed with inadequate tools and methods. The social science of Economics, in an effort to mimic a rigorous thought process, continues to fail to deliver an acceptable conceptual framework for prosperity; finance is highly active in producing unsustainable models of possible wealth creation while undermining any possibility of fully grasping the essence of the problems we face. When it comes to managing organizations, we are still very much trapped in a paradigm of silos, fragmentation, conflicts and a zero sum game. Management remains widely rooted in the idea of command and control, reflected in a traditional, hierarchical/functional organizational design (silo mentality).

Complexity, **in the context of managing organizations**, has two components that are strictly interconnected: the first is related to our increasing understanding of organizations as networks within networks; the more nodes and links there are in a network, the more complex it is. The second component concerns **variation** (the impossibility of repeating any process in exactly the same way). Variation is intrinsic to any human activity, and it strongly impacts the dynamic of the network, because the entropy of a closed system will always increase.

The goal of this chapter is to illustrate how the silo mentality can be overcome, and how complexity and non-linearity can be dealt with in organizations by managing variation and synchronizing activities with a chosen set of **constraints**. We examine how variation and constraints can be brought together in a synergy, how this synergy is at the basis of a tested methodology, how embedding aspects of network theory provides a new organizational design for complexity (the Network of Projects), and how Thinking Process Tools can engender and reinforce the kind of thinking required to act systemically and generate the breakthroughs required to adapt to continuous change.

The contents of this chapter are based on the application of a systemic management methodology, 'The Decalogue', to a wide range of organizations internationally for nearly two decades.

2 Managing Complexity: How a Systemic Methodology Evolved

In order to illustrate the systemic approach for managing complexity conveyed through the Decalogue management methodology, we need to take a step back to see how it evolved as a synergy of ‘disparate’ elements from the world of management methodologies.

Two major approaches to management of the 20th century can be found in Dr. W. Edwards Deming’s Theory of Profound Knowledge (TPK), and Dr. Eliyahu M. Goldratt’s Theory of Constraints (TOC). Deming’s TPK emphasizes the systemic nature, i.e. the *network of interdependencies* that makes up the life of any organization, while Goldratt’s TOC takes a more reductionist stance by focusing on the few elements that account for the overall performance: *the constraints*. Deming stresses the importance of understanding and managing the statistical fluctuations of the links that make up the network, whereas Goldratt is preoccupied with building the set of measures, policies and behaviours that ensure proper focus on the elements that dictate the overall performance of the network.

Until the mid 1990s, the two approaches had always been considered separate, and attempts to engage the “Deming community” with the “Goldratt community” were fraught with difficulty. Dr. Deming dedicated his professional life to promoting better management through better understanding of variation and how this variation permeates every aspect of our lives. His message was loud and clear: reduce variation, promote statistical predictability and improve Quality. Dr. Goldratt, instead, made little explicit reference to variation. He outlined the steps for identifying what is blocking an organization from growing, how to identify what to change and how to make the change happen in a pattern of continuous improvement. Both Deming and Goldratt stressed the centrality of continuous improvement. Both of them used scientific rigour and the pursuit of “intelligence” as a main driver for the transformation of the management style in the western world. The focus of their approaches differed, but there was a clear common ground.

In the mid 1990s, Domenico Lepore, one of the authors of this chapter, was asked to develop Quality Management programmes for small to medium companies in the Lombardy region of Italy. He was fully versed in Deming’s work and shared Deming’s background as a physicist. Lepore approached Oded Cohen, one of the world leading experts in TOC, with his intuition that, not only was there no incompatibility between the approaches of Deming and Goldratt, they could in fact be mutually beneficial, each one providing a missing link for the other. Cohen invited Lepore to formalize his intuition in the form of a ‘Conflict Cloud’, one of the Thinking Process Tools from the Theory of Constraints. This tool is fundamental for framing a cognitive impasse and developing a breakthrough. This is achieved by systematically surfacing all the assumptions (mental models) that have created the state of impasse. As a result of this effort, Lepore and Cohen were able to verbalize the conflict of ‘Manage according to the Theory of Profound Knowledge (Deming)’, *versus* ‘Manage according to the Theory Of Constraints

(Goldratt)'. They then surfaced the major assumptions underlying this conflict, and developed a complete solution that would create a synergy of the two approaches. This analysis became the foundation for a methodology based on managing variation and constraints within an organization with the goal of a sustainable process of continuous improvement. This led to defining the ten macro steps of the Decalogue methodology, published by North River Press in 1999 ('Deming and Goldratt: The Decalogue'). The Decalogue was the first comprehensive attempt to combine cohesively these two allegedly different approaches to the management of complex organizations.

The *perceived* conflict between these two theories mirrors the duality that in science has existed for the last 400 years between a mechanistic approach and a holistic one, and that the awareness of complexity as a challenge for management strongly directs us to resolve. It can be solved only if we challenge the assumptions at the heart of the prevailing organizational paradigm that has dominated the 20th century. Conceptually, these assumptions belong to the realm of control and measurement and the ten steps of The Decalogue provide a logical invalidation and a viable replacement for these assumptions; these steps emerge as a practical answer and pave the way for transforming the prevailing style of management in the western world to one of *systems optimization*, as advocated by Dr. Deming in his 1993 book 'The New Economics for Industry, Government, Education'. In order for this transformation to happen it is necessary (a) to redesign the organization and (b) to cater for the learning difficulties that invariably people encounter when the cognitive landscape associated with their work is altered.

Philosophically and scientifically, the Decalogue methodology attempts to shift management from a mechanistic, Newtonian worldview in which the results of the whole organization equal the sum of its individual, separate and hierarchical parts, towards a systemic and interdependent network. The shift is achieved by combining the "reductionist" approach of the Theory Of Constraints with a systemic view based on interdependencies and interactions. It does so in practical terms by:

1. building interdependent processes managed through the control of variation;
2. subordinating these interdependencies to a strategically chosen element of the system called constraint;
3. designing the organization as a network of interdependent projects with a goal.

We will now take a more detailed look at the two main elements that distinguish the Decalogue approach for complexity: managing variation and managing constraints, how they complement each other, and how the Decalogue methodology brings these elements together to manage a network of interdependent projects.

3 Understanding the Organization as a System: Flowcharting the Processes

What do we mean when we call an organization a system? Deming's definition in 'The New Economics' is the most useful and practical: *A System is a set of interdependent components that work together toward a common goal.*

Deming was able to provide a revolutionary view of an organization as a system in his diagram from the 1950s. It is a complete shift away from a traditional, hierarchical view of an organization. There are no vertical 'lines' to be managed, simply a flow of inputs that are transformed into outputs (Fig. 1).

In his diagram, Deming includes two essential elements that are completely missing in traditional (hierarchical) organization charts: interdependencies and the connection with the external environment that the organization is part of (customers and suppliers). The modernity and the revolutionary character of Dr. Deming's view are even more evident today, in a moment in time where we are aware of how *network theory* shows that everyone is connected.

In order to understand the organizations as a system we have to be able to map out all the interdependencies/linkages that exist. This requires us to understand the company's processes and how to link them together. This can be done simply and effectively by using Deployment Flowcharts to map out every process in the organization, identifying who does what and in what sequence.

A deployment flowchart (DFC) describes who does what. It shows the interactions among people in the various phases of the process. It is crucial to know what these interactions are to really understand how the process works and how to improve it.

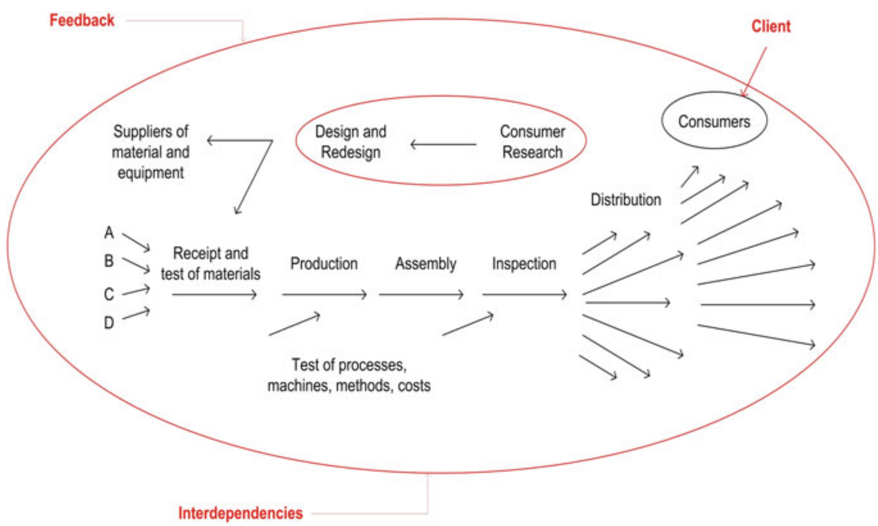


Fig. 1 A rendering of Deming's diagram 'Production viewed as a system'

The steps for drawing a DFC are:

- Identify the boundaries of the process, go through the process following the sequence of events, and achieve an overall vision without too many details;
- Identify the key areas (competencies);
- Arrange all the stages of the process on a flowchart by competency, according to the sequence in which they are carried out.

When we map out the organization as a system in this way, functional roles disappear and what emerges is a network of conversations that need to take place on a regular basis to make the linkages work towards the goal. This map of processes is not static; it develops over time with the life of the organization.

Once we have gained a clear picture of the organization through the mapping process, we identify what we call “key quality characteristics”. These are special places inside the organization that we understand have a major impact on the performance of the organization as a whole. Once identified, these characteristics become the key points for where we plan to continuously monitor *variation* and thus work toward its reduction (if and when possible or appropriate). These actions are the prerequisites for managing variation with Statistical Methods for continuous improvement.

Let’s take a look at why understanding and managing variation is so critical for managing organizations as systems.

4 Variation and Its Importance for Managing Organizations as Systems

The Decalogue methodology had its beginnings within a Deming perspective, and for Dr. Deming, the very essence of management was ‘reducing variation’.

Why is variation so important? Managers need to have the ability to make rational decisions about their organizations, and the work of their organizations consists of processes. Therefore, managers should know how processes behave, both now and in the future. Whether they are aware of it or not, all process are affected by variation.

Indeed, every human process, from getting to work in the morning to carrying out space programs, is affected by variation: a process can never be repeated in a way that is exactly identical. While we can never eliminate variation, statistical methods allow us to understand it, manage it, and take actions to reduce it.

When managers ignore the impact of variation, they do so at great risk as variation strongly impacts the dynamic of the network.

5 Variation and Complexity

When investigating *complexity*, we appreciate even more deeply the need to understand variation. We do not live in isolation; we work and perform activities in connection with other people, usually through cooperation, and these relationships are interwoven in a complex way. It is therefore fundamental to understand that the *output* of any activity we perform is, in turn, an *input* for some other activity or person in the network of interdependencies of which we are part.

When we realize the importance and ubiquity of variation, it becomes clear how fundamental it is for a manager, whose job it is to work *on* the system, to understand the kind of variation the system is affected by so as to make appropriate decisions and take actions that make sense. Not only is it not possible to eliminate variation, it can be passed on from activity to activity, and from process to process. In some ways, dealing with variation is like dealing with infections. If we know what kind of "germ" we are affected by, we can adopt the right countermeasures. We must never forget that infections can spread when nothing is done to limit them.

Let's look at an example of how variation from a supplier's processes can spread to a customer. Suppose we own a factory producing polyethylene film and we buy raw material, in the form of pellets, from a "reliable" supplier, i.e. one that we trust. If the density (mass per unit volume) of the raw material is not uniform, then when we come to melt it the result will not be uniform either. The inevitable consequence of this is that our extrusion process will be affected: we may experience a breakdown caused by an obstruction at the extrusion point (a lump of unmelted material), or a rupture of the film (small fragments of unmelted pellets in the extruded film causing non-homogeneity and areas of fragility), or a problem in the cutting phase of the film.

If we do not know the real cause of the disruption, because we do not know the nature and the "amount" of variation that is affecting the system, we run the risk of trying to fix the problem locally (i.e. we fix the problem of obstruction) and then experiencing a different problem immediately after, i.e. the film breaks. However, regardless of the nature of the breakdown, we first have to make sure that spare parts are available and that the person in charge of maintenance has the right tools to deal with the problem.

In the end, if we do not have enough information about the nature of variation in the density of the material, we will not be able to make any kind of prediction. Instead, we will inject uncertainty into what kind of spare parts or tools we actually need and, consequently, we will not be able to organize maintenance in an effective way. As we can see from this example, variation has spread out from the supplier to the maintenance process of our factory in a similar way that infections caused by germs have the ability to spread over the body. (We have taken this example from a manufacturing environment, but variation is just as relevant to any environment, from nursing homes to software houses, from advertising to theatre management.)

Variation is intrinsic to any human activity, and it strongly impacts the dynamic of the network, because, as we said earlier, the entropy of a closed system always increases. Variation can be monitored through the use of **Statistical Process Control** (SPC). SPC, while simple to grasp and use, provides a sophisticated support that helps managers to understand how the system behaves and how their decisions impact the system.

When we have large interconnected systems, it is virtually impossible to predict the effect that changing a single component will have on the system overall. We face a problem of complexity, where non-linear interactions play an important role.

Understanding and improving the performances of highly interdependent processes in complex organizations is possible only if we understand:

- the variation associated with single processes;
- the cause-effect relationships among them;
- the impact that they have individually and cumulatively on the final result.

In other words, we have to approach the organization (system) as a whole. It is important to understand that SPC is not simply a technique or a tool for measuring. When we fully understand its importance, then managing variation for the *entire, interdependent system* becomes a mindset and *a way of thinking*.

If we do not have a clear picture of the behaviour of variation inside the organization, and we allow it to evolve without control, we will inevitably experience an increase in chaos. Furthermore, every time we consider an organization as "segregated" from the rest of the environment (i.e. we do not consider customers and/or suppliers as part of the same picture) we make a grave mistake as we risk transmitting that chaos beyond our own internal system. Keeping variation low is an exercise that has to include all the parts of the system, internal and external.

6 Gathering Data: The Behaviour Chart

Statistical Process Control (SPC) was introduced by W. Shewhart in the first half of the 20th century as a result of his work with Bell Laboratories. The Decalogue methodology uses SPC to study and manage variation.

If every process in our organization is affected, we need to know *what kind of variation* we are dealing with. There are two kinds of variation, one which we can consider intrinsic to the process; this is due to *normal (common) causes* that are permanent and do not change over time. The second kind of variation is due to *special causes,* i.e. not intrinsic to the process, that change over time. The *two types of variation* are completely different, and must be dealt with differently. Failing to identify the two types leads to taking inappropriate actions on the system that may worsen the situation (what Deming refers to as "tampering with the system").

We use Statistical Process Control to distinguish between these two types of variation, and SPC provides us with an operational definition of how to obtain the maximum from our processes. SPC uses what are known as "control charts", or "process behaviour charts" to analyze variation.

A process behaviour chart is a time chart of a process (or the variables under consideration, e.g. the physical or chemical characteristics of a product) with three extra horizontal lines: the average value and the upper and lower limits of the process.

These limits are NOT specification limits. They indicate the range of variation of the process. They are calculated using a statistical formula, using the actual data of the variables being studied. The meaning of these charts is not probabilistic but empirical and economic (W. Shewhart). The limits are based on the 3-sigma rule (sigma is the standard deviation which measures the spread of the variable around its average value) i.e. they are placed at a distance of three "standard deviations" from the average value. This is what Dr. Shewhart considers the most acceptable, both empirically and economically, as 99 % of 100 % of data of a variable will be found at a distance of 3-sigma from the average (see notes for explanation of calculation of process behaviour chart) (1) (Figs. 2 and 3).

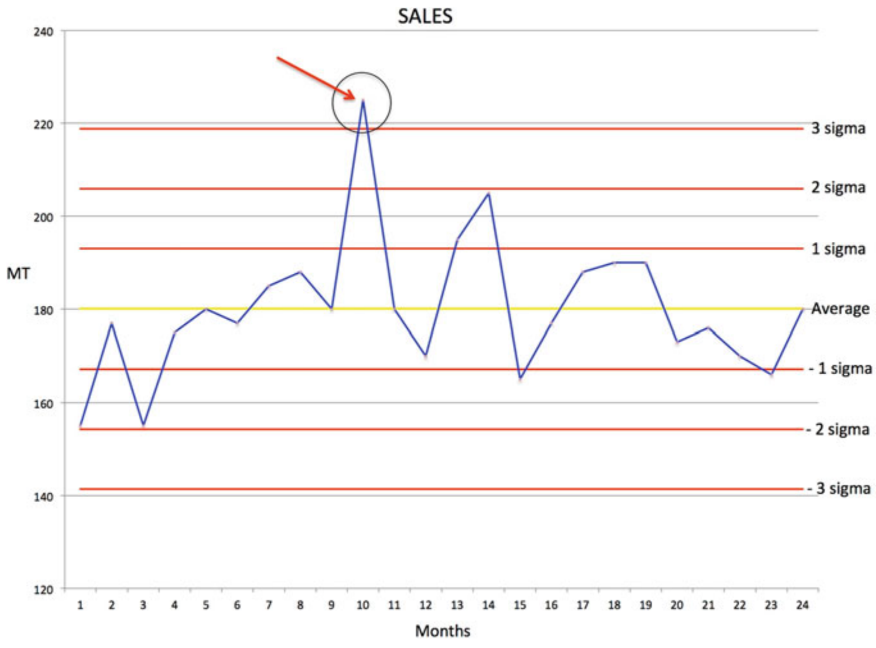


Fig. 2 Example of a process behaviour chart showing a process that is out of statistical control

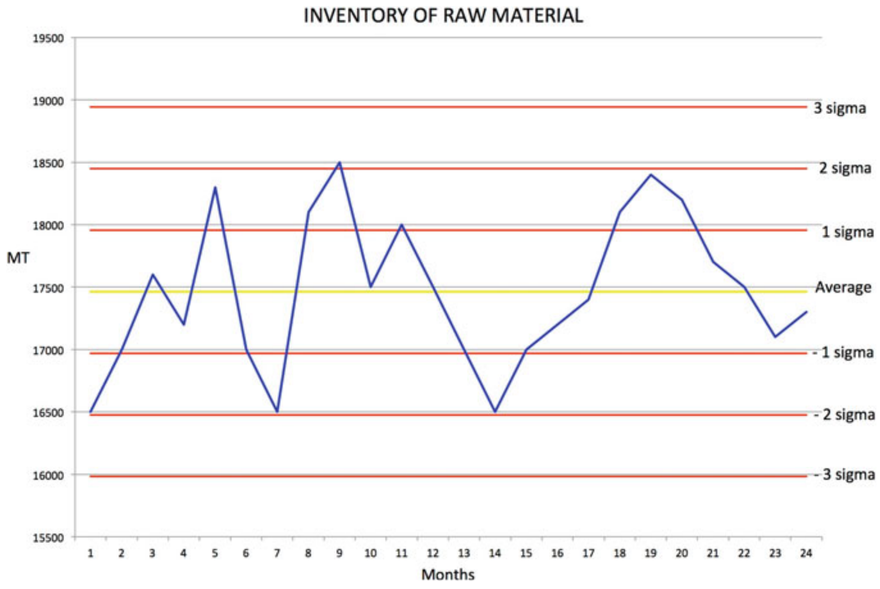


Fig. 3 Example of a process behaviour chart showing a process that is in statistical control

7 Prediction Versus Forecast

Why should a manager go to the trouble of understanding the statistical behaviour of any process? To understand this fully we have to make a distinction between forecasting and predicting. Managers may be asked to make forecasts, and these are empirical suppositions based on previous evidence and, in many cases, fears and hopes. The usefulness of such forecasts is limited and reliance on them perpetrates a totally inadequate empirical approach to management. Managers, instead, need to be able to predict how any given process will behave in the future as a result of their decisions. This prediction must be grounded in statistical understanding and the epistemological stance it portrays.

Statistical Predictability means that the process oscillates "predictably" within its upper and lower limits of variations. This is the only kind of prediction that managers can reasonably make and the only one that gives rational value to their decisions.

8 Adding the Constraint to the Organization Viewed as a System

The concept of constraint is well explained in any book of Analytical Mechanics and it is the starting point for the description of the dynamics of any physical entity. Organizations are *dynamic systems* and Dr. Goldratt made a significant contribution to management theory by pointing out that we can also identify the constraint of an entire organization, i.e. whatever limits its ability to perform.

The intuition to combine managing variation with managing a constraint came from the realization that constraints, just like variation, are intrinsic in organizations, therefore if the idea of constraint is ignored, then no matter how well we manage variation in the system, we will inevitably find ourselves in a system where there are *interacting and constantly shifting constraints*. This is a highly undesirable level of complexity.

A methodology that combines variation and constraint, instead, allows an organization to make a strategic choice about which element they wish to be constrained by and to design the system around the constraint while managing the variation of all the processes (creating stable processes) that impact the constraint.

This intuition of combining the management of variation in a system with managing the constraint took the form of the diagram we call the 'Choked tube'. In this diagram we take Deming's diagram 'Production viewed as a System' and we insert a constraint into it (in this diagram it is the Production phase). This represents a system where stable processes (statistically controlled) have the capacity to subordinate to a well-chosen constraint. In order to protect the whole system, we place a buffer in front of the constraint, and the oscillation of the buffer must be statistically controlled (Fig. 4).

Generally speaking, the constraint of an organization is what limits its ability to generate *value* or, more precisely, *units of the goal*. Considering what we said earlier about flowcharting, we can consider the constraint of an organization as a very particular kind of key quality characteristic because it is the point that *dictates the pace at which the system generates value*. This is the reason why it is of critical importance. As with variation, the constraint cannot be eliminated; we have to learn

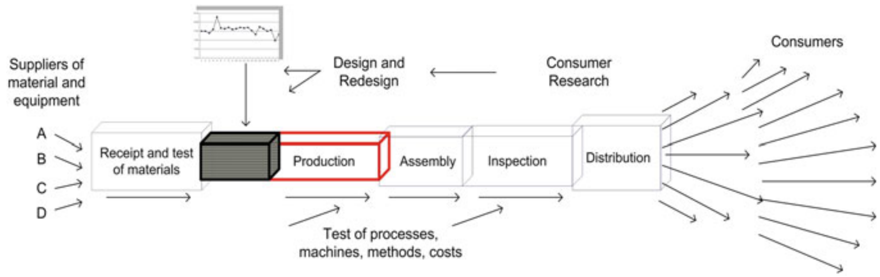


Fig. 4 The 'choked tube' solution with constraint and buffer

how to manage it to the advantage of the whole system, and there is no system without a constraint. In the next section we take a more detailed look at the advantages of managing an organization around a constraint.

9 The Need for a Constraint

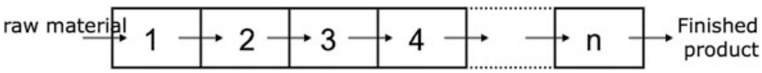
Although the word constraint may sound negative, in practice it is not. It turns out that we actually *need* a constraint and that is very useful. This is true for two precise reasons:

1. we need a constraint to facilitate the synchronization of the different processes in the system (the constraint is the element that dictates the pace at which value is generated);
2. we need a constraint because an “unbalanced” system is more solid and it is more easily managed when the impact of variation is taken into account.

In light of the above, we can in fact **choose** the constraint; we decide where it is possible to conveniently (strategically) position the constraint in order to manage it.

Let’s see in more detail why an unbalanced system is simpler to manage than a balanced one. The simplest way to exemplify the power that stems from focusing only on one constraint in an organizational system is a production flow. However, this is only ONE example. The production line represented in the following example could just as well represent ALL the processes of an organization, or even *the various elements in an entire supply chain*. It would be a huge disservice to the Theory of Constraints to consider it as something that is restricted to manufacturing and logistics. Indeed, the following line of reasoning can and has been applied for decades to a myriad of business environments.

A balanced plant or system is a production flow where the process stages (for the sake of simplicity, machines) that generate the finished products all have the same nominal production capacity. The goal of a balanced system is to match the capacity of the various stages so that there is no excess capacity in any part of the system.



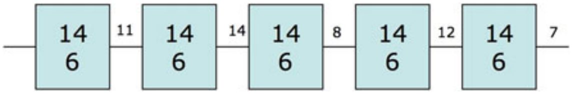
Unfortunately, this scenario is quite unrealistic since we are overlooking the impact of variation on the different stages of the chain. At each stage, the amount of production will be affected by variation resulting in the impossibility of the system being “balanced”.

Let’s look at a simple example.

Let's imagine we have a market demand of 10 units of our product and a production process with 5 stages, where every stage has the same production average and the same amount of variation as the others. On average, every step of the process can produce, and make available to the next step, 10 semi-finished units per hour, with a performance that varies within a range from 6 to 14 units.

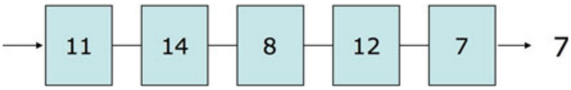
Let's simulate the first production cycle.

The first stage passes on to the second stage something between 6 and 14 units (let's say 11), the second stage will be able to produce any result between 6 and 14 (let's say 14); similarly, the third stage will generate 8, the fourth stage 12, and the last stage 7.

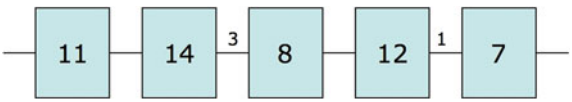


Given this combination of output, which is perfectly compatible with the machines chosen (by average and variation), how much finished product really comes out at the end of the first production cycle?

The first stage will deliver 11 units to the second stage. The second stage is able to process all 11 units. The third stage will receive the 11 units, but, due to *variation*, it will only process 8 of them and pass them on to the fourth stage. The fourth stage has an instantaneous capacity to process 12 units but, as it only received 8, it will only process those and pass them on to the next stage. The last stage has an instantaneous capacity to process only 7 units; consequently, 1 unit will get left behind. The final result is that, after an input of 11 units, only 7 are produced.



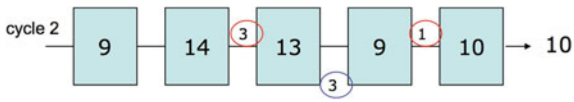
It is clear that 4 units are somehow "lost" inside the production chain as work in process. In this case, 3 units are stuck between machines 2 and 3 and the other unit between machines 4 and 5:



To summarize, even if the market demand was 10 units, equivalent to our "average capacity", we would not be able to satisfy demand because *interdependencies and variation* make it impossible to "balance" the production.

Under the initial assumptions, let's see what happens as time goes by. Since variation over time is the same (the range is from 6 to 14), and all the stages have the same average value, the second production cycle will be able to use the semi-finished units that are still in the system.

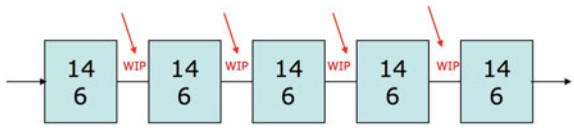
Let's look at a simulation of the second cycle:



The first stage will deliver 9 units to the second stage. The second stage will be able to process all 9 units. The third stage will receive the 9 units plus the three semi-finished already present in the system and will process all of them and pass them on to the fourth stage. The fourth stage is able to process 9 units, leaving behind 3 semi-finished units. The last stage will use these 9 units, plus the one already present as WIP, ending the cycle with 10 units produced and 3 left in front of the penultimate processing stage.

As the system is made up of a series of *interdependent bottlenecks*, in every single cycle the instantaneous production capacity of the entire production flow will be equal to the capacity of the stage that has produced the minimum capacity. Moreover, as every machine has a capacity that varies above and below 10 units per cycle, it is almost certain that at least one of the machines has an instantaneous capacity that is less than the average value. Therefore, the real capacity of the entire system will always be something less than 10 units per cycle, at least as long as the stages are interdependent. We are in a paradoxical situation where we produce WIP without managing to satisfy market demand (10 units/cycle).

As production continues (the number of cycles increases), there is an increase in the semi-finished material that accumulates between one production stage and another; this is due to the effect of variation in each stage and goes on until the production stages become *decoupled*. Now no stage is forced to remain inactive and each stage can operate independently from the previous one, with a global capacity that is close to its own average value.



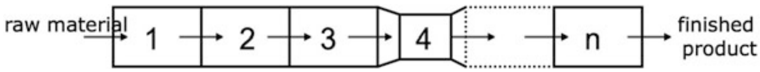
The price of decoupling is an increase in WIP (Inventory); this means keeping money frozen within the system.

With a balanced process we can deliver 100 % of market demand *only* if these two conditions are met at the same time:

- We accept to size the process so that the market demand for every cycle is considerably less than the average value of the production capacity for each stage;
- We wait for the condition of decoupling of the production stages to happen.

These conditions allow us to deliver 100 % of the demand, without generating too much WIP, only by having a much greater production capacity in every stage compared to actual demand. In our example, the system would be able to deliver 100 % of market demand if this demand was 8–9 units/cycle (considerably lower than the average of 10 units/cycle).

A different approach is to increase the capacity of some of the stages of the production process so that there is always **only one bottleneck** in the flow of material.



This choice allows us to eliminate most of the WIP, as long as the capacity of the constraint (and therefore of the other stages) is sized on the basis of market demand (market demand must be equal to the average production capacity of the constraint). Also, the flow of the material has to be managed around the constraint; this strategy also foresees an over-sizing of production capacity, but it also has a number of advantages.

Instead of balancing the system, and then trying to improve it by balancing it and reducing variation in all the production stages, we apply the Theory of Constraints (TOC) solution. After identifying (or choosing) the constraint, we manage the system around the constraint itself. With this solution, we "unbalance" the system because it is simpler and cheaper to manage.

In an unbalanced system everything revolves around the constraint phase and there are many advantages to this. A detailed plan is made for this phase only. This schedule allows us to manage the whole production system. Also, reducing (global) variation in an unbalanced system means concentrating on and investing in the constraint phase only, not in every single part of the production process. Consequently, increasing the productivity and improving the performance of an unbalanced plant is considerably cheaper and less wasteful in terms of time and energy.

The algorithm that embodies this approach to the synchronized scheduling of finite capacity, which has been largely used by a multiplicity of industries all around the world for more than 30 years, is called "Drum-Buffer-Rope" (DBR); it is a three-step process:

- we identify/choose the constraint
- we exploit the constraint
- we subordinate the system to the constraint

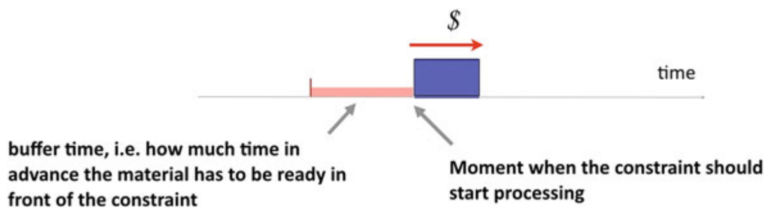
To be more specific, first *we identify the constraint* in the cycle, and then we decide to manage it effectively. Managing the constraint effectively means managing it so it never stops: in other words, it must never be "starved" of input. In TOC this is called *exploiting the constraint*.

For this exploitation to happen, every other stage/process in the system has to *subordinate*. This means that there must be enough production capacity upstream to always produce semi-finished units to feed the constraint continuously and enough production capacity downstream to guarantee that what the constraint produces can be processed. Statistically speaking, this means that the “ranges of variation” upstream and downstream of the constraint phase, must have a lower limit of oscillation that is greater than the upper limit of the constraint phase.

As far as WIP is concerned, while in the case of the balanced system it must be available in front of *all of* the production stages so that uncoupling can occur, in the case of the system with a constraint, WIP must only accumulate in front of the constraint stage to keep it continuously fed. What is more, if the material is released to the whole plant at the pace at which the constraint can process it, the amount of WIP needed to achieve optimal performance can also be kept to the minimum.

10 Protecting the Constraint: The “Buffer”

The algorithm we have just described has the aim of maximizing the performance of the system and it is totally dependent on the correct and continuous functioning of the constraint. Managing the constraint effectively implies that it must never “starve” and that is why we must have some kind of protection mechanism in place. In TOC the protection mechanism is called “buffer management”. In a system that is unbalanced around the constraint and subordinated to it, the buffer protects the constraint from variation. The unit of measurement of the buffer is time.



Once we know the amount of variation the constraint is affected by (both in terms of input it receives and its processing time), we can define how much time in advance the material has to be ready in front of it. The final, and most important, step is to *manage the buffer*. Essentially, we have to have an operational procedure that supports our decision-making process; in order to be sure that the constraint works all the time, we have to guarantee that the buffer is never reduced to zero.

Since we believe that statistical predictability is the foundation of management, we must monitor the consumption of the buffer statistically and act accordingly. If the consumption is “statistically stable” we do not intervene; vice versa, if the consumption is statically unstable, then we must take action.

11 Measuring a Complex System and Its Performance with a Systemic Approach

One of the most remarkable consequences of introducing a "Deming-Goldratt" approach to management is the way it changes how we measure the performance of an organization. Traditionally, performance is measured "locally" because we are accustomed to assigning goals to single "departments"; then, we calculate the performance of the whole organization as the "sum" of all the local performances.

This approach is flawed. A System, as we have described it, is a set of *interdependent components* working towards a common goal. If there were no interdependencies, according to the theory of systems, the "yield" of the system would merely be the sum of the "yields" of its components. Instead, because of interdependencies (and entropy), we have to account for the interactions just as we saw previously when we looked at balanced versus unbalanced systems.

For a system made of three different components A, B, C we have:

$$\begin{aligned}\text{Yield(system)} = {} & \text{Yield(A)} + \text{Yield(B)} + \text{Yield(C)} + \text{Yield(AB)} \\ & + \text{Yield(AC)} + \text{Yield(BC)} + \text{Yield(ABC)},\end{aligned}$$

where the contributions due to the interactions among the three parts are taken into account. These contributions, of course, can be "positive" or "negative" according to the way they combine (work together). What we have just described inevitably impacts the way we measure performance inside the organization.

There is no way we can measure the impact that the single employee, or "department" (or function, whatever we may call the traditional silo-designed elements of the organization), has on the performance of the organization as a whole. When we understand the organization as a system, the only reasonable way to measure performance is to set a *global* goal toward which everybody has to contribute. The prerequisite for the correct functioning of the System toward the goal is the existence of a *set of well-designed interdependencies (procedures)* and the statistical predictability/stability of the processes.

Identifying the constraint and managing the system around it with statistical methods provides a highly focused management approach and a much more effective way of optimizing resources. As everything in the system is interconnected and only the constraint must perform to the maximum, then we must always ensure that there is *extra capacity* to protect the constraint from the variation that will inevitably affect the processes that feed it. This translates into a system where no other resource, human or otherwise, other than the constraint must work to its maximum capacity. We must never schedule the time of any resource except the constraint at (almost) 100 %. Consequently, we can never measure the performance of a resource based on whether they are working to the maximum. It is the system as a whole that dictates performance, and it is the system as a whole that we have to measure.

The Theory of Constraints allows us to further simplify our management efforts by providing the fundamental set of measurements (*Throughput Accounting*) that allow us to understand how our system as a whole is performing:

Throughput (T) is the rate at which the system produces units of the goal (through sales). In for-profit organizations, throughput equals the sales revenues (S) minus the totally variable cost (TVC) of what it pays (often out to suppliers) to produce the goods or services sold (T = S − TVC).

Inventory (I) is the money tied up in the system to be transformed later into sales. This money is in the form of what is generally understood as inventory. Inventory is only valued on the totally variable cost associated with its creation or procurement. It does not include any allocation from overhead or fixed expense.

Operating Expense (OE) is the money the system spends in generating units of the goal, such as rent, utilities, taxes, payroll, maintenance, advertising, training as well as investments in buildings, and machines, etc.

Throughput accounting, unlike traditional accounting, recognizes that time is an important element in throughput generation. Its measurements provide a meaningful report of cash in and cash out (no accounts receivable are considered), and it supports a worldview based on consistently increasing performance as opposed to cost reduction. As such, it is completely interconnected with all other activities within an organization and provides an important support for decision-making in every aspect of how the system operates.

12 Managing Complexity—The Decalogue Methodology

Organizations are dynamic systems. As we have already pointed out, we can always identify (choose strategically) the constraint of the organization in order to manage it. This is the essence of the Theory of Constraints.

Anchoring the system to one point, the constraint, and understanding interdependencies (the actual forces in a dynamic system) is what we mean with managing and leading the system towards Throughput maximization (in For Profit organizations this is the cash generated through sales).

The approach we propose, **The Decalogue**, is a *Systemic* approach. It brings together cohesively two well recognized and time honoured views for the management of complex organizational systems:

- identification of interdependencies, understanding variation and its impact on the network;
- identification (choice) of the constraint, exploitation and subordination of the network to it.

The Decalogue re-defines the ideas of how we:

- **Control** the system: through the constraint using buffer management and relentless application of statistical methods
- **Measure** the performance of the system (Throughput Accounting)
- **Design** the system for continuous improvement: the ‘choked’ system

The ten steps of The Decalogue provide a path to embrace complexity and sustain the necessary efforts for continuous improvement. The ten steps are:

1. Establish the goal of the system, the units of measurement and the operational measurement (without a *common* goal there is no system);
2. Understand the system (draw the interdependencies);
3. Make the system stable (understand variation and its impact on the network, make sure that the oscillation of the processes is statistically stable);
4. Build the system around the constraint (subordinate the organization to the constraint, the only part of the system that can never stay idle);
5. Manage the constraint (protect the constraint from the intrinsic variation present inside the system with a “buffer”—buffer management);
6. Reduce variation at (of) the constraint and the main processes (wider variation implies poorer management; low variation improves predictability, reduces inventory and WIP);
7. Create a suitable management/organizational structure (design the network of interdependencies as a *network of projects* to improve the performance of the system);
8. Eliminate the “External Constraint” (sell all the capacity the system has available);
9. Where possible, bring the constraint inside the organization and fix it there (an “internal” constraint is much easier to manage than an external constraint);
10. Create a Continuous Learning Program (motivate people to learn, improve the system through personal improvement).

These ten steps represent, clearly, more than a simple protocol; they are a transformational process. The Decalogue it is not for the faint hearted and its adoption requires the willingness to challenge strongly rooted (and often unchallenged) mental models.

13 Processes, Projects and Managing Projects with Critical Chain

The effective management of process variation and a powerful algorithm for synchronization are key elements for the “Deming-Goldratt” view of the organization as proposed in The Decalogue. How can we build the appropriate organizational framework for these basic principles to be effective? In other words: how can we move from the realm of debating the principles to one where these principles can produce results?

We believe that any serious conversation about "systems thinking" when it comes to managing organizations must start from acknowledging that a system is a network of interdependent processes (the basic components of the system) that work together for a common goal.

A process is what transforms an input into an output; such a process, no matter how complex, innovative, mental or physical, has a beginning and an end, it has a viable temporal span for its execution, a variation that must be managed and it requires resources. If we accept the idea that resources, human and material, are finite and their role is to maximize their contribution to the overall chosen and accepted goal of the system, then having a metric in place can only be beneficial. If we choose a metric that cohesively integrates resources and time then we have Projects that we can schedule with some hope of success, i.e. that can realistically be on time, in specs and within budget.

In his 1997 novel 'Critical Chain', Dr. Goldratt casts a new light on the controversial issue of managing finite resources in a project environment by offering a radically different view of how projects should be scheduled and how their execution should be managed. By leveraging the concept of co-variance and presenting a powerful finite capacity algorithm, he redefines the rules for successful Project Management.

Traditional project management methods using a critical path cannot guarantee that projects are completed in time, to specs and within budget. The shortcomings of project management were examined by Dr. Goldratt in 'Critical Chain', where he presents a profound innovation for reliable management of projects. Traditional PM is often based on an assumption of infinite capacity and therefore can lead to resource contention.

The traditional critical path method is plagued by wrong-thinking and wrong habits, such as multi-tasking and 'student syndrome', i.e. putting off tasks until the last minute, that can slow projects down artificially. The Critical Chain method tackles head on many of the issues that prevent projects from completing successfully by:

(a) eliminating milestones; instead the entire project is protected with a buffer at the end (project buffer) to protect from accumulated variation;
(b) making realistic assessments of task length instead of adding protection to each task, thus speeding up the project;
(c) resolving resource contention by allowing for finite capacity by calculating the Critical Chain, i.e. the longest sequence of dependent events *taking into consideration the sharing of resources*. This sequence determines the length of the project, and this is the limiting factor (constraint) of the project itself.
(d) Non-critical branches, called feeders, are also protected with a cumulative buffer (not individually) placed at the end of the "feeding chain". (Fig. 5)

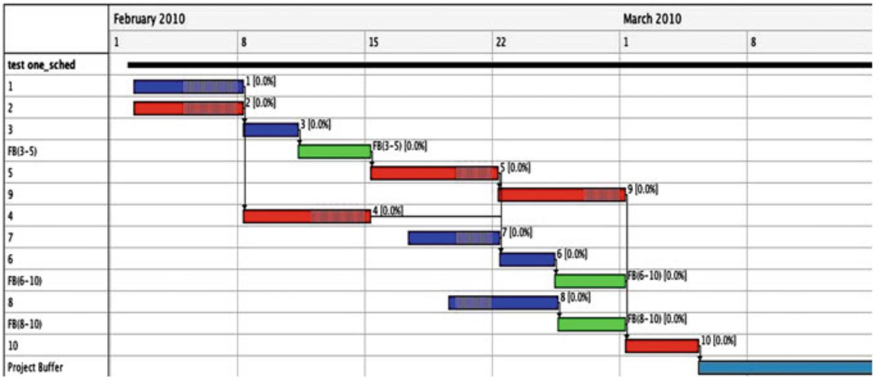


Fig. 5 The *red boxes* represent the critical chain of the project

14 Critical Chain and Organizational Design

Critical Chain is much more than simply an algorithm to accelerate project completion; it is the vehicle to integrate, control and deploy the resources of the organization. In this way, t*he Critical Chain algorithm also provides the foundation for the re-design of organizations*.

In the process of our work over the last two decades, we have come to understand how organizations in their entirety can, in fact, be seen as networks made up of Processes and Projects; some of these processes will be very repetitive and easily managed, DFC and Process Behaviour Charts will suffice; some others will be more innovative, have a higher level of complexity and will require a more comprehensive management approach, i.e. a Critical Chain project management schedule and an execution plan.

Process Behaviour Charts for, essentially, repetitive processes and the Critical Chain approach to the management of projects provide all the *profound knowledge*, as well as holistic measurement and control mechanisms, to transition safely from the largely obsolete Hierarchical/Functional organizational design to a very "all hands on deck" systemic model.

15 Network Theory and the Network of Projects Organization

Once it became clear just how foundational Projects (managed through the algorithm of Critical Chain) are for the organizations we have worked with, from metal foundries to nursing homes, it also became clear that Network Theory was providing important insights for how organizations behave and evolve, and how they can improve.

There are various kinds of networks, both naturally occurring and manmade. In nature, we can find networks such as beehives. An example of a manmade network, instead, is a subway system in a large city. These networks are a collection of nodes that are all interconnected with various degrees of separation among them. Connections in these networks occur randomly, therefore they are referred to as ‘random’ networks. In other words, they are not designed with a specific goal that affects how the nodes interact with each other. The statistical distribution that describes the probability with which these nodes are connected to each other follows a ‘normal’ Gaussian distribution (i.e. the data will cluster around the mean with a few outliers).

A different kind of network is what is known as a ‘scale free’ network. These are networks where interconnection among the nodes is greater with some nodes than with others. The nodes with a greater number of nodes connected to them are called *hubs*. These networks, therefore, have a hierarchy consisting of ‘visited’ hubs and more isolated nodes. The statistical distribution that describes the probability with which these nodes are connected to each other follows a Power Law. This distribution follows an inverse power relation.

The implication of Network Theory for organizations is profound. When we examine an organization in the light of network theory, we can see that there is an inherent network-like nature, and we can analyze its behaviour and development with new understanding. More importantly, this knowledge allows us to consciously design, manage and operate the organization with a much higher level of optimization. We have come to call this organizational model the Network of Projects.

16 Proposing the Organizational Design of the Networks of Projects

A network is a set of “nodes” connected by “links”; it is not a static entity, indeed it is something that continuously evolves, and its sustainable development is governed by a dynamic dictated by the emergence of a few hubs strongly connected to nodes through links whose behaviour is statistically predictable. This dynamic is, especially in the specific case of human networks, non-linear because of the intrinsic non-linearity of the interactions between the nodes (people or groups of people).

At the most fundamental level, organizations are networks of different communities of practices; it seems only reasonable to the authors of this paper that the prevailing silo-based, hierarchical/functional organizational design be replaced with an organic way of structuring such practices. In our book ‘Sechel: Logic, Language and Tools to Manage Any Organization as a Network’ (2011), we present a new model for the sustainable growth of organizations based on the concept of a *Network of Projects*. A Network of Projects leverages the power of the Critical

Chain algorithm developed by Dr. Goldratt to build organizational systems where control mechanisms, feedback cycles and rational allocation of finite resources are more effective and in line with the goals of the organization.

Everything that an organization does can be thought of in terms of a project. Some projects, like book-keeping, are repetitive, and others, like New Product Development, are non-repetitive. The Network of Projects that makes up the life of the organization is a particular kind of Network, called *directed* network, where the "direction" is provided by the goal of the organization. Such networks are called *scale free*, as we described above, with a hierarchy of hubs and nodes. Accordingly, in an organization there will be *hub-projects*, namely the ones more relevant for the success of the organization and "node-projects", i.e. projects that are smaller but still necessary for the development of the organizational network. What ensures the connection among these Hub and Node Projects is the finite capacity algorithm for their synchronization fuelled by an appropriate Database of resources. Within the ten steps of the Decalogue for managing organizations as systems, i.e. based on managing variation and constraints, step 7 regarding organizational design becomes the design of a network of projects.

17 The Network of Conversations in Organizations

The life blood, or the links that connect the elements of an organization are the conversations for action that take place. The effective synchronization of these conversations is possible only if the basic processes that these conversations represent are statistically predictable in their outcomes. The question then becomes: "How can we make the outcome of conversations predictable, how can we frame a human interaction based on language (as opposed to a one-way command to a machine) in a way that leads to predictable and actionable outcomes?

We can replace the outdated Hierarchical/Functional structure with a much more organic design, based on managing variation and constraints, that reflects the intrinsically project-like nature of the work of organizations. This change is not cosmetic, it is transformational and it is rooted in a paradigm of cooperation, togetherness and win-win. The new covenant that everyone in the organization (as well as the value chain in which the organization is embedded) must embrace requires a much higher ability to think, communicate and act; it requires a new "wiring" in the way we measure, manage and sustainably improve our efforts towards our goals.

The real challenge in bringing about a transformation based on a Network of Projects lies in the emotional and cognitive shift that needs to occur in the way people learn and use their knowledge as well as how they see themselves develop and interact in the workplace. The Thinking Processes Tools (TP) from the Theory of Constraints were developed by Dr. Goldratt to aid that shift. Far from being a mere technique, we have found these tools to be a critical element in transforming organizations into "thinking systems" because they foster in people the ability to see interdependencies, resolve conflicts, be empowered, work cooperatively, communicate effectively and, at a higher level, perceive (and act coherently upon) the oneness of the organization with its business and physical environment.

To replace successfully a traditional Hierarchy with a Network of Projects, we need to start from the very foundation of how we think, speak and act. What we need to learn is how to seamlessly connect our uniquely human abilities to (a) systematically develop solutions to seemingly insurmountable conflicts (intuition), (b) understand the full spectrum of these solutions (analysis/understanding), (c) develop and implement a cohesive and coherent action plan to implement the solutions (knowledge), (d) sustain the development of the 'intelligent emotions' needed to harness complexity.

18 The Thinking Process Tools

With the increasing complexity of all environments, humans have an unprecedented need to develop the intellectual and emotional skills to navigate change and adapt on a continuous basis. Any organization that wants to continue to go beyond simple survival and prosper needs to find a way to navigate the intellectual and emotional demands of ongoing change.

The Thinking Process tools were developed by Dr. Goldratt to sustain and focus the change process underpinned by the process of ongoing improvement at the heart of the TOC. Goldratt identified three major phases of change: (1) What to change; (2) What to change to; (3) How to make the change happen.

Goldratt developed logical tools to support and facilitate each of the three phases. He did so as he realized how important it was to provide a strong cognitive support to combat the difficulties associated with change that people inevitably experience. Used as a complete suite, the Thinking Process Tools have proved themselves to be an effective way to supervise and guide the change process. They are also an ideal companion for developing project plans.

Using precise verbalization and simple diagrams, the Thinking Process Tools help people to visualize the complex, highly nonlinear network of cause-effect relationships that mark reality, as we perceive it. They allow us to map the "conversations" that make up our cognitive horizon, and these conversations are in themselves a kind of network. Without appropriate tools, we have no way of grasping the reality of this network, how it defines the semantic boundary of our universe, and how it shapes our actions.

Learning to use these tools takes some practice, but within days they allow people to focus and accelerate their work together. Over time, they enhance and fortify the faculties of the intellect that are responsible for the conception of new ideas (intuition), their full development through analysis (understanding) and the operational deployment of the actions needed to carry out the implementation of the fully analyzed idea (knowledge).

By linking these faculties, the tools enable a higher level of control over the interdependencies among these faculties, and this can often lead to conceiving breakthroughs that did not previously seem possible. The tools also have an important role in reducing variation in our thought processes by focusing our mental efforts towards a goal. They can greatly reduce variation in the way people communicate in an organization by providing a common language. Moreover, they help to harness the powerful forces represented by the emotions involved in the change process, and reinforce and engender the empathy required for collaborative work.

The learning required through a change process can be very de-stabilizing on an emotional level because it continuously pushes forward the limits of our cognition. This means creating a gap between what we know and what we feel we can do, and this gap can be emotionally uncomfortable. In order to leverage the tension resulting from this gap in a positive way, we need to understand our emotions better and refine them. In this way we can transform the potentially destructive power of emotions into a positive force for change. The Thinking Process Tools help people to manage the interdependency of intellect and emotion in the change process. In this way, change can become the transformational effort that is required for any sustainable, as opposed to temporary, shift.

19 Shifting Beyond the Hierarchical Mindset

The major problem with replacing a hierarchical mindset lies in the subliminal, unchallenged mental models that make us believe that an organization requires a superimposed control mechanism, be it a boss, a function, or an accounting structure based on cost accounting type considerations. The Thinking Process Tools help us understand the connections, linkages, and the overall mechanism by which we infer reality. Reality is shaped in our minds by connections that largely remain unchallenged unless we unveil them. By making explicit the cause and effect relationships with which we perceive reality we have an opportunity to challenge all of those assumptions that limit our ability, for instance, to work within a non-silo infrastructure i.e. within a network of projects.

More in general, the good functioning of an organization where conventional hierarchy has been challenged lies in enabling higher forms of thinking systems that are stifled by both current educational systems organized into silos and the corporate world. It is not enough simply to change processes. Flat organizations could easily turn into a short-lived gimmick unless working and, ultimately, existential paradigms governing the image that we have of what it means to live and work together are systematically challenged. This requires a considerable cognitive effort and without the right cognitive tools to support that effort, there can be little guarantee of continued success. The next section is dedicated to explain how the Thinking Process Tools from the Theory of Constraints can do precisely that.

20 The Pattern for Change with the Thinking Process Tools

In the Decalogue approach, the Thinking Process Tools not only support the change process, they are the tools we use to implement actions at every level. All the conversations of the network can be transmitted through the use of these tools, thus focusing the thought processes involved, accelerating discussion and consensus, and providing easy to communicate, visual and verbal results. Through continued and ongoing use, they can reduce the variation that wreaks havoc when points of view and ways of expressing those points of view are allowed to deteriorate. They can be used in a continuous cycle, from creating overall long-term strategy, down to the daily guidelines for carrying out repetitive tasks and new tasks alike. They provide a tangible resource to reinforce the systemic nature of the work, and having such a resource is crucial to support the cognitive challenges involved.

The diagram below illustrates the pattern that we follow with the Thinking Process Tools when we work with organizations in their shift away from an organizational model that is inhibiting their full potential towards a model based on a network of synchronized projects using the Critical Chain algorithm.

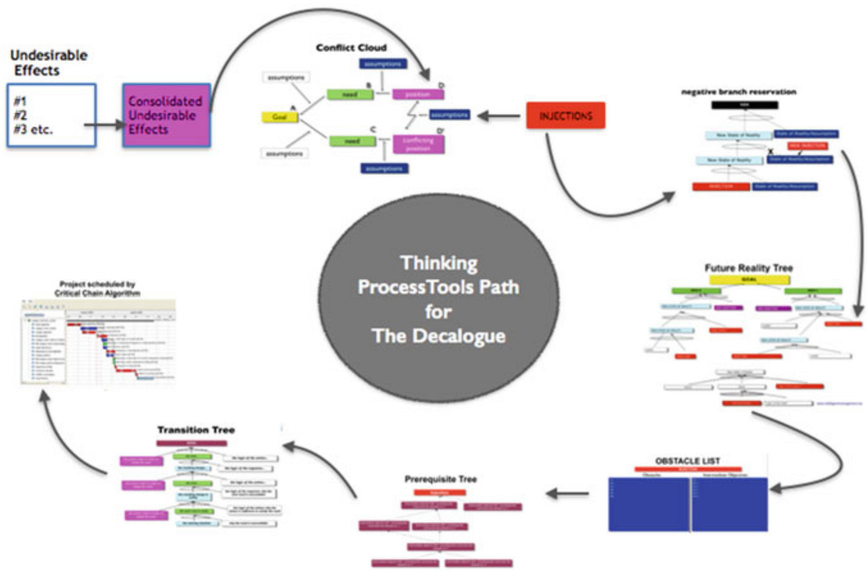
The process starts with the building of a "Core Conflict". Using cause and effect logic, the building of a Core Conflict provides us with a cognitive snapshot of the current reality of an organization. We start by identifying the 'Undesirable Effects' that the organization is experiencing in its way of working. This is a list of factors that are creating discomfort and represents the 'symptoms' of an underlying root cause. Once identified, these Undesirable Effects are summarized into one, overarching Undesirable Effect that sums up the current, unsatisfactory reality. We then verbalize what a desirable reality would look like. These become the two conflicting position of the 'conflict cloud'. This allows us to move on and identify the profound needs underlying these conflicting positions that drive an organization, and these needs are connected with vision, on the one side of the conflict, and control on the other. Once these needs are precisely verbalized, the organization can then derive the common goal that satisfies those needs, thus providing an organic direction rather than artificially imposing a goal. The most challenging aspect of the Core Conflict cloud is to surface systematically all the underlying assumptions (mental models) that connect the statements contained in the conflict. Once completed, the Core Conflict Cloud provides us with a root cause analysis of what is keeping the organization stuck and a clear verbalization of the goal they desire to accomplish. This corresponds with the first phase of change, 'What to change'.

The assumptions that underlie the Core Conflict are what keep the organization stuck in its current reality. By systematically invalidating these assumptions, it is possible to verbalize 'injections' to the conflict, i.e. statements that invalidate the assumptions while respecting the needs verbalized within the conflict. This is where breakthrough solutions can be developed. We call "breakthrough" any comprehensive set of solutions that invalidate assumptions to a conflict; the more "core" is the conflict, the more powerful the solutions must be.

These solutions/injections are then connected together using the Future Reality Tree tool. Using a logic of sufficiency, this tool maps out the solutions in a progressive and integrated pattern towards the goal previously identified in the Core Conflict Cloud. Perceived negative implications of injections can be tackled with the ‘Negative Reservation Branch’ tool. The Future Reality Tree corresponds with the second phase of change, ‘What to Change to’.

In order to move into the third phase of change, ‘How to make the change happen’, the solutions identified need to be broken down into actionable steps. This is done in two stages, first with a Prerequisite Tree for every injection. This Tree is used to transform perceived obstacles into Intermediate Objectives that are sequenced on the basis of which Intermediate Objectives are prerequisites, or parallel, to others. For each Intermediate Objective, a Transition Tree can be built. This tools used a logic of necessity to map out not just the precise actions to take, but the need the actions satisfies and the logic behind them, thus providing a guide to what needs to be done and why. It thus provides a clear and communicable set of tasks that are ready to be scheduled into a project. These tasks can then be scheduled into a project using Critical Chain.

By completing Prerequisite Trees for every injection of the Future Reality Tree, and Transition Trees for all the macro steps contained in the Prerequisite Trees, we are able to generate all the projects required to move towards the goal of the Future Reality Tree. We have the ‘big picture’ of the strategic direction, right down to every task in every project, knowing what has to be done, by whom and when, with a Critical Chain to protect every project so that it can deliver in time and within budget. The cycle of tools can be repeated on an ongoing basis, thus conforming to the Plan-Do-Study-Act cycle of continuous improvement advocated by Dr. Deming.

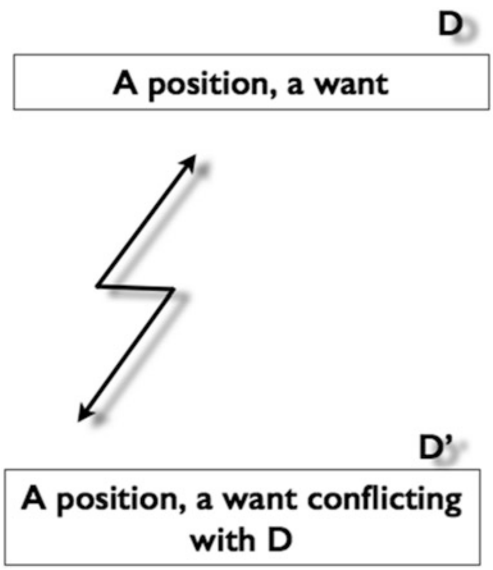


21 A Solution for Generating Continuous Breakthroughs: The Conflict Cloud

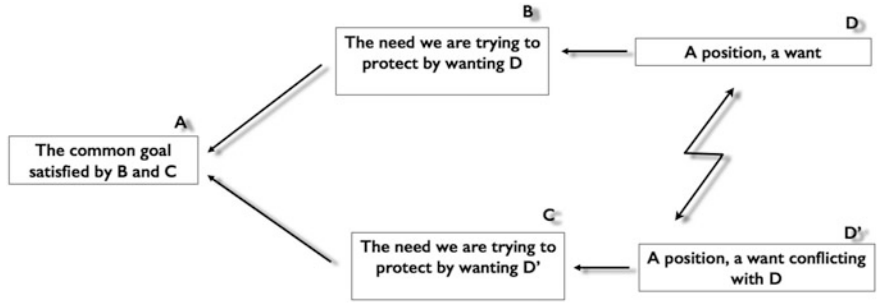
Complexity requires of us a continuous ability to ask the right questions and find breakthrough solutions in rapidly evolving contexts. The development of a breakthrough solution can be seen as the answer to a question. When we formulate questions correctly, we create the opportunity for more meaningful answers. Sometimes, the question may take the shape of a paradox; how can two seemingly contradictory positions both be valid? How could matter behave sometimes like particles and sometimes like waves? Classical Mechanics was not able to explain it. The introduction of the concept of uncertainty summarized in Heisenberg's Principle of Uncertainty led to the understanding of a non-deterministic reality, where probability provides the most appropriate description of nature. In other words, the conflict could not be solved within the existing paradigm (Classical Mechanics) and had to be elevated to a different plane of reasoning (Quantum Mechanics) in order to be solved (2).

What if there were a way to engineer the kind of thought process that takes an apparent paradox to a new realm of interpretation to find a 'breakthrough'? This is exactly the purpose of the Conflict Cloud from the Theory of Constraints.

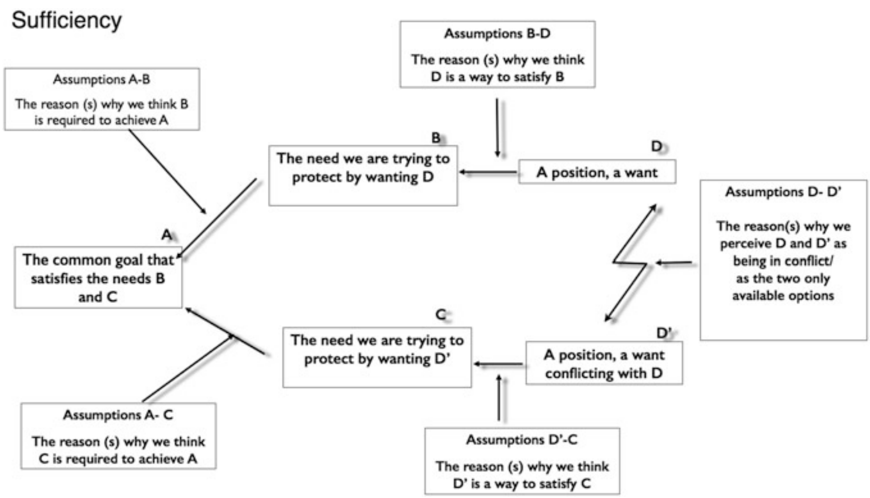
The Conflict Cloud frames a situation of impasse into two conflicting positions:



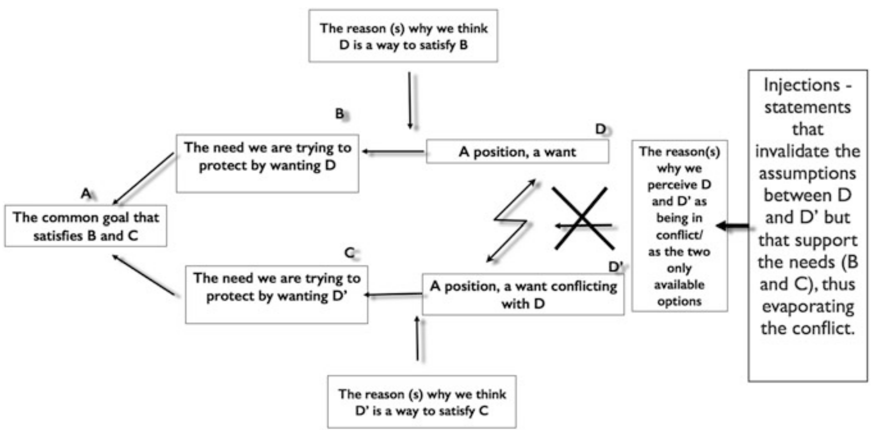
Both positions exist because they protect an underlying and perfectly valid need, and these needs share a common goal.



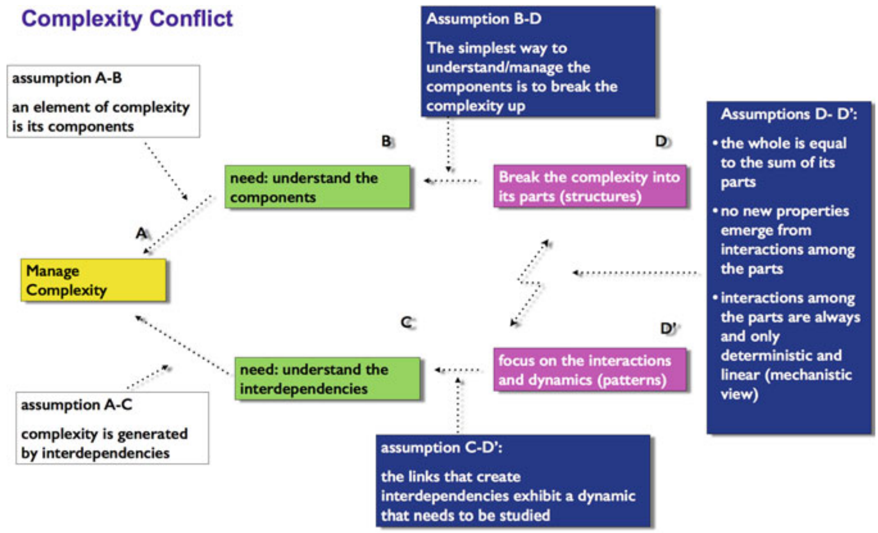
Once we have verbalized the situation of impasse in this way, we have a pattern to examine systematically all the underlying assumptions that create the situation of impasse. We can verbalize those assumptions that connect every entity in the conflict cloud.

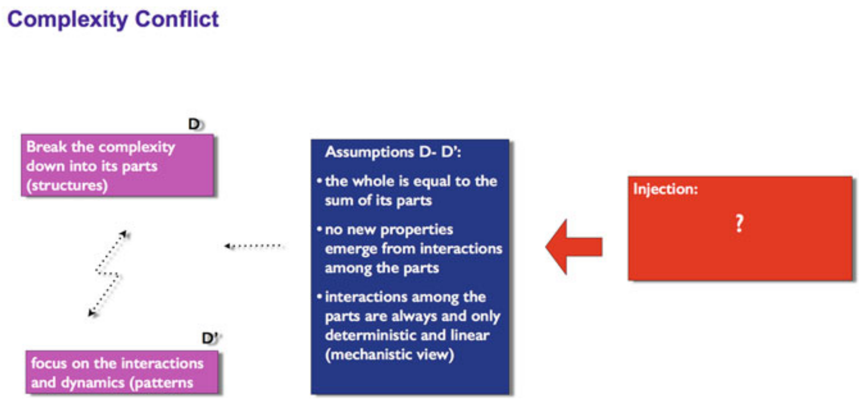


We are now ready to identify breakthrough solutions by finding statements that invalidate the assumptions between D and D′ but that respect the needs in B and C and lead to achieving the goal in A.



Now that we have presented the framework of how a breakthrough solution is developed through the Conflict Cloud, we can look at the example of the conflict connected with Complexity and a practical solution for managing organizations systemically.





22 The Decalogue Methodology as a Solution for Complexity in Organizations

When we map out a conflict using the Conflict Cloud, we can then read it from left to right as follows:

If our goal is *to manage complexity*, and *an element of complexity is its components*, then *we need to understand the components*, and if *the simplest way to understand/manage the components is to break the complexity up*, then *we want to break the complexity into its parts* (*focus on the elements that make up the structures*).

On the other hand, if our goal is *to manage complexity*, and c*omplexity is generated by interdependencies*, then *we need to understand the interdependencies*, and if *the links that create the interdependencies exhibit a dynamic that needs to be studied*, then *we want to focus on the interdependencies and dynamics* (*focus on the patterns*).

We are in the conflict between D and D′ because we make the assumption that: *the whole is equal to the sum of its parts; no new properties emerge from interactions among the parts; interactions among the parts are always and only deterministic and linear* (*mechanistic view*).

Once the complexity conflict cloud is linguistically framed in the above fashion, it is relatively straightforward to see how a Deming-Goldratt based approach to management can be an "injection" to this conflict. The Theory of Constraints (Goldratt) and the Theory of Profound knowledge (Deming) contain, scientifically and philosophically, all the elements to invalidate the assumptions underpinning this conflict; they provide ample room for dealing with the evolving and non-linear nature of human interactions as well as a truly effective way to measure and manage performances, hence enabling effective control.

We claim that the Network of Projects organizational design (graphically represented by the "chocked tube" and supported operationally by the ten steps of the Decalogue) is a coherent, comprehensive and actionable way to implement a truly systemic approach to complexity.

The Network of Projects removes artificial boundaries to communication; it provides an optimal way of leveraging the abilities of all the resources available; it multiplies opportunities for professional development within the organization; it channels energies towards a well understood goal while keeping the focus on the task at hand; it eliminates the conflict between local and global measurement of performances; it allows organic, intrinsic control over the whole organization. Most importantly, it fosters a climate of cooperation and continuous search for win-win solutions.

We also claim that a Network of Projects supported by The Decalogue creates the organizational and learning environment for the systematic development and implementation of breakthrough solutions.

As mentioned before, we call "breakthrough" any comprehensive set of solutions that invalidate assumptions to a conflict; the more "core" is the conflict, the more powerful the solutions must be. We believe that the Network of Projects created through the Decalogue methodology is a *complete solution,* i.e. the minimum set of macro actions that allow us to address the problem of managing complexity for organizations.

23 Towards a New Economics

The New Economics, one where we can all prosper, advocated by Dr. Deming is grounded in the understanding of complexity and stems from the realization that we all exist in a web of ever-increasing interdependencies. Accounting for these interdependencies is neither an exercise of Cartesian reductionism nor the application of outdated business cookbook recipes; it must be guided by a worldview finally cognizant of the finiteness of our resources and by the science and methods available to us today that help the optimization of those resources towards a common goal. Organizations, by choosing to manage themselves and interact with their human and natural environment with a systemic awareness, can play a decisive role in ushering in this New Economics.

In the end, as Dr. Deming would say: “We are here to make another world.”

24 Notes

1. The calculation of the 3-sigma limits that we use in Process Behaviour Charts is not completely straightforward. Since we cannot know how the data of a process distribute themselves, i.e. we do not know the statistical distribution that the data are coming from, then the formula for sigma, the “standard deviation”, cannot be the same one that we use for the “Normal distribution” (Gaussian Distribution). The formula for a “generic” distribution of sigma is quite complex and it requires a helping hand from mathematicians and statisticians to calculate it so as to obtain valid parameters for (almost) any kind of statistical distribution that data may follow (the parameters have been proven valid for more than 1200 different distributions). The starting point for evaluating sigma is the organization of data in “homogeneous” sub-groups and the calculation of the range of each sub-group:

$$R = \mathrm{Max}\{Xi\} - \mathrm{Min}\{Xi\}$$

where $\{Xi\}$ is the set of data belonging to the relevant sub-group and its population is said “dimension” of the sub-group. The range and its average are measures of how data disperse (they have a strong connection with sigma) and the calculated parameters depend on the dimension of the subgroup.

In practice, in the majority of cases we use the so-called "single point" behaviour chart (always valid and useful, with some exceptions); for this special case (sub-groups of dimension "2"), the procedure to calculate the limits is simple:

We define the "moving range" of the variable of the difference of two consecutive data:

$$\mathrm{mR} = \mathrm{X}_{\mathrm{i}+1} - \mathrm{X}_{\mathrm{i}}$$

- we calculate the average value of the variable:

$$\frac{\sum_{1}^{N} X_i}{N}$$

- we calculate the average "moving range" of the variable:

$$\frac{\sum_{1}^{N-1} mR_i}{N-1}$$

- we calculate the limits as follows:
  Upper Natural Limit:

$$UNL = \overline{X} + 2.66\,\overline{mR}$$

  Lower Natural Limit:

$$LNL = \overline{X} - 2.66\,\overline{mR}$$

The constant "2.66" is the parameter that links the average moving range to sigma ($2.66\,\overline{mR} = 3\,\mathrm{sigma}$).

To be more precise, to determine if a process is affected by external causes of variation we do not use just one criterion; in fact, by using a conservative approach, Dr. Shewhart devised four different "rules".

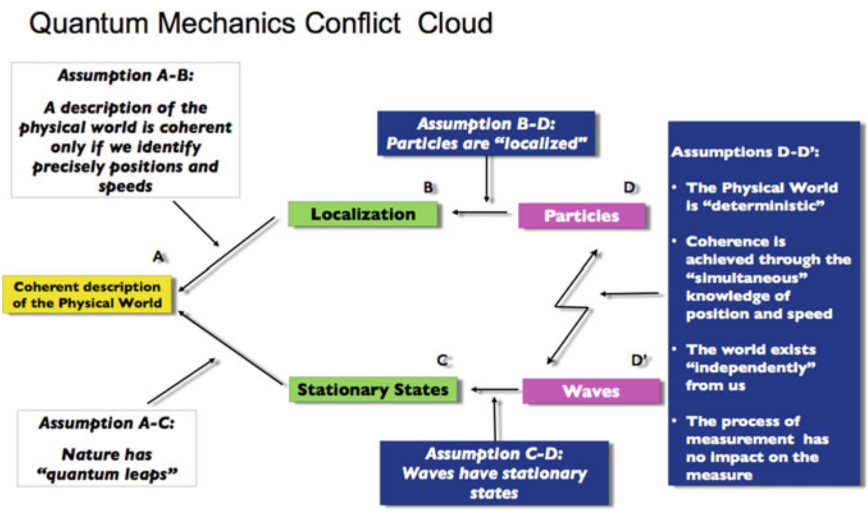
Any process is affected by external causes of variation when:

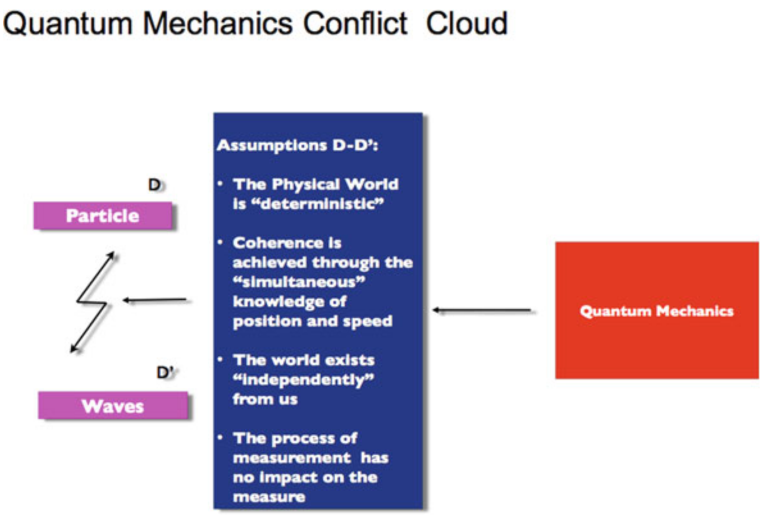
1. one data point falls outside the 3 sigma limits;
2. at least eight consecutive points fall on the same side of the central line;
3. two points out of three fall on the same side of the central line beyond 2 sigma;
4. four points out of five fall on the same side of the central line beyond 1 sigma;

A process affected only by natural (intrinsic) causes of variation is said to be in a state of **statistical control**.

Others have decided over the years to add new criteria in order to improve the process of decision making; however, we prefer to follow the basic guidelines of Dr. Shewhart that we still consider the most acceptable, both empirically and economically.

2. The "conflict" between particles and waves and the solution provided by Quantum Mechanics can be represented using the Conflict Cloud as we have done below:





Bibliography

Barabàsi A-L (2002) Linked: the new science of networks. Perseus Publishing, Cambridge, p 2002
Barabàsi A-L, Reka A (1999) Emergence of Scaling in random networks. Science 286(5439): 509–512
Capra F (1996) The web of life: a new scientific understanding of living systems. Anchor Books, New York
Corbett T (1998) Throughput accounting. North River Press, Great Barrington
Deming WE (1986) Out of the crisis. Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass
Deming WE (1993) The new economics for industry, government, education. Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass
Deming of America (1991) Documentary. The Petty Consulting/Productions, Cincinnati, OH
Goldratt E (1984) The goal: a process of ongoing improvement. North River Press, Great Barrington
Goldratt E (1987) The theory of constraints journal, vol 1–6. Avraham Goldratt Institute, New Haven
Goldratt E (1990) What is this thing called the theory of constraints and how should it be implemented? North River Press, Great Barrington
Goldratt E (1990) The haystack syndrome: sifting information from the data ocean. North River Press, Great Barrington
Goldratt E (1994) It's not luck. North River Press, Great Barrington
Goldratt E (1997) Critical chain. North River Press, Great Barrington
Killian CS (1988) The world of W. Edwards Deming. CEE Press, Washington D.C
Lepore D, Cohen O (1999) Deming and Goldratt: the Decalogue. North River Press, Great Barrington, Mass (Translated into four languages)
Lepore D et al (2011) Sechel: logic, language and tools to manage any organization as a network. Intelligent Management Inc, Toronto
Maci G, Lepore D, Pagano S, Siepe G (2008) Systemic approach to management: a case study. Poster presented at 5th European conference on complex systems, Hebrew University, Givat Ram Campus, Jerusalem, Israel, September 14–19, 2008
Maci G, Lepore D, Pagano S, Siepe G (2008) Managing organizations as a system: the Novamerican case study. Poster presented at international workshop and conference on network science, Norwich Research Park, UK, June 23–27 2008
Mandelbrot, B. (1982) The fractal geometry of nature. W.H. Freeman, New York
Mandelbrot B, Hudson RL (2004) The misbehavior of markets: a fractal view of financial turbulence. Basic Books, New York
Neave H (1991) The Deming dimension. Knoxville, SPC Press , Tenn (1990)
Shewhart WA (1980) Economic control of quality of manufactured product. van Nostrand Company Inc, New York, (American Society for Quality Control, 1931)
Shewhart WA (1986) Statistical method from the viewpoint of quality control. Deming WE (ed) Mineola, Dover, New York
Watt DJ, Strogatz S (1998) Collective dynamics of small world. Nature 393(1998):440–442
Wheeler DJ (1983) Four possibilities. SPC Press, Knoxville, Tenn
Wheeler DJ (1992) Understanding statistical process control. SPC Press, Knoxville
Wheeler DJ (1993) Understanding variation. SPC Press, Knoxville
Wheeler DJ (1995) Advanced topics in statistical process control. SPC Press, Knoxville
Wheeler DJ (1998a) Building continual improvement. SPC Press, Knoxville
Wheeler DJ (1998b) Avoiding manmade chaos. SPC Press, Knoxville

Family of Related Systemic Elements (FoRSE™) Matrix: Big(ger) Picture Thinking and Application for Business and Organizations

Blane Després

Abstract We can best pursue problem framing and solutions by understanding their relationship to the organization's purposes. Part of the process of problem framing involves distinguishing between problems and symptoms. In this chapter I present big(ger) picture thinking as a best fitting framework via the FoRSE™ Matrix system, and clarify big(ger) picture thinking and little window glimpses. Four types of thinking add to the complexity. The main outcome of big(ger) picture thinking is the best understanding of the organization, its purpose and direction, and the ripple effects of its queries and decision-making as these all relate to being. Benefits include a practical model for leaders to understand the complexity and ripple effects of their in/decisions, to have a comprehensive schema of the critical parts, or system elements, of their problems or questions, and greatly improved, sustainable directions.

Keywords Problem framing · System · Complexity · Goals · Big picture · Intervention

1 Introduction

The aim of this chapter is to offer a different take on systems—or what I prefer to call *big(ger) picture*—thinking and practical application such that organizations and business (I will use "organization" from here on to cover both) will want to try a different approach to problem framing, system understanding and seeking sustainable and success-oriented options. The intended benefits to organizations

Some parts of the FoRSE™ Matrix content have been published or presented previously.

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include a practical model for leaders to understand the complexity and ripple effects of their in/decisions, to have a comprehensive schema of the critical parts or system elements of their queries (problems or questions), greatly improved directions for options and develop a clearer perspective of problem areas. I am going beyond "problem" and question here to include these within the term, "query." In essence, a problem or issue and their framing are part of an overall query, a question or series of questions. Thus by query is meant problem, issue or question for an organization as a broader encapsulation.

I will discuss problem framing and solutions along with the vital link to purposes in relation to boundary judgements and the "perspective" dilemma, problems and symptoms issues, big(ger) picture thinking as a best fitting framework, big(ger) picture thinking and little window glimpses along with types of thinking, and the Family of Related Systemic Elements (FoRSE™) Matrix. Finally, the wrap-up will cover a case study as a practical application using the FoRSE™ Matrix. Arguably the main outcome of big(ger) picture thinking is the best understanding of the organization, its purpose and direction, and the ripple effects of its queries and decisions as these all relate to being.[1] My rationale for this structure is to set the stage for a logical sequence of steps in order to better understand big picture thinking and problem framing.

2 Problems with Problem Framing and Generating Solutions

It is a truism that all organizations encounter problems and all have queries regularly. What matters first is determining what is the problem. That requires distinguishing between problems and symptoms masquerading or, more often, misinterpreted as problems. Problems present a threat to the system—the organization as a whole with its interconnections, because it disrupts and potentially fragments. We resist or struggle against fragmentation because it can lead to disorder and ultimately demise of the organization, and we dislike disruption because it messes with the harmony and flow of the organization in pursuit of its goals. Fragmentation is destructive for it remains as separated parts, which helps to understand dysfunctional systems. Systems dissipate or cease to exist or function if fragmentation persists. Optimum performance or completeness, which is achieving our purpose, is wholeness. This has got to be one of the fundamental drivers for employing a big picture thinking method to dealing with problems, their framing and implementing their solutions.

It makes sense that framing a problem demands clear understanding of issues, of the lead up to the problem, of why it's a problem and what it would mean to the

[1]Being as the ultimate reason for, or the ontological significance of, improvement in organizations demands greater discussion than space in this chapter permits.

organization not to address the problem, or conversely, to address the problem incorrectly or tackle symptoms instead. However, how does the perceived problem relate to the organization's purpose(s) or its being? One of the first steps in problem framing is to reflect on that question. Examining answers to that question will help to determine the gravity or significance of the problem. But avoid jumping into seek solutions immediately. We have neither the problem's full context or import—its systemic or whole connection, nor whether the problem is a problem or a symptom.

As the query is checked against the organization's purposes, two conclusions should become clearer. First, it should be clear whether or not the query is germane to the organization's purposes or if it's related to another area in the organization system. Second, it should be clear whether or not the query regards a problem or symptom. The engagement of a query through Stage 1 of the Family of Related Systemic Elements (FoRSE™) Matrix (discussed in more detail further below) will help to clarify the problem-symptom distinction, which in turn opens the way to hone in on the actual problem.

To frame or determine or articulate accurately and clearly a problem is both to preset boundaries around the perceived problem (i.e., what it isn't and what it appears to be) and its effects in the organization. Those boundaries are the limits and language of the problem and they are set by individuals who are influenced by a host of human factors. According to Midgley (2000), to determine if something is complex and/or chaotic or even attempt to bring some kind of order to an event is both an intervention and the drawing of boundaries. Boundaries in big picture thinking are not rigid barriers. They are "fuzzy" in that we create them as mental limits that help us to deal effectively with a query and allow us to develop manageable interventions. Interventions themselves are the products of creative practices including interpretation of events leading to the query and the affected relationships ("being" again). These interventions demand a relationship analysis to determine mis/alignments. Do those relationships support one another or work against one another and the purposes of the organization? Where do those relationships need work, repair or adjustment to bring them into alignment with the purposes? Are they proper relationships? Is the suggested intervention pertinent to or appropriate for the relationship?

But how could organizations ensure adequate boundaries or best distinguish between problems and symptoms? Committees commiserating or consultants collaborating with the organization are bound to come to some agreement about the problem, direction to follow and plans of action. I suspect that many of the symptoms will get attention and solutions will be accepted; however, I also contend that without big(ger) picture thinking applied to queries, problems will not be completely dealt with and symptoms will continue to pop up in the future as "new problems." And unless the whole being of the individuals in the organization is accommodated in the problem framing and/or solving process, the practice of problem framing and/or solving will remain partial or incomplete, thus compounding future problems and thwarting attainment of the organizational goals and purpose(s). It is this inadequate problem framing and solving that militates against sustainable change and positive growth. This continuous cycle of analyze–solve–apply intervention–review ensures a steady work (consulting) lifecycle. It can be likened to a boat with water coming in somewhere. Repainting, refinishing the boat or trying various means of bailing out the boat may help to some degree, but the actual problem isn't necessarily solved. A big picture thinking analysis needs to be put in place to locate the problems and symptoms (e.g., inside of the boat and my feet are getting wet) followed by appropriate interventions.

Part of the difficulty of framing the query has to do with the interpretive lens we bring to the practice. How we interpret or view the world—our hermeneutical understanding—is a composition of worldview (constructed perspective of existence) and socialization beginning with our families of origin. Thus we bring our finite perspective and knowledge, our dysfunctions and quirks, our desires and needs, how we're feeling in the moment, and our psychological and spiritual well-being. Framing is compounded by multiple people working together and hopefully in unison towards the organization's purposes. A means of framing that takes into consideration the whole person in conjunction with the framing practice, corporate or community well-being and the principles that inform and influence these would better position the organization for sustainable success. I will discuss such a model below in the section on the FoRSE™ Matrix system.

Certainly problem framing has to do with more than a knowledge quest although it occupies a large portion of dealing with queries. Problems and their framing could prove troublesome immediately if not later on a) if the problem or symptom and framing practices are treated simply as knowledge issues, and/or b) if only a little window glimpse is applied. In the former, I am saying that because there is more to problems, solutions, framing and interventions than discovering and applying a perceived correct knowledge patch, big picture thinking ought to be applied. Individuals, for example, have emotional connections with the organization and are affected by the query process and/or outcomes of the query. Core beliefs, principles, behaviours and practices are a few additional factors that need to be considered beyond who, what, when, where and how. And in the latter, a partial picture or little window glimpse will not expose enough details either about the problem or framing it to be of sustainable and effective use. If transformation is a goal, then that too will be/come problematic in its own right. Transformation (for organizations) could be the wrong focus. It's understandable that transformation becomes the aim should an organization deem change is necessary because the perception or reality is that the organization is not performing to expectations or desired level. The seeming logical question, "how can we change, and sustain change, in order to achieve our goals?" makes sense because it's a default, learned position. There are more appropriate and fitting questions that set the correct stage for improvements in every aspect of the organization and that enable framing the problem to achieve success. Those questions, I maintain, are developed as a result of a big picture thinking application. Transformation will come and itself will require some direction, but this will come, as it should, after a big picture thinking discovery is performed.

3 Thinking Primer: Basic, Specific Field, Critical and Big Picture (Systems) Thinking

This section picks up on the interpretive lens comment above and delves into the "thinking" part of systems or big picture thinking as an attempt to clarify how I interpret it. Thinking or cognition can be understood on four levels: Basic or fundamental cognition, specific field or discipline, critical and big picture thinking. Basic thinking or cognition performs a fundamental survival function and information processing that allows one to meet essential needs to exist. It serves as a baseline foundation for people to reflect or cogitate at an unsophisticated level and to communicate. I am not suggesting that there a measurable level or demarkation to distinguish basic from advanced, for example. Thinking improves with guidance, volition and practice.

Critical thinking goes beyond basic information processing and response by channelling greater concentration and deliberate tactics or actions to the thinking process. Critical thinking has been described and illustrated with Benjamin Bloom's taxonomy of thinking skills, which include knowledge and recall, understanding through explanation and description, applications, analysis, evaluation and, ultimately, synthesis or creativity. According to Bailin et al. (1999a, b), critical thinking is a quality of thinking through enhanced and deliberate cogitation. It serves to refine and specialize basic thinking when engaged in a problem or topic. That is the additional components attributed to critical thinking, such as reasoning, self examination, analysis of assumptions, arguably creates an improved, more deliberate and sophisticated engagement of a topic which should return better results.

What I call specific field thinking applies basic thinking with a particular lexicon and thinking patterns identifiable with a particular discipline, organizational or social field. Examples of specific field or discipline thinking include mathematical, philosophical, business, medical, scientific, construction and carpentry, design, automotive, agricultural, etc. An example of specific field thinking in business includes marketing strategies, sales chute, advertising, leads, ROI, change management, logistics, organizational change, customer base, service zones, wholesale and retail district sales, and so on. Some fields have overlapping lexicon areas and some people within fields will think more than others depending on their ongoing learning. That learning might include elements of critical thinking and big picture thinking that would enable them to perform advantageously compared to their peers in the same field. Any specific field thinking can be enhanced by the application of critical thinking and/or big picture thinking. I will return to specific field thinking further below as it relates to problem framing.

Big picture thinking enhances and informs specific field and critical thinking further as a broader and deeper engagement. In services, for example, that could include consumer experience, characteristics of the product, safety, revenue-profit-quality balance, employee self-worth, leadership development and skills, management philosophy, past and current practices, ethics of marketing and supply in the world, and so on as integral to the whole. It also considers the organization a system having numerous, nested systems and that interacts with other systems. Big picture thinking, consequently, formulates a challenge in terms of its interdependencies and interconnections. It is often described as a capacity to connect dots, see patterns and structures that tend to lie unobserved or unheeded in the usual scope of vision, including in specific field and critical thinking. It is argued as a descriptive but constructed framework in which the whole is greater than the sum of its observed or known parts. Big picture thinking spans basic thinking, specific field thinking and critical thinking in that it straddles or incorporates both thinking and a perspective of the world, or "world view." Big picture thinking may be viewed as composed of levels and attributes, and it can also be measured and scaled.

Systems thinkers assume the world, indeed the universe, comprises systems. That is to say there are identifiable characteristics associated with an observed phenomenon (event, thing, object, etc.) that makes sense as a whole made up of interrelating parts. This applies to objects as well as to human organizations and natural conditions. People speak of eco-systems, circulatory systems, automobiles, etc., which are examples of "wholes" made up of parts and even nested or sub-systems. The parts working together achieve a greater purpose and function that no singular or smaller grouping could achieve. And it appears to be that systems work in conjunction with other systems and even within other systems not as neat, linear progressions but as complex and sometimes chaotic events.

Is big picture thinking merely a human construct, a principle or perspective that people have developed as a creative response to their experience of things in the world? Or is big picture thinking the most corresponding means of making sense of the world and the cosmos because the cosmos is a system of systems irrespective of our perspective in time? My operating assumption is that systems exist as phenomena independent of observation. The world is dynamic, sometimes chaotic, often showing emergent reactions and exhibiting "systemicity." In other words, the world, as part of the cosmos, displays systemicity not because humans have decided upon an alternative thinking paradigm that counters linear or reductionist thinking and that confers upon the world another conceptual framework called "systems." It is because the cosmos is arguably already a system and includes subsystems and nested systems as an inherent part of its structure. In much the same way that past observers of the physical world discovered its atomic side, so explorers have discovered and continue to uncover systems attributes, or *systemicity*, of the world and beyond. Hence, I argue that the systems—big picture—thinking paradigm is the most appropriate means of perceiving the world because it is, by extension, part of our natural make up. The challenge is how best to apply big picture thinking. That it is an improvement over other modes of thinking practices—or labels—should be self-evident. The more details for a query (problem, issue, policy) that one has, the better equipped s/he is to improve sustainable and positive actions.

4 Big Picture Thinking and Little Window Glimpses

Big picture, or systems, thinking is to engage wholly with an event—something—and that takes into account three, associated big picture clusters (Purposes, Form or Design and Infrastructure—I will expand on these further below) intersecting three elements or components strands (individual, community and principles) *with a view to better understand and/or improve being*.

Systems thinking in action tends to provide what I call "little window glimpses" while fewer systems thinking applications provide a truly big picture perspective. A little window glimpse refers to a cross section of a system—as in system-wide—or a vertical exploration within a system—as in system-deep. These become apparent when one examines the type of engagement of an issue in their organization. It is only a wholistic undertaking if the "critical mass"[2] of system clusters and elements is considered, and even there it is a limited or bounded engagement. System-wide applications or analyses might deal with a strand, a topic or a problem, such as purposes or decision-making model, but these are only part of the whole system.

System-deep applications are similar to system-wide applications but an event is explored within a department or practice or "silo." For example a military organization wants the best means of prognosticating successful achievement in its cyber workforce department, whether as suitable candidates and long-term team members or in ensuring superior results. Profiling might include educational background, intellectual development, IT experience, cognitive agility, emotional quotient, decision-making acuity, motivation, long-term plans and desires, strategic awareness, willingness to learn, and other factors, but the focus is on this one department or grouping from recruit to senior member. In any systems thinking engagement of a query, knowing how one is engaging the project is as vital as what one does for intervention. It ensures a valid study, appropriate strategies and outcomes as well as the breadth and depth of the intervention.

For example, should an organization decide to examine its revenue and profits model, that would entail a system-deep little window glimpse. Or suppose an organization wanted to have all managers trained in a particular technology to help improve their oversight and scheduling activities. That would be a system-wide little window glimpse. Neither of these two examples is a big picture thinking application. They could be and arguably ought to be, because any and every query or action will have ripple effects. The bigger, initial questions to ask here are, how does the current revenue and profit model and query about them help achieve the organization's goals and purposes? And, how do the management training and its query help achieve the organization's purposes? On the surface the justification of either of these two examples might appear to make the most sense. However, without a big picture thinking analysis, there will be further problems, none the least of which is misalignment of the organizational system's elements (constituent parts) and failure to achieve the goals and purposes. Little window glimpses tend to dominate organizational and consulting practices.

Every query may not warrant a full-scale, big picture exploration, but to determine if the query is just or appropriate, or if the proposed solutions are

[2]By critical mass is meant the vital, key elements of a system immediately perceptible and related by purpose, form or design and infrastructure (decision-making, action, resources and timeline).

adequate, pertinent or sustainable does necessitate a big picture thinking application. Arguably it is only in this way that a query can be properly and thoroughly addressed. That this task can be performed at a comparatively moderate cost ensures any size organization can benefit from immediate and in-house consulting.[3] How that could be achieved is the subject of the next section.

5 The Family of Related Systemic Elements (FoRSE™) Matrix

The FoRSE™ Matrix is a product of 18 years of research and development, and application in diverse settings from education to business and organizations. Informed by the writings of Midgely, Flood, Ackoff, Senge, Checkland and Jackson, to name a few, as well as influenced by soft systems thinking, visual analytics, complexity theory, and human dynamics, the FoRSE™ has been refined to a 3 × 3 matrix that successfully guides clients in their decision-making process (see Després 2008a, b, c, 2012, 2014) through three, progressive stages in which the depth and complexity of questions increases. The FoRSE™ Matrix system was developed to equip and empower businesses and organizations to achieve efficient, effective and sustainable change in pursuit of their goals. The results provide a "broadly deep," truer big(ger) picture of a query, and point the way to more focused interventions, many of which might never have been considered.

Why should anyone use big picture thinking and specifically the FoRSE™ Matrix? What need does it fulfil? The bigger needs it helps to fulfil are identity and purpose. Organizations are dependent structures. That is they depend on, and take form from, people. These people are both the workers within the organization and community, from local surroundings to clients or customers. Because of the preceding, organizations will benefit and suffer from these people. What we know about people—type, narratives, frame of identity and core beliefs, habits and behaviours—will have an impact on the organization. Thus interventions in organizations are about people; they are the end receivers or beneficiaries of the interventions.

Any intervention that fails to deal with people will either falter or experience some progress, but at some additional expense, whether time, resources or negative reactions and actions. When or if people learn that they're not the main or prime consideration, "solutions" or interventions will not gain acceptance wholeheartedly, even if people (are invited to) participate in the intervention. On the other hand if people are treated first as a vital part of interventions, then success is closer to reality. What will make any intervention more successful, on a human scale, is a big picture intervention. That demands a specialized approach. Lean and Six Sigma, TQM, Kaizen and the host of practices that help production efficiencies

[3]Based on application of the FoRSE™ Matrix system. See www.rippledeep.com.

are not systems interventions though they may be useful. The FoRSE™ Matrix is about people. It is an online program that requires content input from people. This data provides the necessary information to help expose or uncover the critical values that are important even vital to the organization. In short the FoRSE™ Matrix system helps the organization to ensure as big a picture as possible and to consider the effects of decision-making. Every decision and action will have outcomes. Some will be immediate and some long term. And their effects will ripple throughout the organization though not with the same intensity obviously. The effects of those ripples will affect:

– people in-house (i.e., other leaders, managers, employees),
– people outside the organization (e.g., stakeholders, clients),
– perceptions both in-house and outside,
– outcomes (e.g., vision, missions, goals),
– benefits (e.g., profits, PR, longevity of the organization, growth),
– responses back to the organization or leadership.

The Matrix helps to depict where problems are located as well as determine the intervention strategies at substantial savings.

The Matrix provides a bounded framework that exposes the critical mass of systems elements of a query. That is, the key, contributing elements (or parts) of an organizational system and their interconnections are highlighted, enabling further investigation and queries to give a big picture perspective. Theoretically all systems have a "critical mass" of interrelated elements or components that give it a distinct and identifiable essence or its attributes. For human activity and environments—physical and constructed—these elements appear to group around one of three, interdependent categories entitled Big Picture or System Clusters: Purposes, Form or Design and Infrastructure. That is a system, or a query, has a Purpose or *raison d'être* and it has some kind of appearance or setting—its Form or Design, whether physical or virtual. Supporting these two clusters is the Infrastructure Cluster comprising four sub-clusters: decision-making or power arrangement, actions, resources and timeline.

The overall function of the FoRSE™ Matrix, in its normally three-stage application, is to expose in/congruity between the interrelated elements and the Big Picture Clusters. Stage 1 regards the query through only the three system clusters. Stage 2 provides the addition of three horizontal strands that incorporate personal, social and philosophical elements with leading questions, the response to which increase coverage of the query. Stage 3 adds deeper, penetrating questions beneath each of the leading questions in Stage 2 along with two additional columns for what, if anything, has been communicated by the organization and the stakeholders' perceptions of, or reactions to, the query and information provided. Stage 3 produces feedback, which will typically see far more data in the "Perceived" column than in the "Communicated" (by the organization) column.

Some assumptions that guide the working of the FoRSE™ Matrix include a human tendency to function in one or more foci, in this case pertaining to problem framing and solving:

1. Problem: Clarification, analysis and reformulation (e.g., What is the nature of this query? What makes it a problem? What is missing?)
2. Solutions: Intervention (e.g., Which solution best serves the problem? Is it adequate? What options are available? What problems will the solutions address?)
3. Current state: Status check (e.g., What is happening now? How does it compare with the past state? Is it where we want(ed) to be?)
4. Future or ideal state: Vision and goal correction (e.g., Where is this heading? Is it in the desired or an acceptable direction?)

To these we can add a big picture thinking perspective that enhances them:

5. Systems identification: Identify, discern (e.g., What makes this a system? What are the identifiable characteristics and attributes of this system?)
6. Systems boundary: Limits, delineated borders (e.g., What are the limits of the query? Is this a little window glimpse (or system-wide or system-deep) or a big picture query? What is included and why? What is excluded and why? Who is involved and what are their perceptions about this query?)
7. Systems elements: Critical mass of key components or attributes, interconnections (e.g., What are the Big Picture Cluster statements? What are the responses to the Elements Categories in their intersection with the Big Picture Cluster?)

All seven of these foci enable information gathering, analysis, assessment and evaluation, synthesis and creative responses as we seek to understand something better for either enhancement or for resolving some conflict. But it is more than knowledge or information. Human factors include emotional, physical, spiritual and psychological needs. Enhancement, like conflict, arises when there is a disparity between the ideal or expectations of the original purposes and goals of the organization and the reality of practice, whether in incomplete knowledge, in competing information, in expectations and outcomes, or in intervention options. The Matrix covers the seven knowledge foci making it truly a big picture thinking instrument, by delving into not only knowledge about clusters and elements, but also into core beliefs, perceptions, compromises, etc.

Every query has multiple facets in both the purposes of the query and the elements or factors associated with it. A big picture thinking approach is to examine the vital or key components (elements), explore their interrelationships, and review perceived causes and effects all the while exploring their alignment. Alignment is crucial to the achievement of the organization's purposes and goals. "Alignment" in the FoRSE™ Matrix system requires that the content of each of the cells supports the content of the other cells. For example, if the purpose of the query is to improve the revenue model, the content of the Form or Design and Infrastructure Clusters needs to ensure successful attainment of an improved revenue model. Where content does not support other cells, either a change must be made to that content to bring it into alignment with the other cells, or the other cells' content must change to accommodate. Failure to align these elements will have negative effects on the organization.

Four archetypes, or patterns, of human activity systems underpin the FoRSE™ Matrix:

1. Systems have at least a main or principal purpose. The Purposes cluster includes mission or goals, participants and stakeholders, or the people who perform and/or benefit from them. This cluster concerns those components that are essentially conceptual-ideal and responds to these key questions: What is the mission or what is to be achieved? Who are the participants and stakeholders or for whom and to what end or ends do the purposes serve?
2. Systems exhibit form or design in their setting. The Form or Design system cluster concerns the arrangement, site or setting, or configuration. In other words systems look like something. This cluster serves as the vision-image or depiction of the Purposes and Infrastructure clusters and responds to these key questions: What does it look like? Where is it situated? How is it structured?
3. Systems are supported to achieve implementation, sustainability and success via the Infrastructure system cluster. This system cluster comprises four sub-headings or function-practical characteristics: decision-making or power, actions including communication, resources, and timelines. This cluster responds to these key questions: What is the power arrangement? What resources are available and needed? What are the actions and timelines for implementation and sustainability? What is the communication structure?
4. Furthermore, systems are infused with and influenced by Individual, Community, and Principles elements or factors. These "Elements Categories" elicit further details about the System Clusters through a series of pertinent questions that pertain to personal well-being or "cost," social or corporate well-being and philosophical rationale.

In the following section, I will apply this discussion of the FoRSE™ Matrix system to an actual case study.

6 Case Study

The following case study demonstrates the utility of the FoRSE™ Matrix in assisting an organization to make decisions.

Client: Private school district, multi campus, K-12, student population 300
City and region: Population 120,000, mix rural/agricultural, technological, professional, research university

Query: How could we develop a team of people who will serve the Schools in promotions and fund raising?

Process: Initial meeting with superintendent, CFO and director of development determined the query as a priority and completed Stage 1 of the FoRSE™ Matrix system. The director of development took on the role of key contact person whose additional task was to complete the remaining two stages of the Matrix. The Stage 1 can be found below with the content input found along side "State…" with prompts to guide responses. In these cells, the client is asked to unpack the query along the three, Big Picture Clusters. The first round typically begins as a discussion or brainstorming session. Once all three of the Clusters have been completed, we move on to clarification and refinement of the statements. If left without clarification, or in a state of misalignment, the ripple effects would see disjointed and unclear strategies to successful engagement of the query. The client might achieve their purpose, but at a cost and neither completely nor successfully as a unified, whole project.

QUERY (activity or practice, situation, issue or problem, idea, policy or question):	How could we develop a team of people who will serve the Schools in promotions and fund raising?		
Big Picture or System Clusters	**1 PURPOSES** *Conceptual-Ideal:* Mission or goals, participants & stakeholders (*What is the point or purpose of your question or issue? What do you hope to achieve? How does it relate to the organization's purposes? Who is involved?*)	**2 FORM OR DESIGN** *Vision-Image:* Configuration or setting (*What does or will it look like? That is, how will it appear and in what settings: physical, virtual, blended?*)	**3 INFRASTRUCTURE** *Function-Practical:* Governance, action including communication, resources, time (*To achieve your organization's Purpose —and the purpose of your question or issue— what is the Decision-Making (power) model (D)? List the steps or Actions (A) including communications. List the Resources (R). What is the Timeline (T) anticipated?*)
	STATE PURPOSES: *What is the point or purpose of your query? What do you hope* - Promotions, fund raising, - networking, - communication of mission, - assisting the schools to develop resources	STATE FORM: *What does or will it look like? That is how will it appear and in what* - Committee of parents, - building a list of donors, - fund raising events, - sustain school relationships, - primarily volunteers with direction	STATE INFRASTRUCTURE: *To achieve your organization's Purpose —and the purpose of your query— what is the Decision-Making model (D)? List the steps or Ac-* - D – Director of Development; works from the superintendent's office; - A – Identify team; train director; train team; network with other development teams; - R – Volunteers; 2/3 leadership staff position and office; self-funding ($50k raised over and above committee costs); network thru associations, clubs and parent connections; marketing budgets, strategies and systems; - T – Identify team by March; train team, functioning by June; fund raising events in February and April; introductory tours begin March.

Under the Purposes Cluster, the client developed this list: Promotions, fund raising, networking, communication of mission, and assisting the schools to develop resources. We then reworked this list to arrive at a clearer statement, removing some of the data because it belonged under one of the other clusters. For example fund raising, networking and communication belong under the Infrastructure cluster because they have to do with actions or steps and resources. The final content read as follows:

- Establish a self-funding office of promotion to ensure a renewable and sustainable source of income and positive image for the schools.

It reads as a clearer purpose statement that now needs to have a supportive structure, which we find in the remaining two Clusters. Note the clarification of the content throughout the FoRSE™ Matrix is a normal and necessary activity to ensure clarity and a true, big picture of the query.

Once satisfied with the Purposes Cluster, the client added content to the Form or Design Cluster. We examined those statements in relation to the purpose statements to ensure alignment. That is, the content must be supportive of the content in the Purposes Cluster as well as, eventually, the Infrastructure Cluster. Where they aren't, changes must be adopted or else problems will arise and the achievement of the query will be unsuccessful. Input for the Form or Design statements included:

- Committee of parents, building a list of donors, fund raising events, sustain school relationships, primarily volunteers with direction

Reviewing the Form or Design list shows the statements do not give us a clear picture of what the query Purposes actually look like. For example, what does a "committee of parents" look like? Where will they meet (number and time of meetings belong in Infrastructure)? What does "building a list of donors" look like? Who will build it? How many donors? Will the list be a database or table or simple list? Who will be the primary contact? Without such details, the client will not have a clear depiction of the big picture or a feasible and efficient way of achieving the purpose. We reworked this list to provide additional details and clarification as part of the alignment with the Purposes Cluster:

- Director designated by the superintendent within the organization (2/3 time) overseeing committee of volunteering parents;
- build a list of donors;
- 4 fund raising events spread evenly throughout the academic year (kinds and times to be determined by the committee);
- sustain current and future relationships with parents, graduates, community and donors through communications and special events (to be determined, or TBD);
- designated office space within the organization additional events and activities TBD.

The Form or Design Cluster aligns much better with the Purposes Cluster, which will ensure attainment of the organization's goal. After the Form or Design and Purposes were acceptable as aligned, we discussed the Infrastructure that supports them. This demands consideration of four sub-categories: Decision-making or power (D), Actions (A), Resources (R) and Time (T). As with the first two clusters (Purposes and Form or Design) the Infrastructure cluster discussion produced a list of actionable items. Again the elements in this cluster must align with the other two clusters:

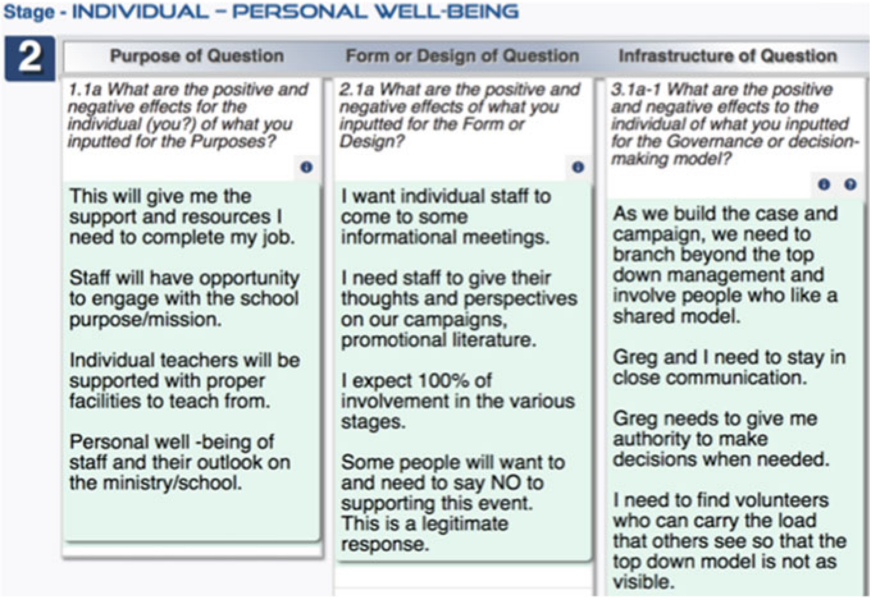
- D—Director of Development; works from the superintendent's office;
- A—Identify team; train director; train team; network with other development teams;
- R—Volunteers; 2/3 leadership staff position and office; self-funding ($50k raised over and above committee costs); network thru associations, clubs and parent connections; marketing budgets, strategies and systems;
- T—Identify team by March; train team, functioning by June; fund raising events in February and April; introductory tours begin March.

A reworked Infrastructure cluster that clarified and added elements to ensure better alignment with the Purposes and Form or Design clusters is as follows:

- D—Director of Development designated by the superintendent within the organization within a month; works from the superintendent's office; decision-making shared among committee and final decision by Director, to advise Superintendent for final agreement; Director's role is 2/3 leadership staff position;
- A—Identify team via communications and invitation to parents and TBD; train director; train team via workshop (time and place TBD) and communications by Director; committee will network with other school development teams via regular (TBD) meetings and communications;
- R—Committee including Director plus volunteers; self-funding ($50k raised over and above committee costs); committee to determine fund raising amounts, targets and timing, and managed by Director; network thru community associations, clubs and parent connections (by committee TBD); marketing budgets, strategies and practices necessary to ensure success (TBD but approximately $80,000);
- T—Identify team by March 1; train team April 1, functioning by June 1; fund raising events in September, November, February and April; introductory community tours begin May 1.

Once the Stage 1 process had been completed the client was ready to move on to Stage 2 in the FoRSE™ Matrix. In this stage the client responds to leading questions in the Matrix that help to understand the ripple effect that queries could have on the achievement of the client's goals and ultimately on the organization. Stage 3, the final stage, mines deeper for each of the leading questions in Stage 2, adding both what has been communicated—or not—by the organization and what stakeholders' perceptions are of the organization or query.

Once the client began to respond to the questions in Stage 2 and 3, the necessity of clarity in Stage 1 became apparent, as did the amount of work required to make their project a successful reality. For example, as can be seen in the initial draft of Stage 2 below, the statements are general and seemingly straight forward:



Stage 2 has 26 key questions intended to draw out details about what was communicated in Stage 1 and Stage 3 has an additional 81 questions with Communicated and Perceived columns beneath each of the big picture clusters.[4] Each stage leads the user progressively into more penetrating or deeper considerations, all of which affect organizational purposes, queries, interventions and the big picture. It is evident, comparing Stage 2 responses with Stage 1 responses, that were we to not make changes, misalignment would continue throughout the exercise and the client would not achieve a big picture perspective let alone their goals and ultimate purpose. For example, after having changed Stage 1 Purposes content, the content in Stage 2 would need to be changed. The third statement belongs under Infrastructure and, with rewording, also under Form or Design. The same is true for each of the questions throughout Stage 2 (and 3). Although a timely process, it should become clear that alignment of the content with the other cells in the Matrix will enable the user to build a comprehensive schema or big picture of the query. For problem framing and solutions or any query, that has to be a positive outcome for leaders.

Take away: In this case the client was able:

- to clarify their purpose in the query and ensure it aligned with the main purposes of the organization,
- to determine how the query would look and where it would work,

[4]To fully demonstrate and extol the virtues of Stage 3 would require far more space and depth and turn this chapter into a book in itself.

- to decide the size and composition of the team,
- to establish the key "owner" of the initiative and team leader,
- to decide key skill sets desired for team members,
- to indicate key actions to undertake, by whom, when and how,
- to locate financial resources in order to fund the initiative,
- to specify a workable timeline for implementation and review,
- to ensure communication to the organization and community,
- to move on to the next stages of the FoRSE™ Matrix system in order to develop a big(ger) picture of what all was entailed in the pursuit of their query topic.

7 Next Steps

This chapter presents an overview of problem framing and steps to solving from a big picture thinking application as modelled through the Family of Related Systemic Elements (FoRSE™) Matrix system. In the case study we examined an actual "problem," the query, followed by the first stage of establishing its boundaries and determining its link to the purposes of the organization. Stage 1 of the FoRSE™ Matrix acts as a kind of triage for queries in that it provides a relatively quick overview of the interrelated elements in relation to the organization's purposes. Though seeming common sense perhaps, the difference from other systems thinking applications lie in beginning to focus on big picture clusters as a step into big picture, or systems, thinking. Arguably big picture thinking uniquely provides an opportunity to more fully, but not exhaustively, examine a query from multiple but related sides. Stages 2 and 3 open the way to a broadly deep penetration into the elements and their crucial alignment with one another and the purposes of the query topic.

The ripple effects of decision-making and the outcomes directly affect the life of the organization. Change, strategies, reviews, programs, repeat will continue in those organizations failing to apply big(ger) picture thinking. Success will always be fleeting, new buzz jargon will move in and out of management-speak with the rhythm and enticement of South Pacific waves, and those same organizations will squander valuable resources in search of sustainable change, achievement of purpose, and security of being. Prefer Kaizen, TPS, System Dynamics modelling, hard data? These can be beneficial. Yet, they lie within the FoRSE™ Matrix as they provide only parts of the big picture or little window glimpses.

The advantages of big picture thinking have been touched on in this chapter. Given that every organization will face queries on a regular basis, many of which will require an in-depth treatment, organizations will need to make decisions with care. They will want to make sure that any interventions will mitigate problems not introduce others, and that decisions are made that will help the organization achieve its purpose and goals. The benefits of employing the FoRSE™ Matrix system include clearly identifying the key elements (the critical mass) that directly affect, and that are affected by, any query, seeing what supports and what hampers the query and achieving success, and helping to determine changes to be implemented as well as the full impact of choices and decisions. It provides leaders with a functional and robust schema from which they can more effectively engage their whole organization.

A challenge to organizations is greater than problem framing and solving, as important as these two are to the longevity of the organization. Ultimately it is their identity, their being. That is wrapped up in purpose. Organizations will want to have more than little window glimpses in their life if they truly wish to succeed, prosper and benefit humanity.

References

Bailin S, Case R, Coombs J, Daniels L (1999a) Common misconceptions of critical thinking. J Curric Stud 31(3):269–283

Bailin S, Case R, Coombs J, Daniels L (1999b) Conceptualizing critical thinking. J Curric Stud 31 (3):285–302

Després B (ed) (2008a) Systems thinkers in action: A field guide for effective change leadership in education. Leading systemic school improvement series. Rowman & Littlefield Education, Lanham (Series Editor: Duffy FM

Després B (2008b) Conclusions and continued beginnings: application of the systemic factors inventory analysis matrix. In Després B (ed) Systems thinkers in action: a field guide for effective change leadership in education. Leading systemic school improvement series. Rowman & Littlefield Education, Lanham, pp. 247–267 (Series Editor: Duffy FM)

Després B (2008c) Tease of the perfect university: mis/matching systemic elements and their effect on organizational dynamics. Syst Prac Action Res 21(3):197–210

Després B (2012) FoRSE matrix: big(ger) picture key to sustainable success. In: Workshop presentation at the 2012 Pegasus conference, systems thinking in action: the power is in the connections. Indianapolis, 12–14 Nov 2012

Després B (2014) Systemic thinking: a walk. In: Keynote presentation at the systems thinkers in action Temenos conference, Seattle, 16–18 Apr 2014

Midgley G (2000) Systemic intervention: philosophy, methodology, and practice. Kluwer, New York

Part II
Disaster Management Theme

Disentangling Wicked Problems: A Reflexive Approach Towards Resilience Governance

Hanneke Duijnhoven and Martijn Neef

Abstract This chapter discusses the complex challenge of dealing with diverging threats in our contemporary hyper-connected society. In recent decades, resilience has become a key notion that has been adopted by policy-makers and academia to embrace the changing risk our society faces. Yet the traditional, modernist rational logic that dominates approaches to resilience management, does not fit with the problem at hand. In this chapter we argue that societal challenges in the current era require a paradigm shift: we need novel perspectives on how to approach the governance of risks and the societal implementation of resolutions. We will argue that the recent focus shift from *risk assessment* to *resilience enhancement* in many disaster management communities is an important aspect of this paradigm shift, but that it is by itself not enough to deal with the 'wickedness' of today's complexity.

Keywords Resilience · Governance · Complexity · Social constructionism · Reflexivity

1 Introduction

The challenges contemporary society is faced with are characterized by great uncertainty and complexity, making it an almost impossible task to develop adequate policies and strategies to deal with these challenges. Confronted with pressures related to climate change, geopolitical tensions, economic crisis, terrorism, resource scarcity and other current developments, our society is faced with the question how we can cope with and adapt to these pressures and continue living our lives in a qualitatively acceptable manner. This is not an easy endeavor.

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The hyper-connectedness that characterizes our globalized world makes it hard, if not impossible to clearly isolate causes and effects of any given threat. The promise of progressing control over our world through science and technology that the Enlightenment brought us and that has governed our beliefs for the past centuries is dissipating as each generation finds itself in a more complex and connected world than the previous. As Giddens (2002: 2) puts it: "rather than being more and more under our control [the world] seems out of our control—a runaway world".

In this chapter we argue that societal challenges in the current era require a paradigm shift: we need novel perspectives on how to approach the governance of risks and the societal implementation of resolutions. We will argue that the recent focus shift from *risk assessment* to *resilience enhancement* in many disaster management communities is an important aspect of this paradigm shift, but that it is by itself not enough to deal with the 'wickedness' of today's complexity. To illustrate the problem that we want to address in the chapter, we start by highlighting a few brief examples that illustrate the intricate nature of the challenges that threaten our contemporary societies. We will then discuss some of the current approaches towards these threats and will argue that some of the cognitive frames that underlie these approaches are to some extent contradictory, leading to suboptimal results. We will conclude the chapter with some of our ideas of how the wicked problem of resilience governance might be addressed.

2 Contemporary Wicked Problems

2.1 Hybrid Threats

In *We have never been modern* Latour (1992) cogently argues that contemporary phenomena, including threats and disasters cannot be divided into categories such as natural disasters, technology failures, terrorism, (geo)political conflict, or human error. Rather, these are what he calls 'hybrids'. Hybrid risks are the result of hyper-connectivity between systems as the society, the environment, technological systems (Masys et al. 2014). In a similar vein, Chandler (2013) describes how in the contemporary era, there is no longer a clear distinction between human and natural risks. Drawing upon the work of Anthony Giddens he argues that whereas the modern 'Enlightenment' discourse is grounded in the notion that there is a distinction between external threats such as natural phenomena (floods, earthquakes, etc.) and internal societal problems caused by humans, today there is no longer a distinction possible between internal and external risks. All risks should be conceived of as 'manufactured', meaning that they are always directly or indirectly consequences of human decisions.

> Giddens clearly articulated the shift away from the liberal modernist belief that developments in science and technology might enable the extension of humanity's control over the external world. He argued that today we have become aware that the aspiration of controlling and shaping our external world is a product of human hubris and misunderstanding. Modern risks and insecurities are conceived in terms of "manufactured uncertainty", as human products (or by-products) that cannot be dealt with through Enlightenment prescriptions of "more knowledge, more control" (Chandler 2013: 218).

According to Giddens it is not only no longer possible to think of threats as being external to the social system, what is more, it is not possible to understand or 'know' the external world altogether (Chandler 2013). The world is shaped by human activity and since we are part of that world, it is impossible to understand it as 'external' to us. In particular when it comes to contemporary threats and risks, it becomes clear that they are created and effected by the social system that is society (Lash and Wynne 1992). Beck, in his famous Risk Society, describes this as the inability of the industrial modern society to control the results of its own ideals of technological progress (Beck 1992). It seems that the advancements that were meant to increase our control over our society has instead created such a complicated system that we have lost control of the consequences of our behavior and actions (Chandler 2013). Therefore, we can no longer distinguish clearly between cause and effect of disturbances.

Nevertheless, in the field of risk management, the dominant framework continues to distinguish between different types of risks and threats such as natural, social and technological (Masys et al. 2014). To a certain extent this is understandable and useful because categorization makes it—from an analytical point of view—easier to limit the scope and focus on specific types of hazards when it comes to developing capabilities to minimize the risk. However, in practice this type of risk framework falls short to fully grasp the complexity, ambiguity and cascading chains of effects of these hybrid risks.

Below we present three short descriptions of a few recent cases that highlight the hybrid and hyper-connective character of contemporary crises. The selected cases vary greatly in scale and scope, because we aim to show that, despite their differences, the characteristics of these crises are similar with respect to their complexity and ambiguity.

2.1.1 Example 1: Hurricane Katrina, New Orleans

Even though hurricanes like Katrina are a natural phenomenon, the devastating impact of this particular hurricane is the product of human decision making. New Orleans was not only vulnerable to storms due to its location and poor quality of building structures, its economy had also severely weakened, leaving many of its inhabitants unemployed and living in poverty. These people were not prepared for a storm of this caliber and had no means to leave the area (Boettke et al. 2007). The media coverage of the disaster showed how large groups of people were waiting for help, without food, water or other necessary resources (Comfort 2006). The storm may have been the direct trigger of the crises, but the cascading consequences it has had on the community can be seen as the actual disaster, one that is difficult to overcome.

In the wake of Hurricane Katrina, the greater New Orleans area has lost close to a quarter of its population, with over 100.000 former residents still displaced. The majority of this loss comes from heavily stricken parishes that were in the direct path of Katrina. Almost the entire city of New Orleans was destroyed. The events following the landfall of Katrina demonstrate how the interaction of vulnerabilities among the physical environment, the engineered systems, and the organizational response system could result in such catastrophe (Comfort 2006). In addition, as research by Boettke et al. (2007) indicates, it seems that the recovery process as guided by the top-down governmental programs executed through FEMA have—unintentionally—actually slowed down the process of rebuilding. The allocation of relief resources are allocated politically, without taking the interests and incentives of other stakeholders such as local businesses and specific community groups. The program is developed with a particular idea in mind of what the intent of rebuilding should be, while ignoring "the innate abilities of individuals, communities, and businesses to use a variety of resources and sources of information to guide their decisions about whether and how to rebuild" (Boettke et al. 2007: 371).

Currently, the New Orleans metropolitan area is almost back to its original numbers, but is facing challenges of a different kind. The social makeup of the city is changing as the number of residents from Afro-American descent is declining, and the number of white and Hispanic residents is on the rise (Plyer et al. 2013). Great economic investments in the area have had their effect, and the city is now regaining much of its luster with newly built arts and community centers, a steady growth of jobs and an influx of new residents that are attracted to the liveliness of the city. However, the city is not the same as it was pre-Katrina, and the city needs to come to terms with new communities, social structures, and demands of its residents in order to become resilient again. Rebuilding the social fabric of New Orleans is a continuing challenge for its residents, and just as relevant to New Orleans' recovery as cleaning up the rubble.

2.1.2 Example 2: Natural Gas Extraction in Groningen

The Netherlands possesses a major natural gas reserve underneath the soil of the Northern province of Groningen. Over the past years, there has been a significant increase in frequency and amplitude of earthquakes, which have been attributed to the geological effects of natural gas extraction (Van der Voort and Vanclay 2015). The recurring earthquakes cause damages to houses, a collapse of property values, social unrest and other related problems. Current public debates revolve around the question how to deal with this problem and whether or not the safety of residents in the vicinity of the extraction site has been taken into regard in the decision making process. Radically decreasing or putting a stop to the extraction of gas in the area would not only cause problems for the regional and national economy, but would also increase the nation's dependency of imported energy sources, which seems unappealing in particular in the face of current geopolitical tensions. Continuing with the extraction would increase the social unrest among the affected community, most likely culminating in the massive deserting of the residents and businesses in the area, causing great economic downfall for the entire Northern region of the country. On the other hand, one could argue that the heavy dependency on natural gas is a risk in itself and more should be invested in the development of alternative energy sources.

This example shows how an activity that, according to some, should be seen as a technological advancement and an important 'energy game changer' is viewed by others as a source of damages or environmental risk (Metze 2014). It clearly shows what in the theorizing of Ulrich Beck is characteristic of the Risk Society: the industrialized society is no longer able to manage the risks that are produced by the technological developments that constitute the industrial society (Beck 1992). More and more, political conflicts in society are about the question who has the authority to decide what is an acceptable danger and what is not, about the distribution of risks, and about who is responsible for the consequences of catastrophes (Beck 1992). And this is also the case in this example.

The controversy of this topic of natural gas extraction topic extends beyond the context of the Netherlands. The debate is not merely a matter of different expert-opinions, but highly influenced by the geopolitical landscape and the high dependency on natural gas of the industrial world. The contested nature of this problem makes it difficult to respond. There is not a single objectively valid solution because its causes and effects are strongly intertwined and public authorities have to consider all aspects in their regulatory decisions.

2.1.3 Example 3: The Eruption of the Eyjafjallajökull

On 14 April 2010, the Icelandic vulcano of Eyjafjallajökull erupted after several years of seismic activity. The eruption blew a large ash plume into the sky and high altitude wind circulation quickly spread the ash cloud over a large part of Northern and Western Europe. Because volcanic ash can pose a serious threat to airplanes, with previous examples whereby airplane engines were severely damaged when flying in an volcanic ash cloud, the European air traffic control collectively decided that airspace in the dispersion area had to be closed off immediately, and it was not reopened until 20 April when the amount of ash had fallen to acceptable levels (Alexander 2013). Even though from a geological point of view this was considered to be a relatively minor event, its consequences were enormous. The airspace closure caused no less than 108.000 flights (48 % of all European air traffic) to be cancelled and affected around 10 million passengers. Aside from the expected direct impact on travel, the ban also had a profound effect on trade, cultural events, public media and economies globally. The ban disrupted many supply chains across the globe and required business large and small to cease operations during the ban, such as automobile makers Nissan, Toyota, BMW and Honda, and logistic carriers TNT, FedEx and DHL.

The escalation of this relatively minor event into a severe crisis with serious consequences is attributed to the combination of several circumstances (Alexander 2013; Castellano 2011). In the first place, the decision to close parts of the airspace was based on knowledge about the damaging effects of volcanic ashes to aircrafts, yet it was unclear at what specific concentration levels the airspace would be safe to fly through. This was further complicated by the extensive media coverage about the risks, leading to increased risk perception among the public and policy makers. In addition, the integration between different modes of transport was lacking, which caused the prolonged disturbance of travel and transport routes, leading to chaos (stranded passengers) and severe economic losses (including bankruptcy of several affected businesses). In particular the dependencies within the European transportation system became painfully clear through this incident. Nobody had foreseen or was prepared for the severe consequences of prolonged disruption of air traffic throughout the world.

In the aftermath of the crisis questions have been raised about the drastic measures to eliminate the risk for air traffic, leading to an increased risk for travelers via other means as well as threats to the livelihoods of many businesses (Alexander 2013; Castellano 2011). It seems that the decision to close the airspace was based on the air traffic safety rationality, not taking into regard other rationalities that point to other types of consequences that might have influenced the decisions. Questions were raised whether the culture of risk aversion when it comes to air traffic safety leads to a trade-off in other parts of the society, and if so, is that an acceptable trade-off?

2.2 The Challenge of Policy Development

Although these brief descriptions do not do justice to the detailed complexity of these real-life crises, what they illustrate is the ambiguity that is involved when dealing with this type of 'hybrid' problems. It is very difficult to oversee the direct and indirect causes and effects and if one attempts to map this, there is a good chance of losing sight of the problem at hand while trying to see the bigger picture. Nonetheless, disaster risk reduction programs and disaster management strategies typically attempt to pinpoint a small number of key factors that would contribute to the inception of a disaster (e.g. vulnerabilities in a critical infrastructure, a lack of resources or unprepared disaster response organisations), or play a significant role in the manifestation of disaster (e.g. public crisis information systems, community mobilization initiatives, government crisis management procedures). The governing assumption is that these factors should form the basis for policies and interventions that aim to minimize risks and increase our disaster resilience. The problem with this rational approach is that it does not fit with the complexity of contemporary problems, or with the nature of policy development.

By nature, policy development and decision-making processes are characterized by the complex interplay of problems, interests, political power struggles, and internal as well as external constraints, especially when many different stakeholders are involved (e.g. Boin et al. 2005; Teisman 2000). Theories of bounded or situational rationality show that decision-making is wrought with biases, public opinions, and subjective argumentation (Rubinstein 1998; Simon 1982). The increasingly complex nature of social systems such as urban environments adds to the already difficult challenge for policy makers dealing with disaster management, because it is no longer possible to isolate specific problems and reduce them to a limited set of controllable variables. When it comes to addressing problems in a complex social system, the notion of expert knowledge as a basis for policy is problematic since it does not take into account the emergent properties of the complex system (Wagenaar 2007). Decision-making is further complicated because the causes of problems and social tensions are often unclear and the effects of interventions difficult to trace (Wagenaar 2007). There are so many influence-factors in any social system that it is virtually impossible to isolate specific drivers for specific changes. In addition, the dynamic interrelations between different aspects in the system make it difficult to predict the outcomes of interventions. As a consequence "The unintended effects overwhelm the intended ones because the world is much more complicated and interconnected than we imagined" based on the rational belief in scientific progress and control (Chandler 2013: 220). This complexity makes disaster- and crisis management even harder than it already is.

Another complicating factor for policy makers in the area of disaster management is the scrutinizing expectation from the entire society (including mass media) that 'our leaders' will avert threats or at best minimize the negative impacts that may occur in case of disaster.

> Citizens whose lives are affected by critical contingencies expect governments and public agencies to do their utmost to keep them out of harm's way. They expect the people in charge to make critical decisions and provide direction even in the utmost difficult circumstances. So do the journalists who produce the stories that help to shape the crisis in the minds of the public (Boin et al. 2005: 7–8).

Furthermore, what constitutes a crisis differs for different groups of people and is dependent upon processes of sensemaking (Weick 1995). Perceptions of threat and crisis are determined by the individual and collective frames of reference (Adams 1995; Boin et al. 2005). Therefore, the response to a threat or crisis (first and foremost the decisions made by public authorities, but essentially everyone's reaction) is also perceived differently by different actors and by nature contested.

All this leads to the conclusion that traditional 'rational' policy development should make way for alternative governance strategies, such as participatory or deliberative policy development (Wagenaar 2007). Traditional control mechanisms based on rational logics of science and politics no longer seem to function in the risk society, which calls for what Beck terms *subpolitics*, whereby politics is taking place in subsystems rather than at the level of the state (Beck 1992). This is also the main idea behind what Beck et al. (1994) call *reflexive modernity*, a social order in which the right conditions are provided to facilitate decision making by individuals and groups in society at large (Beck 1992; Beck et al. 1994; Chandler 2013).

Nevertheless, it seems that in practice the modern ideal of rationality is more powerful than the acknowledgement of complexity in the discourse and practice of policy development (Wagenaar 2007). In the next section, we will briefly discuss the emergence of the focus on resilience in political discourse and highlight some of the main frames that dominate this resilience thinking.

3 From Risk Society to Resilient Society

3.1 The Shift Towards Resilience Thinking

In the last decades the concept 'resilience' has gained much traction in a wide variety of academic disciplines, including systems engineering, organizational sciences, ecological science, psychology, economics, climate change, disaster management, safety and security research. The popularity of the concept is often attributed to its focus on the adaptive capacity of complex systems, which seems to fit well with the current societal landscape. The acknowledgement that the complex and hyper-connected systems that make up society produce risks that cannot be prevented has instigated the emphasis on coping with unintended consequence of this increased complexity. As Woods and Hollnagel (2006) argue, the focus on resilience might even be seen as a paradigm shift through which the emphasis of research in many disciplines has shifted from the retrospective analysis of 'unsafety' (in hindsight) to the comprehension of sources of 'safety' in light of threats to the system performance. In simple terms: instead of looking for system vulnerabilities, one would look for system assets that help to mitigate challenging situations. It shifts attention from preventing future disasters from happening to minimizing the disruptive impacts on society (Chandler 2013).

What is more, resilience thinking moves away from the governance of particular threats and focuses on increasing the capabilities of the system to deal with uncertainty. In this sense, the shift away from risk calculation towards resilience building seems in line with what Beck (1992) is arguing for in terms of reforming society and its inhabitants and organizations in such a way that accidents and disruptions become a normal part of daily life. Accepting the notion that things will go wrong necessarily leads to a change in mindset: being prepared for uncertainty and unexpected failures.

The increased attention for resilience is not limited to academic circles, as policymakers across the world also recognize the value of emphasizing the capabilities of the systems under their influence, rather than pinpointing the weaknesses to more or lesser known threats. Resilience seems to be the answer to a wide range of problems and threats, and therefore garners the attention of policymakers and researchers from different fields and disciplines. The increasing focus on resilience implies that we are moving away from traditional risk management approaches. It is recognized that we cannot prevent or prepare for risks that are unknown and therefore governments are searching for those capabilities that strengthen the performance of society's critical functions regardless of specific threats (Woods and Hollnagel 2006).

Several authors recognize in the rise of the resilience discourse a link with the increasing governmental encouragement of active citizenship, decentralized responsibility and self-organization (e.g. Chandler 2013; Joseph 2013; Kaufmann 2013; Zebrowski 2013). Resilience is about empowering (civil) society to be able to engage with and adapt to change and uncertainty in the face of risk and complexity. As Chandler puts it: "This shift from a focus on the activity and provision of government to the capacity of citizens to effectively respond and adapt to crises or problems—and increasingly to take responsibility for "self-government"—is of vital importance to our understanding of resilience as a set of discursive practices of governing through societal security" (Chandler 2013: 212). Joseph (2013) is more critical in his analysis. He argues that the encouragement of active citizenship in the resilience discourse suggests an increasing freedom and room for different perspectives, whilst in fact it masks the rationality of competition and the mechanism of free market economy in the distribution of resources and power that is dominant in the logic of neoliberalism.

It is beyond the scope of this chapter to unravel the political meaning of the rise of resilience but the point we want to take from these contributions to the debate is that is more to the emergence of the logic of resilience in the area of disaster management seems to be related to the changing governance landscape, much like influential thinkers such as Beck (1992) and Giddens (1990) already identified in their writings at the turn of the century.

3.2 Approaches to Resilience Enhancement

There are quite a few examples of studies that attempt to build conceptual and theoretical models of societal resilience (e.g. Cutter et al. 2008; Jordan and Javernick-Will 2012; Longstaff et al. 2010; Norris et al. 2008) in order to inform policy making, to empower communities, and ultimately increase society's resilience. Inspired by systems theory, societies are often approached as complex (adaptive) systems composed of different components or subsystems: social, economic, physical, environmental, organizational, institutional, and so on. These components are closely related and the functioning of the system is determined by the interplay between them. This means that if we talk about enhancing the resilience of a system, we need to define/understand the functional relationships that exist between the various components of that system. In other words, we need to define the extent to which there is reliability and continuity of the systems, functions and principles that are most important to the functioning of the whole system (Flynn 2011).

Yet, given the hyper-connectedness of society and the hybrid risks that are the result of the technological advancements in the industrialized world, it is virtually impossible to isolate causes and effects in the complex network of systems and subsystems. As a consequence, most approaches to resilience enhancement focus on a specific aspect in order to reduce this complexity. We have identified four broad types of approaches (Duijnhoven and Neef 2014): *Phase-oriented* approaches focus on a specific stage of a disaster, such as preparation or recovery. In the typical preparedness phase, the focus would be on enhancing the capability of a society to resist a threat, and in effect prevent a disaster from happening. In a disaster response phase and the later recovery stages, the value of resilience enhancement would be to increase the absorption, accommodation and recovery capabilities of a society. *Threat-oriented* approaches limit their scope to specific types of threats such as natural disasters, technological or man-made disasters. These approaches are often quite similar to scenario-based risk assessment methods, in a sense that they simulate where the vulnerabilities of the system emerge in case of a specific threat. *Community-oriented* approaches aim to facilitate self-assessment of resilience in communities (both communities of place and communities of interests such as a specific sector) by bringing together different stakeholders to identify critical functions, vulnerabilities and to develop specific enhancement activities. *Comprehensive* approaches, finally, aim to transcend societal sectors, disaster types or disaster phases, and rather focus on actions that increase resilience in general sense. These approaches are usually generic in nature, target the whole of society, and are rather process-oriented than solution-oriented.

If we look at the entire landscape of resilience enhancement approaches, it becomes clear that the majority of approaches depart from a similar assumption: if we are able to identify and map the core components of the system and understand their interrelations, we will be better equipped to reduce vulnerabilities and increase the resistance, robustness, flexibility, adaptive capacity against disruptive pressures. This systems analogy applied to social systems such as a society may theoretically be valid, but it undermines the idiosyncratic interpretations of what the core functions of a system are. Because of the complexity of the system and its socially constructed nature it is impossible to objectively define the absolute set of functional relationships that build up the system. Depending on the background of the stakeholders involved, different functions are seen to be critical.

Adopting a social constructivist perspective (Berger and Luckmann 1966), to resilience enhancement we argue the functions of a system are defined by the perspective through which actors make sense of the system. In addition, depending on the specific situation and the specific stakeholders involved, the emphasis of resilience (resilience óf what and resilience tó what) will differ. As such, resilience enhancement policies are shaped and negotiated by the continuously changing political climate, cut-backs and dominant societal discourses ('trending topics'). Furthermore, the very definition of the problem (i.e. specific threats to the system, and thus the resilience of that system) is shaped by local historical and political experience. For instance, a threat of flooding might not be very relevant for a desert community. Therefore, their perspective on resilience will most likely not encompass their capacity to withstand such a threat. In that sense, their intrinsic definition of the term resilience will differ from that of a community in a flood-prone area. In addition, as the three cases previously described show, threats and crises are often extremely complex, leading to ambiguous interpretations and controversy, not in the least due to the negotiated meaning making processes that take place through political debate, media coverage and information from different ‘experts’. If we accept the view that risk and crisis perception are determined by intersubjective interpretation it logically follows from that conclusion that resilience is perceived equally different by different actors.

As a consequence, it does not suffice to build a model of (system) resilience, since the exact definition of critical components and functions will depend on the specific context and purpose for which the model is formulated. We do not want to dismiss the value of such approaches, but instead, we argue that the knowledge about resilience and the intricate relations between different components within a complex system should be used to develop an approach to *resilience governance*. Taking into account the influence of processes of sensemaking and framing by stakeholders involved in addressing resilience matters, it would be useful to design a *reflexive* management process that guides policymakers and other actors through the steps of situationally defining and identifying both what the critical components of the system are to them, as well as understanding which factors they can influence to strengthen the resilience property of the system.

In the next section we will draw out some of the essential characteristics of a reflexive approach to *resilience governance* that embraces the socially constructed nature of the social world and that takes the complexity of contemporary society into account. We argue that in many of the current resilience strategies there is an inconsistency in the underlying assumptions and cognitive frames they are built upon, which leads to approaches that do not entirely fit with their intent.

4 Towards a Reflexive Approach to Resilience Governance

In order to disentangle the inconsistencies that underpin many resilience strategies we adopt, an interpretive, constructivist approach to policy analysis (see for instance Fisher and Forester 1993; Schön and Rein 1994; Yanow 1996). The main reasoning behind this approach is that the production and implementation of policies is not a rational, objective matter. Interpretive policy analysis fundamentally criticize the positivist, technocratic stance of traditional policy analysis. The basic assumption underlying traditional policy analysis is that the best solution for a wide range of problems can be obtained through the application of scientific methods (Hajer and Wagenaar 2003a). In contrast, interpretive policy analysis recognizes the socially constructed nature and intersubjective interpretations of the problem that shape policies and policy targets. Everyone’s perspective on the world is influenced by and mediated through contextualized (socio-cultural) systems of meaning. Such cognitive frames provide our experiences in reality with meaning. This means that our construction of reality is determined by the specific socio-cultural system of meaning that we use to interpret it. As a result, there is not a single, absolute truth about reality 'out there', but only intersubjectively constructed interpretations of reality. Following this reasoning, policymakers draw from their specific cognitive frames to evaluate the situations and problems which they address in their day-to-day work. It is the aim of interpretive policy analysts to uncover the underlying frames and processes of sensemaking to understand how specific policies and political discourse come to dominate the public arena.

4.1 Dominant Frames in Resilience Strategies

If we apply the ideas of interpretive policy analysis to the field of security policy and disaster reduction strategies in the industrialized world, there are several dominant, yet conflicting frames through which policy development takes places. The incongruousness becomes clear with regard to the question of responsibility in relation to security and resilience. There is a dominant view that governments have the quintessential task to take responsibility for the security of citizens and society at large, while at the same time, there is a clear movement towards governance models that stimulate active citizenship, which has been emerging in the last decades, in particular in the Anglo-Saxon regions, but also in other industrialized societies such as Germany or The Netherlands. This movement involves the participation of citizens in their wellbeing, welfare and increasingly also their safety and security.

It has been widely accepted that people take up responsibility in areas that were previously governed by state authorities, and relation between the state and society is changing. The emergence of resilience strategies can be seen in a similar light. Resilience is often defined as the capacity to cope with changes (disruptions) in the system. Essentially this implies that the resilience capacity ultimately lies with the actors that are make up the system, including the citizens. Therefore, it makes sense that active citizenship also applies to resilience strategies. Nevertheless, governments are under heavy scrutiny when it comes to disaster management and, as becomes clear in the aftermath of catastrophes such as Katrina, public authorities still have the lead in the distribution of relief resources and rebuilding decision-making.

The dominant position of public authorities in disaster management is not only problematic when looking at the question of responsibility. Another important shift that is necessary to fully adopt the logic of resilience is a change in mindset across all levels of society with regard to the acceptance of disruption and uncertainty. Truly accepting disruptions and uncertainty as a normal part of our daily life is needed because, as was discussed extensively in the previous sections, it is impossible to prevent them due to the complexity and hybrid nature of our contemporary society. Achieving this change in mindset across all levels of society seems only possible if we are able to depart from the dominant view that governments are ultimately responsible to keep the society safe and functioning regardless of any disruptions. The government framework in which—through knowledge and rationality—our political leaders are able to identify the best possible solutions to society's problems is no longer viable, since the problems in the current risk landscape cannot be fully grasped through rational, instrumental approaches (Beck 1992). This means that other modes over governance are needed that are based on reflexive knowing and reflexive action and involving a range of actors. Hajer and Wagenaar (2003b) propose the adoption of deliberative approaches to governance.

> Such deliberative approaches to public policy emphasize collective, pragmatic, participatory, local problem solving in recognition that many problems are simply too complicated, too contested and too unstable to allow for schematic, centralized regulation (Hajer and Wagenaar 2003b: 7).

Nevertheless, it seems that instrumental, rationalist logics still dominate policy-making, leading to the search for models of societal resilience that map resilience indicators and serve to identify the best possible measures to enhance resilience. Taking into regard the tensions that underlie most of the resilience approaches, what does this mean in practice? In the next, concluding, section we will present our ideas on how to move towards a more reflexive approach to resilience governance, taking the previous points into regard.

4.2 Reflexive Resilience Governance: A Five-Point Manifesto

In the previous sections, we have discussed the tensions that underlie most of traditional, risk-driven resilience approaches. We have also put forward that there is a need for a paradigm shift that better aligns with the complexity of our society, and that offers a better point of departure for enhancing societal resilience against disruptions. We have identified some key elements that should drive this paradigm shift. We would like to give this transformation direction through a five-point manifesto: five fundamental propositions that novel resilience governance strategies should adhere to in order to be reflexive, and thus be, in our view, more effective than traditional risk reduction and management strategies.

1. ***Resilience is built* in-situ**

Resilience management strategies and interventions should be conceived in the context where they are to be deployed. The pervasive complexity of our societies makes it so that we cannot rely on pre-defined solutions that have been defined in other contexts. Any effort to strengthen the resilience of a society against disruption needs to be situated in its own locality, driven by local characteristics and conceived by those who influence the process, have a stake in the design and are affected by its effects. Pre-defined strategies and established best practices can serve as a point of inspiration, but should not be adopted without a systematic local translation.

2. ***Building up resilience requires a wide lens***

Efforts to enhance resilience must be driven by a comprehensive perspective. It is important to adopt a wide lens to view the target environment in a manner that does justice to its complexity. For a typical urban setting that would, for instance, include social, economic, infrastructural, governmental, environmental and physical aspects of the target environment and their inherent interdependencies. Efforts that work from a narrow scope, or over-compartmentalize the environment will not yield effective interventions as they encourage oversimplification of reality. Resilience governance efforts need to embrace the complexity of our society and find novel manners that make it manageable.

3. ***Resilience comes from closing feedback loops***

It is essential to view resilience enhancement as an open-ended process, not as an isolated act. The complexity of the world means that we should accede that we cannot grasp and understand all cause-effect relationships and therefore we should accept that resilience can only be advanced by probing the solution space, assessing effects and adjusting interventions. Solutions should not be exclusively geared towards preparing for the known risks, but should explicitly involve increasing the acceptance of and coping capacity towards uncertainty and unexpected events. In a practical sense, this means that we need to view resilience enhancement as an ongoing process that includes both intervention design and performance feedback. In the realm of disaster resilience management, it is not straightforward to obtain objective feedback criteria because of the absence of actual disasters. Nonetheless, it is vital to pursue to close feedback loops in order to obtain an effective handle on resilience enhancement, as resilience itself is a positive result of interacting feedback loops.

4. ***Resilience is built up together***

The degree of resilience of a society against disruptions is the result of the interplay of many actors and many factors. Any effort to enhance resilience therefore demands the involvement of a wide range of actors. This is necessary to ensure that enough perspectives are taken into account and to ensure that there is wide commitment to directions taken. In a practical sense, this means that governmental parties need to allow non-typical parties to have a stake in the process, such as citizens and private parties. This might seem obvious as these communities can offer significant capacities to enhance resilience. In practice however, these parties rarely play a significant role in the development and decision making on interventions. The responsibility and authority to decide on measures and intervention is often placed by a small number of authoritative bodies, which—despite efforts to include multiple perspectives or interests—results in a vantage point that is based on a single rationality. An essential aspect of the aforementioned paradigm shift therefore, is the inclusion of a wider range of societal partners into the process of resilience governance, including the actual decision-making process.

5. ***Governing resilience demands a reflexive attitude***

In a resilience governance effort, it is vital to maintain a reflexive and critical stance to all its aspects. It should include a continuous process of problematization and reflection with regard to the underlying rationalizations and principles. It accepts the inherently contextual nature of knowledge. A reflexive attitude involves asking critical questions. Are all the right actors involved in the process, not just the 'usual suspects'? Are decisions based on assumptions that have been properly problematized? Do proposed interventions align with the perspectives of those who are expected to contribute? Biases arise where reflexivity is absent, so a critical stance should be the cornerstone of resilience governance.

References

Adams J (1995) Risk. Routledge, London

Alexander D (2013) Volcanic ash in the atmosphere and risks for civil aviation: a study in European crisis management. Int J Disaster Risk Sci 4(1):9–19

Beck U (1992) Risk society. SAGE, London

Beck U, Giddens A, Lash S (1994) Reflexive modernization. Politics, traditions and aesthetics in the modern social order. Stanford University Press, Stanford

Berger PL, Luckmann T (1966) The social construction of reality. A treatise in the sociology of knowledge. Anchor Books, New York

Boettke P, Chamlee-Wright E, Gordon P, Ikeda S, Leeson PT, Sobel R (2007) The political, economic, and social aspects of Katrina. South Econ J 74(2):363–376

Boin A, 't Hart P, Stern E, Sundelius B (2005) The politics of crisis management. Public leadership under pressure. Cambridge University Press, Cambridge

Castellano GG (2011) Rising from the ashes: a governance perspective on emerging systemic risks. In: Alemanno A (ed) Governing disasters. The challenges of emergency risk regulation. Edward Elgar Publishing, Cheltenham

Chandler D (2013) Resilience and the autotelic subject: toward a critique of the societalization of security. Int Political Sociol 7:201–226

Comfort LK (2006) Cities at risk. Hurricane Katrina and the drowning of new Orleans. Urban Aff Rev 41(4):501–516

Cutter SL, Barnes L, Berry M, Burton C, Evans E, Tate E, Webb J (2008) A place-based model for understanding community resilience to natural disasters. Glob Environ Change 18(4):598–606

Duijnhoven H, Neef M (2014) Framing resilience. From a model-based approach to a management process. Procedia Econ Finance 18:425–430

Fisher F, Forester J (1993) The argumentative turn in policy analysis and planning. Duke University Press, Durham/London

Flynn S (2011) A national security perspective on resilience. Resilience: interdisciplinary perspectives on science and humanitarianism, vol 2, pp i–ii

Giddens A (1990) The consequences of modernity. Standford University Press, Stanford

Giddens A (2002) Runaway world. How globalisation is reshaping our lives. Profile Books, London (New Edition)

Hajer M, Wagenaar H (2003a) Preface. In: Hajer M, Wagenaar H (eds) Deliberative policy analysis. Understanding governance in the network society. Cambridge University Press, Cambridge, pp. xiii–xv

Hajer M, Wagenaar H (2003b) Introduction. In: Hajer M, Wagenaar H (eds) Deliberative policy analysis. Understanding Governance in the Network Society. Cambridge University Press, Cambridge, pp 1–30

Jordan E, Javernick-Will A (2012) Measuring community resilience and recovery: a content analysis of indicators. Constr Res Congr 2012:2190–2199

Joseph J (2013) Resilience as embedded neoliberalism: a governmentality approach. Resil: Int Policies Pract Discourses 1(1):38–52

Kaufmann M (2013) Emergent self-organisation in emergencies: resilience rationales in interconnected societies. Resil: Int Policies Pract Discourses 1(1):53–68

Lash S, Wynne B (1992) Introduction. In Beck U(ed) Risk society. SAGE, London

Latour B (1992) We have never been modern. Harvard University Press, Cambridge

Longstaff PH, Armstrong NJ, Perrin K, Parker WM, Hidek M (2010) Building resilient communities a preliminary framework for assessment. Homel Secur Aff 6(3)

Masys AJ, Ray-Bennet N, Shiroshita H, Jackson P (2014) High impact/low frequency extreme events: enabling reflection and resilience in a hyper-connected world. Procedia Econ Finance 18:772–779

Metze T (2014) Fracking the debate: frame shifts and boundary work in Dutch decision making on shale gas. J Environ Policy Plan 1–18 (ahead-of-print)

Norris FH, Stevens SP, Pfefferbaum B, Wyche KF, Pfefferbaum RL (2008) Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. Am J Community Psychol 41(1–2):127–150

Plyer A, Ortiz E, Horwitz B, Hobor G (2013) The New Orleans index at eight: measuring greater New Orleans' progress toward prosperity. New Orleans Community Data Center, New Orleans

Rubinstein A (1998) Modeling bounded rationality. MIT Press, Boston

Schön DA, Rein M (1994) Frame reflection: toward the resolution of intractable policy controversies. Basic Books, New York

Simon H (1982) Models of bounded rationality, vol I and II. MIT Press, Boston

Teisman GR (2000) Models for research into decision-making processes: on phases, streams and decision-making rounds. Public Adm 78(4):937–956

Van der Voort N, Vanclay F (2015) Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands. Environ Impact Assess Rev 50:1–15

Wagenaar H (2007) Governance, complexity, and democratic participation. How citizens and public officials harness the complexities of neighborhood decline. Am Rev Public Adm 37 (1):17–50

Weick KE (1995) Sensemaking in organizations. SAGE, Thousand Oakes

Woods DD, Hollnagel E (2006) Prologue: resilience engineering concepts. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience engineering. Concepts and precepts. Ashgate Publishing Limited, Aldershot, pp 1–16

Yanow D (1996) How does a policy mean? interpreting policy and organizational actions, Georgetown University Press, Washington, DC

Zebrowski C (2013) The nature of resilience. Resil: Int Policies Pract Discourses 1(1):159–173

Post-disaster Reconstruction—What Does It Mean to Rebuild with Resilience?

Kristen MacAskill and Peter Guthrie

Abstract There is a growing awareness that we live in times of uncertainty and change; this is fuelling increased consciousness of city and community vulnerability to natural and man-made hazards. In recent years the concept of resilience—the ability to both withstand and recover from a "shock"—has become a core term in international, national and local policy for urban development. Because resilience has been adopted in a range of decision-making contexts, various interpretations of the concept are potentially confusing for those attempting to adopt it in their own decision making. To help provide clarity, this chapter presents a framework that captures different interpretations of resilience as a concept to frame decisions for disaster risk reduction in our communities and cities. This framework acknowledges that resilience is a trans-disciplinary concept; its purpose is to help create a coherent understanding of how sector-specific applications of resilience lie within a broader conception of resilience in disaster risk management. More specifically, the framework is used to examine how resilience is considered in the post-earthquake reconstruction of infrastructure networks in Christchurch, New Zealand. There is still much to learn from case studies of post-disaster recovery, where the recovery environment introduces different and perhaps unfamiliar levels of complexity in decision-making compared to business as usual planning and development.

Keywords Resilience · Post-disaster recovery · Disaster risk management

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1 Introduction

This chapter comprises three main parts. Firstly, we provide background context through briefly addressing developments in international policy related to disaster risk management (DRM) and the emergence of resilience as a guiding concept.[1] We then introduce a framework that captures different interpretations of resilience in DRM, where resilience is essentially about the ability of being able to resist or recover from a shock. Finally, we use the framework to examine the institutional and organisational arrangements for reconstructing infrastructure networks in the post-disaster environment in Christchurch, New Zealand, following a series of earthquakes that occurred over 2010–2011. The rebuild of infrastructure networks such as water supply, wastewater reticulation and roads is often overlooked in post-disaster recovery case studies. This is (at least) in part because discussion on disaster risk reduction is often oriented towards less developed countries where such networks may not exist in a substantial form. Yet, developed countries are also vulnerable to disaster and infrastructure networks provide services critical to supporting developed urban areas. Our resilience framework will provide a basis for analysing roles and responsibilities for decisions that shape the recovery of Christchurch's infrastructure, with references to the broader recovery processes occurring in the city. This analysis demonstrates how the resilience framework can be a useful tool for understanding how sector-specific resilience strategies can contribute to a broader, integrated approach.

2 Background to Resilience in Disaster Risk Management Policy

As Coaffee et al. (2009) describe in their historical review of security policy, resilience has long been a core element of city development, even if it has only more recently become an explicit term in policy. The Sendai Framework for Disaster Risk Reduction 2015–2030, coordinated by the United Nations Office for Disaster Risk Reduction, represents the epitome of the growing global concern around the on-going viability of our communities and cities. The Sendai Framework, following its predecessor the Hyogo Framework for Action, will continue to lead international policy, guiding efforts towards building the resilience

[1]We adopted the UN definition of DRM, which is: "The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster" (United Nations Office for Disaster Risk Reduction 2009, p. 10).

of nations and communities to the impacts disaster.[2] Its goals are clearly designed around the idea of building resilience through DRM. The Hyogo Framework for Action has been successful in raising awareness and generating political commitment, with action from stakeholders from local to global level.[3] Priority for the future action under the Sendai Framework includes a need to:

> …focus action on understanding risk and how it is created; strengthen governance mechanisms at all levels; invest in economic, social, cultural and environmental resilience; and enhance preparedness, response, recovery and reconstruction at all levels.
>
> United Nations 2014, p. 5

Note here both the emphasis on resilience in enhancing all phases of the DRM cycle—not just longer term planning, but also the process of recovery. It is the recovery aspect that forms the focus of discussion in this chapter.

Supporting progress at an international level, the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) released a *Guide to Developing Disaster Recovery Frameworks* in September 2014. The aim of that guide is to help governments and other stakeholders plan for a "resilient" post-disaster recovery that aligns with goals for longer-term development, rather than just responding to the immediate hazard. The guide itself does not outline a resilience assessment process, but uses the concept of resilience as descriptor of what recovery should be, even though this is difficult to define:

> The notion of Resilient Recovery is much more nuanced, less understood and inconsistently perceived by most development practitioners. As countries develop their own standards and definitions on what constitutes resilience in recovery, due consideration might be given to: building back better; concerns over gender, equity, vulnerability reduction; natural resource conservation, environmental protection and climate change adaptation.
>
> GFDRR (2014a, p. 21)

The guide offers counsel on policy and institutional arrangements with a strong emphasis on governance of the recovery process.[4] It covers various key topics associated with recovery governance, including: conducting disaster assessments; policy and strategy setting, institutional frameworks; financing; implementation arrangements and recovery management; and institutionalising recovery in national and local governance systems. It does not give prescriptive advice, but provides a platform for learning through case study examples. No clear definition is given

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[2]Evidence of progress to-date can be viewed through national progress reports accessible from the United Nations Office for Disaster Risk Reduction portal for disaster reduction knowledge: http://www.preventionweb.net/english/hyogo/framework/progress/.

[3]The Sendai Framework was agreed at the time of finalising this chapter. The Hyogo Framework for Action has led progress to date. Its goals were: the integration of disaster risk reduction into sustainable development policies and planning; development and strengthening of institutions, mechanisms and capacities to build resilience to hazards; the systematic incorporation of risk reduction approaches into the implementation of emergency preparedness, response and recovery programmes (United Nations Office for Disaster Risk Reduction 2007).

[4]This emphasis on "governance" for resilience is an important concept that we will address in the development of a conceptual framework later in the chapter.

around what constitutes "Resilient Recovery", reinforcing the view that it will change in different contexts. Rather, the case studies describe elements of recovery that governments and stakeholders can learn from or choose to emulate in some way. Beyond the guide's focus on governance for "Resilience Recovery", resilience is also referred to in relation to more particular aspects of case studies, such as through:

- Physical measures in construction of housing—for example building houses on higher ground or on plinths to reduce risk of flood damage.
- Infrastructure interventions such as development of embankments to increase public safety.
- Increasing resistance in vulnerable points of a road network through slope stabilisation, drainage and surface treatments.
- Adoption of design codes for seismic design.
- Allowing a more participatory approach to recovery.
- Improving hazard assessment process to make more informed land use decisions.
- Institutionalisation of resilience through policies that focus on risk management.

At times it is not clearly explained in the case studies what is meant by incorporating resilience, such as a reference to "community resilience projects" in Yemen where there is no explanation of what those projects actually were and how they supported community resilience (GFDRR 2014b). However, it is clear from these examples that resilience may be adopted through a variety of perspectives and applied to different systems—covering communities, physical infrastructure, land use and institutional arrangements. It is this variety of perspectives that formed our motivation for creating a framework to capture different interpretations of resilience.

3 Development of the Conceptual Framework

This section outlines how we developed a conceptual framework to describe the facets of resilience as a concept for informing decisions in DRM. For those less concerned with the more formal construction of our approach, go straight to Sect. 4 for discussion on the Christchurch recovery.

Resilience has developed into a concept far beyond its literal definition as a term describing a property or quality of resistance, or bouncing back from adversity. It represents a way of thinking, a process to understand system (or people's) behaviour and performance. The idea has developed to a point where resilience is not necessarily a property of a system, but a means for governance, as demonstrated through the GFDRR framework for disaster recovery.

It is widely acknowledged that there are multiple interpretations of resilience. It has proven a useful concept to describe and understand phenomena in many facets of life, including ecology, psychology, community development, organisational performance and engineered systems. It is an idea that has resonated in popular culture. For example, Zolli and Healy's *Resilience*: *Why Things Bounce Back* (2012) drew the public's attention to the concept of resilience as a way of understanding the global economy. The book provides a narrative of how major, complex systems work, promoting resilience as a useful concept for shaping organisational and development decisions. More recently, Rodin (2014), President of the Rockefeller Foundation, authored *The Resilience Dividend*: *Being Strong in a World Where Things go Wrong*. Rodin focuses on cities and government, providing stories from around the world on how communities have responded to disruption. There are also a growing range of more formalised processes for resilience assessments described in academic literature. For example, Longstaff et al. (2010) discuss a framework of assessment for building resilience of communities, addressing resilience in terms of core attributes in a community system. Their framework (outlined in Fig. 1a) establishes a community model of resilience that involves an analysis of resources available to a community (to determine robustness of the community) and the ability of the community to utilise them (to determine the adaptive capacity of a community). Longstaff et al. outline what communities might theoretically consider in a self-assessment for resilience. As a comparison, Chang et al. (2014) also express an interest in community resilience, but their approach involves analysing the infrastructure systems that support communities. Through a case study, they collect expert opinions to determine potential disruptions and interdependences in infrastructure services, based on various hazard scenarios. Resilience here is essentially represented in terms of classifying service disruption interdependencies between infrastructure networks (see Fig. 1b).

Various forms of 'resilience assessments', such as in the examples outlined above, are emerging in abundance to help prioritise investment in ecosystems,

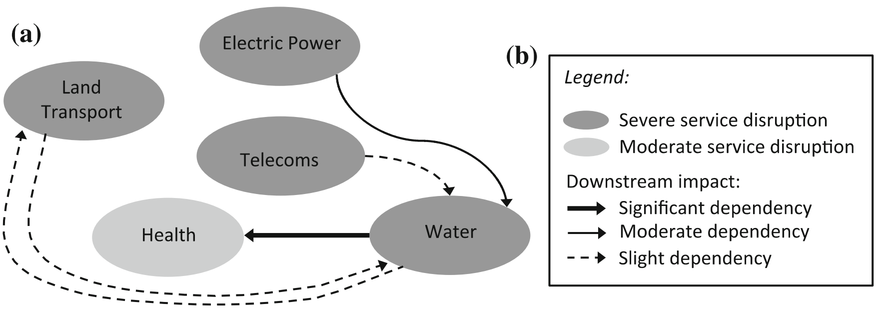

Fig. 1 Comparison of interpretations of resilience in DRM: **a** a general framework for community resilience reproduced from Longstaff et al. (2010) and **b** a model of infrastructure interdependencies produced in Vancouver case study showing expected service disruption immediately after an earthquake, reproduced from Chang et al. (2014). For simplicity, this diagram is only a partial reproduction, highlighting the immediate dependencies associated with water infrastructure only

cities, infrastructure and communities. Some commentators (such as Manyena 2006) highlight the risk that the term "resilience" can lack substance rather than be a useful concept. Nearly a decade on, Manyena's sentiments remain understandable, as there is not a basis for finding common ground between different analyses of resilience. However despite differing interpretations, resilience is proving to be a useful concept in which to define a problem and frame appropriate solutions.

Given the broad application of resilience, we sought a way to systematically understand how different applications correlated within the broader context of DRM. DRM involves a range of different actors with different priorities and interests. These actors will naturally construct different meanings or realities when given the same information (as discussed by Fischer 2003 in relation to public policy), each following their own "internal logic" (Aldunce et al. 2014 p. 261).[5] The intent of our framework is to recognise sector-specific and trans-disciplinary applications of resilience within DRM. The framework does not provide a new interpretation of resilience, but captures how resilience is applied in different ways, understanding boundaries around specific interpretations and how better connections may be made across different disciplines.

An initial version of the framework was first published as a conference paper at the *4th International Conference on Building Resilience* in 2014 (MacAskill and Guthrie 2014).[6] The structure of the framework emerged through an adaptation of a linguistic study that examined the changing meaning of a concept over time and through culture. In the study, different definitions of the same concept were displayed in a simple sunburst-style diagram as a way of showing categories of interpretation in a multi-level, radial format. For resilience, we found there were not just different conceptions of the term, but a number of key themes or categories that give shape to any interpretation of resilience. Thus, we set out to identify key differences in application as a way of developing the main categories. These categories were established through an iterative literature review covering a range of texts focused on resilience in DRM. This has been an inductive, iterative process and the framework shown Fig. 2 is a refined version of our initial published framework, where we have made adjustments based on feedback and further review.

Essentially, Fig. 2 catalogues various conceptions of resilience, grouped under broader themes. The first level of definition highlights two main aspects that shape any interpretation—context and application.

[5]Perceptions of different groups of people is also discussed in Duijnhoven and Neef's chaper in this book on "disentangling wicked problems".

[6]This conference bought together practitioners and academics to explore the concept of resilience as a framework for analysis of how society can cope with the threat of hazards.

Fig. 2 A conceptual framework for defining resilience in DRM (updated from MacAskill and Guthrie 2014)

Context factors describe the environment in which resilience is applied. The environment may influence what categories within the application theme are emphasised. The *societal* factor refers to the level of economic development of the location. This is represented by a basic distinction between *developed* and *developing* countries, where developed countries typically have more stable institutions, greater access to capital and higher levels of technological sophistication in the structure of urban areas. The *scale* indicates a focus on the *community*, *city*, or *nation/state* scale, where the scale can have an impact on perspective and nature of an analysis. *Threat* describes the stimuli for considering resilience, where responses to acute shock such as a hurricane or an earthquake are markedly different than planning to mitigate impacts of chronic stress such as climate change. Different areas are exposed to different threats, thus the nature of focus of what communities are seeking to be resilient *to* will change. This may have an impact on what perspectives or objects of resilience are prioritised.

The *application* theme describes the nature of the analysis in terms of the system or network under consideration. The *perspective* category defines the type of system that forms the focus of assessment, which may be related to: the development of *infrastructure/urban structure*; *organisational* performance; *institutional* arrangements that set the overarching political and economic framework; or more of a *social* focus, concerned with capabilities and resources available to communities. This relates to United Nations Office for Disaster Risk Reduction's definition of resilience, which emphasises a similar multiplicity of perspective in terms of what is exposed to a hazard, where resilience is described as:

> The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions
>
> United Nations Office for Disaster Risk Reduction (2009, p. 24)

The *object* describes the mode of resilience, that is, way or manner in which resilience is taking place. This may be by way of *governance* (which tends to be associated with a decision process), a measure of a *system* or a *component* property that supports the preservation or restoration of basic structures or functions. The idea of governance in resilience is the most unusual interpretation in terms of the more literal understanding of resilience as a quality or property *of* something. However the role of governance, institutions and the ability to gather knowledge and learn has become part of a broader understanding of how resilience is achieved. These factors form a critical part of the ability of systems to recover. As such, they were recognised in the Hyogo Framework for Action, where one of the five priorities was to: "Use knowledge, innovation and education to build a culture of safety and resilience at all levels." That is, the process of governing a system has become a representation of the system's resilience. As another example, Park et al. (2013) describe resilience as an approach to the design and development of engineering systems that requires a recursive cycle of sensing, adaptation, anticipation and learning. They maintain Hollnagel et al.'s (2011) view that resilience of an engineered system is informed by expert knowledge and judgement, rather than through an analytic analysis. This view is supported by other authors such as Olsson et al. (2006), who describe adaptive governance for social-ecological systems, and Davoudi (2012) who reinforces that system governance is an essential part of the scope of a resilience, which is a dynamic concept that spans scale and time.

While governance for resilience is coming into significant focus, physical and system properties are still relevant. Park et al. (2013, p. 4) argue against this, suggesting that resilience is not a "static property of state" but an "ongoing adaptive *process*". However to claim that physical property does not contribute to resilience of a system is to ignore part of the broader understanding of resilience. Indeed, a reference to the basic definitions of resilience demonstrates this. The Oxford English Dictionary provides definitions for both literal applications and figurative uses. Literal applications define resilience as the action or act of rebounding and the property of elasticity or ability to absorb energy. Figurative uses include some obsolete or rare interpretations such as "going back upon one's word", an instance of recoiling from something or a representation of antagonism. The final figurative definition outlines resilience in a way that is more fitting to much of our discussion thus far, that is:

> The quality or fact of being able to recover quickly or easily from, or resist being affected by, a misfortune, shock, illness, etc.; robustness; adaptability.
>
> OED Online. December 2014.

Both the literal interpretations and the figurative usage do not exclude the idea of resilience as a property of state. This is reflected in the United Nations Office for Disaster Risk Reduction's outline for a holistic approach to resilience that embraces both structural and non-structural measures in the *application* of resilience:

> **Structural measures**: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems.
> **Non-structural measures**: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.
> United Nations Office for Disaster Risk Reduction (2009 p. 28)

However, such broad coverage typically only appears in the form of international or national policy frameworks (such as in the goals in the Hyogo or Sendai Frameworks). Applications closer to planning and implementation tend to be narrower in scope, focusing in on a specific selection of measures. Such as (using our previous example) in Park et al. (2013), who describe approaches to catastrophe management in engineering systems. Their focus is very much on the governance of physical infrastructure through processes associated with design and management. They pointedly do not address resilience as a physical property, taking a view that resilience lies in the process of governance. They also do not discuss community resilience. Chang et al. (2014) also focus on infrastructure systems (their approach was previously shown in Fig. 1), but take a broader view of governance, system and physical properties of resilience, addressing system interdependencies in service disruption. By way of contrast, Allan and Bryant (2014) look at resilience in urban theory—analysing the system properties of urban environments and how communities interact within these environments in a recovery situation. These examples are just a small selection from recent literature, but represent a wider trend where resilience is used as a concept for analysing system performance. We are not criticising the authors of these works for taking a sector specific view. In fact, we have yet to find a paper that analyses the full spectrum of categories associated with the *application* segment of the resilience framework. There is a higher level of complexity associated with attempting to cover all perspectives in one analysis, to the point where it compromises the ability to come to meaningful conclusions. However, the key point is that each interpretation needs to be made with an awareness of the broader context of resilience in DRM. The purpose of our framework is not to place different interpretations at odds, but to discover how these interpretations may be complementary or where there are potential points of divergence that need to be addressed in any approach to building resilience.

We also do not propose that the framework provides definitive way to categorise resilience. While the diagram implies definite categories, the reality is the boundaries are fuzzy. We have ourselves adapted it over time as our thoughts developed around how to best represent various categories and to better capture differences in use. Our aim was to keep the framework simple enough that it is accessible as a quick reference, but with enough detail that it acts as a useful and constructive tool for understanding how sector-specific interpretations lie within broader considerations of resilience.

While the framework identifies different systems and types of resilience (the "what"), it does not go as far as highlighting measures (the "how")—i.e. it does not describe measures or metrics of resilience, which may be entirely sector specific. In terms of reconstruction for example, it is difficult to define exactly how building resilience should (or could) be incorporated into the process. It is not just a matter of the cost involved in building back better, but the time needed to understand the impacts and consult on alternative options, all while considering context-specific factors. It is possible that methods associated with "how" to build in resilience could form another layer in the hierarchy. This relates to both methods of implementation and capacity or willingness to ultimately implement the required action. This however, adds another layer of complexity and the framework has value in simply highlighting different perspectives, as will be demonstrated in the Christchurch case study.

4 Post-earthquake Reconstruction in Christchurch New Zealand

The resilience framework is broadly applicable to all phases of DRM but it is longer-term recovery to which we pay particular attention in this section. The following analysis of post-earthquake reconstruction in Christchurch demonstrates how the framework can be useful in shaping insights into the complexity of a multi-sector process. To provide some context, we will briefly introduce the institutional environment for DRM in New Zealand. We will then move into a more detailed analysis of the recovery process currently underway in Christchurch—the second largest city in the country with a population of approximately 370,000 (see Fig. 3 for a simple map of New Zealand, locating Christchurch). We discuss the recovery in terms of different perspectives in the resilience framework, with a focus on the recovery of publically owned and operated infrastructure networks—roads, stormwater, wastewater and water supply. This study of Christchurch is informed by a broader research project involving a longitudinal study of infrastructure network recovery in New Zealand. The research involves interviews with engineers and executives leading the reconstruction in Christchurch, supported by a range of documentation such as design reports, recovery plans and government reviews.

We have completed a similar analysis for a special issue journal on resilience for Elsevier's Civil Engineering and Environmental Systems (MacAskill and Guthrie 2015). However, this earlier paper focuses on a range of interventions associated with resilience in infrastructure recovery, that is, "how" resilience has been integrated into the infrastructure networks during reconstruction. While we borrow some examples from this earlier paper, we are more concerned here with the broader interpretation of resilience in DRM and how the institutional and

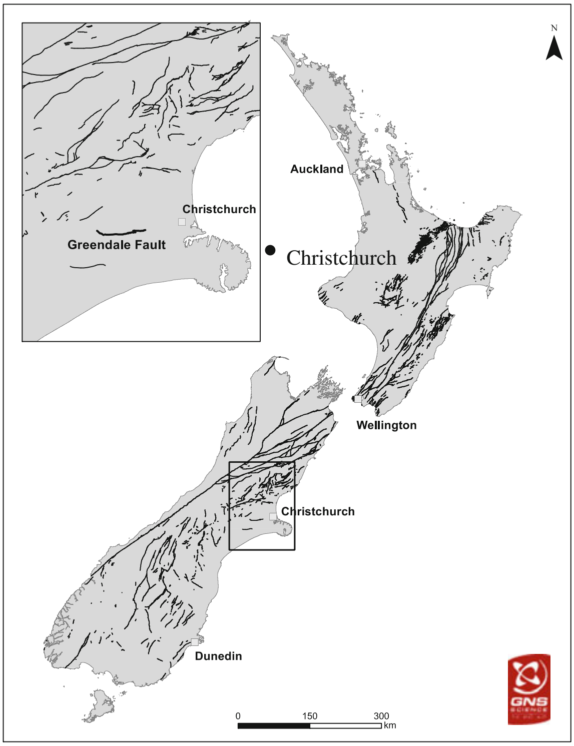

Fig. 3 Map of New Zealand indicating active faults. New Zealand is a geologically active country, sitting on the boundary between the Australian and Pacific plate. The Greendale Fault (see inset) was the major cause of the September 2010 earthquake in Canterbury. See www.gns.cri.nz for a more detailed analysis. Map courtesy of William Ries, GNS

organisational arrangements facilitate or prevent a holistic approach to a "Resilient Recovery" (GFDRR 2014a) in Christchurch. We maintain a focus on the restoration of infrastructure services, but with more emphasis on how infrastructure recovery sits within the wider recovery arrangements in Christchurch.

4.1 Institutional Context

New Zealand operates through two main tiers of government—central/national government and local government. There are then two parts to local government: regional councils are responsible for managing regional concerns such as water management, land transport and civil defence; district and city councils are responsible for the general well-being of the local communities and provision of infrastructure services.

A National Civil Defence Emergency Management (CDEM) strategy sets the strategic direction for hazard management across the country (Government of New Zealand 2013). The strategy is guided by an integrated approach to CDEM that addresses the lifecycle of DRM through what is known in the industry as the '4Rs':

reduction, readiness, response and recovery. The associated CDEM 2002 Act does not provide a prescriptive guide to recovery; it only requires councils and CDEM groups to facilitate recovery. As will be explained shortly, the nature of the recovery arrangements in Christchurch changed quite dramatically in a flexible response to different scales of damage.

From 2010 to 2011, the Canterbury region of New Zealand experienced a sequence of earthquakes. Amongst thousands of earthquakes recorded in this sequence were several major events that caused significant damage in Christchurch and the surrounding Canterbury region. The first major earthquake occurred in September 2010 with a magnitude of 7.1, centred approximately 40 km from Christchurch. The most damaging event occurred in February 2011 with a magnitude 6.3, located only 5 km from the city centre. This event resulted in 185 deaths (the only event in the sequence where there was loss of life) and damaged most of the buildings in Christchurch's central business district. While many of the buildings survived the earthquake, they were damaged beyond economical repair and have subsequently been deconstructed. There was also extensive damage in residential areas and infrastructure services across the city. Some areas experienced loss of water supply and wastewater reticulation along with severe damage to transport networks; it is the recovery of these infrastructure services that forms the focus of this case study.

Following the first earthquake in September 2010, Christchurch City Council set up an Infrastructure Recovery Management Office (IRMO). The key role of IRMO was to administer the overall programme management for reinstating services provided by roads, water supply, wastewater and stormwater. The repairs were to be completed through four separate design-build contracts with companies that specialise in civil construction. Each company was allocated a specific area of the city to repair. Progress under these contracts was just starting to gain momentum when the second major earthquake occurred in February 2011, just five months after the first event.[7] The larger scale of damage caused by this event called for a more integrated, city-wide approach to repair, where division of the city through four separate contracts was no longer an effective or efficient means for coordinating the recovery (more detail regarding the IRMO arrangements is provided in Office of the Auditor General's (OAG) report, 2012).

This led to the creation of an alliance organisation, SCIRT, under which the original design-build contracts were transferred into an alliance arrangement. An alliance contract is a collaborative arrangement where contract participants (the owner-participants and the service providers) work together as a team in a temporary or virtual organisation, with joint responsibility over project risks. It is worthwhile highlighting here that the alliance arrangement had not been a pre-determined concept for disaster recovery in New Zealand. It emerged as a result of a complexity of factors, where: alliance arrangements had been successfully used

[7]It is worth noting that the February earthquake generated unexpectedly strong ground movements relative to the magnitude of the earthquake.

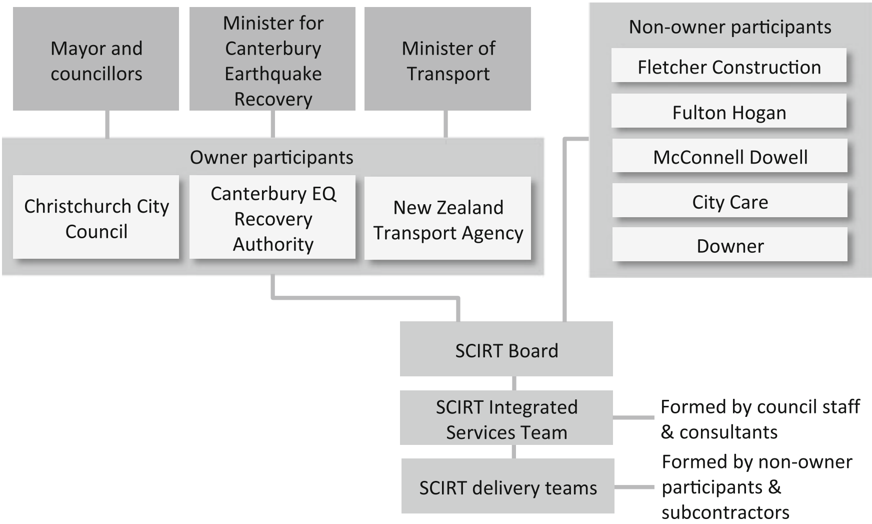

Fig. 4 Organisational arrangements at SCIRT (see OAG 2013 for a more detailed diagram)

on large projects in New Zealand; key leaders had prior experience in alliancing; and, there was no prescriptive policy on how recovery is to be managed. There was also an opportunity to develop an innovative arrangement while the existing IRMO arrangement continued to manage repairs—SCIRT was not formally established until September 2011. Christchurch City Council became a main client of SCIRT, with some council staff directly seconded into the alliance. SCIRT's work covers 85 % of the infrastructure rebuild in the city, with the remaining work covered by the Christchurch City Council's in-house operations (as outlined in the Stronger Christchurch Infrastructure Rebuild Plan, 2011). The estimated figures for the rebuild are in the order of $NZ 2 Billion.[8] The general organisational arrangements are outlined in Fig. 4. SCIRT has a five-year contract that is due for completion in 2016. As of January 2015, the reconstruction of the infrastructure networks was about 60 % complete.

4.2 *Integrating Resilience into Infrastructure Recovery*

SCIRT's primary focus is on restoring infrastructure services. A guiding document, the *Infrastructure Recovery Technical Standards and Guidelines* (IRTSG), was

[8]For a rough comparison $NZ 1 is approximately $US 0.84 (12 month rolling average to December 2014). Note the mid-month rate for December 2014 was $US 0.77.

developed as to provide scope and context to the repair and reconstruction process. This document specifies the primary objective of SCIRT, which is

> To return the infrastructure networks to a condition that meets the levels of service prior to the 4 September 2010 earthquake within the timing constraints of the rebuild.

This is supported by a secondary objective:

> Where restoration work is undertaken, and where reasonably possible and economically efficient and viable, greater resilience is to be incorporated into the network.

The critical element for discussion here is the IRTSG definition of resilience:

> **Resilience:** the ability of a system to withstand or quickly recover from significant disruption. The important concepts are as follows:
>
> - Service interruptions are expected
> - Quick restoration of service is required
> - Infrastructure networks must be robust
> - Infrastructure networks must be flexible
>
> **Resilience Measures** include additional components to ensure that modern materials can withstand, or quickly recover from, significant hazards or disruption. This includes network system components for the same purpose, beyond a standard modern design and may include additional levels of redundancy and network connectivity.
> SCIRT IRTSG (2013)

Clearly, resilience forms a key part of the decisions around restoration or repair in Christchurch, but it is inevitably a sector-specific perspective. In terms of the day-to-day business in SCIRT, resilience is defined as a concept that addresses the physical and system properties of the infrastructure networks. Figure 5 demonstrates this application of resilience in the framework.

The IRTSG definition guides the integration of resilience principles for reinstating infrastructure services through interventions in *component* and *system* properties. Enhanced infrastructure resilience may be through the use of modern materials and design standards. Greater strength (such as ground reinforcement and improved structural design) and flexibility (such as the use of flexible plastic materials in piping) are often inherent in the use of modern materials. Also, some standard design details were adjusted in Christchurch to help vulnerable points in the systems better withstand earthquake damage. These changes in *components* are the most widely applied means of increasing resilience. Also, designs for the worst affected areas have involved some significant changes in *system* properties. These are areas where the level of damage justified complete reconstruction of the infrastructure assets, rather than more patch-type repair. One such change has been the introduction of pressure sewer technology in some locations. Engineers at SCIRT judged that pressure sewer technology would be better able to withstand earthquake damage compared to the existing gravity-fed systems (reliant on relatively low grades to carry wastewater towards the treatment plant), which sustained complete loss of service in some areas. This is because gravity-fed systems are vulnerable to land movement and differential settlement associated with earthquakes; without sufficient pipe gradient in the right direction, these systems fail to

Fig. 5 Interpretation resilience at SCIRT: Resilience in the recovery of Christchurch's infrastructure. Our analysis here is focused on the post-earthquake context, following a rapid-onset natural disaster that had city-wide impact. Key aspects of resilience in this case are emphasized in *dark grey*

operate. Significant system changes also included relocation of wastewater pump stations away from ground vulnerable to liquefaction, reducing the risk of structural damage in a future earthquake.

There have also been major *urban structure* interventions in Christchurch that impact the reinstatement of infrastructure networks. A Residential Red Zone was created in particularly liquefaction-prone or rock-fall-prone areas of land. The red zone has effectively become areas of interim retreat, with no clear plan regarding future land use. Given this uncertainty, reconstruction of infrastructure has been avoided, where possible, in these areas. While avoiding vulnerable ground could assist in providing infrastructure system resilience, decisions regarding land use were made at a national and political level. SCIRT responded to these decisions through the design process, but the major decision directing this response was beyond the organisation's remit and is thus not clearly reflected in the organisation's definition of resilience.[9]

This leads us to the challenges in organisational, technical and financial arrangements of the infrastructure rebuild in Christchurch that influence how much resilience may be added to the systems. We discuss several of these points in MacAskill and Guthrie (2015). Firstly, there is marginal utility in paying for interventions and a subsequent differential investment in networks, where some resilience interventions are more cost effective than others. Also, the fixed scope of work of an organisation and the level of autonomy the organisation has over

[9]All these examples regarding physical, system and land use intervention are discussed in greater detail in MacAskill and Guthrie (2015).

decisions will impact on the feasibility of possible interventions for resilience. There is also a matter of scale, where it is only the result of considerable damage where extensive, systemic intervention is justified. Finally, financing arrangements have significant impact, not just in terms of the amount of funding available but also because there are restrictions on what funds can be used for. For example, insurance policies are typically structured around the concept of like-for-like replacement.

While the sector-specific interpretation of resilience at SCIRT reduces some of the complexity surrounding recovery decisions, complexity remained in determining exactly what introducing resilience meant in reality. SCIRT is an engineering-based organisation that operates on the basis of a technical interpretation of resilience. Resilience assessment at SCIRT is aimed at informing design decisions for the reconstruction of infrastructure. However, despite this relatively narrow perspective (compared to all perspectives in the resilience framework), resilience is just one factor in the design process, evaluated alongside other technical and financial considerations. There is an important qualification in SCIRT's objectives in that resilience is introduced "where reasonably possible and economically efficient and viable". This fuzziness is also reflected in the United Nation's definition which describes recovery as the "restoration, and improvement *where appropriate*, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk" (United Nations Office for Disaster Risk Reduction 2009 p. 23, emphasis ours). Initially, determining an "appropriate" solution for damaged infrastructure was not completely clear in Christchurch. Designing infrastructure repairs involved a process of testing boundaries of the guidelines on a case-by-case basis. This process was formalised through a "Scope and Standards" committee, whereby client representatives would consider: what level of intervention was appropriate, where extra funds should be spent and what precedents might set for projects scheduled later in the programme.

Complexity also remains in the fact that infrastructure networks are inherently linked to the community, where a technical or infrastructure-oriented perspective of recovery will not be successful without acknowledging potential social impact or the needs and desires of the community. This is discussed in the following sections on linking the infrastructure reconstruction to the broader recovery and identifying where there is potential to create stronger links across perspectives of resilience.

4.3 Linking to the Wider Recovery

Despite a clear focus on the technical features of infrastructure resilience in recovery, it is recognised within SCIRT that infrastructure reconstruction does not occur in isolation of the wider community. In fact, SCIRT's core goal to create "resilient infrastructure that gives people security and confidence in the future of Christchurch" recognises that the infrastructure exists in order to serve the community.

Through interviews with staff at SCIRT, we identified two major factors that create a link between the infrastructure recovery facilitated by SCIRT and the wider community. The first relates to the overall prioritisation of the city-wide programme of repair over SCIRT's five-year contract. This programme was developed in coordination with staff at the Canterbury Earthquake Recovery Authority (CERA—one of SCIRT's owner participants), which gathered stakeholder views on the infrastructure rebuild in the context of the wider recovery. Consultation with representatives from groups concerned with issues such as economic development and social well-being brought to attention the factors of the wider community recovery that may be impacted by choices in prioritisation of suburbs. Such concerns were considered alongside the more traditional technical considerations of asset managers relating to operational priorities and network interdependencies. Generally, work in the worst affected areas was prioritised, which were often areas comprising more vulnerable communities.

The second factor is the nature of the communication strategy with the community throughout the rebuild programme. A communications team at SCIRT keeps Christchurch residents informed of infrastructure work in their community and across the city. We report here on some reflections from representatives of this team on the process of communication in recovery.

Initially, communities were generally accepting that the earthquakes had created a situation where disruptive repair work was necessary. However, tolerance levels declined over time with no clear ramp-up or ramp-down in construction work. There was a risk of 'consultation fatigue', a phenomenon recognised in attempts to create more participatory processes to policy-oriented decision-making. In light of this, the communications team recognised that sending more communication notices did not necessarily lead to a better informed community who will be more accepting of ongoing construction work. The team also learnt that even though a notice of work may have been delivered, the message might not have been completely received, understood or accepted. When it came to face-to-face discussions with the community in particularly vulnerable or badly affected areas, team members learnt to allocate extra time. This allowed time for residents to express frustrations surrounding the wider recovery process and to develop rapport before attempting to discuss infrastructure repairs in the area. The communication process was also not just about informing residents, but also creating transparency in the process through education. This included campaigns to explain what infrastructure services/utilities run through a road corridor and the process for repair for each service, or to explain why a different style of wastewater system is proposed for certain areas of the city.

These examples help to demonstrate the connections between the more technical aspects of the infrastructure reconstruction and the wider community recovery (Fig. 6). However, finding the right balance proved to be a difficult task. In terms of community involvement in decisions, typically, only an "inform" approach is

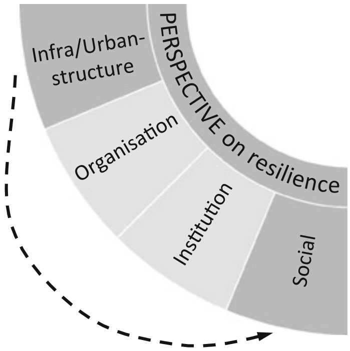

Fig. 6 Linking infrastructure recovery with a more social perspective

required where the recovery involves replacing assets that already existed.[10] This approach formed the basis of a lot of the communication programme at SCIRT. However, introducing change that has a tangible affect on the community requires gaining acceptance of affected parties through consultation. The Local Government Act 2002 provides guidance on requirements for consultation however the choice of appropriate method is a discretionary judgment and obligation to consult is dependent on the matters of significance. Contention over a particular case of infrastructure recovery in Christchurch led to a High Court hearing.[11] In Bailey versus Christchurch City Council (2013), a local resident challenged the legitimacy of Council's plans to introduce pressure sewer systems as a means of reinstating wastewater services in some Christchurch communities. The argument was essentially over the need for putting pumps on private property, which had not been part of the existing (but badly damaged) system. This required connecting the pumps to private dwelling electricity supply. The judge ruled that the Council failed to adequately consult when introducing new wastewater technology as a recovery solution. The judge found error in the decision not to consult with residents on the need to place pumps within private property boundaries, where the Council placed emphasis on the technical aspects of system performance without appropriate consideration of the potential social impact of the decision. This judgement reinforces that even during the time-constrained pressure of post-disaster recovery, there is a need to recognize that different perspectives among stakeholders will affect perception of priorities. In this case, there was conflict over the direct impact on private property versus reduction in risk of system damage in the future.

[10]See Arnstein (1969) for discussion on the "ladder of citizen participation". The "inform" level is at the lower end of participation in decision-making, where residents are informed of decisions, rather than actively participating in them.

[11]The High Court is mid-level court in New Zealand. It sits above the District Court below the Court of Appeal and the Supreme Court. It tends to deal the most serious criminal offences and civil cases that are beyond the jurisdiction of the District Court.

4.4 Potential for Stronger Links Across Perspectives?

SCIRT's mandated role and objectives in Christchurch's recovery is unmistakably oriented towards the rebuild of infrastructure networks. The definition of resilience in the technical guidelines is expressed in terms of the physical and system resilience of these networks. However, there is also clear consideration of how actions associated with the reconstruction of infrastructure would impact on the community, managed through a major communications process. This required certain judgments to be made about appropriate levels of communication with the community, which were not always fully supported by all affected parties. This is in part due to the strong technical framing of resilience within SCIRT, but also due to lack of clear understanding as to how business as usual consultation processes may be affected in a post-disaster context. There was a perceived need at Council to fast-track infrastructure reconstruction projects, but this came into contention with requirements for consultation. This is an issue that spans a range of contexts in post-disaster recovery, as highlighted in one of the GFDRR case studies supporting the guide to recovery:

> The post-Sidr experience [in Bangladesh] has demonstrated that design and construction processes are largely driven by experts and engineers with limited community involvement. Owner-driven construction, on the other hand, is often perceived to be time consuming and difficult to implement in a deadline-driven situation. Although the use of private contractors is a feasible option, there is a need to strengthen communication between the private sector and humanitarian actors.
> GFDRR (2014c)

While humanitarian involvement is not a significant feature in the recovery of Christchurch, appropriate levels of community involvement in recovery decisions remains a contentious point. The High Court case highlighted inadequacies in the Council's focus on technical factors in their decision-making. While this approach ultimately meant the Council failed to execute due process according to its statutory obligations, this was done with the intention of a good outcome for the community, where the aim was to:

> …build stronger systems, better able to withstand any future earthquakes. Many thousands of residents were left without functioning toilets for several months because of significant earthquake damage to the system.
>
> We went through a thorough process to determine the best system for different areas of the city. In some areas, we concluded that the gravity system was not damaged enough to require replacement; in others we are introducing new pressure or vacuum sewers to make the system stronger…
>
> Terry Howes, Council's City Environment Acting General Manager, quoted in Christchurch City Council 2013

This quote demonstrates how the Council looked for a long-term solution for the community, where a stronger system would reduce the risk of loss of service to residents. However, this perspective of a "stronger" system was in contention with community concerns. This conflict resulting from a divergence in perspective

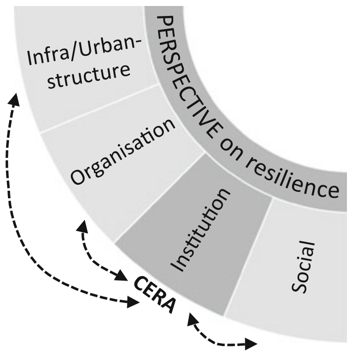

Fig. 7 CERA is the leading agency for the recovery effort in Canterbury (the wider region encompassing Christchurch). CERA administers the Canterbury Earthquake Recovery Act and works with other Councils, Te Rūnanga o Ngāi Tahu (the local Maori tribal council) and engages with the local communities, private and business sector to coordinate across the range of perspectives in recovery

ultimately led to the Council rescinding its decision to install pressure sewer systems. This has been followed by further consultation and a feasibility study of installing pumps in council-owned land, slowing the intended programme for reconstruction in these areas. This example confirms ideas raised earlier regarding different actors having their "own internal logic" regarding what is important and that there is a need to find ways to negotiate across different perspectives (Aldunce et al. 2014).

In terms of the broader recovery of the region, development of organisational and community resilience fall under the responsibilities of other organisations, overseen and coordinated by CERA (see Fig. 7). The relationship between CERA and other organisations involved in recovery is critical in achieving an integrated *application* of resilience in the process. However, these relationships have proved to be fractured and difficult to maintain. In 2013 an official review by the Office of the Auditor General (OAG) in New Zealand highlighted two main risks to the delivery of the infrastructure rebuild programme—lack of the CERA's engagement in the programme and lack of agreement over the exact nature of the scope of work. We will concentrate here on the first risk, where CERA's absence of engagement created uncertainty in the strategic leadership of the SCIRT alliance. This was due to lack of clarity around clear objectives and roles in leading the rebuild programme and an apparent lack of commitment from CERA to the infrastructure rebuild, where staff turnover and restructuring impeded development of a working relationship. The OAG report clearly stated that CERA "needs to facilitate better connections between SCIRT and other government agencies to better integrate the horizontal infrastructure with the rest of the Canterbury recovery" (para. 5.6). This issue was subsequently addressed, but there has been continued uncertainty over financial arrangements. For example, a cost-sharing agreement between the national and local government was signed in mid-2013, setting out funding commitments.

This agreement included a clause that allowed for future review, however different views remained amongst owner-participants in the alliance as to what this review would entail.

5 Conclusion

In this chapter, we have presented a framework that provides a means of placing different perspectives of resilience within a broader classification of resilience in DRM. An essential element of the framework is to demonstrate that a holistic approach to resilience in DRM addresses a range of perspectives covering infrastructure/urban structure, organisations, institutional arrangements and social considerations. The reality is that approaches to addressing resilience are often more limited in application, but they need to be considered within this broader context.

To demonstrate the merit of the framework, we used it as a basis for critiquing the post-earthquake recovery in Christchurch. We discussed how a technical, infrastructure-specific interpretation of resilience shaped decision making for reconstruction of infrastructure networks. This technical framing provided a clear basis on which to consider resilience in restoring infrastructure services. However, while engineers tend to treat infrastructure design as a technical process, infrastructure exists to provide services to the community. A purely technical interpretation of resilience focused on physical attributes of the infrastructure network itself will ultimately present shortfalls in implementing a successful recovery, which requires a broader, more integrated approach.

Despite an infrastructure-specific definition of resilience, infrastructure recovery goals in Christchurch were based on an awareness that infrastructure exists for the community and that the city-wide programme of infrastructure repair has a significant impact on residents. While an extensive consultation programme was in place, key decisions did not always achieve the right balance between technical rigour and consideration of community perspectives. Furthermore, competing perspectives within the governance of the infrastructure reconstruction have challenged the delivery of infrastructure reconstruction programme.

Such issues emerged through examining not just the basic arrangements of the recovery process, but a finer level of detail in terms of how certain perspectives influence the decision making process. The resilience framework provided a means of understanding the trade-offs that were made in integrating resilience in reconstruction and sources of conflict along the way. Insights gained from examining the Christchurch case demonstrate the usefulness of the resilience framework in understanding the role of resilience in DRM.

References

Aldunce P, Beilin R, J Handmer, Howden M (2014) Framing disaster resilience: the implications of the diverse conceptualisations of 'bouncing back'. Disaster Prev Manage 23(3):252–270

Allan P, Bryant M (2014) The attributes of resilience. Int J Disaster Resil Built Environ 5(2): 109–129

Arnstein SR (1969) A ladder of citizen participation. JAIP 35(4):216–224

Bailey versus Christchurch City Council (2013, Aug 2) NZHC 1933

Chang SE, McDaniels T, Fox J, Dhariwal D, Longstaff H (2014) Toward disaster-resilient cities: characterizing resilience of infrastructure systems with expert judgments. Risk Anal: Off Publ Soc Risk Anal 34(3):416–434

Christchurch City Council (2013, Aug 8) High Court decision on pressure sewers announced [online]. http://www.ccc.govt.nz/thecouncil/newsmedia/mediareleases/2013/201308082.aspx. Accessed 27 Jan 2014

Christchurch City Council (2011) Stronger Christchurch infrastructure rebuild plan. Christchurch: Christchurch City Council. http://resources.ccc.govt.nz/files/canterburyearthquake/scirt-infrastructure-rebuild-plan_web.pdf. Accessed 21 Mar 2015

Coaffee J, Murakami D, Wood D, Rogers P (2009) The everyday resilience of the city: how cities respond to terrorism and disaster. Palgrave Macmillan, Basingstoke

Davoudi S (2012) Resilience: a bridging concept or a dead end? Plan Theory Pract 13(2):299–333

Fischer F (2003) Reframing public policy: discursive politics and deliberative practices. Oxford University Press, Oxford

GFDRR (2014a) Guide to developing disaster recovery frameworks—world reconstruction conference version. World Bank, Washington, DC

GFDRR (2014b) Yemen: tropical storm, October 2008—recovery framework case study—conference version. World Bank, Washington, DC

GFDRR (2014c) Bangladesh: planning and implementation of post-Sidr housing recovery: practice, lessons and future implications—recovery framework case study—conference version. Washington, DC, World Bank

Government of New Zealand (2013) Progress of the national civil defence emergency management strategy. New Zealand: Office of the Minister of Civil Defence. Sourced from: http://www.civildefence.govt.nz/assets/Uploads/publications/national-CDEM-strategy-progress-report-april-2013.pdf. Accessed on Feb 2015

Hollnagel E, Paries J, Woods DD, Wreathall J (2011) Resilience engineering in practice: a guidebook. Ashgate Pub Co, Burlington

Longstaff PH, Armstrong NJ, Perrin K, May W, Hidek MA (2010) Building resilient communities: a preliminary framework for assessment. Homel Secur Aff 6(3)

MacAskill K, Guthrie P (2014). Multiple interpretations of resilience in disaster risk management. In: 4th international conference on building resilience, Salford Quays, 8–10 Sept 2014. Elsevier, UK

MacAskill K, Guthrie P (2015) A hierarchy of measures for infrastructure resilience—learning from post-disaster reconstruction in Christchurch, New Zealand. Civil Engineering and Environmental Systems. doi:10.1080/10286608.2015.1022728

Manyena SB (2006) The concept of resilience revisited. Disasters 30(4):433–450

Olsson P, Gunderson LH, Carpenter SR, Ryan P, Lebel L, Folke C, Holling CS (2006) Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecol Soc 11(1):18

OAG (2012) Roles, responsibilities, and funding of public entities after the Canterbury earthquakes. Office of the Auditor General, Wellington

OAG (2013) Effectiveness and efficiency of arrangements to repair pipes and roads in Christchurch. Office of the Auditor General, Wellington

Park J, Seager TP, Rao PSC, Convertino M, Linkov I (2013) Integrating risk and resilience approaches to catastrophe management in engineering systems. Risk Anal 33(3):356–367

"resilience, n." OED online. December 2014. Oxford University Press. http://www.oed.com/view/Entry/163619?redirectedFrom=resilience. Accessed on 15 Feb 2015
Rodin J (2014) The resilience dividend: being strong in a world where things go wrong. PublicAffairs, USA
SCIRT (2013) Infrastructure recovery technical standards and guidelines. Christchurch City Council, Christchurch
United Nations (2014) Post-2015 framework for disaster risk reduction—zero draft submitted by the co-chairs of the Preparatory Committee. United Nations, Geneva. Sourced 15 Feb 2015 from http://www.wcdrr.org/uploads/1419081E.pdf
United Nations Office for Disaster Risk Reduction (2007) Hyogo framework for action 2005–2015—building the resilience of nations and communities to disasters—extract from the final report of the world conference on disaster reduction (A/CONF.206/6). United Nations Office for Disaster Risk Reduction, Geneva
United Nations Office for Disaster Risk Reduction (2009) UNISDR terminology on disaster risk reduction. United Nations Office for Disaster Risk Reduction, Geneva
Zolli A, Healy AM (2012) Resilience: why things bounce back. Business Plus, Great Britain

'Black Swans', 'Dragon Kings' and Beyond: Towards Predictability and Suppression of Extreme All-Hazards Events Through Modeling and Simulation

Anthony J. Masys, Eugene Yee and Andrew Vallerand

Abstract Shocks to regional, national and global systems stemming from natural or man-made hazards can have dramatic implications. Disasters such as Katrina (2005), Hurricane Sandy (2012), Alberta (Canada) Floods (2013), and Super Typhoon Haiyan (2013) are examples that highlight the vulnerability of communities to natural hazards and the crippling effect they have on the social and economic well-being. Through foresight and scenario planning, such events can be expected but can they be predicted to support resilience and enable suppression of the impacts? With consideration of emerging and systemic risks and inherent uncertainty associated with surprising events, planning for and managing risk, crisis and disasters requires understanding of the outliers that challenge our resilience. 'Black Swans' represent the unpredictable. They represent "… our misunderstanding of the likelihood of surprises" (Taleb in The black swan: the impact of the highly improbable, 2007). A 'Black Swan' is described by Taleb (2007) as that which is an outlier, that which is outside the realm of regular expectations which carries with it an extreme impact such as natural disasters, market crashes, catastrophic failure of complex socio-technical systems and terrorist events such as 9/11. Sornette (Int J Terraspace Sci Eng 2(1):1–18, 2009) identifies a different class of extreme events (outliers) that he calls 'Dragon Kings'. Sornette (2009) argues that Dragon Kings may have properties that make them not only identifiable in real time but also predictable. The evolving science on complexity (and, more specifically, on complex networks) and on resilience suggest that modeling and simulation of such extreme events can assist in the predictability and the suppression of low probability extremely high consequence events such as natural hazards (flood, earthquake, wildfire, tsunami, extreme weather), cyber-attacks, and financial events. Furthermore, the science of complex networks is developing rapidly and has

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fundamentally reshaped our understanding of complexity, potentially leading to innovative methods for the prediction of emergent behavior on natural and technological networks, as well as specific strategies for designing networks that are more resistant (resilient) to both failure and attack. Governments and owners of critical physical and digital infrastructure may benefit from analyses, advice and exercises that involve predictable and suppressible "Dragon-King" type of low probability extremely high consequence extreme events, as well as from the utilization of recent advances in complex network theory, to ultimately enhance resiliency. This chapter contributes to the discourse on Dragon Kings arguing for continued and concerted efforts to explore this domain.

Keywords Dragon King · Black Swan · Modeling · Simulation · Disasters · Natural hazards · Risk · Capability · Complexity · Complex networks · Emergency management · Emergency response · Emergency recovery · Homeland security

1 Introduction

Typhoon Haiyan (2013) devastated portions of south-east Asia and was one of the most intense storms ever documented. The Great East Japan Earthquake (2011) was the most powerful earthquake ever recorded to have hit Japan. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 m. The earthquake and tsunami caused extensive and severe structural damage to north-eastern Japan and resulted in the meltdown of three nuclear reactors. These events and others such as Hurricane Katrina (2005), Blackout Canada-US (2003), Hurricane Sandy (2012), Alberta (Canada) floods (2013), Heartbleed cyber incursion (2014) and global terrorist actions highlight the vulnerability of social and critical infrastructures to natural hazards, natural hazard triggered technological disasters (NATECHs) and man-made disasters and the crippling effect that such events can have regionally, nationally and globally on social and economic well-being (Masys et al. 2014). This networked risk landscape is one characterised by hyper-risks (Helbing 2013) and hybrid risks (Masys et al. 2014). As noted in Weick and Sutcliffe (Weick and Sutcliffe 2007), 'Unexpected events often audit our resilience' and thereby challenge response and recovery activities. With our hyper-connected world, the impact of unexpected events such as floods, earthquakes, financial crises, and cyber-attacks has revealed the fragility and vulnerabilities that lie within the social/technological/economic/political/ecological interdependent systems (Masys et al. 2014). In particular, events that impact physical and digital critical infrastructure such as damage to electric power, telecommunications, transportation and water-supply systems can ripple across local, regional and global regions. There exists a rich body of knowledge regarding the statistics associated with the occurrence of such outlier events. Taleb (2007) calls these extreme events '**Black Swans**' to describe their inherent quality of surprise, sometimes viewed as an 'Act of God'. The question arises: can we predict the occurrence of some Black Swans' (extreme events)? As described by Johnson and Tivnan (2012) '… understanding, controlling and predicting extreme behavior is an important strategic goal to support resilience planning'. As noted by Sornette (2009).

> …extreme events should be considered to be rather frequent and to result from the same organization principle(s) as those generating other events: because they belong to the same statistical distribution, this suggests common generating mechanism(s).

Outliers that represent those extreme events that exist beyond the extrapolation of power laws are referred to as "Dragon-Kings" (Sornette 2009) as differentiated from "Black Swans" (Taleb 2007). It has been suggested that evolving complexity science has enabled the modeling and the prediction of what many thought was not yet predictable. Chikumbo et al. (2014) describe efforts to predict and influence (suppress) catastrophic events. The 'dragon-king' research of Sornette (2009) and Cavalcante et al. (2013) figure prominently. Chikumbo et al. (2014) describe how Cavalcante et al. (2013) set out to demonstrate the predictability of extreme events and how they can be suppressed by applying tiny perturbations to a system composed of coupled chaotic electronic oscillators. Dai et al. (2013) experimented with budding yeast to show that critical slowing down and/or increased variability of measurable system quantities near the bifurcation point holds the key to forecasting an impending event.

Moving beyond chaos theory and the quantification of emerging patterns in self-organizing systems, the new science of complex networks (that are ubiquitous in natural and technological systems) promises to provide a unifying paradigm for the development of a full-blown theory of complexity (which is certainly one of the grand challenges for 21st century science) (Barabasi 2003; Caldarelli 2007; Newman et al. 2006). Moreover, nascent efforts have been made to apply to complex network theory to obtaining a deeper fundamental understanding of the collective responses of human populations to large-scale emergencies such as bombings, plane crashes, earthquakes, and power outages (blackouts) (Bagrow et al. 2011) with important implications for improvements in emergency detection and response. Finally, very recent efforts on the application of control theory to complex networks (Liu et al. 2011) has been initiated, and this seminal effort is expected to have a potential long-term impact for the improvement of the robustness of technological and infrastructure networks against failures and attacks.

Such results suggest applications to the disaster management domain. Through the lens of these various emerging and evolving paradigms of complexity science and the application of modeling and simulation (M&S), insights can be derived that can uniquely inform disaster risk reduction through anticipation, avoidance or mitigation of systemic risks associated with such outlier disasters.

2 Black Swans, Dragon Kings and Beyond

Sornette (2009) argues that extreme events (high Impact, low probability) are amalgamated in the population of other events described by a power law distribution, '… the common wisdom is that there is no way to predict them because nothing distinguishes them from their small siblings: their great sizes and impacts come out as surprises, beyond the realm of normal expectations'. What differentiates Dragon Kings from Black Swans is that these particular extreme events are distinguishable by their sizes or by other properties from the rest of the statistical population. Sornette (2009) argues that Dragon-Kings '… result from mechanisms that are different, or that are amplified by the cumulative effect of reinforcing positive feedbacks'.

Sornette (2009) presents a generic phase diagram to explain the generation of Dragon-Kings and documents their presence in six different examples (distribution of city sizes, distribution of acoustic emissions associated with material failure, distribution of velocity increments in hydrodynamic turbulence, distribution of financial drawdowns, distribution of the energies of epileptic seizures in humans and in model animals, distribution of the earthquake energies). What emerges from the discussion is the association of Dragon-Kings with such dynamics as '… *a phase transition, a bifurcation, a catastrophe, or a tipping point*' (Sornette 2009). Hence, Sornette (2009) argues that the presence of a phase transition provides foresight '**weak-signals**' pertaining to the occurrence of Dragon-Kings. What this suggests from a disaster risk reduction perspective, is that through modeling efforts, extreme events (Dragon Kings) '… can exhibit a degree of predictability' (Johnson and Tivnan 2012) thereby supporting planning and mitigation of risks. In essence, it is argued that through M&S we can proactively examine conditions of vulnerability to decrease the likelihood and/or impact of extreme events (dragon-kings) through scenario analysis. This is essentially a 'flight simulator' framework to test drive and explore different scenarios to facilitate decision making.

In a broader perspective, modern societies and the engines of civilization are built on an intricate framework of diverse networks—various economic, infrastructure and technological networks such as enormous networks of power stations, intricate transport networks, comprehensive communication networks, financial markets, and the Internet to name but a few, which are all built up of many (relatively) simple components (agents such as humans, power stations, businesses, airports, etc.) that interact with each other leading to patterns of interaction exhibiting extreme (unlimited) complexity and potentially resulting in emergent forms of behavior that are difficult (if not impossible) to predict. The dependencies of the various components of a network on each other only become clear when failures (catastrophes) occur in the network such as the rapid spreading of a computer virus over the Internet, the collapse of a global financial system, or the large-scale breakdown of an electrical power grid. Yet, researchers (Barabasi 2003; Caldarelli 2007; Newman et al. 2006) are discovering general concepts and properties that appear to be intrinsic to the various diverse complex networks, leading to the intriguing concept that there may be a few fundamental organizing principles that determine the topological characteristics and ultimately the behavior of complex networks. In other words, there may be a set of basic universal rules (generic organising principles) that would allow one to predict the emergent behavior in a complex network (despite the seemingly intractability of this enormous task) which according to Barabasi (2005) would allow one '… *to understand the key to nature's code for multitasking—the one that orchestrates the actions of uncountable components into a magic dance of order and ultimate elegance*'.

3 Predictions and Suppression?

Extreme behaviors, such as those exhibited by financial crashes, flooding (Alberta, 2013), earthquake triggered disasters (Fukushima, 2011) emerge spontaneously across a wide range of natural, biological and socio-economic domains. However, from the economic domain, weak signals (warning signs) have been flagged that suggest emerging dramatic changes in the global financial markets. Johnson and Tivnan (2012) describe how on 6 May 2010, '…it took just 5 min for a spontaneous mix of human and machine interactions in the global trading cyberspace to generate an unprecedented system-wide Flash Crash. For reasons which are still not entirely clear, the interaction between the global ecology of market participants (both human and computer trading algorithms) was able to produce a self-induced extreme change which had no definitive nucleating event, and yet drove the market to values it would ordinarily never reach—all within a few minutes'.

Mitigating the impacts of extreme events rests on the ability that encompasses anticipation and preparedness. Alfieri et al. (Alfieri et al. 2013) describe the success of the Global Flood Awareness system (GloFAS) in terms of predictability. Their research has shown that '… hazardous events in large river basins can be skillfully detected with a forecast horizon of up to 1 month. In addition, results suggest that an accurate simulation of initial model conditions and an improved parameterization of the hydrological model are key components to reproduce accurately the streamflow variability in the many different runoff regimes of the earth' (Alfieri et al. 2013). It was reported that "… ten days before Calgary was inundated last summer, supercomputers half a world away were spitting out predictions that showed the city would soon be flooded" (McClure 2014).

Catastrophic events such as that experienced through Katrina (2005) and Fukushima (2011) involve interactions between structures at many different scales. Hurricane Katrina (2005) devastated New Orleans thereby revealing inherent vulnerabilities that resided in the socio/political/ecological/technical infrastructure (system) of the city and the nation. As described in Masys (2014a), these 'unseen' vulnerabilities that emerged at the 'seams' of interconnection and interdependencies can be characterized as 'resident pathogens', in that the hurricane as a 'triggering mechanism' interacted with the '… city's fragile physical environment, aging infrastructure, and declining economic and social structure' (Comfort 2006) as well as policies, regulations and politics. Comfort (2006) asks the question 'Was the damage in New Orleans due to Hurricane Katrina, or was it some combination of human and technical factors that failed under the stress of the hurricane?' Applying the notion of complex systems to the Hurricane Katrina case highlights the interdependencies, interconnectivities and inherent non-linearity that preclude 'linear, experience-based or intuitive approaches' (Helbing 2010) to disaster management.

Dragon-kings emerge from such complex systems characterized by such mechanisms as ruptures, phase transitions, bifurcations, catastrophes, and tipping points. The significance of this to disaster management is that such phase transitions often take planners by surprise '… because of the ubiquitous tendency to extrapolate new behavior from past ones' (Sornette 2009). Sornette (2009) presents examples in the field of material science and financial economics whereby recognizing the role of phase transitions '… allow us to unify different regimes under a synthetic framework, sometimes with encouraging potential for prediction of crises'. That being said, Sornette (2009) is cautious to emphasize '… that there is no unique methodology to diagnose dragon-kings. One needs a battery of tools'. Dragon-kings can be observed:

- sometimes directly, in the form of obvious breaks or bumps in the tail of size distributions;
- through the construction of novel observables, which are more relevant to the dynamics of the system; and/or
- through comparison of distributions obtained at different resolution scales that allows one to diagnose the existence of a population of dragon-kings (Sornette 2009).

Hence, M&S and analysis tools and methodologies such as that in Table 1 have been shown to provide value and support disaster risk reduction through the diagnosis of extreme events.

It is emphasized by Janczura and Weron (2012) that the qualification of dragon-kings as described by Sornette (2009) is strongly model dependent. Sornette (2009) does present supporting evidence for the concept that meaningful outliers (called "dragon-kings") exist and through the analysis of the characteristics and dynamics of these events one can '… learn how to diagnose in advance the symptoms of the next great crisis'. Nonetheless, it is the disciplined exploration of the regime of extreme events through modeling and simulation that is the key message to support disaster risk reduction. Such supporting methods as scenario planning (Masys 2012) and vulnerability analysis leveraging complexity theory and systems thinking (Masys 2013, 2014a, b) figure prominently in analyzing the cascading effects of shocks to systems.

Table 1 Managing complexity: a suite of related M&S tools and methodologies

Large-scale data mining
Complex networks
System dynamics
Scenario modeling
Agent-based modeling
Sensitivity analysis
Catastrophe theory
Systems theory
Statistical analysis of extreme events
Non-linear dynamics and chaos theory
Complexity theory

Complexity theory emerges as a key lens to better understand extreme events. It recognizes the interdependencies and interconnectivity that characterizes these extreme events. Such extreme events cannot be inferred from the properties of their parts; hence local events can have far-reaching consequences that are often difficult to anticipate. The question is posed by Sornette and Ouillon (2012) as to how much the understanding obtained on dragon-kings could lead to operational utility. To this, Janczura and Weron (2012) find such a notion controversial, but nonetheless do not outright discount it, but rather call for more research. Sornette and Ouillon (2012) describe the value of modeling and simulation to explore this regime of complexity, and particularly to support decision making. Their analysis of this domain highlight that failures such as Deepwater Horizon Oil spill (Masys 2012; Wattie and Masys 2014) and subprime crisis, exhibit common patterns including: ‘lack or decreasing questioning of assumptions over time; insufficient prior analysis; failure to anticipate side effects; incorrect interpretation of the system’s reaction (no immediate obvious negative effect wrongly interpreted as “all is well”)’ (Sornette and Ouillon 2012). This resonates with such Natural Disaster Triggered Technological Accidents as the Fukushima Daiichi nuclear disaster (Ray-Bennett et al. 2015), as well as humanitarian crisis (Masys 2013) and violent extremism and radicalization (Masys 2014b). In these analysis and simulations, complex interdependencies and nonlinearity characterize the problem space. Weak signal detection emerges as requirement to facilitate management of such disasters. Suveges and Davison (2012) present an example of a catastrophic event (extreme rainfall) that was apparently impossible from scientific extrapolation or common sense based on the past. In effect, disaster risk reduction through modeling and simulation support planning for and mitigating these types of extreme events.

Sornette and Ouillon (2012) are adamant that the cost is too large to learn from real-life crises. They argue that ‘… it is possible to develop simulators for decision makers to understand the complex dynamics of out-of-equilibrium systems whose behavior intrinsically includes changes of regimes, bifurcations, tipping points and their associated dragon kings’.

> The decision maker thus first needs to understand the dynamics of his system holistically, in a systemic way, which means that he needs to understand the existence of dragon-kings as one of the dynamical solutions of the evolution of his system. He needs to have a classification of the different regimes possible, a phase diagram in which he understands which control leads to the region of the dragon-kings and which do not. He needs to understand that bifurcations and changes of regime are a natural and expected part of natural and social systems (Sornette and Ouillon 2012).

The rapid advances in complex network science may lead in the early part of the 21st century to the discovery of common operating principles governing the behavior of diverse networks (Barabasi 2005) whose basic understanding would allow not only the prediction of the emergent and complex behavior arising from the interactions of the individual units in a large system, but also the development of a range of specific strategies to defend the network against either a failure or an attack (e.g., stopping the spread of an epidemic on a human or computer network) providing potentially significantly improved resiliency in response to disasters (e.g., global epidemics such as SARS and Ebola, large electrical blackouts, computer viral epidemics such as the Blaster and SoBig worms). For example, some initial seminal work (Liu et al. 2011) has already been conducted to determine the degree of controllability of some real networks. This effort can potentially lead to the development of a tool box that can be applied to the control of arbitrary complex networks, providing a framework to increase the robustness of a network to failures or to an attack (viz., to better resist random or intentional attacks). Finally, new avenues involving novel concepts of multiscale connectivity within networks (Dodds et al. 2002) have been shown to possess the characteristic of ultra-robustness by *simultaneously* minimizing the likelihood of failure (i.e., avoiding the failure) in the network as well as the effect of the failure if and when this occurs (i.e., minimizing any further loss from the failure if it should occur). Ultra-robustness is a key determinant in the characterization of a complex network with respect to catastrophe recovery whether from a failure or from an attack. Another interesting application of complex network theory is to the prediction of human mobility (Song et al. 2010) and, more specifically, to the deeper understanding of the role and impact of human dynamics and activity patterns in emergency detection and response (Bagrow et al. 2011). Network thinking described by (Masys et al. 2014) figure prominently as a paradigm for examining black swan, dragon king and extreme events.

The complexity arises from the inherent interdependencies and interconnectivity resulting in an entangled state of relations and a causal chain that is non-linear. Hence, models and simulations inform risk awareness thereby supporting disaster risk reduction. Systemic risks emerge from our hyper-connected world. These risks are no longer contained geographically or temporally but are transnational. These risks are characterized by their apparent uncertainty and ambiguity and emerge as complex (multi-causal). M&S can be used to explore this very regime and characteristics.

4 Conclusion

Though “**Black Swan**” events in regional, national and global systems can be viewed as an unpredictable “Act of God”, there is a type of extreme event that appears to be predictable and thus suppressible: the “**Dragon-King**” event. Modeling and simulation of such extreme events can assist in the predictability and the suppression of some low probability extremely high consequence events such as natural hazards (flood, earthquake, wildfire, tsunami, extreme weather), cyber-attacks, financial events, mass crowd evacuation. However, this positive view should be balanced by ‘the fact that this remains a very delicate and difficult field, if only due to the scarcity of data as well as the extraordinary important implications with respect to hazard assessment, risk control and predictability’ (Sornette and Ouillon 2012). Addressing the Dragon-Kings and Black Swans to support disaster risk reduction requires embracing the inherent uncertainty, complexity, and ambiguity that characterizes the problem space. Hence the application of M&S tools and techniques coupled with involvement of experts, stakeholders and the public can provide insights and unique and timely advice to support disaster risk reduction and the resulting risk handling and response strategies. Furthermore, emerging research areas focused on the elucidation of some fundamental organising principles that govern the behavior of diverse networks may confer significantly improved predictive power in a theory of complexity, and this increased understanding of natural or technological networks may facilitate the design of network topologies that are much more tolerant to both failure and attack. Emergency Managers in Governments and owners of critical physical and digital infrastructure may benefit from analyses, advice and exercises that involve predictable and suppressible “Dragon-King” type of low probability extremely costly and extremely high consequence events, as well as from recent advances in complex network theory, to ultimately enhance resiliency.

References

Alfieri L, Burek P, Dutra E, Krzeminski B, Muraro D, Thielen J, Pappenberger F (2013) GloFAS—global ensemble streamflow forecasting and flood early warning. Hydrol Earth Syst Sci. 17:1161–1175. doi:10.5194/hess-17-1161-2013, www.hydrol-earth-syst-sci.net/17/1161/2013/

Bagrow JPD, Wang D, Barabasi A-L (2011) Collective response of human populations to large-scale emergencies. PLoS ONE 6(3):e17680. doi:10.1371/journal.pone.0017680

Barabasi A-L (2003) Linked: the new science of networks. Plume Books, Cambridge

Barabasi A-L (2005) Taming complexity. Nat Phys 1:68–70

Caldarelli G (2007) Scale-free networks. Oxford University Press, London, p 2007

Chikumbo O, Lewis S, Canard H, Norris T (2014) Futuristic smart architecture for a rapid disaster response. In: Masys AJ (ed) Disaster management-enabling resilience. Springer, Berlin

Comfort LK (2006) Cities at risk: Hurricane Katrina and the drowning of New Orleans. Urban Affairs Review

Dai L, Vorselen D, Korolev KS, Gore J (2013) Generic indicators for loss of resilience before a tipping point leading to population collapse. Science 336:1175–1177
Cavalcante HLDS, Oriá M, Sornette D, Ott E, Gauthier DJ (2013) Predictability and suppression of extreme events in a chaotic system. Phys Rev Lett 111(198701):2013
Dodds PS, Watts DJ, Sabel CF (2002) The structure of optimal redistribution networks. Institute for Social and Economic Research and Policy Working Paper, Columbia University
Helbing D (2010, Oct) Systemic risks in society and economics. IRGC—emerging risks, Helbing
Helbing D (2013) Globally networked risks and how to respond. Nature 497:51–59
Janczura J, Weron R (2012) Black swans or dragon kings? A simple test for deviations from the power law. Eur Phys J Special Topics 205:79–93
Johnson N, Tivnan B (2012) Mechanistic origin of dragon-kings in a population of competing agents. Eur Phys J Special Topics 205:65–78
Liu Y-Y, Slotine J-J, Barabasi A-L (2011) Controllability of complex networks. Nature 473:167–174
Masys AJ (2012) Black Swans to Grey Swans—revealing the uncertainty. Int J Disaster Prev Manage 21(3):320–335
Masys AJ (2013) Human security—a view through the lens of complexity. In: Gilbert T, Kirkilionis M, Nicolis G (eds) Proceedings of the European conference on complex systems 2012, Springer proceedings in complexity, pp 325–335
Masys AJ (2014a) Critical infrastructure and vulnerability: a relational analysis through actor network theory. In: Masys AJ (ed) Networks and network analysis for defence and security. Springer, Berlin
Masys AJ (2014b) Radicalization and recruitment: a systems approach to understanding violent extremism. Int J Syst Soc
Masys AJ, Ray-Bennett N (2015) Network thinking: understanding interdependencies and interconnectivity to support vulnerability analysis and DRR. Presented at UN World conference on disaster risk reduction, Sendai, Japan, 14–18 Mar 2015
Masys AJ, Ray-Bennett N, Shiroshita H, Jackson P (2014) High impact/low frequency extreme events: enabling reflection and resilience in a hyper-connected World. In: 4th international conference on building resilience, 8–11 Sept 2014, Salford Quays, UK (Procedia Economics and Finance 18:772–779)
McClure M (2014) Computer model forecast flooding in Calgary 10 days before deluge. Calgary Herald. http://www.calgaryherald.com/news/Computer+model+forecast+flooding+Calgary+days+before+deluge/9488235/story.html
Newman MEJ, Barabasi A-L, Watts DJ (2006) The structure and dynamics of complex networks. Princeton University Press, Princeton
Ray-Bennett N, Masys AJ, Shiroshita H, Jackson P (2015) Reactive to pro-active to reflective disaster responses: introducing critical reflective practices in disaster risk reduction (DRR). In: Collins AE, Samantha J, Manyena BS, Jayawickrama J (eds) Natural hazards, risks, and disasters in society: a cross-disciplinary overview. Elsevier Inc, Amsterdam
Song C, Qu Z, Blumm N, Barabasi A-L (2010) Limits of predictability in human mobility. Science 327:1018–1021
Sornette D (2009) Dragon-Kings, Black Swans and the prediction of crises. Int J Terraspace Sci Eng 2(1):1–18 (http://arXiv.org/abs/0907.4290)
Sornette D, Ouillon G (2012) Dragon-kings: mechanisms, statistical methods and empirical evidence. Eur Phys J Special Topics 205:1–26
Suveges M, Davison AC (2012) A case study of a dragon-king: the 1999 Venezuelan catastrophe. Eur Phys J Special Topics 205:131–146
Taleb NN (2007) The Black Swan: the impact of the highly improbable. Penguin Books Ltd, London

Wattie J, Masys AJ (2014) Enabling resilience: an examination of high reliability organizations and safety culture through the lens of appreciative inquiry. In: Masys AJ (ed) Disaster management—enabling resilience. Springer, Berlin

Weick KE, Sutcliffe KM (2007) Managing the unexpected: resilient performance in an age of uncertainty, 2nd edn. Wiley, San Francisco

"Unproblemising" the Technical Complexity of Shelter in Post Disaster Reconstruction

Regan Potangaroa

Abstract The provision of shelter after a disaster is a complex problem that manifests itself in all post disaster contexts. Its intractable and 'wicked' nature means that donors and agencies involved in humanitarian aid see it as "easy to get into, but hard to get out of". There are seemingly no one-off, "silver bullet" solutions and where such "cookie cutter" solutions are applied, their weaknesses soon become apparent to all involved. While most lessons learnt and evaluations have pointed towards better coordination, stronger leadership, more innovation and integration of service delivery there remains little appreciation of the role of technical complexity in resolving the apparently 'intractable' problem of shelter provision. This chapter uses a case study approach to identify and propose an approach that is not evident in the current literature. The technical complexity of shelter provision is seemingly relegated out of the decision making. However, the presented case study and experiences from the shelter sector when re-framed suggest another reality; that the technical resolution can untangle parts of its social complexity that can foster solutions that were prior to that considered 'intractable'. And the idea that 'engineers have feelings too'. Thus, appropriately addressing the technical aspects releases the social complexity and allows better solutions to be determined for affected communities. This process has been termed 'unproblemising' because while technical resolution can release the pressure on the social dimension final resolution ultimately still rests with the social, albeit with a much better fit than would have been otherwise been possible. The appropriate technical resolution is through reflective 'design' that is a design not only mindful of the material realities of working in the field usually in a fragile and developing infra-structure but also of the goals and context of a 'humanitarian' situation. Consequently, the chapter firmly positions itself between the problem framing to problem solving domain.

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1 Introduction

Shelter in post disaster reconstruction is very difficult. The 2011 Humanitarian Emergency Response Review (HERR) undertaken by the Department for International Development (DFID) underlined that difficulty with its comments that (DFID 2011);'…providing adequate shelter is one of the most intractable problems in international Humanitarian response. Tents are too costly and do not last long enough. Plastic Sheeting can be good but most often is low quality and falls apart immediately. Rebuilding houses takes years, even when land issues are not major obstacles'. The review went on to single out shelter with criticism over weak coordination and the usage of 'transitional shelter' under the 'transition to what' question.

The shelter community discussion that followed the HERR focussed on its implementation and identified the three thematic areas of leadership, professionalisation and innovation and the five cross cutting issues as follows (CENDEP 2011):

1. Institutional commitment to shelter: while the number of dedicated shelter positions in large international non-governmental organisations (INGOs) has increased from three in 2004 to twelve in 2011 experience and familiarity with shelter remains centralised, organisationally isolated and ineffective.
2. Humanitarian leadership and organisational structure possibly beyond the usual cluster approach.
3. Innovation beyond technical design.
4. Professionalisation and the need for a regulatory framework that would enable accountability.
5. Private Sector utilisation especially given the role of logistics.

Thus, at first sight the potential role of design that this chapter proposes could (or would) be missed under the above 'innovation beyond technical design'. Moreover, all of the other cross cutting issues appears to be top down (and organisational or institutional) rather than bottom up (and community or design focused). These issues seem to be framing the current 'shelter problem' and hence its solutions which we should keep this in mind as we develop the shelter context where practitioners operate and humanitarian aid is provided.

2 Post Disaster Context

Why is providing shelter in a post disaster context apparently 'intractable'? (Sanderson and Burnell 2013). It starts with the post disaster shelter context which is characterised by the following (IFRC 2013; UNHCR 2007):

- The lives and well-being of people are at stake;
- Reaction time is short;
- Risk factors are high and consequences of mistakes or delays can be disastrous;
- There is great uncertainty;
- Investment in contingency planning and other preparedness activities is crucial;
- Staff and managers may be under great stress due to security problems and harsh living conditions;
- There is no single obvious "right answer".

This context is dynamic and seemingly changing constantly. Moreover, as noted by Simon Levine you are not starting with a 'clean slate' (ODI 2014) and part of that can include the following:

- Having to deal with problems that are perhaps more symptomatic of deeper social and community issues (Clermont et al. 2011).
- Having to deal with non-reversibly problems, where going back to what was "normal" before the disaster is not possible and there is the need to instead move forward to an as yet unknown "new normal" (da Silva 2010).
- An inability to indentify whose perspective should be addressed and moreover the existence of multiple seemingly valid viewpoints that at the same time can be contradictory (Mannakkara and Wilkinson 2014).
- A definitive and often scarce amount of resource availability (Burke and Fan 2014).

Still further, the outwardly 'endless' debate over the ability of aid agencies to link relief, rehabilitation and development (LRRD) has not been resolved (Buchanan-Smith and Fabbri 2005). The view of Buchanan-Smith and Fabbri from their 2005 study suggests that '…the challenge of linking relief, rehabilitation and development (LRRD) has preoccupied aid organisations for well over a decade, conceptually, institutionally and programmatically…' and that '…it is a debate that has neither reached closure nor consensus. Most of these questions continue to exercise all types of aid organisation'. They also suggest that shelter has this 'intractable' quality.

They track its historic development from being an instrument of foreign policy in the 1980–90s, to being an issue of security post 9/11 to more recently and its rights based approach that has been seen as a shift away from the continuum of the phases. Furthermore, the view seems to remain that 'the concept of rights seems to be honoured more in rhetoric than in practice' (Darcy and Hofman 2003) and current 'operational frameworks' seem to be increasingly based on the following:

- Vulnerability
- Risk Reduction
- Livelihoods

Thus, problem framing and any resultant solutions quickly becomes complex and also 'value laden'.

And if that were not enough, the loss of shelter or housing in a disaster has impacts well beyond the shelter or house. For example, it means a sudden loss of security and privacy. It means that the health of the family that lived in it could be compromised; and it means that education could be postponed (or at least interrupted) and that the economy around the neighbourhood could collapse. In addition, "informal" rebuilding could have detrimental impacts on the environment and resources, it may drive building materials and labour costs up and potentially pull quality and standards further down. The social structures and cultural places and practices that were there before may not be after the disaster. The economics and livelihoods of the family can be affected by the need to replace the former house while at the same time continue paying off loans perhaps on the previous house or contents but now being 'unemployed'. This may (by necessity) result in "women and children being forced to work in dangerous conditions to gain income and food, a social impact" (Wikipedia 2010). Consequently, the loss of housing and a lack of shelter are connected to many (if not all) of the other concerns of aid agencies; well beyond its simple 'tarp's and tents' image. These connections can mean that 'poking over here can produce results over there' and hence the loss of shelter or housing can trigger other unexpected and unintentional impacts outside its immediate proximity. Such physical connectiveness and proximity is seemingly moving the urban shelter question to centre stage, driven by the acknowledgement that more than 50 % of the world now live in urban contexts (and hence more urban based disasters could be expected) but also there is an apparent lack of any 'urban game' plan for shelter which aid agencies are trying to rapidly address (NRC 2014), (Pavanello 2012), (Babister 2014), (IFRC 2014a, b), (EPYPSA 2011), (Clermont et al. 2011), (ALNAP 2012).

On the other hand, the construction of appropriate housing/shelter can seemingly have long lasting impacts as portrayed in the movie "The Shelter Effect" produced by the International Federation of the Red Cross Red Crescent Societies (IFRC 2014b). In that short video, changes such as raising the house by two steps, treating the timber for water flooding and putting a concrete floor under it had dramatic and positive outcomes in terms of safety, savings, livelihoods, water access, health and finally education and a school for the community, albeit over the subsequent years. And while it is a scripted animation, it still manages to strike a deep chord within the shelter community.

Hence, despite the prominence of housing or shelter to people's well being, supplying and providing it is problematic; and problematic to the point of being 'intractable'.

3 The Log(ical) Frame and Log(ical) Frame Approach

The shelter problem and context outlined above has been ‘traditionally’ analysed using the Logical Framework Approach (LFA) (AusAid 2003). It is a ‘linear’ objective based approach that consists of the nine sequential steps; (Örtengren 2004)

1. Analysis of the project’s Context.
2. Stakeholder Analysis.
3. Problem Analysis/Situation Analysis.
4. Objectives Analysis.
5. Plan of Activities.
6. Resource Planning.
7. Indicators/Measurements of Objectives.
8. Risk Analysis and Risk Management.
9. Analysis of the Assumptions.

The results of this approach and analysis are communicated by a 4 × 4 matrix shown shaded in Table 1; with different agencies and donors having slightly different formats and syntax. Nonetheless, this is the form referred to as the ‘Log Frame’ (LF). It was devised and deployed by the United States Agency for International Development (USAID) in the 1970s because aid funding was not being effectively used and there were the following problems (PCI 1970):

1. The Planning was too vague: Objectives were not stated clearly and there were no indications of what the project would look like if it was successful. Thus, evaluators could not compare in an objective manner, what was planned with what actually happened.
2. The management responsibility was unclear: Project managers were reluctant to be considered responsible for development impact. The impact expected was ambiguously stated; there were too many important factors outside their control. All of which they found it difficult to articulate what they should be responsible for, and consequently ended up not wanting to accept any responsibility.
3. Evaluation was an adversary process. The absence of clear targets and disagreements among project team members as to what the project was about and frequent disagreements between donors and fellow evaluators ended up with the evaluation looking for ‘good things’ and ‘bad things’ and blame. Not surprisingly the reviews of evaluation results frequently ended up as adversary relationship between project proponents and those that thought the ‘bad things’ were important.

The ‘logic’ of the LFA was designed so that (Wikipedia 2015):

- If these Activities are implemented, and these Assumptions hold, then these Outputs will be delivered.

Table 1 The log frame [adapted from Jensen (2010)]

Narrative or project summary	Objectively verifiable indicators and measures	Sources and means of verification	Assumptions
1. Overall objectives/goals It is about the shared vision that your shelter project contributes to	The extent of your contribution (not always possible)	How you will measure your contribution (not always possible)	Important events, conditions or decisions beyond the project's control necessary for maintaining the progress towards the goal
	These are the basis for review (not usually possible)		
2. Specific objective/purpose What you intend to change during project period	How you will know the intended change has occurred and is sustainable	How you will measure change	Assumptions about external factors that need to be in place if project is to contribute to the goal
	These are the basis for evaluation		
3. Expected results/outputs Tangible results of each activity intended to bring about change	How you will know the expected results of your project have been achieved	How you will measure results	Assumptions about external factors that may affect whether the project purpose is achieved
	These are the basis for periodic review		
4. Activities (and processes) Groups of tasks needed to achieve each expected result	The means or inputs and resources needed to carry out the each task	Proof that each activity/task completed	Assumptions about external factors that may affect activities achieving the expected results Preconditions (that need to be fulfilled before the project can start)
	These are the basis for regular monitoring and consist of the planned practical activities on the ground		

- If these Outputs are delivered, and these Assumptions hold, then this Purpose will be achieved.
- If this Purpose is achieved, and these Assumptions hold, then this Goal will be achieved.

It took away the adversarial position between the project managers and the administrators/evaluators by separating the 'means' from its 'ends' by setting up a 'shared understanding' of what needed to be done (this notion will be picked up later).

The sequence to produce a Matrix is to start from top left hand corner and with a 'Problem Tree' methodology track down that column to the planned project activities. Then, at each level work across to do the Indicators and Verification and finally, starting from the bottom right hand corner work up through the assumptions. This hierarchy and levels are planned to identify exactly what project managers working at the activities level are expected to do that then feeds into the bigger picture of higher levels over seen by the administration. So the sequences are usually to think/reflect going up the Matrix and plan going down wards; mindful of both the vertical and horizontal logic inherent in it.

However, the LFA and LF's did have short comings that included the following (Jackson 1997; Bakewell and Garbutt 2005):

- They were not suitable where there was a degree of uncertainty or disagreement about what was the main 'problem'.
- They were seemingly rigid once they were formulated and could not readily be altered as any 'new reality' was realised. Because of this project managers tended to treat them as an administrative tool and a requirement of the funding agency rather than a useful planning and design management tool. There was minimal 'ownership'.
- Consequently, they did not readily enable monitoring of unintended consequences.
- They can limit the emergence of potential solutions, innovative thinking and adaptive management.

But '…although the logical framework has become universally known, it is far from universally liked. It has been the subject of much criticism over the years, concerning both the theoretical basis of the approach, and the way it is applied in practice'. It remains nonetheless as the standard.

4 Tame and Wicked Problems

At about the same time that the LFA was developed it was also becoming evident that there existed a type of problem that was resistant to traditional processes. Rittel and Webber realised that (Rittel and Webber 1973) '…one of the most intractable problems is that of defining problems (of knowing what distinguishes an observed condition from a desired condition) and of locating problems (finding where in the complex causal network the trouble really lies)'. They were thinking of Planning problems such '…the location of a freeway, the adjustment of a tax rate, the modification of a school curricula or the confrontation of crime'. They postulated that there were two types of problems; one were 'Tame' or benign while the other was 'Wicked'. A Tame problem is one that: (Ritchey 2013)

- Has a relatively well-defined and stable problem statement.
- Has a definite stopping point, i.e. we know when a solution is reached.
- Has a solution which can be objectively evaluated as being right or wrong.
- Belongs to a class of similar problems which can be solved in a similar manner.
- Has solutions which can be tried and abandoned.

This can be more useful in deciding whether a problem is 'Wicked' (by deciding that it isn't 'Tame'). Wickedness is not caused by any degree of difficulty but (Camillus 2008)'…they're the opposite of hard but ordinary problems, which people can solve in a finite time period by applying standard techniques. Not only do conventional processes fail to tackle wicked problems, but they may exacerbate situations by generating undesirable consequences'. They are not the kind of problem where the LFA could be expected to perform. Their characteristics are tabulated below and have been adapted from Rittel and Webber's ten characteristic list using simplifications suggested by Conklin (2005) together with examples from the shelter literature.

WP Approaches are becoming more 'mainstream' evidenced by their uptake by various Government Aid Agencies (Ramalingam et al. 2014; Australian Govt 2007; Spratt 2011). Problems do not need to have all six characteristics to be a WP with the first two characteristics of Table 2 above usually being sufficient, at least in the field of shelter provision in post disaster reconstruction. Moreover, WP's can be

Table 2 Characteristics of wicked shelter problems[a] and linkages to the later case studies

Characteristic	Description	Shelter response	
		Problem framing	Solution formulation
1. You don't understand the problem until you have developed a solution. There is no definitive formulation for a WP (EPYPSA 2011), (SPHERE 2011)	Every solution exposes new aspects of the problem that requires adjustment. There is no definitive problem as such but rather one that seemingly releases itself as aspects that can be dealt are dealt to leaving the unknown (and potentially unknowable) behind	WP's are difficult to clearly define and their nature and extent depends on who is asked. Each version will have some element of truth and hence cannot be completely verified or rejected	Many solutions probably need to be formulated earlier than what would be the case for the tradition systems approach
2. WP's have no stopping rule (Levine et al. 2012)	A lack of a definitive problem makes finding any solution let alone 'a' solution nebulous. Successfully addressing wicked policy problems usually involves a range of coordinated and interrelated responses, given their multi-causal nature; it also often involves trade-offs between conflicting goals	Wicked problems have many interdependencies and are often multi-causal. There are also often internally conflicting goals or objectives within the broader wicked problem	You stop when you get to 'good enough', or run out of resources or there is a significant change of context. Not when you have arrived at any correct or optimal solution. It should be noted that these stopping rules are often outside the problem-solution domain

(continued)

Table 2 (continued)

Characteristic	Description	Shelter response	
		Problem framing	Solution formulation
3. Solutions to WP’s are not right or wrong,…and difficult to measure objectively because they are judged in a social context in which different stakeholders have different values and goals (Sanderson and Ramalingam 2015)	They are simply better, worse, good enough or not good enough or do no harm. Attempts to address wicked problems often lead to unforeseen consequences because wicked policy problems are multi-causal with many interconnections to other issues, it is often the case that measures introduced to address the problem lead to unforeseen negative consequences elsewhere	Judgement of solution quality is not necessarily objective	Usually based on the social context of many agencies that can have a wide variation of possible solutions depending on the mandate of agencies
4. Every WP is essentially unique and novel. There is no immediate and no ultimate test of a solution to a WP (IFRC 2014a, b)	Consequently, the number of stake holders, variables, factors and context make each situation essentially unique requiring a ‘custom’ fit	Each problem formation will also need to be unique despite the initial commonality of shelter response	Over time one comes to understand the context they have been working in; but with each new WP means that all start again as ‘beginners’. Any solutions are therefore ‘perishable’
5. Every solution to a WP is a ‘one-shot’ operation, because there is minimal opportunity to learn by trial and error and every step counts significantly. (Jean and Bonino 2014; Shelter Case Studies 2010; Shelter Case Studies 2013)	Any attempt to solve a WP will have consequences, some of which will be unintentional. Wicked problems usually have no clear solution. Since there is no definitive, stable problem there is often no definitive solution to wicked problems. They are	The option to iterate may not exist with WP’s as the problem formation changes after any attempt to address it. They are typically unstable and their constraints such as legislative, scientific evidence, resources and political alliances are being settled at the same time that	To pursue approaches based on ‘solving’ or ‘fixing’ may cause decision makers to act on unwarranted and unsafe assumptions and create unrealistic expectations. In such cases, it may be more useful to consider how such

(continued)

Table 2 (continued)

Characteristic	Description	Shelter response	
		Problem framing	Solution formulation
	effectively a 'moving target'	shelter strategies are being addressed	problems can be managed best
6. WP have no given alternative solutions. Every WP can be considered to be a symptom of another problem (Ramalingam et al. 2009)	There maybe many solutions or there maybe none. This requires creativity to devise potential solutions and judgement to determine which are followed through	WP's situations are socially complex, and the literature appears to conclude that its social complexity (rather than their technical complexity) overwhelms most current problem-solving and project management approaches	WP's solutions involve firstly changing behaviour and secondly usually involve coordinated action by a range of stakeholders

[a]The list has been adapted from Rittel and Webber's ten characteristic list using simplifications suggested by Conklin that preserve the essence of the original list of ten with examples from shelter literature
WP wicked problem

embedded in Tame ones as 'sub problems' which will be common for the Unproblemising Approach as noticeable from the linked case studies.

4.1 'Managing' WP's

Organisations and decision makers have reacted to WP's in two or possibly three ways (Conklin 2005);

- They will study the problem.
- They will try to 'Tame' it.
- And they can try to ignore it, but usually not for too long.

Studying a problem is natural for a 'Tame' problem, but with wicked ones where problem framing is elusive it quickly becomes procrastination. WP's require making a decision, perhaps experimenting or piloting or prototyping.

The other 'Taming' option is an interesting one as it attempts to convert a WP into a 'Tame' one by taking away its wicked character by any one of the following methods;

- Freeze the problem framing or lock down the problem definition for ease of delivery.

- Unilaterally decide when the problem has been solved or decide and select the metrics for measuring solution success.
- Direct the use of a previous resolution for it or cast the problem as 'just like' another that has been solved.
- Independently decide which alternatives can be selected as potential solutions or declare that there are just a few possible solutions.
- Give up on trying to find a good solution or accept what is available and move ahead with that and fix up as you proceed.

Like the studying option, trying to Tame WPs by these methods fails (and it is usually only a matter of degree).

Putting these 'reactions' aside, there are perhaps surprisingly several possible approaches for managing WP's that include the following:

- Grint (2008) suggests Clumsy Solutions which are derived from an Egalitarian, Individualist and Hierarchist solutions that are merged to give the Clumsy Solution.
- Conklin (2005) who is probably the most well known, suggests Dialogue Mapping that represents both the social complexity and Wicked Problems aspects in one seemingly 'mind map' approach to achieve a shared understanding.
- Branenburger and Nalebuff (1999) suggest changing the 'Rules of the Game' rather than accepting the 'Game' you are given.
- Roberts (2000) suggests (in a similar way to Grint) that if power is not dispersed to use an Authoritarian coping strategy. If on the other hand it is and it is contested to use a Competitive strategy; or otherwise use a Collaborative one. The Authoritarian, Collaborative and Competitive coping strategies appear to be similar to the Hierarchists, Egalitarian and Individualism respectfully from Grint's analysis.
- Alexander et al. (1977) and the Hierarchical Decomposition Approach (Set theory or Network Analysis). This approach breaks a complex network into a family tree with the 'parent' or root issues at the top of the tree and the many 'children' or dependant issues at the bottom.
- Potangaroa and Wilkinson (2014) have used a Quality of Life Approach to measure community 'well-being' and resilience. The approach seeks to metricate the process and thereby manage it.

In addition, several researchers seem to suggest a 3rd class in addition to Tame and Wicked. Grint suggests a 'Critical' classification, while Roberts suggests a 'Complex' one. Both are a form of Tame Problem that either has a critical time-frame or are the cause of conflict over how they could be solved. They remain essentially Tame nonetheless.

And the literature contains lessons from applying such approaches. For example Rayner reported in Frame (2010) noted that each of Robert's typologies '…reflects a coherent organisational worldview that shapes the definition of the problem to be addressed …. Hierarchical strategies which simplify issues and apply routine, such as new forms of legislation that exert authority… Competitive strategies which rely upon expertise to control resources, such as market-based mechanisms or use of incentives…Egalitarian strategies which open the problem to more stakeholders, through participatory processes such as citizen juries. The characterisations and types of solution strategies provide a useful means by which to examine and understand wicked problems in, for example, development of the Auckland Sustainability Framework' puts it neatly.

Conklin's approach should have special mention because the idea of a shared understanding is quietly seen throughout the literature and in the field because "… the Holy Grail of effective collaboration—is in creating shared understanding about the problem, and shared commitment to the possible solutions. Shared understanding does not mean we necessarily agree on the problem, although that is a good thing when it happens. Shared understanding means that the stakeholders understand each other's positions well enough to have intelligent dialogue about the different interpretations of the problem, and to exercise collective intelligence about how to solve it. Because of social complexity, solving a wicked problem is fundamentally a social process" (Seybold 2013). And the idea that it is fundamentally a social process needs to be revisited. None of the approaches consider or include technical complexity other than a seemingly background noise; except for the approach suggested by Branenburger and Nalebuff.

Their idea is instead of 'accepting the game you are given' is to 'change the rules of the game'; to be a 'Game Maker rather than a Game Taker'. This seems to reflect the sense in the later Case Study where addressing the technical complexity through Design did result in a 'Change of Game'. They identified five strategy traps to be avoided summarised as follows:

1. The first mental trap is to think you have to accept the game you find yourself in. Just realizing that you can change the game is crucial. There's more work to be done, but it's far more rewarding to be a game maker than a game taker.
2. The next trap is to think that changing the game must come at the expense of others. Such thinking can lead to an embattled mind-set that causes you to miss win-win opportunities. The coopetition mind-set—looking for both win-win and win-lose strategies—is far more rewarding.
3. Another trap is to believe that you have to find something to do that others can't. When you do come up with a way to change the game, accept that your actions might well be imitated. Being unique is not a prerequisite for success.
4. The fourth trap is failing to see the whole game. What you don't see, you can't change. In particular, many people overlook the role of complementors. The solution is to draw the Value Net for your business; it will double your repertoire of strategies for changing the game. Any strategy toward customers has a counterpart with suppliers (and vice versa), and any strategy with substitutors has a mirror image for complementors (and vice versa).

5. The fifth trap is failing to think methodically about changing the game. To understand the effect of any particular strategy, you need to go beyond your own perspective. Be allocentric, not egocentric.

And while it is couched in business lingo, the idea that even in a disaster context, there could be the possibility to Change the Game is a powerful strategy. This seems to be at the heart of an 'Unproblemising Approach'.

5 Social and Technical Complexity

While WP's are about the problem/solution domain and the cognitive dynamics involved, social complexity is how that problem engages with its social network. According to Conklin '…social complexity is a function of the number and diversity of players who are involved in a project; the more parties involved in a project, the more social complexity. The more diverse those parties are [in terms of their mandates],the more social complexity'. His view is that projects are fragmented by three factors namely WP's, Social Complexity and Technical Complexity.

Social complexity adds to the 'wickedness'. For example in the Case Study, social complexity splits the WP issue of 'not-understanding-the-problem' into several 'coherent organisational world views'; as suggested earlier by Frame's experience with water allocation in Canterbury, New Zealand. Everyone is convinced they are 'right' and one feels more (quiet) evangelical fervour rather any 'shared understanding'. And perhaps the point is that each feels or knows that the others are 'wrong' in addition to their being 'right'. Consequently, it is often difficult to distinguish between the characteristics of a WP (and hence whether one is dealing with a WP) and Social Complexity. The nature of WP's is seemingly 'hard wired' to the social context and one perhaps understandably finds it difficult to accept that it had anything to do with the expensive house foundations.

Technical Complexity is about difficulties in finding technical information, fact finding and knowing their likely consequences. It is essentially about risk. But according to Conklin (2005) '…so much has been written about technical complexity and how to deal with it, so many tools and methods are available, that there is little to add here……and the point of this book, is to provide an approach and a set of tools for dealing with the nontechnical side of fragmentation; wicked problem dynamics and social complexity'. The experience from the field represented suggests there is more to this and that Technical Complexity may have more of a role in the provision of shelter and housing and that 'Design' is a key element of it.

5.1 Aid Agencies

This has left aid agencies somewhat 'adrift' as summed up below (DARA 2014): '…. NGOs are critical of the application in practice of the humanitarian principles and expressed concern over the independence of humanitarian decisions from other government priorities (political, economic, military, etc.). Participating Member States report that their non-humanitarian colleagues in government are not sufficiently familiar with humanitarian principles, but overall they are not particularly concerned about this unfamiliarity affecting humanitarian decisions. NGOs, on the other hand, see this as an issue that needs more attention. The interference with the humanitarian agenda from the political side of governments is seen as problematic, especially in high profile crises when ministers want their constituents to see them taking action. A significant number of survey responses stressed that one of the most important aspects of the Consensus was its focus on needs-based funding—i.e. practice derived from the core principle of impartiality. However, the NGO perception is that funding is often linked to non-humanitarian considerations'.

In a similar vein, shelter and its provision in a post disaster situation seemingly looses itself in the reduction to outputs, such as the number of houses built (Hofmann et al. 2004). And while this is commonly done (often because of the LFA requirement for indicators), the underlying complexity discussed thus far seems to unfortunately and despite the best intentions mitigate positive 'impacts'. In response to these unintended consequences the shelter community have documented case studies to demonstrate good practice and how this was achieved (Shelter Centre 2010). However, these case studies while useful seem to demonstrate that such lessons learnt are actually not learnt (Ramalingam et al. 2009) and a call to 'not to re-invent the wheel' (IFRC et al. 2014). This possibly suggests that shelter agencies are typically dealing with WPs most of the time; and in particular Governments and the difference of values for humanitarian agencies is at odds with the current context of aid.

5.2 What Is Meant by 'Design'

According to Conklin 'Any design problem is a problem of resolving tension between what is needed and what can be done' (Conklin 2005). Moreover every need has a 'price tag' and every 'done' requires 'resources' (such as time) and hence the balancing between these two poles that doesn't necessarily 'build or produce' anything is the design domain.

In the shelter sector 'need' is often interpreted as a house design and moreover is probably where the 'practitioners/industry' sees its value add proposition (IFRC 2011, 2013). And hence the Case Study Approach adopted to establish the possible role of design from a designer's point of view for the provision of shelter and housing in the post disaster context.

This is a point about the role of design is made by several authors (Hamdi 2010; IDEO 2015). For example, IDEO's Field Guide to Human-Centered Design suggests there are three stages to Design that are as follows:

INSPIRATION: In this phase, you'll learn how to better understand people. You'll observe their lives, hear their hopes and desires, and get smart on your challenge.
IDEATION: Here you'll make sense of everything that you've heard, generate tons of ideas, identify opportunities for design, and test and refine your solutions.
IMPLEMENTATION: Now is your chance to bring your solution to life. You'll figure out how to get your idea to market and how to maximize its impact in the world.

IDEO's approach is about '….believing that all problems, even the seemingly intractable ones like poverty, gender equality, and clean water, are solvable. Moreover, it means believing that the people who face those problems every day are the ones who hold the key to their answer. Human-centered design offers problem solvers of any stripe a chance to design with communities, to deeply understand the people they're looking to serve, to dream up scores of ideas, and to create innovative new solutions rooted in people's actual needs.' This maybe a naive philosophical approach given the discussion thus far but it does use an iterative approach inside it that moves between solution and problem that allows it to 'frame-the-problem' and understand the nature of the problem. This is a WP strategy with design grounded in the community of concern and using a holistic approach (Melles and Holmlid 2013).

It is difficult to capture design problems because they often involve many factors to a greater or lesser degree. Thus designers often use drawing and sketching, prototyping, models, simulation that are about learning by doing or learning by design that goes beyond 'conventional answers' to produce new processes products systems or thinking that have added value. They are innovative. The Case Study does not examine how that occurs but instead tries to present it sequentially.

6 The Case Study Approach

However, there is the issue of methodology. Yin comments that (Yin 2003)'….in general, case studies are the preferred strategy when "how" or "why" questions are being posed, when the Investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context. Such explanatory case studies also can be complemented by two other types-exploratory and descriptive case studies. Regardless of the type of case study, investigators must exercise great care in designing and doing case studies to overcome the traditional criticisms of the method.'

One of these is the causality capacity of a case study. For example, a scientific experiment is set up to determine such causality by being repeated but under differing conditions. Case studies by their nature seemingly cannot. However, Groat and Wang (2002) argue that case studies can and are "explanatory, descriptive and/or exploratory" and back this up with several examples. This chapter has used one case study essentially due to constraints of page space. Nonetheless there was a sense given the literature and the apparent 'bad press' that technical seems to have been dealt to have a technical response and defence.

WP's probably require a change of language and terminology given that the Unproblemising Approach is grounded in a WP context. There is probably no 'problem' and also no 'solution' and instead terms such as 'domain of concerns and needs' for problem and 'domain of resolution and satisfaction' for solution could be substituted. However, for ease of writing such terms as problem and solution will remain with the above meaning.

7 Case Study: Afghanistan, Northern Provinces Flooding Response 2014

7.1 Disaster Context

Heavier than normal seasonal rain over the 24 April–20 May period in 2014 caused flooding/flash floods that affected around 125,000 people in 27 provinces in 123 districts in the North of Afghanistan (OCHA 2014a, b). It caused severe damage to infrastructure, crops and livestock and resulted in 175 deaths. Further heavy rains, triggered two landslides on 2 May at the village of Abi Barik in the Agro district of the province of Badakhshan. The second landslide happened within hours of the first and consequently killed rescuers. As at 4 May 2014, there were 256 confirmed deaths due to the landslides (Fig. 1).

Assessments were conducted jointly by provincial and district authorities and the humanitarian community that resulted in multi-sectoral emergency relief for 17,608 families (OCHA 2014b) (which with an average family size of 7.0–7.5 persons/family represents between 123,000 and 133,000 people). Access both for assessment and immediate assistance was affected by ongoing flooding and damage to roads and infrastructure. Security was an issue in the some areas and in particular

Fig. 1 Images from the response to the flooding (*Source* Field Northern Shelter Cluster, Mazar)

Fig. 2 Flooded houses in Northern Afghanistan. Note the silting up to the window

in the Sar-e Pol (Sari Pul) area that meant United Nation Agencies and even the Afghanistan Red Crescent found access problematic.

The National Shelter Response Plan (NSRP) (ES&NFI 2014a, b) was developed from that assessment and set up as the roadmap for the flood and land slide response. It followed a LFA but was presented as a full strategy because of the unanticipated scale being outside normal planning levels. That plan set out the following response:

- 8128 houses to be constructed by 31 October 2014.
- This would require funding of $24 USD million (average cost of $3000 USD per house).
- Their construction would be based on the Shelter Guidelines.

It had a well defined problem statement, a definite stopping point and seemingly belonged to a group of similar problems resolved within the shelter guidelines. It was a Tame Problem (Fig. 2).

7.2 Wicked Problem Domain

That quickly changed; the accuracy of the 8128 case load was questioned, only $5.5 USD million was donated instead of the requested $24 USD million and the Shelter Cluster Guidelines were questioned as to whether they were an appropriate shelter solution given their cost and construction time. So, the problem statement became unstable, the stopping point was lost and the Shelter Guidelines were no longer a ‘similar problem’. It was suddenly a WP.

7.3 Social Complexity Domain

There were several stakeholders involved in this ‘domain’ and while there was seemingly agreement on whether families should rebuild back on previous sites despite the flooding risk each had their own reasons and conditions. For example, many of the villages were well established and had been in their current location for over a hundred years. The affected villagers, fearful for their security, for food, for family and historic alliances with other families, wanted to rebuild on the same site. They wanted to go ‘home’. Their neighbours were fearful. Perhaps some of their land would be ‘requisitioned’ and what impact would their moving have on the alliances and understandings about access to water and to grazing? Hence they preferred them to stay rather than relocate. But they also wondered why they weren’t being given assistance and found such aid destabilizing in terms of the local and social politics. The provincial governors were also supportive for them to stay as it meant that the family would be ‘obligated’ to support and vote for their candidature; they wanted to be seen as being pro-active, having ‘contacts’ and therefore ‘powerful’. The Government Minister responsible for the response program came from the affected area and in part because he was an architect, also supported their rebuilding on existing sites. However, he was aware of the bigger issues such as climate change and the need to promote a robust disaster risk reduction policy using ‘build back better’ techniques and in particular appropriate foundations for flood proofing. He wanted to be seen as enabling a ‘Quality’ house especially in his home of origin. Both political wings were very interested in who was on the lists. And finally there were aid agencies that were accountable to their donors and under pressure to make the best use of any funding and reduce vulnerabilities through a Disaster Risk Reduction (DRR) perspective in their programs. They supported staying but only if houses were flood proofed but that had economic and timing implications reduced the reach of their assistance and they were mindful of the bad press agencies had received the year before when urban based families living in slums died through lack of heating assistance. Hence, while there was general agreement that they should stay, it was for quite different reasons (Fig. 3).

However, there was not the same agreement about the need to differentiate between acute and chronic caseloads. A chronic caseload is due to ‘a slow-onset emergency that does not emerge from a single, distinct event but one that emerges gradually over time, often based on a confluence of different events.’ (OCHA 2011).

Fig. 3 A Typical Village Meeting. This meeting was high in the mountains of Samangan Province

The acute on the other hand is the caseload from a sudden onset essentially one off disaster, such as this flood. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) through whom most of the funding was supplied for this response were insisting that aid agencies purposely separate out between these two case loads. The local authorities and certainly the village leaders wanted aid agencies to assist both case loads, because both had ‘needs’ albeit that one was from another previous ‘disaster’. This presented a dilemma for aid agencies. On one hand they were there to help but if they helped people affected from other disasters how would they ascertain that they were actually from other disasters….and would assisting them be a ‘pull’ factor for others to realise aid when perhaps they shouldn’t? And still further, instances did start to appear where there seemed to be a genuine case of DRR usually associated with river or stream entrainment that perhaps should be addressed as requested by the villagers. Despite their validity, such cases had to be put aside because regardless of whether it was right or not it would undoubtedly created tensions within the communities. But it did take the edge of the notion of ‘engagement’ with villages.

And finally, you soon noticed that women were not in any of the meetings or apparent decision making. And while female staff could talk to the women of the affected households it remained difficulty maintaining a women’s perspective of the ‘problem’.

Aid agencies also had the usual questions of whom to help and to what degree, especially given the reduced funding for the NSRP (and also why strict targeting of whom should be assisted was required). Agencies were concerned that assisting could firstly have a de-motivating impact on those that had started rebuilding their houses by recycling materials from their old house and manufacturing new materials such as mud bricks. But secondly, may also encourage some to deliberately damage their house or some other building to get assistance. Observations on the ground showed that some households mindful of the forth coming winter had started retrieving and recycling material, fabricating new mud bricks and rebuilding. On the other hand those that had not apparently done anything when asked why replied that they ‘had waited for us [The United Nations] to arrive’.

All of this complexity will most likely look ‘normal’ to readers who have worked in the humanitarian field; and they are probably right. However, in the context of WP’s it probably means that wickedness is also the norm rather than the exception and perhaps this is why shelter has such an ‘intractable character’?

Finally, if that was not enough on May 27 President Obama (NYT 2014), declared that it was ‘time to turn the page on a decade in which so much of our foreign policy was focused on the wars in Afghanistan and Iraq,’ announced the withdraw of the last American troops from Afghanistan by the end of 2016. That was interpreted by local NGO’s as a final closing off of funding and assistance with early evidenced by the low response to the NSRP? In response, they initiated a ‘Don’t Forget Afghanistan’ campaign. But the closing off of the decade for a country with an official unemployment rate of 35 % (unofficially around 60 %) was grim.

Without question, this was a socially complex situation.

8 Technical Complexity and the Unproblemising Approach

So what do you do? The first seemingly reasonable issue was to ascertain the extent of the problem? This does appear to be a heading back to a systems approach which as shown earlier in the literature doesn't succeed with WP's because there is 'no one problem' and 'no one solution' and the theoretical possibility of 'no resolution'. However, the use of an iterative process between a solution and its current problem definition as indicated earlier from the literature is one way to understand the nature of the framing of a WP. Such a process is inherently 'natural' for designers and indicated in the holistic design process outlined by the IDEO Approach. The original caseload of 8128 houses had been questioned because it had been 'plucked' and 'gleaned' from different assessment forms that aid agencies had used. Moreover, there were also questions about whether the Category A criteria had been appropriately applied especially given the earlier feedback that 'they had been waiting for us to arrive'. Hence a second assessment was done using the Rapid Assessment Form (RAF) developed by IOM with supported by Office for the Coordination of Humanitarian Affairs OCHA and a commitment to using the Category A criteria (Cat A). Those criteria were that the house had been 'completely' destroyed due to the April-May flooding which usually was associated with the loss of foundation support and that the family had one of the following seven vulnerabilities:

1. Female head of household;
2. Elderly head of household;
3. Disabled head of household;
4. Large family (8 members or more, later increased to 10);
5. Low income;
6. Child head of household;
7. Other vulnerability (specify).

The numbers from that second assessment are tabulated below; and while it is interesting noting which provinces went up or down, the overall number went down to 6579 households or houses. What was also disturbing was the poor progress in constructing houses since the floods in April and the truly important number was the apparent gap of 5638 houses. This rang 'alarm bells' within the aid community.

The alarm was triggered firstly because of the gap which represented between 40,000 and 43,000 people; and secondly because of the sub arctic conditions that people would be subjected to when winter arrived in December through till March. Tents and tarpaulins had been provided as part of the emergency response phase of the flooding. But with 60 % of the affected villages being between 2500 and 3500 m elevation and 10 % in the 3500–4000 range meant that temperatures would commonly go down to −20 °C. Tents and tarps can take up to −2 °C when they are 'winterised' but beyond that the logistics of providing heating fuel and of tents sustaining snow loads without collapse made them incredibly inappropriate. Heads of agencies started to imagine photographs of collapsed tents with their logo on them, or at least that was the sense.

The Emergency Shelter and Non Food Items (ES&NFI or Shelter Cluster) then set about trying to address this issue. They looked at 11 different strategies and estimated their impact on this Gap that had become ‘The Gap’; it was on the face of it now ‘personal’. The strategies consisted of the following:

1. Areas inaccessible due to security issues (of which there were around 674) could be done by the Afghanistan Red Crescent. This needed to be confirmed and the question of their ability to access insecure areas ascertained.
2. Prioritise aid based on altitude, village size to minimise the logistics and perhaps a Cat A+ criteria; namely raise the aid threshold.
3. Make the two room shelter-guideline house into two one-rooms (at least for the winter), economise on the foundations and technical verify by calculation the heating requirements for shelter design.
4. Use Non Food Items NFI from the winter pre-positioned stocks to assist families in whatever situations they were get through the winter.
5. Omit the toilet/latrine from the house design to reduce the house cost and build more houses (this was later discarded because it linked directly to women’s health).
6. Foster more ‘host family’ situations at least for the winter.
7. More focus on DRR options in the field to provide alternative shelter options. For example, it was observed that houses had typically silted up to their windows (see earlier photograph in Fig. 2). This happened because families had dug down over their land plot and used that material to construct firstly the walls (for security and privacy) and then the houses but at a level that was now below the road. The flood water that occurred then went down the streets outside and where walls broke resulted in the immediate ponding of the plots followed by adjoining plots till the water rejoined the flood flow. This resulted in silting up to the window level and alternatives such as raising the roofs levels rather than digging out the house be considered. This was cost effective and reduced the risk of future flooding.
8. Move to a location based project management approach rather than a resourced based one so as to optimise the speed and cost of funded houses.
9. Carefully monitor the Cat A in the field and scrutinise whether families are Cat A or whether they have been able to find alternative housing in say a host family situation with a relative.
10. Encourage recycling and self community self reliance/resilience.
11. Carefully prioritise housing allocation especially where there were several Cat A’s in one cluster of connected houses.

These were discussed with the Shelter Cluster partners in the North and it was determined that the Gap of 5638 could be reduced to 3972 and that another 500 families/houses could be funded under the current funding levels leaving a gap of $3972 - 500 = 3472$ houses/households/families (assuming ideal conditions). Thus, further funding was going to be required but that aside could the local building

Table 3 The re-assessed category A housing by provinces as at the 19 August 2014

Provinces	Initial findings	Re-assessment findings	Houses constructed	Funded	Gaps
Faryab	1433	828	16	0	812
Sari Pol	727	790	17	540	233
Jawzjan	2976	1760	0	170	1590
Balkh	794	864	4	194	666
Samangan	537	446	0	0	446
Baghlan	867	985	0	0	985
Takhar	330	330	0	0	330
Badakhshan	500	576	0	0	576
Total	8164[a]	6579	37	904	5638

[a]There had been some small increases following the NSRP based numbers

industry cope given that it was seemingly struggling with the current construction (refer to the 'houses constructed' column in Table 3 above). Mindful that there was only 4 months till winter and effectively white out conditions through till March. The sense of the Shelter Cluster members based on the numbers from the assessment and their situational awareness on the ground was that an additional 10 houses/day throughout the Northern Provinces would be reasonable and so the final Gap under ideal conditions came down to 3472 − 1000 = 2472. This was still immensely disturbing.

The shelter solution presented in the Shelter Guidelines was referred to as 'transitional' but was in reality quite 'permanent'. It had a permanent rock foundation 1000 mm below the ground and at least 500 mm above. It was designed as a flood mitigation requirement of the Afghanistan Government but also supported by the Shelter Cluster partners. The house had 500 mm thick mud brick walls because of the sub arctic temperatures and essentially was permanent and not transitional. Figure 4 shows some of the examples from the flood response in the North but that design was typical for shelter aid throughout Afghanistan beyond the flood affected families. It had been discussed and debated and was essentially codified into the Shelter Guidelines. It was a known entity to shelter partners…or was it?

Several of the key Shelter Cluster partners mindful of the need not to create beneficiary dependency by their shelter assistance had set up a system whereby the

Fig. 4 The 'transitional' house proposed by the Shelter Cluster Guidelines

beneficiary had to supply the land and construct the house up to the top of the foundations. This also over came past issues associated with land tenure while recognizing that (ES&NFI 2014b) '….a transitional shelter programme is a community based, self-help programme. The primary responsibility of identifying shelter beneficiaries lies with the community. The Ministry of Refugees and Repatriation or its provincial directorates and Shelter Cluster members play an advisory and coordinating role' though the flooding response in the North was under the Ministry of Rural Rehabilitation and Development (MRRD).

It became apparent that the foundations were expensive and had not been readily identified because they were often not shown as a cost to the agency because they were a cost to the beneficiary who then used their own networks to complete the construction with verification by the aid agency's engineers. The issue that surfaced was that the cost of the foundation had climbed to around half of the cost for the complete house (not including land). This was verified by those Shelter Cluster partners that included the costs of the foundations and suddenly the nature of the problem changed but also intensified, those costs had to be addressed.

What became apparent was the foundations were affecting other non technical areas for the response in the North but also had been impacting on beneficiary targeting outside of that response since the Shelter Guidelines had been in place which was the certainly the last 5 years and possibly as much as 10 years of all shelter response in Afghanistan. For example the beneficiary targeting was on paper at least the poorest of the poor…however the land tenure and the having to pay for half a house in terms of the overall house cost would hardly be the poorest of the poor. In addition, the land tenure requirements when half of the cost of the house is in the ground (albeit by the owner) meant that there needed to be quite a strong one 20+ years lease and preferably ownership of the land.

Determination of the soil bearing capacity was set up using a Scala Penetrometer. Training was provided and made available to Shelter Cluster Partners. It is a robust test that manually drives a steel point into the soil and from the number of blows and the result depth of the point one is able to determine the soil bearing capacity. This would minimise the required depth of any foundations whether they were the standard rock type or some other one. A minimum depth of 200 mm was set based on anticipated and averaged scour depths. Moreover, field testing of house foundations suggested that this would/could be expected to be the typical founding depth of the foundations; this is compared to 1000 mm of the shelter guidelines and hence was a significant saving using the standard rock foundations of the Shelter Guidelines.

An improved "below" ground approach was also possible. In this approach the soil from the excavated foundations was mixed with cement at a rate of 7 % based on weight. The excavated material was placed back in the excavated trench, compacted and watered to hydrate the cement. The top was levelled or stepped to suit site and house requirements. This required only 10 standard bags of cement that could be readily purchased at a cost of less than $30 USD plus labour compared to $650–750 USD for the below the ground foundations. In addition, it also meant that the work could be completed by the family or other labourers and not foundation experts with minimal observation from the aid agency's engineers. Thus, it could be finished quickly and to a timetable that the family controlled.

The technical redesign than looked at the above ground requirements. Again, rock foundations could be used that were intrinsically flood resistant because of their material nature and the construction process but there were several alternatives that were possible. That started with the use of mud bricks that were available on site, could be easily transported, were much cheaper and used local labour that could be supplemented or even replaced by the family's contribution. Mud brick unlike rock were not flood resistant and this is where the design strategising started. The options included the following:

- Using a controlled erosion approach. This strategy could include over sized foundations that allowed for a 'sacrificial loss of mud brick' without failure. Another more manageable strategy would be to construct a veranda in front of the mud brick foundations that protected it but would absorb the impact of any flood waters.
- Material modification. This strategy made a stabilised earth block approach by incorporating cement into the mud brick mix. A factor of safety would probably require this approach to be combined with a level of 'over sizing' as suggested above.
- New material. This strategy used the option of 'sand bagging' or earth bags (Kracht 2008). This is where the soil material is bagged and the bags then used for the foundations. The approach has been used in humanitarian situations and is recognised in the literature. It is an option that perhaps should have a wider application in the humanitarian shelter response.

These options cut the price again and if the sand bags at a cost $20–40 USD were provided by the aid agency could mean that the cost would be minimal (or labour only to fill them and place them) to around $30 USD to have bricks that were stabilised plus the labour to place them. In a similar way to before the cost savings would be against $600–650 USD cost for the rock foundations. This would effectively get the house up to the floor level.

9 The Technical-Social Connection

Technical resolution as outlined above certainly changed the nature of the initial problem. It also changed the social complexity in an unexpected way that could not have been anticipated. For example, it meant that the 'poorest of the poor' could be helped in reality in addition to the rhetoric. It allowed aid to be spent in the affected communities and it meant that timetables were back in the control of the affected families.

It also meant that targeting of beneficiaries could be (and should be) reviewed. Given that only 5 % (and certainly less than 10 %) of the cost of a house was in the ground would allow less stringent land tenure requirements. So that instead of having to own the land or have a 25 year lease, the possibility of being able to take 90–95 % of the house with them (or sell it) meant that the shelter assistance could follow the beneficiary. Consequently, leases of perhaps 10 years or 5 would be possible without the need to actually owning it.

10 Conclusion

The Unproblemising Approach is elegant in its potential simplicity. It firstly requires that any shelter problem be identified as a WP; which means can the ‘problem’ be framed and is it stable. The next step is to map the social complexity and in particular who are the stake holders and what are their ‘problem-frames’ or mandates. This is followed by identifying what are the current technical issues associated with each of the stakeholders and starting probably from the beneficiary commence the iterating between possible solutions of its technical complexity and their problem frame. This should yield limited but useful ‘benefits’ to the shelter program and to the beneficiaries. But as the iterations progress and pull in further ‘social’ issues from the other stakeholders (mindful of any potential changes of problem framing dealt with thus far) there could emerge a platform for a significant step change. This is the point of it becoming a ‘Game Maker’ rather than a ‘Game Taker’ situation and it is not ‘incremental’ any longer.

The case study does suggest that such an approach can and ultimately does have extensive positive social outcomes. The technical-social linkage may not be obvious or direct but linked nonetheless. Moreover, the significance of technical complexity is missed in the WP literature. And while I can hear the thoughts of those reading this that it is only one case study, it is still the one in-the-face of none that is significant. Evidently technical complexity does not have a significant role but it seemingly does for shelter in the post disaster context. Moreover, the case study has a familiarity to shelter practitioner in the field that perhaps suggests it is much wider than just this case study. That will need to be documented. But the original draft uses seven different disaster examples but at just over 80 pages it was consequently narrowed down to this one. According to the current WP literature even that one should not exist.

The case study does point to some draw backs. One of them is that the step change cannot be identified or even detected at the start of the process. There is no obvious road map or compass; except that so long as there are small incremental ‘value add’ on the way, whether there ‘is-or-isn’t’, is not a question. Another possible drawback is that it probably requires a ‘mature’ or reflective designer. On one hand they need to be proficient to deal with the technical complexity while on the other ‘understand’ the current social issues. This is so that links can be made between the two and solutions in the technical domain can be realized that have additional social outcomes. Such skills are not common. Finally, the Unproblemising Approach has difficulty in picking the difference between the issues related to a problem’s wickedness and its social complexity; though this might be common when dealing with WP's and maybe a point of frustration rather than significance.

However, the need for a new way of thinking is evident in the literature. Ramalingam et al. state that (Ramalingam et al. 2014) "…that is, they can be explicit about and continually test and probe their intervention logic and assumptions, to work towards programmes that are 'best fit' rather than 'best practice'. These methods can help navigate a middle ground in the face of complex and wicked problems: to ensure development professionals neither have to surrender to uncertainty on the one hand nor construct convenient but false and potentially unhelpful log frame 'fictions' on the other'.

In Australia, the Government approach suggests (Australian Govt 2007): '…. tackling wicked problems is an evolving art. They require thinking that is capable of grasping the big picture, including the interrelationships among the full range of causal factors underlying them. They often require broader, more collaborative and innovative approaches. This may result in the occasional failure or need for policy change or adjustment'.

Consequently an Unproblemising Approach for post disaster shelter does seem to have a possible role for shelter practitioners in the face of such possible donor support. The challenge now as put by Jones is that (Jones 2011); '…..what is clear, however, is that complexity can no longer be swept under the carpet—individuals and organisations must recognise it and take responsibility for implementing appropriate solutions.'

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Dedication

To my kid Sister Dianne and her 'Unproblemising' struggle with cancer. Some problems I guess just remain 'wicked'…. no matter what perspective you take or in your case are given.

References

Alexander C, Ishikawa S, Silverstein M, Jacobson M, Fiksdahl-King I, Angel S (1977) A pattern language. Oxford Press, Oxford

ALNAP (2012) "We're not in the field anymore" Adapting humanitarian efforts to an urban world. In: 27th meeting of the active learning network for accountability and performance in humanitarian action ALNAP, Chennai, India, 17–18 Jan 2012

AusAid (2003) AusGUIDElines. The logical framework approach AusAID updated 20 June 2003, Australian Aid and Development Canberra Australia, p 1

Australian Govt (2007) Contemporary government challenges tackling wicked problems. A Public Policy Perspective © Commonwealth of Australia 2007. ISBN 978-0-9803978-4-0

Babister L (2014) Extended note: Humanitarian response to Urban crises. Department for International Development DFID 14th UK Shelter Forum 13 Mar 2014. The Meridian House, London. Hosted by save the children and the International Organisation for Migration (IOM)
Bakewell O, Garbutt A (2005) The use and abuse of the logical framework approach. Swedish International Development Cooperation Agency SIDA, Nov 2005, p 3
Brandenburger A, Nalebuff B (1999) The right game: use game theory to shape strategy HBR review on managing uncertainty, pp 67–105
Buchanan-Smith M, Fabbri P (2005) Thematic evaluation on LRRD linking, relief, rehabilitation and development—a review of the debate tsunami evaluation coalition TEC, Nov 2005, p 3
Burke J, Fan L (2014) Humanitarian crises, emergency preparedness and response: the role of business and the private sector Indonesia case study. Humanitarian Policy Group Overseas Development Institute ODI, Feb 2014
Camillus J (2008) Strategy as a wicked problem. Har Bus Rev 86(5):98
CENDEP (2011) HERR and Shelter: implications for practice. Humanitarian Emergency Response Review. Centre for Development and Emergency Practice Oxford Brookes University and the International Federation of Red Cross and Red Crescent Societies (IFRC) September 2011
Clermont C, Sanderson D, Sharma A, Spraos H (2011) Study of member agencies’ responses to the earthquake in Port au Prince, Haiti, January 2010. Report for the Disasters Emergency Committee (DEC) pp 2 and 23
Conklin J (2005) Dialogue mapping: building shared understanding of wicked problem. Wiley Press, New York
da Silva J (2010) Lessons from Aceh: key considerations in post disaster reconstruction. Practical Action Publishing, Warwickshire. ISBN 978-1-85339-700-4
DARA (2014) The European consensus on Humanitarian aid: an NGO perspective commissioned by VOICE (It was carried out by DARA, with Ed Schenkenberg as team leader, Marybeth Redheffer as main researcher, and supported by Belén Paley 2009)
Darcy J, Hofman C-A (2003) According to Need? Needs assessment and decision making in the humanitarian sector, HPG report 15, ODI, London, p 22
DFID (2011) Humanitarian emergency response review. Department for International Development (DFID), UK
EPYPSA (2011) An evaluation of the Haiti earthquake 2010 meeting Shelter needs: issues, achievements and constraints Estudios Proyectos y Planificación S.A for International Federation of Red Cross and Red Crescent Societies IFRC Geneva, Dec 2011, pp 35–39
ES&NFI (2014a) The national Shelter response plan version 7 June 2014. Report by the Emergency Shelter and Non Food Items Cluster, Kabul
ES&NFI (2014b) Shelter guidelines Afghanistan. Transitional Shelter guidelines Afghanistan May 2014. Emergency Shelter and Non Food Item Cluster, Kabul, pp 5–6
Frame B (2010) Sustainability technologies 101: HATCHED: wicked problems and other such technical terms Chapter 19. Canterbury Region’s Water Allocation Canterbury New Zealand, Water Board Christchurch, New Zealand
Grint K (2008) Wicked problems and clumsy solutions: the role of leadership. Clinical leader Vol 1 Number II Dec 2008. The British Association of Medical Practitioners BAMM Stockport, UK. ISSN 1757-3424
Groat L, Wang D (2002) Architectural research methods. Wiley, New York, pp 348–350
Hamdi N (2010) The placemakers guide to community building. Earthscan, London. ISBN 978-1-84407-803-5
Hofmann CA, Roberts L, Shoham J, Harvey P (2004) Measuring the impact of humanitarian aid. A review of current practice (Researched, Humanitarian Policy Group at ODI)
IDEO (2015) The field guide to human-centered design by IDEO.org, 1st edn. San Francisco, © 2015. ISBN 978-0-9914063-1-11
IFRC (2011) Transitional shelters. Eight designs International Federation of Red Cross and Red Crescent Societies, Geneva
IFRC (2013) Post-disaster shelter: ten designs International Federation of Red Cross and Red Crescent Societies, Geneva, pp 13–20

IFRC (2014a) Regulatory barriers to providing emergency and transitional shelter after disasters Country case study: Nepal. Nepal Red Cross Society and the International Federation of Red Cross and Red Crescent Societies, Geneva, pp 19–21

IFRC (2014b) The shelter effect video. https://www.youtube.com/watch?v=Lf2z38u2djA. Accessed May 2015

IFRC, UN-HABITAT, UNHCR (2014) Shelter projects 2013–2014. IFRC, Geneva

Jackson B (1997) Designing projects and project evaluations using the logical framework approach. IUCN Monitoring and Evaluation Initiative, Oct 1997

Jean, I, Bonino, F (2014) Investing in listening: international organization for Migration's experience with humanitarian feedback mechanisms in Sindh Province'. ALNAP/CDA Case Study, London

Jensen G (2010) The logical framework approach. How to guide. Bond for International Development, p 4

Jones H (2011) Taking responsibility for complexity when is a policy problem complex, why does it matter, and how can it be tackled? Overseas Development Institute ODI. Briefing Paper 68, Aug 2011. ISSN 0140-8682

Kracht S (2008) The Sandbag house; high living comfort, economical and ecological. Sandbag Houses, South Africa

Levine S, Bailey S, Boyer B, Mehu C (2012) Avoiding reality. Land, institutions and humanitarian action in post-earthquake Haiti HPG. Working Paper, Sept 2012

Mannakkara S, Wilkinson S (2014) Re-conceptualising "Building back better" to improve post-disaster recovery. Int J Manag Proj Bus 7(3)

Melles G, Holmlid S, Arvola M (2013) Operationalizing wicked problem solving to create desirable futures: the design agenda

NRC (2014) Lessons from Baghdad a shift in approach to urban shelter response. Norwegian Refugee Council, May 2014

NYT (2014) US troops to leave Afghanistan by the End of 2016 New York Times. http://www.nytimes.com/2014/05/28/world/asia/us-to-complete-afghan-pullout-by-end-of-2016-obama-to-say.html?_r=0. Accessed 31 May 2015

OCHA (2011) OCHA and slow-onset emergencies OCHA occasional policy briefing series brief No. 6 policy development and studies branch, UN Office for the Coordination of Humanitarian Affairs (OCHA), Apr 2011

OCHA (2014a) Country emergency report No. 9, 1 June 2014

OCHA (2014b) Afghanistan flash floods situation Report No. 8 as of 1800 h (local time) on 22 May 2014. http://reliefweb.int/report/afghanistan/afghanistan-flash-floods-situation-report-no-8-1800h-local-time-22-may-2014. Accessed on 31 May 2015

ODI (2014) Can disasters become an opportunity? Building back better in Aceh, Myanmar and Haiti. http://www.odi.org/events/3850-disaster-haiti-haiyan-aceh-myanmar-disaster-recovery. Accessed May 2015

Örtengren K (2004) The logical framework approach a summary of the theory behind the LFA method, SIDA, Jan 2004, p 7

Pavanello S (2012) Rethinking the humanitarian response: emerging approaches for engagement in urban crises. Advanced Training Program on Humanitarian Action ATHA, Apr 2012

PCI (1970) Guidelines for teaching logical framework concepts practical concepts incorporated (PCI) 1730 Rhode Island Avenue, N.W. Suite 200 Washington, DC. 20036

Potangaroa R, Santosa H. Wilkinson S (2014) The application of quality of life metrics. In: Masys AJ (ed) Disaster management: enabling resilience. Springer, Berlin

Ramalingam B, Scriven K, Foley C (2009) Innovations in international humanitarian action Chapter 3. The active learning network for accountability and performance in Humanitarian Action ALNAP, 8th Review of Humanitarian Action

Ramalingam B, Laric M, Primrose J (2014) From best practice to best fit Understanding and navigating wicked problems in international development. Working paper ODI, July 2014, pp 38–41

Ritchey T (2013) Wicked problems modelling social messes with morphological analysis. Acta Morphologica Generalis AMG, vol 2(1), © Swedish Morphological Society. ISSN 2001-2241
Rittel H, Webber M (1973) Dilemmas in a general theory of planning policy science, vol 4. Elsevier Scientific Pub, Amsterdam, pp 155–169 (p 159)
Roberts N (2000) Int Publ Manage Rev 1(1):1. Electronic Journal at http://www.ipmr.net © International Public Management Network
Sanderson D, Burnell J (2013. Beyond shelter after disaster: practice, process and possibilities. Routledge\Taylor and Francis, Oxon\NY. ISBN 13:978-0-415-81423-2 (also pub in Environmental hazards: human and policy dimensions, vol 10(3–4) July 2011)
Sanderson D, Ramalingam B (2015) Nepal earthquake response: lessons for operational agencies. The active learning network for accountability and performance in Humanitarian action ALNAP
Seybold P (2013) How to address “wicked problems” use dialogue mapping to build a shared understanding and evolve a group’s thinking, 23 May 2013 (Patricia B. Seybold, CEO & Sr. Consultant, Patricia Seybold Group)
Shelter Case Studies (2010) Shelter projects 2010. IFRC, UN-HABITAT and UNHCR. Joseph Ashmore, with additional editorial support from Carlo Gherardi, Jim Kennedy and Wan Sophonpanich
Shelter Case Studies (2013) Shelter projects 2011–2012. IFRC, UN-HABITAT and UNHCR. Project coordinated by: Esteban Leon (UN–HABITAT), Miguel Urquia (UNHCR), Sandra D’Urzo (IFRC) and Joseph Ashmore
Shelter Centre (2010) Literature review for shelter after disaster. FP innovations, Royal Roads University
SPHERE (2011) The sphere project, 3rd edn. ISBN 978-1-908176-00-4
Spratt J (2011) Is development wicked? Using a wicked problems framework to examine development problems. NZADDs Working Paper, Dec 2011
UNHCR (2007) Handbook for emergencies, 3rd edn. The United Nations High Commissioner for Refugees, p 58
Wikipedia (2010) 2010 Haiti earthquake. http://en.wikipedia.org/wiki/2010_Haiti_earthquake. Accessed May 2015
Wikipedia (2015) Logical framework approach. http://en.wikipedia.org/wiki/Logical_framework_approach. Accessed May 2015
Yin RK (2003) Case study research design and methods. In: Robert K (ed) Yin applied social research methods series, vol 5, 3rd edn. Sage, Thousand Oaks, p 1

Part III
Systems Approaches Theme

Supporting Intelligence Analysis Through Visual Thinking

Steve Strang and Anthony J. Masys

Abstract Today's threat landscape is characterized by uncertainty and complexity stemming from the interconnectivity and interdependence of the hyper-connected world (Masys et al. in Procedia Econ Finance 18:772–779, 2014). Threats stemming from terrorism and transnational crime are more diverse and interconnected thereby calling upon an expansion of the analytic envelope and vocabulary of intelligence. This complex problem space is value-laden, open-ended, multidimensional, ambiguous and unstable and can be labeled as 'wicked and messy'. Events such as 9/11 highlight "surprising events" that reflect an organizations inability to recognize evidence of new vulnerabilities or the existence of ineffective countermeasures (Woods in Resilience engineering: concepts and precepts, 2006). This necessitates the requirement to readjust to their existence and thereby the need to consider the extremes (Taleb in The Black Swan: the impact of the highly improbable, 2007), to challenge dominant mindsets and explore the space of possibilities. In Limits of Intelligence Analysis, Heuer (Orbis 49(1):75–94, 2005) argues how limitations in perception, perspective, and resistance to change, as well as understanding and communicating uncertainty all contribute the complexity of intelligence analysis. To support this, Richards (The art and science of intelligence analysis, 2010) argues that key components that support intelligence analysis include: critical thinking, creativity, powers of judgment, and communication. Addressing the unique challenges associated with transnational threats as terrorism and organized crime requires creative and collaborative efforts among key intelligence and security stakeholders that facilitate questioning judgments and underlying assumptions, and employing critical and creative thinking in order to explore the possibility space. This chapter explores the application of 'visual thinking' to support the complexity and challenges associated with intelligence analysis.

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1 Introduction

The purpose of intelligence is to provide knowledge and understanding of a current or anticipated threat. The more complex the threat environment, the more difficult it becomes to understand, explain, and intervene. This complexity is not only due to the scale of the threat, or to how complicated the threat is, it is also caused by pervasive uncertainty. The threats studied by intelligence analysts are groups and networks of other people who are actively hiding their intentions and activities through secrecy and misinformation. To examine such complex intelligence problems requires multi-methodologies. For example, a systems approach such as network visualization provides rich description of the important features of a terrorist or an organized crime group structure and activities by representing information about interrelationships of actors, groups and their connection patterns in the network. The visualization, interpretation and communication of such a representation of concepts, entities, places, and their interrelationships is characterized as visual thinking. Visual thinking is an important part of understanding complex situations. Making knowledge visible so that it can be better accessed, discussed, valued or generally managed is a long-standing objective in intelligence.

Eppler and Burkhard (2007: 114) describe the emerging field of knowledge visualization to support knowledge management. Within the context of intelligence analysis, visualization of knowledge '…aim to create, assess, reference or transfer insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions'. Sketches, diagrams, graphics, visualizations, external representations play significant roles in thought and communication supporting intelligence analysis. Exploring mental models and revealing assumptions, visual thinking helps to externalize internal thought, and serves as a methodology for inference, reasoning and insight.

Intelligence clients increasingly demand visual presentation of assessments, as charts, diagrams, maps, images, and presentation slides. Like visual thinking, visual communication plays an important role in intelligence analysis but could be used more effectively. The visual communication of complex qualitative information is difficult, and lacks the range of resources available to guide quantitative information visualization. The three connected themes explored in this chapter are: complexity, visual thinking, and visual communication. All are considered specifically through the conditions and requirements of intelligence analysis, however many of the issues and approaches are applicable to other disciplines.

2 Complexity

Intelligence problems vary not only in the extent to which they are complex, but also in the nature of their complexity.

2.1 Puzzle, Problem, or Mess?

The types of complexity found in intelligence issues may be categorized as: puzzles, problems, and messes (also known as wicked problems).

These three formal categories of problems were developed in the field of morphological analysis, but are also relevant to intelligence. These categories are an expansion of the distinction between tame problems and wicked problems, first outlined as such in a 1973 paper on dilemmas in urban planning by Horst Rittle and Melvin Webber.

A puzzle has clearly defined boundaries, and only one correct answer. All criminal investigations are puzzles, an example of this is: "Who put the bomb on Air India flight 182?". There is one right answer, and that answer is theoretically knowable, even if it is difficult or impossible to discover and prove in court. Puzzles are structurally the simplest of the three categories despite the complications which may arise in solving them.

A problem has clear boundaries, but has multiple possible answers which are more-or-less correct depending on context. An example of a problem in this sense is: "How do we bring the perpetrators of the Air India bombing to justice?" This is a problem for several reasons, one of which is that different individuals and legal systems have different opinions and rules on what constitutes justice in a case of ideologically-motivated mass murder. Another example of a problem is: "Which organized crime group should we give priority to investigating?" All organized crime groups are worth investigating and disrupting; but some pose greater threats than others, and some are easier to investigate and disrupt than others.

A mess is the most complex of the three, and is also known as a "wicked problem" (Rittel and Webber 1973). A mess is a complex issue without defined boundaries, and may even lack a clear formulation. Messes tend to be interactive open systems, unquantifiable, and contain multiple interrelated uncertainties. Messes do not have single, correct solutions, and they may not even provide any way of knowing when a partial solution has been reached. Instead they have a range of approaches which may improve the situation, but which carry with them both intended and unintended consequences which change the nature of the mess. An example of a mess is: "How do we prevent terrorism?", or "How do we win the war on drugs?".

Puzzles can be solved, problems can be resolved, messes can be addressed.

Applying this to the world of intelligence, the nature of the problem determines the type of analysis applied to it. Puzzles, such as criminal investigations, are usually tactical intelligence issues. Strategic intelligence assessments most often examine problems and messes. “One of the greatest mistakes that can be made when dealing with a mess is to carve off part of the mess, treat it as a problem and then solve it as a puzzle—ignoring its links with other aspects of the mess” Michael Pidd, quoted in Ritchey (2006: 3).

2.2 Complexity and Secrecy

Our ability to effectively target and disrupt organized criminal groups, including both organized crime and terrorist groups, depends on our ability to understand them. The two most significant barriers to understanding these covert criminal groups and networks are the complexity of the problems and the secrecy of the participants.

Organized crime is a term used to describe a wide variety of groups and networks engaged in criminal acts for profit. The diversity of organized crime groups poses a challenge to estimating the threat posed by organized crime as a whole. This includes differences in: structure, size, activities, membership requirements, specialization, operational capabilities and limitations, and resilience to law enforcement, amongst other qualities. To give an example, structural differences range from groups with formal membership and hierarchical distribution of authority, to fluid networks of collaborating career criminals.

This challenge of understanding the specific criminal organizations is compounded by the secrecy that organized crime groups and networks operate under. Secrecy is their key defence against disruption by the justice system, and is achieved by concealing criminal activity, camouflaging it as licit activity, or corrupting public officials.

Organized crime is also a term used to categorize criminal acts committed by individuals working together, and includes three main types of criminal markets or activities:

- Production and sale of illegal goods such as drugs, and counterfeit products
- Management and supply of illegal services, such as prostitution, smuggling, or money laundering
- Acquisition of goods or money through predatory crimes such as theft, robbery, extortion, or fraud

The first two types of criminal activities are particularly difficult to measure. Although these crimes are not victimless, the transactions they are based on, such as cash for drugs or cash for sex, are primarily consensual in nature and occur in relative secrecy. The chain of production of illegal goods may be long, multi-national, and may take place partly in the licit economy.

The principle of secrecy has some market-driven exceptions within the milieu of organized crime groups and customers. For example, gangs attempting to control turf must be visible to their competitors, whether through mutually recognizable territorial markings such as graffiti, or through personal markings such as specific clothing or tattoos.

The problems of complexity and secrecy are also echoed when attempting to disrupt terrorism. Terrorist groups also show a wide variety of structural forms, motivations, objectives, levels of sophistication, internally-acceptable levels and types of violence, and other attributes. There are four main organizational structures used by terrorists:

- Hierarchical/Paramilitary
- Centralized Cells
- Decentralized Cells
- Lone Actors and Ad Hoc Cells

These structural categories are not exclusive, some groups/networks/movements combine two or more of these at different times or for different purposes. Each of these structures is a compromise between the competing needs to control the activities of the group and to maintain security in the face of intelligence and investigative efforts by the security forces. Terrorist activities are not limited to violent attacks, they also engage in indoctrinating and training new members, propagandizing, fund-raising, and the acquisition of weapons and other materiel. Some of these activities may be legal, and some are public.

Secrecy, however, is also a requirement for a terrorist group or network to survive and operate, and surprise is a necessary element of any successful attack.

2.3 Uncertainty of Information

The sources of information vary in their reliability. Most individuals or organizations which provide information to the police and intelligence services are motivated by public interest and a concern for public safety. However, some are motivated by self-interest. Some are more or less honest than others, just as some are in a better or lesser position to know the information they are sharing.

The accuracy of information collected also varies: some is true or partly true; while some is accidentally or deliberately false. The validity of any piece of information is not determined only by the reliability of the source, since an unreliable source may still tell the truth, and a reliable source may deliberately or accidentally pass on false information.

2.4 Foresight and Warning

Intelligence clients consistently ask for two things: actionable intelligence supporting ongoing operations against current threats, and predictive intelligence helping them identify and prepare for the next threat. The problem of uncertainty becomes even more pressing when analysts are tasked with giving warning of events which may happen in the future.

Strategic early warning is usually rooted in a military/national security paradigm in which a hostile nation or group uses strategic surprise in order to launch an attack or acquire and field a new strategic capability. There are numerous examples of nations, guerrillas, and terrorists using strategic surprise. The Imperial Japanese attack on Pearl Harbour, the Indian Government's first nuclear weapons test, and the Al Quaeda 9-11 attacks are the most widely cited. There are few, if any, examples of organized crime groups using strategic surprise against the authorities, although some have used it against competitors.

The task of providing strategic warning about emerging and anticipated threats in organized crime has its own additional set of challenges. New organized crime threats come from within the constant turmoil of the domestic and international criminal economy. The drivers of these changes include: technological, economic, cultural, environmental and/or political developments. These drivers are revealed in emerging criminal businesses, shifting supply routes and sources, and changing criminal markets driven by a combination of consumer choices and new opportunities for criminal exploitation.

The indications of emerging organized crime threats are inevitably scattered and fragmentary. For example, they might consist of pieces of information discovered at border crossings, in emergency rooms or at crime scenes. The indications might be reported on as emerging issues in banking, fire safety, or community health; and the links to organized crime may be deeply concealed.

Indicators and Warning (I&W) is the military intelligence standard for producing warnings. It is an effective intelligence technique for situations with a clear warning question, such as the threat of invasion or of the development of nuclear weapons capability by a specific hostile power. These situations are "known unknowns"—the threats we know to be worried about. It is not, however, the best technique to forecast and warn against unanticipated threats, which tend to be "unknown unknowns".

2.5 Data, Big and Small

Intelligence analysts, depending on their agency and the specific problem in front of them, need to deal with either too much data or too little. Usually the problem is too much irrelevant data and too little relevant information. For agencies with access to large-scale collection the problem is invariably one of big data, the metaphor of "drinking from a fire hose" is so often heard that it seems almost like a verbal tic in some parts of the intelligence community. Big data brings not only complications but additional complexity to an intelligence problem, since this data is big in volume, velocity, and variety (Liao et al. 2013):

- Volume is the sheer amount of information to monitor, sort, and assess.
- Velocity is the rate at which the information is dynamically updated and added.
- Variety is the range of different types of information an analyst may need to understand, consider, and incorporate into an assessment.

What needs to be added to Liao et al.'s list of criteria is the fourth "V" of intelligence information, which is Validity. As described above, the assessment of how accurate or truthful a piece of information is may be persistently uncertain, or may change over time. In ordinary big data, validity is merely an issue of data entry error or other relatively random accidents. In intelligence, validity is also affected by deceit and deception on the part of the people being studied who are attempting to impose a false understanding of their activities and intentions.

3 Visual Thinking

The two key elements in analyzing an intelligence issue are to dissect and externalize the problem. "There are two basic tools for dealing with complexity in analysis—decomposition and externalization…. Externalization means getting the decomposed problem out of one's head and down on paper or on a computer screen in some simplified form that shows the main variables, parameters, or elements of the problem and how they relate to each other" (Heuer 1999: 86). The externalization may take the form of text giving narrative, description or explanation. It may also take the form of information organized for quick reference in a table or matrix of text or numbers. The third form of externalization is as an illustration, such as a map, diagram or chart.

In practice, decomposition and externalization need to be simultaneous symbiotic processes. Analysts need to be able to hold the required information outside of working memory while examining, dissecting, and processing it. This problem is not at all new, nor is it limited to the field of intelligence. When we consider the technology and techniques of scholarship and scientific analysis we see a wide range of approaches to use visual thinking to extend working memory and aid mental processing.

Visual thinking in this sense is not necessarily about thinking in images rather than words, but describes "the cognitive processes involved in orchestrating visual information in the mind" (Clair and Jia 2006: 158) and the process of analysis through visually arranging and rearranging information to explore and challenge relationships including cause and effect. The information may not be inherently visual, but is presented visually for the purposes of analysis. This is essentially the same as the concept of visual analytics, defined as "analytical reasoning facilitated by interactive visual interfaces" (Liao et al. 2013: 2). The purpose of visual thinking is "to make the complex understandable by making it visible—not by making it simple" (Roam 2008: 105).

The need to hold the information physically in front of us for examination and decision-making is the purpose of game boards. Few people can play chess without a board holding the pieces in view, and the problems facing an intelligence analyst are far more complicated and complex than a chess game. Similar physical tools have great antiquity in mathematics to extend working memory and aid mental processing, such as Roman calculating boards, the medieval exchequer and the abacus.

At most basic, the visual display of information may be achieved by organizing the information for accessibility in plain view. The purpose is to extend the working memory by placing the information as text or image where it will be a constant or linked reminder, since out of sight does mean out of mind. A well-documented early example of this process for scientific analysis of a large and complex data set is Carl Linnaeus' use of paper slips, tree diagrams, and interleaved books in tracking, organizing, and making sense of the information he needed to build his taxonomy of plant and animal species (Muller-Wille and Scharf 2009). An interleaved book is one bound so that each printed page is faced by a blank one, providing more space than the margins would for annotations, additions, and commentaries. Linnaeus' use of standard-sized paper slips to store and flexibly organize information was an example of the earliest form of card catalogue, the physical ancestor of our digital databases. His taxonomy was developed and illustrated with the aid of hierarchical node-link diagrams showing relationships from the most general categories of life down to the most specific.

The basic types of two-dimensional information visualization have been around for centuries.

- Maps and nautical charts to display and develop geographic information
- Diagrams to illustrate the otherwise hidden structures of the solar system, human anatomy, and genealogy

While there are many practical advantages to two-dimensional representations, they require "flattening" of information which has three or more dimensions.

Physical models are techniques for representing and exploring three-dimensional information. These are also of considerable antiquity, but for technical reasons of production have not been normally used in intelligence analysis. Advances in three-dimensional digital modelling and printing should allow analysts to make increasing use of these approaches in physical objects as well as digital representations.

Examples of physical models include:

- Scientific tools, such as armillary spheres and other astronomical models, and chemical models of atoms and compounds
- Medical models of internal organs and examples of physical symptoms of diseases

Animations and cinema/video are modern techniques to show events and changes over time. These are rooted in technology first developed in the late 19th century, but with advances in computing are now available to anyone with a smartphone.

The technology available to engage in visual thinking includes the basic pencil and paper, whiteboards and blackboards, objects arranged in physical space, as well as digital media. While the more complex technology is generally preferable for professional-looking visual communication, the simpler technologies such as pencil and paper appear to be superior aids to visual thinking.

3.1 Thinking Diagrams

Visualization techniques for analysis require more flexibility than those used only for visual communication. Visual analysis is a process of experimentation, of exploring multiple possible arrangements of information and multiple possible representations of the relationships between the elements of the problem. Research on these thinking diagrams has shown that spontaneous hand drawing on a large easily-erasable surface such as a whiteboard is still more useful than drawing software (Walny et al. 2011). The reasons for preferring hand-drawn charts include flexibility, immediacy, and physical size. Interestingly, the subjects of Walney et al.'s study were computer graphics researchers, computer scientists, and others with very high levels of computer literacy and a demonstrated interest in working with computers, yet they still expressed a clear preference for the superior immediacy and flexibility of physical media for their thinking diagrams.

One of the authors has developed thinking diagrams for intelligence analysis using: blackboards, whiteboards, adhesive notes on walls, sheets of plotter paper, notepads, and paper napkins. The conceptual model for this chapter was drawn on a placemat at a sushi restaurant. As with Walney et al.'s findings; immediacy, availability and flexibility were essential in every instance.

These spontaneous visualizations are not limited to the standard forms of information visualization charts, nor are they bound by standards of presentation or completeness. The users of thinking diagrams are the analysts themselves. The diagrams are working notes meant to explore and tentatively organize information, and to communicate ideas with collaborators rather than clients. Physically larger drawing surfaces provide more space to retain information and to compare and revise multiple versions of the same thinking diagram. Larger surfaces also allow the analysts to physically incorporate photographs and other documents into the thinking diagram.

Flexibility of thinking diagrams is essential since sensemaking using information visualization is a cyclic and iterative process which incorporates discovery and creativity (Yi et al. 2008). This research showed four distinctive processes which people use to gain insights while using information visualization:

- Provide Overview—using visualization to show the 'big picture' and to find gaps in knowledge
- Adjust—exploring the information by adjusting the level of abstraction or detail represented
- Detect Pattern—finding trends, patterns, structure and outliers in the data
- Match Mental Model—helping the analyst adjust their mental model to the patterns in the information

In Walney et al.'s research on visual thinking in action (2011), four main types of thinking diagrams were observed:

- Node—link diagrams
- Tree diagrams (directional node-link diagrams)
- Data charts (line graphs, scatterplots, or bar charts showing patterns with few or no numbers)
- Timelines

The researchers also noted that the visual thinking representations included a spectrum of importance of words to diagrams which range from fragments of text to diagrams without words. They developed an eight-point scale to describe these uses (Walney et al. 2011: 4):

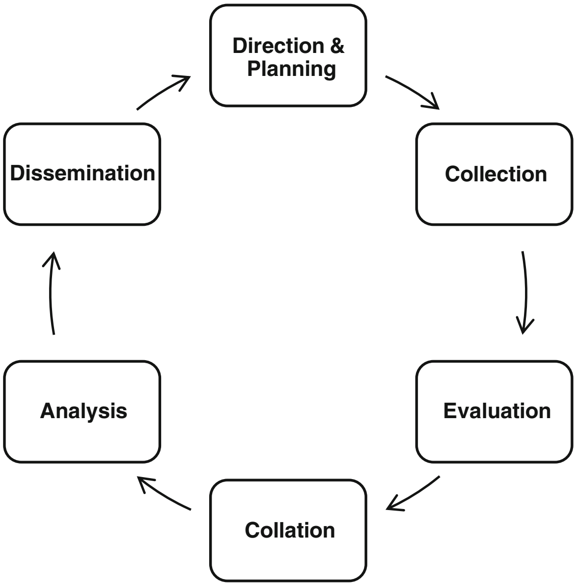
- Sentences and paragraphs
- Word lists
- Words in spatial organization, with few or no diagrammatic elements
- Simple diagrammatic constructs—words with some diagrammatic elements, but the type of diagram is not obvious
- Words in visual constructions—words are the major elements in a recognizable type of diagram
- Mixed words and diagrams—diagrams where major elements include words as well as symbols or icons
- Diagrams with labels
- Pure diagrams with no words

This range of different types of diagrams and charts used to explore ideas and conduct collaborative analysis, and the varying extent to which the visual thinking records make use of words and diagrammatic elements, demonstrates the need for flexibility in visual thinking techniques and technology.

3.2 Thinking Diagrams for Intelligence Analysts

In the standard intelligence cycle (Fig. 1) "analysis" is shown as something done after all the planning, collection, evaluation and organization of information. The typical diagram of the intelligence cycle is actually a simplified conceptual model, though unfortunately often presented as if it were a process diagram of sequential

Fig. 1 Intelligence cycle



steps. In reality, analysis is being done throughout every step of the process. Thinking diagrams, as part of those analyses, are most important during the planning phase, and again in the main analysis element.

Planning is the phase when the analyst has to clarify the question asked him or her, examine and challenge assumptions embedded in the question, and frame a conceptual model of the problem which includes a tentative description of the issue, an initial set of alternative explanations (hypotheses) and an initial set of probable sources of information needed to test those hypotheses.

The work done in the planning phase can be the most important piece of analysis, since it constructs the frame for all the subsequent elements of the intelligence work. As Kang and Stasko discovered (2014: 138) in their research into the intelligence analysis process: "intelligence is about determining how to answer a question, what to research, what to collect, and what criteria to use. This process becomes part of the analysis—analysis implicitly occurs during the process of the construction." The process of "constructing a frame" they are describing here is the development of the conceptual framework for the intelligence project.

3.3 Conceptual Models

The conceptual framework is the first step in analysis, and from this preliminary analysis and provisional understanding come the plans for collection and further analysis. This first exploration of the intelligence problem is necessary for the analyst to organize their thinking, establish the focus of research, and develop a draft project plan. Depending on the results of this exploration, the preliminary analysis may lead to minor or major changes to the original intelligence tasking.

Developing the conceptual framework requires several analytic tasks:

- Checking assumptions embedded in the question
- Reviewing previous work on the problem
- Decomposition and externalization
- Drafting a conceptual map or diagram of the problem, its components, and implications
- Drafting a set of hypotheses to serve as testable provisional explanations

The data-frame theory of sensemaking is another way of examining and explaining this process (Klein et al. 2006; Moore and Hoffman 2011). This macrocognitive model of sensemaking focuses on how people develop, test, modify and replace frames. Frames in their meaning are the mental framework or model, however minimal, which people start with when attempting to understand and explain events. The frame can be expressed as stories, maps, and diagrams.

The value in the data-frame theory for intelligence analysis is the emphasis on testing, changing or replacing a frame depending on how it accords with the data. Klein et al. (2006: 88) describe this as: "the basic sensemaking act is data-frame symbiosis" with the frame functioning as a hypothesis (Fig. 2). The frame is preserved and may be elaborated by information which supports it, or may be discarded and replaced in response to information which disproves it.

Any approach used to represent the frame and the extent to which the data currently supports or refutes it needs to be easy to modify and update, since: "frames are things that you think with but also things you think about" (Klein et al. 2006: 90).

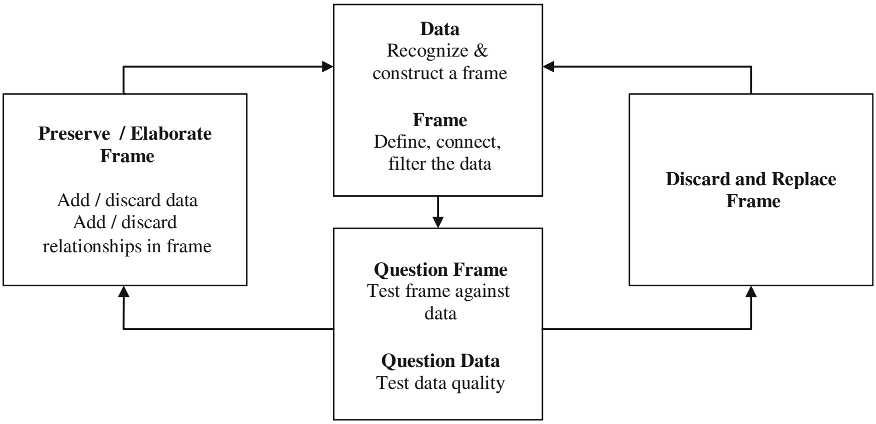


Fig. 2 Data-frame theory of sensemaking

3.3.1 Systems Thinking

The complexity associated with intelligence analysis pertaining to terrorism and organized crime is rooted in the interdependencies, interconnectivity and ambiguity. Jackson (2003: 65) defines systems thinking as '…a discipline for seeing the 'structures' that underlie complex situations … it helps us to see the deeper patterns lying beneath the events and the details Senge (1990)' and challenges simplification, opening up to a space of possibilities. Systems thinking, characterized by seeing wholes and interconnections is critical to understanding complex intelligence scenarios. As described in Masys (2010), the systems lens can enable decision makers to see beyond events and detect underlying patterns as well as the forces and causal relationships that hold these patterns in place. Van der Merwe (2008: 220) argues that '…a systems worldview, together with tools and techniques to make structure visible, is important for building quality scenarios' in this way supporting possibility exploration regarding terrorist networks and counterterrorism strategies. The systems lens '…acknowledges that knowledge is multiple, temporary and dependent on context—with different points of view providing a constant challenge to any existing viewpoint or system' (Wilkinson and Eidinow 2008: 9). Systems thinking thereby features 3 key attributes that are important to intelligence analysis: an understanding of interrelationships; a commitment to multiple perspectives; and an awareness of boundaries.

3.3.2 Rich Picture and Metaphorical Thinking

Rosenhead and Mingers (2001: 4–5) describe 'messy problems' as that which have inherent complex interdependencies and dynamic complexity. They argue that 'Individual problems may be solved. But if they are components of a mess, the solutions to individual problems cannot be added, since those solutions will interact'. This resonates with intelligence and counter-terrorism strategies. Examining the problem space thereby requires unique approaches such as Soft Systems Methodology. SSM is defined by Checkland and Poulter (2010: 191) as follows:

> Soft systems methodology (SSM) is an approach for tackling problematical, messy situations of all kinds. It is an action-oriented process of inquiry into problematic situations in which users learn their way from finding out about the situation, to taking action to improve it.

Drawing from general systems theory, SSM (Checkland 1981, 1999; Checkland and Scholes 1990) recognizes the interconnectedness, interdependencies and complexity inherent in open, dynamic systems. Soft Systems Methodology brings together alternative ways of viewing situations that can be used to address problem situations.

It addresses the following questions:

- What are the different ways in which a situation can be framed?
- How does each of these ways, on its own, provide a means of comprehending how a situation behaves?
- What are the implications for any changes to the situation?

A key element of soft systems methodology, Rich Pictures provide a mechanism for learning about complex or ill-defined problems by drawing detailed ("rich") representations of them. The rich picture reflects an emergent process that captures multiple perspectives garnered from various stakeholders. Checkland (1999) proposes the rich picture as a representation to be used at the beginning of the SSM process. It is a diagrammatic way of sharing one's own experiences and perceptions regarding a given problem situation through the identification and linking of a series of concepts.

As sketches, rich pictures are drawings that are used for individual or group reflection and model building. They reflect preliminary ideas and are used to make concepts explicit and debatable. In the context of knowledge management, these drawings can be called heuristic sketches to highlight their problem solving potential. The main benefits of heuristic sketches are as follows (Eppler and Burkhard 2007: 115):

- 'They represent the main idea and key features of a preliminary insight.
- They are flexible and highly accessible because they are accompanied by explanations and developed jointly.
- They are fast and help to quickly visualize emergent notions.
- The use of a pen on a flipchart attracts the attention towards the communicator.
- Heuristic sketches allow room for one's own interpretations and foster the creativity in groups'.

Through the development of interpretive rich pictures, group members learn to share and increase their individual and collective understandings of the problem situation thus enabling them to better understand the dynamic behavior and complex impact of different options. The qualities of transparency (easy to understand), accessibility (easy to make) and collaboratively developed, make this visual method highly successful in framing the problem space. By having everybody collaboratively contribute to a Rich Picture; a shared understanding of a given situation emerges.

With the visual thinking approach of rich pictures there is no commonly agreed syntax. The rich picture is comprised of symbols, sketches or "doodles" and may 'employ heavily visual displays (e.g. cognitive and causal maps, causal loop diagrams, stocks and flows pictures, decision graphs, value trees)' (Franco and Montibeller 2010: 493). Metaphorical thinking provides an approach to facilitate insights and understanding of something familiar to something new using visual metaphors such as an iceberg, mountain, light bulb. Metaphors help to organize information meaningfully for structure and insight.

Rich pictures and systems thinking, as described in Masys and Vallerand (2014) are powerful approaches to tackling a difficult problem and for seeing where the high leverage lies. This is particularly relevant when designing intervention strategies for counterterrorism and counter organized crime.

3.4 Thinking Diagrams for Exploratory Analysis

The most important thinking diagrams for intelligence analysts are generally the node and link family which includes: Concept Maps, Mind Maps, Argument Maps, Hypotheses Maps, Link Charts, Social Network Analysis Charts, organizational charts, flow charts, and kinship charts. These different specific types of diagrams have specialized uses and norms which should be adhered to when using them for visual communication. However, as visual thinking tools, node and link diagrams can take in and blend elements of any one of the specialized forms while the analyst explores the information, the nature of the relationships found, and the most effective approaches of inquiry to take.

Node and Link diagrams can be structured to show hierarchy, centrality, or sequence. Diagrams showing hierarchy (such as: Concept Maps and Hypotheses Maps) are laid out like organizational charts, with the most important or general nodes at the top, and the least important or most specialized nodes at the bottom. Diagrams showing centrality (such as: Social Network Analysis charts and Mind Maps) should be composed with the most central nodes in the middle, and the least central towards the outer edge of the network. Diagrams showing sequence of events (such as: flow charts, decision trees, and timelines) usually start on the left hand side and flow in order towards the right with the direction of flow shown by arrows on the linking lines.

The following are the main types of node-link diagrams of potential use to intelligence analysts. Aspects of any or all of these can be used in thinking diagrams. Combining different visualization formats can compensate for the limits of each (Eppler 2006: 204). Using elements from different visualization techniques during analysis also allows the analyst to test which approach or combination of approaches will be most useful to communicate his or her findings.

3.4.1 Mind Maps

Mind maps are radial diagrams used to show connections between elements of learned material. The core topic is in the centre, with sub-topics arrayed around it in sequence and/or related clusters. Usually taught as a note-taking method, they can also be used to structure and restructure information. Labels and colours are used to record the nature of links and nodes.

3.4.2 Concept Maps

Concept maps (Ahlberg 2004; Canas et al. 2005; Tergan 2005) are another form of diagrams and also use diagrammatic representations to visually reference knowledge or for visualizing the relations among concepts. Concept maps are diagrams made up of concepts connected by lines. The lines are labeled to describe the nature of the relationship between the two linked concepts. The concepts are defined as: "perceived regularity in events or objects, or records of events or objects, designated by a label" (Novak and Canas 2008: 1). Concept maps as developed by Novak are hierarchical, with the focus question or most general concepts at the top and more specific concepts towards the bottom. The links are directional and must be labeled to show what the relationship is.

A concept map generally consists of two elements: an item and a relationship between two items. Concept maps illustrate both an overview and detail, and interrelationships among these details. Concept maps are helpful for different learning and communication tasks (Eppler and Burkhard 2007: 115–116):

- 'to brainstorm or summarizing contents;
- for sense making by illustrating and overview and details;
- for structuring digital information;
- as visual interface to databases; and
- for shared understanding of contents'.

3.4.3 Argument Maps

Argument maps are diagrams showing the structure of an argument. The nodes represent the elements of the argument, such as the contention, premises, rebuttals, and conclusion; and directional links represent inferences. Some experiments in educational setting have shown argument mapping to be an effective way to improve critical thinking skills (Harrell 2008; Twardy 2004). Argument maps have a hierarchical structure, with the contention at the top and the lines of reasoning which prove or disprove it flowing upwards.

3.4.4 Hypotheses Maps

Hypotheses maps are recently developed as specialized argument maps. The nodes represent the elements of multiple hypotheses testing, including the question, hypotheses, supporting information, inconsistent information, and sub-hypotheses. The links represent the flow of the inquiry, from initial question, through hypotheses to sub-hypotheses and eventually to explanations. Hypotheses maps have a hierarchical structure with the initial question at the top, and the lines of reasoning and evidence flowing downwards. This is an alternative to Analysis of Competing Hypotheses for testing multiple hypotheses simultaneously (van Gelder 2009).

3.4.5 Decision Trees

Decision trees are directional diagrams where the nodes are specific decision points and the links are specific possible outcomes leading to further decisions. These can be used to explore alternative future actions, for example when forecasting possible reactions of a terrorist group to a foiled attack. Decision Trees run from their starting point (the root node) at the left side of a page or screen, towards the right.

3.4.6 Flow Charts

Flow charts are directional diagrams showing processes. Nodes are represented by a variety of different shapes representing elements of a process such as: decisions, activities, documents, and outputs. Directional links show the flow of the process. These are used in a variety of fields, and can be an effective way to show the processes of a conspiracy or of a criminal business. Flow Charts are also known as Process Maps.

3.4.7 Link Analysis Charts

Link analysis charts organize and present the patterns of connections between entities, which include the individuals, groups, objects, places and events relevant to a criminal intelligence assessment or criminal investigation.

These charts can use:

- Annotations on links to document the content of conversations, the amounts of money transferred, the number of times calls were placed between two telephones, or any other information relevant to the analysis of that link. This can also include the source(s) of our knowledge of that link, our assessment of the source's reliability, and our assessment of the validity of the information
- Different types of lines to indicate whether a link is known or suspected. The standard convention is to use solid lines for proven links and dashed or dotted lines for uncertain or suspected links. The lines can also be marked to show the direction of the link
- Distinct symbols or icons to indicate clearly whether the entity is a person, business, address, vehicle, weapon, or other specific type of thing relevant to the assessment. Some software packages allow the use of individuals' photographs as their icons on a link chart.

3.4.8 Social Network Analysis Charts

Social Network Analysis charts develop and present the patterns of relationships between individuals within an organization or community.

These charts can use:

- Directed links which use arrows to mark the direction of exchanges relevant to the intelligence question, such as the movement of goods, money, advice, permission and information between the individuals charted
- Weighted or valued links which show the relative strength, intensity, frequency, duration or quantity of the link. The weight can be shown through numbers attached to the link, by varying the thickness or colour of the line, or by other appropriate techniques such as showing close relationships as physically close on the chart
- Weighted nodes which show the relative importance of individuals by varying the size, colour, or placement of the node
- Layout to reveal structural features, for example by clustering kinship groups or business partnerships, or by overlaying the chart on a map to show the correlation of links to geographic locations

The above examples of node-link diagrams are not the only approaches which can be used in visual thinking. Following are some examples of visual techniques based on ways of organizing words into visual patterns other than narrative text, in order to hold them in mind and to reveal relationships and patterns.

3.4.9 Causal Loop Diagrams

The use of causal loop diagrams (Fig. 3) is a method drawn from systems dynamics (Sterman 2000) that maps how components of a situation relate to each other. This method is used to explore nonlinear interrelationships.

It addresses the following questions:

- What are the key variable in the situation that interests us?
- How do they link to each other?
- How do they affect each other? Does a variable have a reinforcing or dampening effect on the variables to which it is linked?

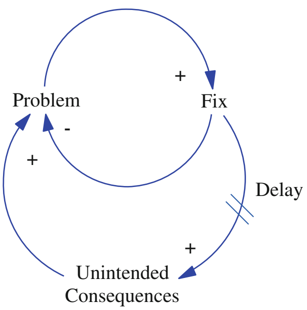


Fig. 3 Causal loop diagram —fixes that fail

3.4.10 Force Field Analysis

Force Field Analysis is used for comparing and contrasting information. At its simplest this consists of two parallel lists, one of factors for a goal or judgment and the other of factors against. The factors can be weighted as part of the analysis, and some of the pros and cons may cancel each other out.

3.4.11 Matrices

Matrices are grids used to sort and organize information, and to compare the relationships between variables. While Analysis of Competing Hypotheses is probably the best known specialized matrix technique in intelligence, there are many other uses of matrices. Other specialized matrix analytic techniques include Complexity Manager and Decision Matrices (Heuer and Pherson 2011).

3.4.12 Analysis of Competing Hypotheses

Analysis of Competing Hypotheses (ACH) is an example of a matrix analytic technique (Heuer 1999: 95–109). In ACH the hypotheses are listed horizontally across the top row, and the data points are listed vertically down the left hand side. Each cell is then the intersection between a piece of information and one of the hypotheses and can be marked as Consistent, Inconsistent, Neutral or Not Applicable. This is a method for disconfirming hypotheses and countering certain cognitive biases. ACH matrices are tools for use while doing analysis, as well as effective records of information considered and judgements made.

3.4.13 Alternative Futures Quadrants

Alternative Futures Analysis quadrants are a way to develop and represent possible future scenarios based on multiple drivers. Pairs of drivers are used as the x and y axes of a chart. These drivers are continua, for example if "terrorist weapons" was one driver it could be shown as a continuum from "common object (knife, hammer, car)" at one end to "WMD" at the other. If the other driver of concern was "intended target" it may be a continuum from "random individual" to "VIP". Each quadrant has a different type of scenario based on the four different relations between the drivers.

A thinking diagram may incorporate several techniques through transformations and additions, as new information is collected and as new understandings of the problem develop. The analyst might also use multiple thinking diagrams to explore different aspects of the problem. For example, the analyst might start with a link chart of a wholesale drug trafficking deal showing connections between individuals, bank accounts, drugs, and places. This reveals a point-in-time picture of activity by an organized crime group. It could be expanded into or overlaid with a flow chart of the group's business model and place in the production, transportation, wholesale and retail of the drugs; looking for chokepoints or other vulnerabilities in their business process. This could then be used to explore the flow of profits from the retail dealers through group members and money laundering processes, again looking for chokepoints and other vulnerabilities for disruption. The network of individuals involved could be analyzed using SNA attributes such as centrality, brokerage, and cutpoints. The diagram could also be overlaid on a physical map to show which jurisdictions the business process and money laundering flows through, and which physical routes are used to transport the drugs, again looking for vulnerabilities. Decision trees could be drawn to explore the group's options should one of these key connections or routes be cut off through enforcement action.

The results of this process are highly valuable to the analysts, but in this form are probably unreadable by anyone else. This highlights two problems, one of complication, the other of complexity.

The problem of complication is: how much information can an analyst put on the chart?
The problem of complexity is: how many dimensions of information can the analyst put on the chart?

The answer to both questions is much the same. A chart which is a working tool for the analytic process can be data dense, show multiple dimensions of analysis and be messy. The analyst is already deeply familiar with all the information in the chart, so the chart is a reminder of that information and the analysis of it. A chart which is a communication tool to convey the analytic finding needs to be clear to the reader, who is usually not intimately familiar with the information.

4 Visual Communication

Illustrations used in visual thinking need to be substantially developed and revised if they are to be used for visual communication, just as textual notes and rough drafts need to be expanded and edited to be used as a written report.

The principles of visual communication for intelligence are driven by the needs of the audience, who are usually operational or policy decision makers. The analyst must minimize the effort readers have to make to read and understand intelligence products, in order to maximize the effort they can put into considering and using the analysis.

Comprehensive presentations of complex sets of information are easier to study and communicate through visualizations than through narrative text. For example, the famous PowerPoint slide showing a concept map of the security situation in Afghanistan may be simplistically critiqued as an incomprehensibly complex presentation slide. However, a diagram is the only way for the reader to hold that set of interrelationships between those issues at one time and explore them at his or her will. There are 13 broad issues shown on that diagram, including: popular conditions and beliefs, overall government capacity, tribal governance, outside support to insurgent factions, infrastructure services and economy, and coalition domestic support. Within those 13 categories are about 100 specific issues, each subject to multiple links with other issues. A narrative description of the same information would be forced into a linear sequential stream, most of the connections would be lost, and the issue would be made more difficult to understand.

4.1 Clarity

One of Edward Tufte's rules of graphical excellence can be summed up as: use the least ink possible to convey the necessary information (Tufte 2001). This principle is as true for intelligence illustration as it is for intelligence writing.

Five steps for clarity in diagrams and other illustrations:

1. Determine the purpose of the illustration
2. Select the information which must be shown to meet that purpose
3. Eliminate the elements which are not relevant
4. Reduce the visual complexity while maintaining accuracy and completeness
5. Arrange and present the elements to best convey the information to the reader

Clarity is not the same as simplicity. The goal of the analyst in visual communication is not to simplify a complex situation, but to show it as clearly as possible so the client can understand it complete with the important nuances, uncertainties, and gaps in knowledge.

Clarity is contextual, for example a link chart of a Mafia group may be clear to an experienced investigator who is new to that specific project, but still be incomprehensible to someone with no prior understanding of organized crime. As Cairo (2013: 60) describes the situation, designers encode data into visualizations and readers decode that information. So the ability of the reader to understand the intelligence visualization depends on the amount of knowledge and visual language shared between the analyst and the client.

As an example of this approach to graphic clarity, consider how different maps of the same city include and exclude details depending on the intended use of the map.

- A nautical chart for boaters will include water depths and buoy locations, but will omit much of the detail on land other than bridges and navigational landmarks.
- A street map for drivers will show roads in detail but will normally omit topographical contour lines and other distractions.
- A public transit map may show only a schematic representation of the subway lines and the names of subway stations.

4.2 Elements of Design

The following principles are useful for illustrations which the analyst makes in order to further his or her analysis, as well as for illustrations used to communicate the assessment to clients and customers. They incorporate techniques the mind uses to very quickly detect patterns, a behaviour known as 'preattentive detection' (Cairo 2013: 114). This recognition of differences and similarities is faster than reading, and is one of the reasons well-designed visualizations can convey more information more quickly than paragraphs of text.

4.2.1 Composition

Composition is the relative positions of elements of a diagram or image. Composition or layout includes the placement of the elements and their proximity to other elements.

The composition of diagrams illustrating qualitative information can be used to show sequence, hierarchy, or centrality of information; depending on which is most important to the assessment.

- Sequence: the readers' eyes will usually enter the illustration from the upper left of the page, just as they would enter a page of text. For a timeline or other diagram showing a chain of events, put the information the consumer should see first at the upper left. Exceptions: this tendency is culturally specific, since not every written language is laid out from left to right.
- Hierarchy: put the most important element or information in the upper centre of the diagram, in the same way that we put the highest-ranking position in an organizational chart at the top centre.
- Centrality: for a social network analysis, concept map, or other network diagram put the central individual or concept in the middle. The most important entities in any grouping in a diagram should be in the centre of that group.

Relative position of two elements on a chart can imply their real proximity, e.g. representing a close relationship between two people by placing their icons very near each other on a link chart.

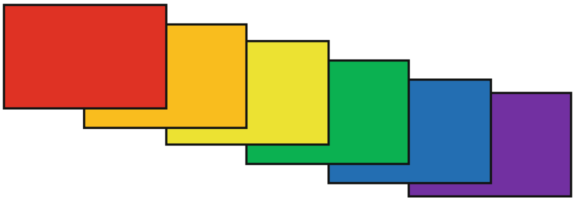
There are ways to present large amounts of information in one diagram without visually overwhelming the consumers:

- Show only the most important elements in an 'executive summary' or 'key findings' version of the diagram first, then add details with explanations in a series of increasingly comprehensive diagrams as you progress through the report or presentation.
- Highlight the most important elements (entities and links) using colour, size, or other contrasts so the consumers will notice them first.

The composition of charts illustrating quantitative information, such as pie charts, bar charts, and heat maps, are largely predetermined by the type of chart used.

4.2.2 Colour

Our eyes and minds react differently to specific colours. We will normally look at something red first and blue later. This pattern generally follows the spectrum: red, orange, yellow, green, blue, violet.



Using eye-catching colours draws the readers' eyes to the most important information, but overusing these colours reduces their impact and increases visual clutter and distraction.

Similar colours can link similar elements of the graphic, e.g. to point out similarities of product, alliance, or modus operandi of different groups.

Analysts and consumers have a set of implicit colour associations, e.g. red = stop, or danger; green = go, or safe. Warning levels are often colour coded, such as warning flags at beaches, and warning cards used by soccer referees. Red is normally the highest level, followed by orange and yellow. However, some colour associations are culture-specific. If the colours in the chart are intended to convey information or judgments, include a key to the colour meanings to ensure they are easy to read.

4.2.3 Shape

There are several sets of meanings associated with specific shapes in charts and diagrams. These conventions are different depending on the type of chart. It is important to be consistent within the chart. It may be necessary to include a legend or key to the shapes' meanings to help the client read the chart easily.

4.2.4 Size

The bigger it is, the more important it seems, even when the graphic isn't a quantitative chart. If one object or element of the chart is larger than the others, the viewers will normally assume the analyst believes it to be more important.

4.2.5 Contrast

Contrast and harmony in colour, shape, size and position are the means to give emphasis to the most important elements of a diagram, and to representing differences and similarities between entities in your chart or graphic.

4.3 Creating Visual Intelligence Products

The common visual communication shortfalls in intelligence products are:

- Too much information
- Failure to focus on key findings
- Overcomplicated with "Chart Junk"
- Careless or distracting use of composition and colour

Intelligence illustration is as complex and difficult as intelligence writing, it takes the same attention to detail, and should be held to the same standards of clarity and accuracy.

The analyst needs to start planning by answering a few basic questions.

- Who are the readers, what are their roles & backgrounds?
- What are the clients trying to achieve, and how will this document help them?
- What information and judgments need to be given to the readers?
- What information and judgments are best given as text, and which in a graphic form,

With those answered, the analyst must decide what kind of graphic(s) best communicates the information and judgments.

Showing qualitative relationships between multiple entities and/or concepts

- Diagrams such as: link analysis charts of individuals in a network, flow charts of information exchange or economic process, organizational charts of hierarchical groups, concept maps or mind maps showing causal or relational links between concepts, argument maps, hypotheses maps, or Venn diagrams showing overlaps between multiple categories.

Showing relationships between multiple entities and physical space

- Maps showing relationships between entities or stages in a process in context of geographic space, plans showing relationships between entities or stages in a process in context of physical space such as inside a building, or inside a device or machine.

Showing relationships between multiple entities/activities and time

- Time lines, critical path charts, and Gantt charts all show different aspects of activities over time.

Showing quantitative relationships between two or more variables

- Graphs and charts showing patterns and relationships between quantitative data, such as: bar graphs, pie charts, and scatter graphs. These can show changes over time, proportions of a whole, and relative amounts.

Showing relationships between two or more entities and variables

- Matrix diagrams, such as Analysis of Competing Hypotheses, Sleipnir matrices for rank-ordering organized crime or terrorist groups, and Alternative Futures quadrants.

Show images to set context, aid memory

- Photographs and drawings can be very useful in intelligence assessments. For example, photographs of individuals used as icons on a link chart can be more memorable and recognizable than standard icons or circles. Photographs, drawings, and physical models are often the most effective way to show the size of an object, the details of a location, or the context of an event.

5 Conclusions

Visual thinking and visual communication have significant advantages in conducting and delivering intelligence analyses. Diagrams and other illustrations are highly effective ways to represent and summarize large amounts of information and complex issues. Using thinking diagrams while conducting analysis helps the analyst extend their working memory and clarify complex and uncertain issues.

Thinking diagrams provide several advantages in analysis:

Speed—it is faster to sketch a notional diagram of a complex situation than to describe it in words. Representing analytic thought needs to be, as nearly as possible, as quick as the thought process and needs to happen while the thought is occurring.
Flexible—to deal with the Four versus of intelligence information (Volume, Velocity, Variety, and Validity) and the multiple ways in which an intelligence problem can be examined.
Exploratory—a thinking diagram explores alternate conceptual views of a problem, so does not necessarily pressure the analyst to premature conclusions.
Collaborative—a thinking diagram can be part of a discussion among analysts, and serve as a provisional record of their thinking. It needs to be drawn while the discussion takes place in order to be useful.
Sketchy—a thinking diagram is a tentative exploration, not a final product. Sketchy diagrams encourage revision, discussion, and use as part of analysis.

Visual communications also provide several advantages to the intelligence analyst, probably the most important of which is that it is expected and demanded by clients. Diagrams and charts can present complex issues and situations clearly and concisely. Well-designed visualizations allow the clients to explore the information and judgements efficiently.

The overriding principle of visual communication in intelligence is clarity. The design challenge for the analyst is to minimize the effort readers must make to read and understand intelligence products, in order to maximize the effort they can put into considering and using the analysis.

This is true of all intelligence analysis communications, including charts, presentation slides, and reports.

To achieve this standard in analytic visualizations analysts need to learn and make most effective use of the intuitive ways in which we process visual information, including preattentive cues, the effects of composition on the way in which the diagram is read, and standard meanings given to certain colours and shapes. This is the same as the requirement to use standard language and commonly-understood terminology as much as possible in analytic reports and presentations.

While thinking diagrams are best drawn with common materials at hand, such as pencil and paper, analytic visualizations for clients need to be as professionally-produced as possible. Drawing and charting software and laser printers are now considered essential, and the assistance of professional graphic designers is valuable in many instances.

Looking to the future, what opportunities are emerging for using 3D modelling and printing in order to avoid "flattening" complex situations into two dimensional representations? Should we make more use of animations to show a diagram or other illustration change over time? The technologies for these options are becoming more common and less expensive. As with the introduction of digital presentation slides and colour printing, it will only be a matter of time before intelligence clients expect and demand such products from us.

Overall, visual thinking supports the creation of new knowledge in groups, thus enabling innovation and insight. The nonlinearity associated with visual thinking leverages the creative power of imagery. By capturing explicit and implicit 'aspects of personal knowledge (Polanyi 1958) that cannot be expressed easily through verbal means, but rather shown through graphic analogies or symbols' (Eppler and Burkhard 2007: 120), helps expose our mental models and inherent assumptions, uncertainly and ambiguity.

References

Ahlberg M (2004) Varieties of concept mapping. Concept maps: theory, methodology, technology. In: Proceedings of the 1st international conference on concept mapping, Universidad Pública de Navarra, Pamplona, Spain

Cairo A (2013) The functional art: an introduction to information graphics and visualization. New Riders, Berkley

Canas AJ, Carff R, Hill G, Carvalho M, Arguedas M, Eskridge TC, Lott J, Carvajal R (2005) Concept maps: integrating knowledge and information visualization. In: Tergan S-O, Keller T (eds) Knowledge and information visualization. Springer, Berlin, pp 205–219

Checkland P (1981) Systems thinking, systems practice. Wiley, Chichester

Checkland P (1999) Systems thinking, systems practice: includes a 30-year retrospective. Wiley, Chichester

Checkland P, Poulter J (2010) Soft systems methodology. In: Reynolds M, Holwell S (eds) Systems approaches to managing change: a practical guide. The Open University, Springer, Berlin

Checkland P, Scholes J (1990) Soft systems methodology in action. Wiley, Chichester

Eppler MJ (2006) A comparison between concept maps, mind maps, conceptual diagrams, and visual metaphors as complementary tools for knowledge construction and sharing. Inf Vis 5:202–210

Eppler M, Burkhard RA (2007) Visual representations in knowledge management: framework and cases. J Knowl Manage 11(4):112–122

Franco LA, Montibeller G (2010) Facilitated modelling in operational research. Eur J Oper Res 205(2010):489–500

Harrell M (2008) No computer program required: even pencil-and-paper argument mapping improves critical thinking skills. Teach Philos 31:351–374

Heuer RJ (1999) Psychology of intelligence analysis. Central Intelligence Agency

Heur RJ (2005) Limits of intelligence analysis. Orbis 49(1):75–94. http://www.worldaffairsboard.com/attachments/staff-college/20727d1273228985-ebo-sod-limits-intelligence-analysis-fpri-winter-2005-heurer-.pdf

Heuer RJ, Pherson RH (2011) Structured analytic techniques for intelligence analysis. CQ Press, Washington

Jackson MC (2003) Systems thinking: creative holism for managers. Wiley, Chichester

Kang Y, Stasko J (2014) Characterizing the intelligence analysis process: informing visual analytics design through a longitudinal field study. Inf Visual 13(2):134–158

Klein G, Moon B, Hoffman RR (2006) Making sense of sensemaking 2: a macrocognitive model. IEEE Intell Syst 21(5):88–92

Liao Q, Shi L, Wang C (2013) Visual analysis of large-scale network anomalies. IBM J Res Dev 57(3), Paper 13. International Business Machines Incorporated

Masys AJ (2010) Fratricide in air operations: opening the black box- revealing the social. PhD Dissertation, University of Leicester, UK, June 2010

Masys AJ, Vallerand A (2014) Major event security planning: secure by design—through the strategic use of integrated modeling and simulation. M&S J

Masys AJ, Ray-Bennett N, Shiroshita H, Jackson P (2014) High impact/low frequency extreme events: enabling reflection and resilience in a hyper-connected world. 4th international conference on building resilience, 8–11 Sept 2014, Salford Quays, UK. Procedia Econ Finance 18:772–779

Moore DT, Hoffman RR (2011) Data-frame theory of sensemaking as a best model for intelligence. Am Intell J 29(2):145–158

Muller-Wille S, Scharf S (2009) Indexing Nature: Carl Linnaeus (1707–1778) and his fact-gathering strategies. Working papers on the nature of evidence No. 36/08. London School of Economics, London

Novak JD, Canas AJ (2008) The theory underlying concept maps and how to construct and use them. Technical report IHMC Cmap Tools 2006-01 Rev 01-2008. Florida Institute for Human and Machine Cognition

Polanyi M (1958) Personal Knowledge. Towards a Post-critical Philosophy, Routledge, London

Richards J (2010) The art and science of intelligence analysis. Oxford Press, Oxford

Ritchie T (2006) Modelling complex socio-technical systems using morphological analysis. Swedish Morphological Society. www.swemorph.com. Accessed 15 Feb 2015

Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. Policy Sci 4:155–169

Roam D (2008) The back of the napkin: solving problems and selling ideas with pictures. Penguin Group, New York

Rosenhead J, Mingers J (2001) A new paradigm of analysis. In: Rosenhead J, Mingers J (eds) Rational analysis for a problematic world revisited. Wiley, West Sussex

Senge P (1990) The fifth discipline: the art and practice of the learning organization. Doubleday Currency, New York

St Clair RN, Jia YX (2006) Visual metaphors, Visual Communication and the Organization of Cognitive Space. Intercultural Commun Stud 15(1):157–167

Sterman JD (2000) Business dynamics: systems thinking and modeling for a complex world. McGraw-Hill Publishing, Boston

Taleb NN (2007) The Black Swan: the impact of the highly improbable. Penguin Books Ltd, London

Tergan S-O (2005) Digital concept maps for managing knowledge and information. In: Tergan S-O, Keller T (eds) Knowledge and information visualization. Springer, Berlin, pp 185–204

Toulmin S (1958) The uses of argument. Cambridge University Press, Cambridge

Tufte E (2001) The visual display of quantitative information, 2nd edn. Graphics Press, Cheshire, Connecticut

Twardy CR (2004) Argument maps improve critical thinking. Teach Philos 27:95–116

van Gelder T (2009) What is hypothesis mapping? 20 Jan 2009. http://www.timvangelder.com. Accessed 10 Mar 2015

Van der Merwe L, (2008), Scenario-based strategy in practice: A framework. *Advances in Developing Human Resources*, 10(2):216–239

Walny J, Carpendale S, Riche NH, Venolia G, Fawcett P (2011) Visual thinking in action: visualizations as used on whiteboards. IEEE Trans Visual Comput Graph 17(12):2508–2517

Woods DD (2006) Essential characteristics of resilience. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience engineering: concepts and precepts. Ashgate Publishing Ltd., Hampshire, UK

Wilkinson A., Eidinow E (2008) Evolving practices in environmental scenarios: a new scenario typology, *Environmental Research Letters*, 3:1–11

Yi JS, Kang Y, Stasko JT, Jacko JA (2008) Understanding and characterizing insights: how do people gain insights using information visualization? Association for Computing Machinery CHI Conference, Italy

The Benefits of a Systems-Thinking Approach to Accident Investigation

Simon A. Bennett

Abstract The origins of disaster are complex. Systems-thinking offers the best chance of identifying contributory factors. Two disasters are discussed with reference to actor-network theory (ANT) which, thanks to its 'principle of generalised symmetry', supports holistic, high-fidelity analysis. It is suggested that the 2014 Malaysia Airlines Flight MH17 disaster originated in a mélange of factors, from cognitive bias to the economic organisation of commercial aviation. There are overheads associated with the methodology. Systems-thinking-informed investigations are intellectually demanding. Further, they are potentially time-consuming and costly. Liberal terms of reference are a prerequisite. Vested interests that seek to constrain, obstruct or undermine the investigation must be challenged. During the early stages of his investigation into the 1989 Dryden aircraft accident, The Honourable Mr Justice Virgil P. Moshansky and his team were subjected to what he later described as intimidation. Because of the inevitable clamour for answers, systems-thinking-informed investigations may be unpopular with politicians, constituents, managements, shareholders, regulators, journalists (whose disaster coverage can be hyperbolic) and other interested parties. Lead investigators must be politically shrewd and emotionally resilient.

Keywords Accidents · Investigation · Reductionism · Systems-thinking · Actor-network theory

1 Introduction

Systems-thinking takes in the interactive complexity, non-linear interactions and emergent behaviours of large socio-technical systems like financial services, mineral extraction, nuclear power generation, health care provision and commercial air

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service. It focuses on the system-as-found and work-as-done. To this end it references the first-hand accounts of front-line personnel rather than system blueprints, mission-statements or press releases. It describes the 'lived reality' of the system in question.

Systems-thinking explores both linear (predictable) and non-linear (unpredictable) interactions. Non-linear interactions, where (through time) identical inputs generate non-identical outputs, can lead to instability, system malfunction and perturbations within a 'system of systems': "In complex systems, outcomes are often emergent, and not simply a result of the performance of individual system components. Hence system behaviour is hard to understand and often not as expected … success and failure … come from … performance variability …" (Shorrock et al. 2014).

The 'truth' of a socio-technical system lies in the often unpredictable and sometimes invisible interactions between system components (liveware, hardware and software) (Dorner 1996). The risk inherent in a complex system "arises not from a singular cause but from … interactions at the systemic level" (Miller 2009). Systems-thinking transforms our understanding of the 'social'. Systems-thinking frames the social as 'materially heterogeneous'. In this counter-intuitive conception, the 'social' encompasses both human and non-human actors (actants). Systems are purposeful, bounded assemblies of mutually-affecting actants, where human performance (for example, the likelihood of poor workmanship or mistake) is influenced by context (for example, system architecture, rules and regulations, terms and conditions, chain-of-command, training, ergonomics, information supply and resourcing). Performance is contingent: "Work in complex systems is impossible to prescribe completely for all but fairly routine situations. Demand fluctuates, resources are often sub-optimal, performance is constrained, and goals conflict … Often the choices available to us are not ideal. We have to make trade-offs and choose among sub-optimal courses of action" (Shorrock et al. 2014). System stress may lead to satisficing—a process whereby employees settle for adequate rather than optimal results. Hollnagel's (2009) theory of system stress-induced 'efficiency-thoroughness trade-offs' (ETTOs) encompasses satisficing. Systems-thinking requires that ETTOs "must be considered … in light of system conditions" (Shorrock et al. 2014).

Systems-thinking is the antithesis of reductionism, which looks for singular rather than multiple causes of failure. Reductionism supports blamism. The desire to blame encourages reductionist analyses. By individuating responsibility for failure, blamism denies the contribution of wider societal and organisational factors like political self-interest, bureaucratic incompetence, under-funding, poor training and unrealistic deadlines. Dekker (2006) observes: "[I]t is critical to capture the relational dynamics and longer-term socio-organisational trends behind system failure". Hollnagel (2004) argues that "… accidents [should be] seen as emerging phenomena in complex systems … the result of an aggregation of conditions …".

Investigations that settle for simple, reductionist answers to complex questions both represent and create latent errors. The reductionist tendency to blame the 2014 ebola outbreak on Africa's 'backwardness' meant that other factors, like the impoverishment of that continent by Britain, France, Belgium, Germany, China and other powerful, self-interested nations went undiscussed. In the case of the ebola outbreak, reductionism led to victim-blaming. Bennett (2014) observed: "Seen in the context of global power-plays between countries like Britain, China, Russia and the United States, the ebola crisis is less a product of Sierra Leone, Liberia and Guinea's under-development and associated social, economic and political problems than of developed countries' greed and ambition. Seen through a systems-thinking lens, ebola is fundamentally a crisis of developed nations' exploitative behaviour. Ebola is a crisis of ideology".

1.1 The Promise of Actor-Network Theory

Determinedly holistic, inclusive and non-discriminatory, actor-network theory (ANT) is a systems theory *par excellence*. ANT recognises the primacy of intent: a system is a purposeful assembly of things. Central to ANT is the principle of generalised symmetry, which holds that all components (animate or inanimate, tangible or intangible) act. Consequently, all merit attention: "Often in practice we bracket off non-human materials, assuming they have a status which differs from that of a human. So materials … are said to be passive; to be active only when they are mobilized by flesh and blood actors. But if the social is really materially heterogeneous then this asymmetry doesn't work very well. Yes, there are differences between conversations, texts, techniques and bodies. Of course. But why should we start out by assuming that some of these have no active role to play in social dynamics?" (Callon and Law 1997). Risan observes: "In networks of humans, machines, animals, and matter in general, humans are not the only beings with agency, not the only ones to act; matter matters" (Risan 1997). ANT's principle of generalised symmetry posits that systems (purposeful assemblies) consist of, amongst other things, people, equipment, financing, contractual obligations, rules, regulations, ideologies, values, beliefs, priorities and aspirations. Each actant "bends space around itself" (Callon and Latour 1981). Actant alignment influences system strength. The more closely aligned a system's actants, the more resilient and effective the system (other things being equal). Societies consist of n overlapping actor-networks of varying longevity. Actor-networks compete to enrol (translate) actants. The actor-network topography fluxes.

To summarise, systems-thinking, reified in theories like ANT, is anti-reductionist. It examines the impact of contextual factors on human decision-making and performance. It reveals the often complex and messy origins of failure. It eschews blamism. Systems-thinking is inconvenient to those who seek Biblical retribution.[1]

[1]Denialism and blamism "have strong psychological 'drivers'" (Reason 2013) and operate at both the individual, organisational and societal level.

This chapter offers two systems-thinking-informed analyses. First, of the loss on 17 July, 2014, of a Malaysia Airlines Boeing 777-200 (Flight MH17) over Hrabove, Ukraine (Dutch Safety Board 2014), at the time of a regional conflict between western-backed Ukrainian forces and Russian-backed Ukrainian separatists. Secondly, of the loss on 31 October, 2014, of Virgin Galactic's SpaceShipTwo reusable sub-orbital space vehicle.

Malaysia's 777 was probably destroyed by a surface-to-air missile (SAM). The conflict in eastern Ukraine, which intensified following Russia's annexation of the Crimea, was in some respects a proxy-war between Europe and Russia.[2] The analysis presented here is deductive and inductive:

> It uses systems theory to demonstrate that MH17's destruction originated in a range of socio-political and organisational factors, and suggests that such factors may have played a part in the loss of SpaceShipTwo
>
> It treats the losses as learning opportunities. For example, lessons are drawn from the immediate reaction to MH17's shoot-down (an unedifying mélange of claim and counter-claim).

2 Systems-Thinking in Action

There are two ways to investigate accidents. First, identify the single most important failure. Secondly, identify as many failures and contributory factors as time and resources allow. Sociologists call the first method the reductionist approach and the second the systems approach. In recent years the systems approach has gained traction, partly because it produces better results (more profound insights, for example). On 2 September, 2006, RAF Nimrod XV230 crashed in Afghanistan killing all on board. On 3 September, 2006, a Board of Inquiry (BoI) was convened. Besides identifying the 'probable physical causes' of the accident, the BoI also identified possible contributory factors, including an under-estimation of the risks associated with airframe modifications. Put simply, the Nimrod Safety Case (NSC) was found wanting. Building on the BoI report, Mr Charles Haddon-Cave QC's *Independent Review into the Broader Issues Surrounding the Loss of the RAF Nimrod MR2 Aircraft XV230* (Haddon-Cave 2009), identified a range of systemic factors, including:

> Significant failings within the 'system of systems' (composed of BAE Systems, QinetiQ and the Nimrod Integrated Project Team) charged with delivering the NSC. Errors of fact in the NSC went unnoticed or unreported. Team members' quiescence may have been caused by groupthink – a process whereby, over time, the members of a tight-knit in-group begin to think and act in the same way (Janis 1972). The Kennedy Administration's 1961 Bay of Pigs invasion – a poorly planned anti-Castro coup – resulted from groupthink within the President's inner circle

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[2]Other proxy wars include the 1950s and 1960s Vietnam War between Asian communist powers like China and Western powers like the United States and Australia (Ambrose 1985).

A failure to actively learn from past incidents, like the November 2004 rupture of the Supplementary Cooling Pack (SCP) duct in Nimrod XV227 (the fire that brought down XV230 is thought to have started when spilled fuel came into contact with an element of the SCP)

A failure to respond to warnings. In 1998, the Nimrod Airworthiness Review Team highlighted the problem of "ever-reducing resources and … increasing demands; whether they be operational, financial, legislative or merely those symptomatic of keeping an old aircraft flying"

Government-inspired reform of the MoD's procurement and asset-management practices that, according to Haddon-Cave (2009), caused the Ministry to suffer "deep organisational trauma". Outsourcing ruptured the Ministry's organisational culture

A cultural shift within the MoD that elevated financial criteria over safety criteria. According to Haddon-Cave (2009), an under-pressure MoD evolved a safety culture "that allowed 'business' to eclipse Airworthiness".

During the accident's decades-long gestation period (SCPs that, according to Haddon-Cave (2009), "increased the potential for ignition", were fitted in the late 1970s, and an air-to-air refuelling capability was added during the Falklands War) the RAF operated a variety of reporting systems. These systems gave personnel the opportunity to draw attention to the Nimrod spilled-fuel/SCP resident pathogen. If reports were raised, it is reasonable to ask why no remedial action was taken. Was it that the MoD's determination to repel the Soviets, liberate the Falklands and support Operations Herrick and Iraqi Freedom outweighed the perceived negative consequences of losing an airframe and fourteen personnel?

All systems—including those like the MoD that deliver national defence—are subject to internal and external pressures that may render system behaviour unpredictable. Large systems are complexly interactive. Non-linear interactions, where identical inputs generate non-identical outputs from the same sub-system, are commonplace. Non-linear interactions cause systems to behave unpredictably. In the argot of systems theory, the behaviour of the system-as-found will not match expectations.[3] The MoD is a large and complex system *par excellence* that exists in a volatile political and economic environment (Haddon-Cave 2009).

Shorrock et al. (2014) describe the down-side of organisational complexity in this way: "In complex systems, outcomes are often emergent, and not simply a result of the performance of individual system components. Hence, system behaviour is … often not as expected". Put simply, unpredictable and complex interactions within the MoD (for example, between sub-systems with different agendas) may have impeded its error-reporting systems.

The Haddon-Cave review of the immediate and proximate causes of the loss of XV230 is a systems-theory-informed accident investigation *par excellence*. It should be required reading for all air accident investigators. The first systems-theory-informed investigation was that conducted by The Honourable

[3]Predicted/expected behaviours are described in, for example, system blueprints, operations manuals and organisation charts.

Mr Justice Virgil P. Moshansky into the 1989 Dryden accident, where wing ice brought down a Fokker F28 passenger aircraft. Despite significant opposition from the aviation establishment, Moshansky conducted a no-holds-barred systems investigation that encompassed both the immediate circumstances of the accident *and the culture of Canada's commercial aviation sector* (Maurino et al. 1998). Moshansky (cited in Maurino et al. 1998) observed: "It would have been a simple matter to assign the blame to pilot error … as had been done in approximately 80 % of aviation accident investigations … A conscious decision was made to … investigate fully the impact of Human Factors throughout the aviation system upon the events at Dryden". Instead of identifying a 'probable cause' from an exhaustive list of failings, die-hard systems-thinker Moshansky made 191 recommendations. For Moshansky, Dryden was a systems accident. It originated in the economy, organisation and culture of Canada's aviation system. "This accident was the result of a failure in the air transportation system" he observed in his 1992 Final Report on the Dryden accident (Moshansky cited in Maurino et al. 1998).

3 The MH17 Disaster

3.1 Introduction

On 17 July, 2014, a Malaysia Airlines Boeing 777-200 was destroyed over Hrabove, Ukraine. Commencing its journey at Schiphol in The Netherlands, the aircraft was carrying 283 passengers and 15 crew. According to the official investigation "the aircraft was penetrated by a large number of high-energy objects from outside". The impacts would have compromised the aircraft's structural integrity (Dutch Safety Board 2014). It is likely the aircraft was brought down by shrapnel from a SA-11 Gadfly (9K37BUK) surface-to-air missile (SAM). The SA-11 can carry a 70 kg high explosive (HE) fragmentation warhead to 72,000 ft. (22,000 m). At the time it was intercepted, the aircraft was flying at 33,000 ft. (10,000 m), 3.6 nautical miles north of airway L980's centreline. A fragmentation warhead relies on the ejection of shrapnel (metal spheres, cubes or rods) rather than an overpressure pulse to destroy. The relatively thin, pressurised skin of an aircraft offers almost no resistance to shrapnel (Fig. 1).

Both Ukraine and Russia operate the SA-11 (Jane's Publishing 2011). The aircraft was lost when relations between Ukraine (and its European allies) and Russia were at a low ebb. There was open fighting on the ground between separatists and Ukrainian soldiers, and a war of words in the media. Sanctions, travel bans, import bans, asset freezes and other economic weapons had been deployed.[4]

[4]By the end of 2014, falling oil prices and Ukraine-related Western sanctions had weakened the Rouble significantly. During the year the currency had lost over 50 % of its value against the US Dollar. At the beginning of 2014, Russians needed thirty Roubles to buy one US Dollar. By the

Fig. 1 Flight MH17 was routed over a war zone

Commentators warned of a new Cold War. During the November, 2014 celebrations to mark the twenty-fifth anniversary of the fall of the Berlin Wall, former Soviet President Mikhail Gorbachev said: “The world is on the brink of a new Cold War. Some are even saying that it’s already begun” (Gorbachev cited in Deutsche Welle 2014). Levgold (2014) observed: “The crisis in Ukraine has pushed the two sides [the US and Russia] over a cliff and into a new relationship, one not softened by the ambiguity that defined the last decade of the post–Cold War period, when each party viewed the other as neither friend nor foe. Russia and the West are now adversaries”. By the Autumn of 2014, the fate of eastern Ukraine hung in the balance.

A survey conducted in late 2014 (Levada Centre 2014) confirmed a sharp difference of opinion between Ukrainian and Russian respondents over the future of the disputed Donbass[5] region of eastern Ukraine (see Appendix 1).[6] While 21 % of Russian respondents wanted Donbass to be absorbed into the Russian Federation, only 5 % of Ukrainian respondents wanted this. While 12 % of Russian respondents said there was no doubt that Russia gave active support to separatist forces, nearly 50 % of Ukrainian respondents said there was no doubt that Russia did this. Asked ‘Do you think that Russia bears responsibility for the bloodshed [and] death of people in eastern Ukraine?’, 17 % of Russian respondents answered ‘Yes’ or

(Footnote 4 continued)

end of the year they needed eighty. On December 17, 2014, the *Daily Mail's* Hugo Duncan quoted the Deputy Governor of Russia’s Central Bank as saying: “The situation is critical”.

[5]Sometimes referred to by Ukrainian separatists and Russians as Novorossiya, the Donbass includes the Donetsk and Luhansk oblasts of Ukraine. The separatist uprising commenced on 6 April, 2014.

[6]The tables are reproduced in Appendix 1 exactly as they appeared in the Levada Centre and Kiev International Institute of Sociology research report (2014).

'Mostly Yes', while 63 % of Ukrainian respondents answered 'Yes' or 'Mostly Yes'. While 26 % of Russian respondents believed that Russia and Ukraine were at war, 70 % of Ukrainian respondents believed this to be the case. It is clear that at the time the survey was conducted, Russians and Ukrainians held very different views about the Donbass uprising. It is also clear that there was a deep mistrust between the two countries. Russian President Vladimir Putin constructed the February, 2014 ousting of President Viktor Yanukovych as a fascist insurrection (thereby invoking the spirit of the USSR's 1941–1945 Great Patriotic War against Nazi Germany). Kiev's pro-Western lobby constructed the ousting of their fourth president as a blow against a self-interested, interfering, backward-looking Russia. These divisions and incommensurate world views formed the backcloth to the July, 2014 destruction of Malaysia Airlines Flight MH17.

Elections were held on 2 November, 2014 by the Donetsk and Lugansk People's Republics (that together make up the Donbass region of eastern Ukraine). The election results, recognised by neither the European Union nor the United States, supported the Donbass's cessationist ambitions. On October 28, Russia's Foreign Minister Sergey Lavrov (cited in Gregory 2014) welcomed the unofficial plebiscite: "The elections of November 2 in the territories of the declared Luhansk and Donetsk people's republics will be important for the legitimization of power … We expect the elections to take place as agreed and we will of course recognize the results. We consider that the expression of the will of the people will be free and no one from outside will attempt to disrupt them". Having been roundly chastised for his interference in Ukraine (that, earlier in the year, had seen Russia's annexation of the Crimea), Russian President Vladimir Putin left the mid-November G20 Brisbane summit early. British Prime Minister David Cameron (cited in Wintour and Doherty 2014) observed of the Russian President's mind-set: "This is going to be a test of the stamina and political will of the United States and the EU. I think we will meet that test. We are very clear with Russia that the continued destabilisation of Ukraine is simply unacceptable. If Russia continues to destabilise Ukraine there will be further sanctions. There is a cost to sanctions, but there would be a far greater cost to allow a frozen conflict on the continent of Europe to be maintained. President Putin can see he is at a crossroads".

3.2 MH17 Through a Systems-Thinking Lens

In her analysis of media reporting of the MH17 disaster, Oates (2014) investigated how two news outlets, *Vremya*, "the flagship news program on the state-run First Channel in Russia" and *BBC Online*, "one of the most popular worldwide news sites" covered the story. The coverage generally concerned itself with the question of *who* shot the 777 down. Oates (2014) observed of the BBC's coverage: "Little blame attached to Malaysian Airlines for flying through a conflict zone; the airline was primarily framed as a victim." The coverage had an 'episodic rather than thematic' flavour (Oates 2014). The question of who pulled the trigger dominated.

The West accused Ukrainian cessationists and Russians. Moscow blamed pro-Western Ukrainians (Oates 2014).[7]

Reductionism—attributing the MH17 disaster to an error on the part of the Ukrainian or Russian military—gives us only half the story. Systems-thinking gives us the whole story. It shows us that the disaster originated in history, contemporary politics, ethnic division, a regional war and interactions between the elements that comprise the commercial aviation system. The following actants contributed to the disaster (this is not an exhaustive list):

- Russian leaders' distrust of the West. Forged in the 1941–1945 Great Patriotic War and tempered in the 1947–1991 Cold War, this distrust is deep-rooted
- The incommensurate world-views and aspirations of western-facing Ukrainians (who sparked the Euromaidan insurrection of November 2013) and eastern-facing, Russian-speaking rebels
- The Euromaidan perception that Ukraine's Putin-endorsed President Viktor Yanukovych headed a corrupt puppet regime
- A regional war fought on ethnic lines
- The transformation by the United States, European Union and Russia of a regional war into a superpower proxy-war
- The expansionist tendencies of the European Union
- The expansionist tendencies of NATO
- Russia's historic desire to influence, if not control, its 'near abroad'[8]
- The capabilities of the SA-11 SAM system
- The 'normalisation' of shoot-downs since the beginning of the unrest in Donbass on *circa* 6 April, 2014 (see Appendix 2)[9]
- Airway L980[10]
- The shrapnel ejected when the SA-11's warhead exploded in proximity to the 777

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[7]Two Russia Today (RT) journalists, Liz Wahl and Sarah Firth, resigned over what they claimed was biased coverage by their Russian employer of the Ukrainian crisis. Firth claimed RT showed a "total disrespect to the facts" (Saul 2014). Liz Wahl, who resigned live on air, claimed RT's coverage was "whitewashed" (Saul 2014).

[8]Imperial ambitions persist on the fractious continent of Europe. Buffer states like Ukraine are under the greatest pressure. Will Europe ever be truly modern? Will it forever be a prisoner of its chaotic and bloody past?

[9]Although most of the downed machines were helicopters or ground-attack aircraft, larger machines, like the twin-engined Antonov 30 and four-engined Ilyushin 76 strategic transport were also destroyed.

[10]And, possibly, the fact that MH17 had drifted 3.6 nautical miles north of airway L980's centreline. An aircraft not on centreline may have looked suspicious to a SAM missile crew, although deviations for weather are not uncommon.

- The vulnerability of pressurised aircraft like the 777 to shrapnel[11]
- Airlines' willingness to overfly contested territory[12]
- Malaysia Airlines's culture, risk perception and risk calculation
- The International Civil Aviation Organisation's polices
- Eurocontrol's policies
- The European Civil Aviation Conference's policies
- The State Aviation Authority of Ukraine's policies and risk perception
- The Ukrainian State Air Traffic Service Enterprise's policies and risk perception
- The Flexible Use of Airspace concept, which holds that "airspace should no longer be designated as military or civil airspace, but should be considered as one continuum" (Eurocontrol 2014)
- The shareholder agenda (maximise profit and dividend)
- The passenger agenda (generally to pay as little as possible for a ticket)
- The aviation system's cost-reduction culture (Fig. 2)[13]

Viewed through a systems-thinking lens, the actions of the SAM missile crew were but one element of a *complex* of failures (like allowing commercial aircraft to overfly war zones where the protagonists possess advanced anti-air weaponry). With reference to Turner's (1978) six-stage model of failure, we can see that the incubation period for the disaster stretched back to (at least) the Great Patriotic War of 1941–1945.

3.3 The Aviation System Actant-Component of the MH17 Disaster

Systems-thinking argues that the origins of disaster are complex and messy: "[I]t is better to think of a problem of understanding disasters as a 'socio-technical' problem with social organization and technical processes interacting to produce the phenomena to be studied" (Turner 1978). Further, in an open system there are many routes to disaster: "[S]ystems theory predicts that any open system … can arrive at a given end state … via different routes" (Toft 1996). Systems theoreticians call this 'equifinality'.

[11]Some military aircraft, like the Fairchild Republic single-seat A-10 'Warthog' ground-attack aircraft, can survive shrapnel. The A-10 demonstrated "incredible resilience" during the First Gulf War: "Some Warthogs returned from battle with as much as 20 ft. of wing missing, tails shot off, and gaping holes in the fuselage" (Funding Universe 2014). Unlike the 777, the A-10 is un-pressurised. Consequently, there is no risk of an explosive decompression.

[12]According to former staff member at the US Joint Chiefs of Staff, retired airline pilot and Embry-Riddle Aeronautical University academic, Professor Kees Rietsema (cited in Halsey 2014): "Airliners overfly conflicted areas all the time".

[13]Robert Crandall (cited in Petzinger 1995), Chief Executive Officer (CEO) of American Airlines, argued that aviation is "intensely, vigorously, bitterly, savagely competitive". Cost reduction is a key objective of most airlines (Lawton 2002; Massachusetts Institute of Technology 2011; Franke and John 2011).

Fig. 2 Dutch and Australian police officers examine wreckage

The behaviour of the aviation system contributed to the loss of MH17. It was a systems accident, the causes of which included both an error of judgement—a missile battery crew mistaking Malaysia's 777-200 for a hostile aircraft—and policy decisions, including Ukraine's decision to allow passenger aircraft to overfly a war-zone and Malaysia Airline's decision to take advantage of the Ukrainian authorities' concession. Attributing the disaster to a missile battery crew's error of judgement is too simplistic. The causes of the MH17 loss lie partly in the politics, economics and risk calculations of the aviation system's component parts. Specifically, in the agendas of its regulatory agencies, air navigation service providers, airlines, customers and investors. It was the aviation system that put MH17 in contested airspace. It was the aviation system that exposed MH17's 298 passengers and crew to the risk of shoot-down. The launching of the missile(s) was just one of a number of errors-of-judgement that brought down the 777. *Had MH17 not been in eastern Ukraine it would not have been shot down*. Had the aviation industry internalised the lessons of past incidents and accidents, it probably would not have allowed flights through contested airspace. Systems-thinking encourages us to think of past events not as footnotes in the historical record but as potentially life-saving learning opportunities. Systems-thinking finds expression in Toft's theory of passive and active learning (Toft 1992; Toft and Reynolds 1997). Passive learning describes a situation where there is knowledge but no remediation. Active learning where there is remediation (Fig. 3).

3.4 The Passive Learning Actant-Component of the Disaster

In his 1982 book *Major Technical Risk: An Assessment of Industrial Disasters,* Lagadec (1982) noted: "The disaster must not be seen like a meteorite that falls out of the sky on an innocent world; the disaster, most often, is anticipated, and on multiple occasions. By force of deafness and blindness, misfortune unfolds … The history of disasters is the history of the irresponsibility of the public powers …".

Fig. 3 Schiphol remembers the victims of the MH17 disaster

Most often, disasters are foretold. This is certainly the case with that type of aviation disaster known as the shoot-down. It will be shown that the destruction of MH17 over the Ukrainian village of Hrabove on 17 July, 2014 'was anticipated, and on multiple occasions'. For example:

> **Flight KAL007**
> In September 1983, a Soviet Su-15 fighter shot down a Boeing 747 operated by Korean Air Lines. Flight KAL007, *en route* from Anchorage to Seoul and carrying 269 passengers and crew, strayed into Soviet airspace around the time of a U.S. military reconnaissance sortie. KAL007 was at 35,000 ft. when the Su-15's missile hit. The Soviets initially denied responsibility. KAL007's flight-plan saw it skirt some of the Soviet Union's most sensitive military installations, specifically those on Sakhalin Island and the Kamchatka Peninsula. Although not war-zones, Sakhalin and Kamchatka were hot-zones that should not have been overflown.[14] The Soviets claimed that KAL007 "flew deep into Soviet territory for several hundred kilometres, without responding to signals [radio calls] and disobeying the orders of interceptor[s]" (Sputnik 1983). It is possible that wider events, like the US deployment of Pershing II missiles to Europe and NATO's imminent Exercise Able Archer, skewed perceptions of KAL007, increasing the likelihood of a shoot-down. Johnson (1986) comments: "[T]he first two years of the Reagan Administration … had seen the military build-up press ahead further and faster than many had believed possible". Six months before the shoot-down, US President Ronald Reagan (cited in Ambrose 1985) had remarked: "The Soviet Union is the focus [sic] of evil in the modern world".[15] Troy (2009) says: "Reagan believed in peace through strength, that a long-term accommodation with the Soviet Union could only come after some short-term intimidation …. In that spirit, Reagan wanted a visionary, aggressive, resourceful and unapologetic foreign policy". The cultural milieu (composed of myriad events) shapes perceptions (Douglas and Wildavsky 1982).

[14]Johnson (1986) describes Sakhalin and Kamchatka as "perhaps the most dangerous part of the world's surface".

[15]Aping Reagan's unsubtle approach to foreign policy, President George H W Bush talked about a multi-nation 'Axis of Evil'. Like father, like son: Following the 2001 World Trade Centre attacks. President George W Bush told the world community: "Either you are with us, or you are with the terrorists". Some thought it unwise for the United States to conduct bilateral relations on the basis of how a country reacted to the attacks. Discriminating friend from foe with such a calculus was possibly a mistake.

Our beliefs, experiences, prejudices and memories—concentrated in cognitive 'short-cuts' called heuristics—influence how we interpret and react to objective reality (Williams 2007). Heuristics have positive and negative aspects. On the positive side, they speed information processing. They are 'fast and frugal' (Gigerenzer et al. 1999). On the negative side, they can cause us to misinterpret objective reality. In high-risk situations, the consequences of misinterpretation may be severe for both the subject and object: "[Heuristics] can lead to severe and systematic biases that influence the search for information and subsequent interpretations, often resulting in less rational … decision-making. This is particularly pertinent when making … uncertain or risky decisions" (Williams 2007). Less rational decision-making is especially problematic in life-or-death situations, as when a missile crew has to interpret a radar plot, or a fighter pilot has to determine an aircraft's intentions.

Flight IR655
In 1988, a missile fired from the *USS Vincennes* brought down an Iran Air A300 Airbus *en route* from Tehran to Dubai. All 290 passengers and crew were killed. The aircraft was intercepted in Iranian airspace over the Strait of Hormuz. Prior to the shoot-down, there had been a confrontation between Iranian small boats and the *Vincennes*'*s* helicopter. The shoot-down occurred in the context of the long-running Iran-Iraq war (that saw the United States favour Iraq), attacks on United States warships and attacks on commercial vessels transiting the Strait. These events may have persuaded the *USS Vincennes*'*s* crew that they were watching a military aircraft flying an attack profile rather than a civilian aircraft navigating an airway. Crewmembers said they believed they were tracking an Iranian F14 Tomcat fighter (Bennett 2001). Events shape perceptions. In hindsight, regional aviation authorities should have diverted aircraft around the Strait of Hormuz hot-zone.[16]

Flight SB1812
In 2001, Siberia Airlines Flight 1812 was destroyed by an errant Ukrainian surface-to-air missile. The missile, fired during a military exercise, is thought to have overshot a target drone. It exploded close to the TU-154M. Seventy-eight passengers and crew perished. Following this incident, Ukraine reportedly banned the testing of such systems for a period of seven years. Flight 1812, from Tel Aviv to Novosibirsk, was intercepted at an altitude of 36,000 ft.

These shoot-downs were system accidents. While those who pushed the firing button were the instigators, it was the aviation system that placed the aircraft in jeopardy. Had those aircraft not been overflying hot or live-fire zones, they would not have been destroyed. A systems-thinking interpretation of the KAL007, IR655, Flight 1812 and MH17 shoot-downs suggests that risk-taking is an emergent property of an aviation system predicated on free-market competition and associated profit-seeking behaviours. Other things being equal, the shorter an airliner's route, the more profitable the service. Inevitably a compromise must be struck between the need to keep passengers safe and the need to make a profit. An industry that was excessively risk-averse would atrophy. The aviation industry wrestles with numerous difficult operational questions, including: How much involuntary risk should passengers bear? Such questions have ethical and economic dimensions.

[16]Of course, hindsight is always 20-20 (perfect).

Fig. 4 The NTSB's Go-Team inspects the remains of SpaceShipTwo

4 The Spaceship 2 Disaster

At the end of October 2014, a Virgin Galactic spacecraft[17] experienced a 'serious anomaly' that sent it crashing earthwards. One pilot died, the other was badly injured (National Transportation Safety Board 2014). The National Transportation Safety Board is familiar with the systems-thinking approach to accident investigation: "The NTSB investigation of the crash will be broad … the investigation team will consider a wide array of factors, including the safety culture at Scaled Composites and Virgin Galactic" (Trimble 2014) (Fig. 4).

Hopefully, the Board's investigation will examine one of the programme's key assumptions—that, with time and effort, space travel can be made routine. The same belief permeated NASA's Shuttle programme, until the Challenger and Columbia disasters broke the Agency's routinisation mind-set. The belief that space travel can be routinised produced the same latent error (see Reason's 2013 definition) in both the Shuttle and Virgin Galactic SpaceShipTwo programmes—the non-provision of an engineered crew-escape system.

The Spaceship Company, set up by Sir Richard Branson to build his sub-orbital spacecraft, is jointly owned by Branson's Virgin Group and Scaled Composites of Mojave, California. Scaled Composites was founded by flight-test engineer Burt Rutan. In post-crash interviews, Branson referred to Rutan as a 'visionary'.[18] Over the years the press has referred to Rutan variously as a "bold visionary" (Space.com 2014), an "aerospace visionary" (Linehan 2011) and a "maverick genius" (Noland 2004). Was Rutan's ascribed status of 'genius-visionary' one of the disaster's actant-components? Did it inhibit reflection and critique? Did it dissuade employees from asking questions? Did it deter people from questioning Rutan's design

[17]SpaceShipTwo is a 60 ft. long, air-launched reusable space vehicle that is boosted to the edge of space at *circa* 2500 miles per hour. Its flight profile resembles that of North American's X-15 aircraft, the first air-launched reusable space vehicle.

[18]On his Virgin web log, Branson described Rutan as a "genius aerospace engineer" (Branson 2014).

philosophy, described in a 2004 *Popular Mechanics* article as "keep it simple, cheap and, above all, practical" (Noland 2004). Referring to the pared-down design of Rutan's record-breaking SpaceShipOne, Noland (2004) observed: "NASA wouldn't dream of building something so primitive".

Branson promised that the first Virgin Galactic passenger-carrying sub-orbital flight would take place in October 2009. Then he promised it would take place in 2011, then on Christmas Day, 2013. In September 2014, Branson promised the first flight would take place in February or March, 2015. Were Branson's very public promises[19] actant-components in the disaster? Did they put Spaceship Company employees under too much pressure? Did The Spaceship Company sacrifice safety for production? The following actants merit attention:

- The tendency of a launch-boost flight-profile to induce vertigo and disorientation during climb-out
- The premature activation of SpaceShipTwo's feathering system (that facilitates descent from altitude)[20]
- The unforgiving nature of high-altitude, high-speed flight[21]
- The safety culture at Scaled Composites[22]
- Rutan's alleged design philosophy ('keep it simple and cheap')
- A passenger-carrying launch date that had been slipped several times[23]
- The lionisation of Burt Rutan by colleagues, journalists and biographers

[19]Branson is adept at publicising his Virgin empire, often by risking his own life in pursuit of a record (Cadzow 2013). "Playing chance and breaking the rules [is] his fun and his source of profit" claims Bower (2014).

[20]The feathering system requires two actions. First, a lever must be moved to the 'unlock' position. Then a handle must be moved to the 'feather' position.

[21]Tom Wolfe described the dangers of flying at the edge of space in his celebrated 1979 book *The Right Stuff*. Wolfe described the experiences of many of the USA's military test pilots, including those who flew the rocket-powered North American X-15, an aircraft capable of flying at Mach 6.7 at an altitude of 67 miles (354,000 ft.). Death was an expected overhead of test flying exotic machines at speed at high-altitude. SpaceShipTwo's apogee is 68 miles.

[22]In July, 2007, an explosion at Scaled Composites killed three and injured three more. The explosion occurred during testing of SpaceShipTwo's hybrid rocket motor. The California Occupational Safety and Health Administration (COSHA) suggested a lax safety culture may have contributed to the accident. According to Rhian (2013): "The findings in [the COSHA] report highlight concerns that have been raised regarding the manner in which a number of the commercial start-up companies conduct their business". Following the loss of SpaceShipTwo and questions about the 2007 deaths and injuries, Virgin Galactic said: "[A]n industrial accident with tragic consequences during a nitrous cold flow test … clearly has no bearing on the events of last week" (cited in Ensor and Mendick 2014). If the NTSB finds that the 2014 accident resulted partly or wholly from a lax safety culture at main contractor Scaled Composites then, clearly, the 2007 accident *would* have a bearing.

[23]Virgin Galactic has a backlog of over 700 passengers, each of whom has paid *circa* $250,000 to be carried to the edge of space.

Fig. 5 SpaceShipOne—the prize-winning, attention-grabbing actant that helped the commercial manned space flight industry to grow by 'bending space around itself' (see Callon and Latour 1981)

- Scaled Composites's achievements (like SpaceShipOne winning the US $10 million Ansari X-Prize, awarded to the first non-governmental organisation to launch a re-usable, manned craft into space twice in two weeks)[24]
- Entrepreneurs' and shareholders' determination to prove that large, government-funded programmes employing thousands are not a prerequisite for manned space flight[25]
- Government support for the commercial spaceflight industry, expressed in, for example, the 1984 Commercial Space Launch Act and creation of the US Office of Commercial Space Transportation (Fig 5).[26]

The premature deployment of the feathering system suggests that the first actant (launch-boost-induced vertigo and disorientation) may be especially relevant. High-speed climb-outs of the sort performed by the North American X-15 boost-glide research aircraft, SpaceShipOne and SpaceShipTwo (also boost-glide craft)

[24]In the parlance of actor-network theory, this singular triumph would have 'bent space around itself' (see Callon and Latour 1981), creating a supportive network of media attention, enthusiasts, sympathetic investors, reliable funding and new ideas. The SpaceShipOne actor-network boosted confidence in the embryonic commercial manned space flight industry.

[25]The fifteen-year Apollo programme, that put twelve men on the moon, cost $109 billion in 2010 dollars. At its peak the programme employed 400,000 and required the support of 20,000 contracting firms and universities. According to NASA: "Only the building of the Panama Canal rivalled the Apollo programme's size … only the Manhattan Project was comparable in a wartime setting". The cost of the Shuttle programme was *circa* $200 billion in 2010 dollars. Each Shuttle mission cost about $1.4 billion (Lafleur 2010). By November, 2014, the SpaceShipTwo programme had cost $1 billion (£626 million). The programme employed around four hundred engineers.

[26]Prior to the rationalisation of the commercial spaceflight industry, launch companies had to deal with seventeen US Government agencies.

Fig. 6 Like SpaceShipOne and SpaceShipTwo, the X-15 was launched from a mother ship, in this case a B52 strategic bomber

can induce vertigo and other cognitive impairments: "The X-15 programme had 11 flights above 50 miles (80 km) and two above 62 miles (100 km); SpaceShipOne had three flights to 62 miles-plus. Pilots of both vehicles reported feeling 'extreme disorientation' and 'intense pressures'" (David 2013). On November 15, 1967, Mike Adams's X-15 suffered an electrical failure. Unable to cope with the consequent increased workload, Adams lost control (David 2013). His machine dived through 65,000 ft. at almost Mach 4. It disintegrated. Drawing on systems-thinking, NASA considered the possibility that Adams's performance *may* have been impaired by boost-glide-induced vertigo. The investigation team recommended that NASA medically screen X-15 pilot-candidates for labyrinth (vertigo) sensitivity (National Aeronautics and Space Administration 2014) (Fig. 6).

5 Understanding Failure Holistically

5.1 The MH17 Disaster

Blaming shoot-downs on wilful negligence or vindictiveness is the easy option. Blamism panders to the, perhaps, understandable impulse to exact revenge. Blamism is the wrong response, however, because blaming obscures the underlying causes of error. Regarding shoot-downs, systems-thinking encourages us to think about *how* a civilian airliner transiting an airway could be mistaken for a legitimate target. It encourages us to reference theories pertaining to cognition and perception. Our interactions with the world are mediated by cognitive structures known as mental models. A mental model is a predisposition that leads us to perceive our environment in a certain way. Mental models reflect our experiences and understandings. In routine work situations, they are influenced by things like career path, role, position, mission statements, organisational cultures, peer-interactions and esprit-de-corps.

In the military they are influenced by personal observation, intelligence reports, briefings, life-threatening encounters and beliefs about the character of the enemy. Preconceptions about the Soviets persuaded many German soldiers that it was better to surrender to the Americans, British and Canadians. Influenced by propaganda and first and second-hand accounts, members of the Wehrmacht developed a shared mental model of the Soviets as vengeful. According to Cordery (2002), shared mental models "are knowledge structures that a team uses in order to help it understand and react to its operating environment". Within the team there resides "shared knowledge related to the job or task" and "shared knowledge about the values and attitudes of team members". A missile crew is an example of a close-knit team.

5.2 The SpaceShipTwo Disaster

The SpaceShipTwo disaster is the subject of a National Transportation Safety Board investigation. In recent years the NTSB has developed a high-fidelity, systems-theory-informed investigation method that addresses both technical and wider organisational factors: "NTSB investigation efforts are broken down into logical groups. Historically these may have included groups such as: Operations; Control Systems; Mechanical; Human Performance … More recently, NTSB investigation groups have reflected the organization's broader mission of preventing future transportation accidents … [The Board investigates] Corporate Policies and Governance; Organizational 'Safety Culture'; Industry Practices; Regulatory Oversight. NTSB Safety Recommendations are rarely focused upon a single probable cause of an individual accident. The opportunity is frequently taken to offer broader recommendations to transportation operators, manufacturers, industry associations, labour associations, regulators, and others as to how related future transportation accidents might be avoided" (Tochen and Tobin 2013). Hopefully, the NTSB will investigate not only why the feathering system activated, but also the policies, organisational cultures and performance of Scaled Composites, The Spaceship Company, Virgin Galactic, third-party suppliers, the Office of Commercial Space Transportation, the Federal Aviation Administration and anyone else connected (either directly or indirectly) with the project.

6 Conclusions

Disasters have complex aetiologies. The roots of disaster may lie in pressures generated within, and between 'imperialist' actor-networks. Low-fidelity reductionist analyses miss important details. Latent errors go undetected or unresolved—ready to catch us out at some future date. Where safety is concerned, reductionist analyses come a poor second to high-fidelity, systems-thinking-informed analyses. As the saying goes, the Devil is in the detail. That said, the systems-thinking approach to accident investigation is not without its problems—like deciding the boundaries of the network space. Inevitably, an investigation method grounded in inclusivity (ANT, for example) produces long lists of contributory factors (actants) —from rules, regulations and cultural predispositions to physical objects like radar sets, missile launchers, warheads and shrapnel. The size of the network space considered by a systems investigation influences the direction the investigation takes and the conclusions reached—because size determines which factors are considered and which are not. Investigations are vulnerable to gerrymandering. The behaviour of politicians, regulatory authorities and other interested parties towards an investigation should be monitored. The Honourable Mr Justice Virgil P. Moshansky's ground-breaking Dryden investigation provides a salutary lesson: "[Counsel] for the regulator attempted to limit the scope of the Inquiry with threats to limit my mandate by seeking an order in the Federal Court of Canada. When it became clear that intimidation would not succeed, these attempts were abandoned …" (Moshansky cited in Maurino et al. 1998). Terms of reference that are considered too narrow should be challenged. Constraints—bureaucratic, financial, temporal, experiential and intellectual—preconfigure investigations.[27] A hamstrung investigation may miss important details. Active learning may be inhibited, to the detriment of public safety.

Appendix 1

What do you think about the political future of the Donbass (Donetsk, Lugansk regions)? Which of the following versions would you prefer?

	According to **residents of Russia** Aug.14, Levada —Centre	According to **residents of Ukraine** Sep.14, DI + KIIS
For Donbass to remain a part of Ukraine on the same terms as before the crisis	6	45
For Donbass to remain a part of Ukraine but receive greater independence from Kyiv	18	32
For Donbass to become an independent state	40	7
For Donbass to become a part of the Russian Federation	21	5
It is difficult to say	16	10

[27]In 2014, Northern Ireland's budget for the retrospective investigation of murders committed during the Troubles was cut, delaying inquiries and undermining public confidence. The Police ombudsman commented: "The reduction in budget has undermined our ability to deal with the past".

Do you agree with the view that Russia actively supports pro-Russian-oriented forces in eastern Ukraine?

	According to **residents of Russia** August 14, Levada—Centre	According to **residents of Ukraine** September 14, DI + KIIS
Definitely yes	12	49
Mostly yes	38	25
Mostly no	22	8
Definitely not	8	7
It is difficult to say	20	11

Do you think that Russia bears responsibility for the bloodshed, death of people [sic] in eastern Ukraine?

	According to **residents of Russia** August 14, Levada—Centre	According to **residents of Ukraine** September 14, DI + KIIS
Definitely yes	5	44
Mostly yes	12	19
Mostly no	25	10
Definitely not	50	17
It is difficult to say	8	10

Do you agree with the view that there is a war between Russia and Ukraine?

	According to **residents of Russia** August 14, Levada—Centre	According to **residents of Ukraine** September 14, DI + KIIS
Yes	26	70
No	59	19
It is difficult to say	15	11

Appendix 2

Aircraft destroyed		
Date	Aircraft	Specification and role
16/07/14	Sukhoi Su-25M1	Single-seat, twin-engined ground-attack
16/07/14	Sukhoi Su-25M1	Single-seat, twin-engined ground-attack
14/07/14	Antonov 26	Twin-turboprop transport
12/07/14	Mil Mi-24	Helicopter gunship
02/07/14	Sukhoi Su-25M1	Single-seat, twin-engined ground-attack
02/07/14	Sukhoi Su-24	Twin-seat, twin-engined supersonic strike
01/07/14	Sukhoi Su-25UB	Single-seat, twin-engined ground-attack
24/06/14	Mil Mi-8TV	Twin-engined transport helicopter
21/06/14	Mil Mi-8T	Twin-engined transport helicopter
14/06/14	Ilyushin 76MD	Four-jet strategic transport
06/06/14	Antonov 30	Twin-turboprop photographic reconnaissance aircraft
05/06/14	Mil Mi-8	Twin-engined transport helicopter
04/06/14	Mil Mi-24RhR	Helicopter gunship
04/06/14	Mil Mi-24VP	Helicopter gunship
04/06/14	Mil Mi-24VP	Helicopter gunship
04/06/14	Mil Mi-24VP	Helicopter gunship
03/06/14	Mil Mi-24VP	Helicopter gunship
29/05/14	Mil Mi-8MT	Twin-engined transport helicopter
05/05/14	Mil Mi-24P	Helicopter gunship
02/05/14	Mil Mi-8MT	Twin-engined transport helicopter
02/05/14	Mil Mi-24P	Helicopter gunship
02/05/14	Mil Mi-24P	Helicopter gunship
25/04/14	Mil Mi-8	Twin-engined transport helicopter
22/04/14	Antonov An-30B	Twin-turboprop photographic reconnaissance aircraft

Note All the above aircraft were operated by the Ukrainian armed forces
Source Aviation Safety Network (Aviation Safety Network 2014)

References

Ambrose SE (1985) Rise to globalism, 4th edn. Penguin, New York
Aviation Safety Network (2014) Aviation safety network—flight safety foundation. http://aviation-safety.net/wikibase/dblist.php?Country=UR&page=1. Accessed 19 Nov 2014
Bennett SA (2001) Not context-contexts: an 'outside-in' approach to understanding the vincennes shoot-down. Int J Mass Emerg Disasters 19(1):27–57
Bennett SA (2014) Ideology and greed at root of ebola crisis. The Leicester Mercury, Leicester
Bower T (2014) Ego, spin and a disaster waiting to happen: Richard Branson's biographer on how the Virgin tycoon is scrabbling to save what remains of his reputation—and his fortune—after

space plane crash. http://www.dailymail.co.uk/news/article-2818140/Ego-PR-spin-disaster-waiting-happen-Branson-s-biographer-Virgin-tycoon-scrabbling-save-remains-reputation-fortune.html. Accessed 4 Dec 2014

Branson R (2014) The Ansari Xprize—standing on the shoulders of giants. http://www.virgin.com/richard-branson/the-ansari-xprize-standing-on-the-shoulders-of-giants. Accessed 5 Dec 2014

Cadzow J (2013) Outer reaches. http://www.smh.com.au/technology/sci-tech/outer-reaches-20130614-2nyxd.html. Accessed 4 Dec 2014

Callon M, Latour B (1981) Unscrewing the Big Leviathan: how actors macro-structure reality and how sociologist help them to do so. In: Knorr-Cetina K, Cicouvel AV (eds) Advances in social theory and methodology: towards an integration of micro and macro-sociology. Routledge, London

Callon M, Law J (1997) After the Individual in society: lessons on collectivity from science, technology and society. Can J Sociol 22(2):165–182

Cordery J (2002) Team Working. In: Warr P (ed) Psychology at work. Penguin Books, London

David L (2013) 1960s Rocket plane tests may boost suborbital spaceflight safety. http://www.space.com/20023-suborbital-spaceflight-safety-x15-program.html. Accessed 26 Dec 2014

Dekker S (2006) Resilience engineering: chronicling the emergence of confused consensus. In: Hollnagel E, Woods DD, Leveson N (eds) Resilience engineering: concepts and precepts. Ashgate Publishing Ltd., Aldershot

Deutsche Welle (2014) Doors sealed shut as Merkel receives Gorbachev. Chancellor Merkel has met with former Soviet leader Mikhail Gorbachev, one of the players in the diplomatic drama that led to German unity 25 years ago. Now a new conflict is threatening ties between east and west. 10 November. http://www.dw.de/doors-sealed-shut-as-merkel-receives-gorbachev/a-18055222. Accessed 12 Nov 2014

Dorner D (1996) the logic of failure: recognizing and avoiding error in complex situations. Perseus Books, Cambridge

Douglas M, Wildavsky A (1982) Risk and culture: an analysis of the selection of technological dangers. University of California Press, Berkley

Dutch Safety Board (2014) Preliminary report. Crash involving Malaysia Airlines Boeing 777-200 flight MH17, Hrabove, Ukraine—17 July, 2014. Dutch Safety Board, The Hague

Ensor J, Mendick R (2014) Virgin galactic crash: 'don't let more die'. Daily Telegraph

Eurocontrol (2014) Flexible Use of airspace. http://www.eurocontrol.int/articles/flexible-use-airspace. Accessed 15 Nov 2014

Franke M, John F (2011) What comes next after recession?—airline industry scenarios and potential end games. J Air Transp Manag 17(1):19–26

Funding Universe (2014) Fairchild Dornier GmbH history. http://www.fundinguniverse.com/company-histories/fairchild-dornier-gmbh-history. Accessed 15 Nov 2014

Gigerenzer G, Todd PM, The ABC Research Group (1999) Simple heuristics that make us smart. Oxford University Press, Oxford

Gregory PR (2014) Russia uses semantics to walk back recognition of donbass elections before G20 Summit. http://www.forbes.com/sites/paulroderickgregory/2014/11/08/russia-uses-semantics-to-walk-back-recognition-of-donbass-elections-before-g20-summit. Accessed 15 Nov 2014

Haddon-Cave C (2009) The Nimrod Review. An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006. HC 1025. Her Majesty's Stationery Office, London

Halsey A (2014) Airlines often use eastern Ukraine route. http://www.post-gazette.com/news/world/2014/07/18/Airlines-often-use-eastern-Ukraine-route/stories/201407180097. Accessed 16 Nov 2014

Hollnagel E (2004) Barriers and accident prevention. Ashgate Publishing Ltd., Aldershot

Hollnagel E (2009) The ETTO principle: efficiency-thoroughness trade-off. Why things that go right sometimes go wrong. Ashgate Publishing Ltd., Aldershot

Jane's Publishing (2011) Jane's land-based air defence 2011–2012. Jane's Publishing, Coulsdon

Janis IL (1972) Victims of groupthink: a psychological study of foreign-policy decisions and fiascos. Houghton Mifflin, Boston
Johnson RW (1986) Shootdown. The verdict on KAL007. Book Club Associates, London
Lafleur C (2010) Costs of US piloted programmes. http://www.thespacereview.com/article/1579/1. Accessed 7 Dec 2014
Lagadec P (1982) Major technical risk: an assessment of industrial disasters. Pergamon Press, Oxford
Lawton TC (2002) Cleared for Take-Off. Structure and strategy in the low-fare airline business. Ashgate Publishing Ltd., Aldershot
Levada Centre (2014) Levada—Centre and KIIS about crisis in Ukraine 11/05/2014. http://www.levada.ru/eng/levada-center-and-kiis-about-crisis-ukraine. Accessed 13 Nov 2014
Levgold R (2014) Managing the new cold war. What Moscow and Washington can learn from the last one. Foreign Affairs. July/August
Linehan D (2011) Burt Rutan's race to space: the Magician of Mojave and his flying innovations. Zenith Press, Minneapolis
Massachusetts Institute of Technology (2011) Airline industry overview. http://mit.edu/airlines. Accessed 6 Mar 2011
Maurino DE, Reason J, Johnston N, Lee RB (1998) Beyond aviation human factors. Ashgate Publishing Ltd., Aldershot
Miller KD (2009) Organizational risk after modernism. Organ Stud 30(2–3):157–180
National Aeronautics and Space Administration (2014) X-15 Biographies: Michael J. Adams. http://history.nasa.gov/x15/adams.html. Accessed 26 Dec 20141
National Transportation Safety Board (2014) NTSB investigative update on crash of virgin galactic SpaceShipTwo. http://www.ntsb.gov/news/2014/141112.html. Accessed 22 Nov 2014
Noland D (2004) The X Factors. Popular Mechanics
Oates S (2014) Russian state narrative in the digital age: rewired propaganda in Russian television news framing of Malaysia Airlines Flight 17. Paper prepared for the American Political Science Association Annual Meeting (Political Communication Pre-Conference at George Washington University). Washington, D.C., August 2014. http://www.media-politics.com/presentationspublications.htm. Accessed 20 Nov 2014
Petzinger T (1995) Hard landing. How the epic contest for power and profits plunged the airlines into chaos. Aurum, London
Reason J (2013) A life in error. Ashgate Publishing Ltd., Aldershot
Rhian J (2013) Report: lack of adequate precautions caused accident that killed three during SpaceShipTwo test. http://www.americaspace.com/?p=31681. Accessed 7 Dec 2014
Risan LC (1997) Artificial life: a technoscience leaving modernity? An anthropology of subjects and objects. http://www.anthrobase.com/Txt/R/Risan_L_05.htm. Accessed 9 Nov 2014
Saul H (2014) MH17: Russia today presenter Sara Firth quits over Malaysia Airlines crash coverage. http://www.independent.co.uk/news/media/mh17-russia-today-presenter-sara-firth-quits-over. Accessed 20 Nov 2014
Shorrock S, Leonhardt J, Licu T, Peters C (2014) Systems thinking for safety: ten principles. Eurocontrol, Brussels
Space.com (2014) Burt Rutan: space tourism and the Next Giant Leap. http://www.space.com/18997-burt-rutan-space-tourism-and-the-next-giant-leap.html. Accessed 5 Dec 2014
Sputnik (1983) The truth and lies about the South Korean Airliner. A Digest of the Soviet Press, Sputnik
Tochen D, Tobin TW (2013) The ANatomy of an NTSB accident investigation: a guide for 'parties-to-the-investigation' and their lawyers. Wilson Elser, White Plains
Toft B (1992) The failure of hindsight. Disaster Prev Manag Int J 1(3):48–63
Toft B (1996) Limits to the mathematical modelling of disasters. In: Hood C, Jones DKC (eds) Accident and Design. UCL Press, London
Toft B, Reynolds S (1997) Learning from disasters. Perpetuity Press, Leicester
Trimble S (2014) Analysis: NTSB will have no quick answers after Virgin Galactic crash. http://www.flightglobal.com/news/articles/ Accessed 20 Nov 2014

Troy G (2009) The Reagan revolution. Oxford University Press, Oxford

Turner B (1978) Man-made disasters. Wykeham, London

Williams DJ (2007) Risk and decision-making. In: Cook M, Noyes J, Masakowski Y (eds) Decision-making in complex environments. Ashgate Publishing Ltd., Aldershot

Wintour P, Doherty B (2014) Vladimir Putin leaves G20 after leaders line up to browbeat him over Ukraine. Russian president says he's leaving early to get some sleep after long meetings in which he refused to give ground. http://www.theguardian.com/world/2014/nov/16/vladimir-putin-leaves-g20-after-leaders-line-up-to-browbeat-him-over-ukraine. Accessed 16 Nov 2014

Systems Theory as a Foundation for Discovery of Pathologies for Complex System Problem Formulation

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Abstract This chapter articulates a set of systems theory-based pathologies that act to limit performance of complex systems. In response to the common mantra that problem formulation is the most important activity in successfully dealing with complex system problems, this research elaborates on the utility of systems theory as the basis for problem formulation through the discovery of system pathologies. Pathologies are taken as circumstances that act to limit system performance or lessen system viability (continued existence) and as such they reduce the likelihood of a system meeting performance expectations. As an extension of contemporary developments in systems theory, this chapter is focused on three primary objectives. First, systems theory is examined to generate a comprehensive set of 45 principles, laws and concepts that explain system behavior and performance. Second, a set of systems theory-based pathologies that can be explained as deviation in application of systems theory (i.e., lack of use or violation) are articulated. Third, the chapter discusses implications of the developed pathologies for practitioners faced with the task of formulating complex system problems. The chapter concludes with proposed future research.

Keywords Ambiguity · Complexity · Emergence · Interdependence · Management cybernetics · Metasystem · Problem formulation · Sustainability · Systems pathology · Systems theory · Systems theory-based pathology (STBP) · Uncertainty · Viability · Viable system model (VSM)

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1 Introduction

The operating landscape for 21st century systems can best be described as ambiguous, complex, emergent, interdependent, and subject to uncertainty (Flood and Carson 1993; Katina et al. 2014a, c; Keating and Katina 2012). To remain viable (continuing present existence) and sustainable (evolving for future existence) under such conditions, organizations must be viewed as whole interdependent complex systems as opposed to isolated simple systems (Hammond 2002; Laszlo 1996). Instrumental in viewing organizations as 'whole' systems are systems ideas and their methodological approaches used for intervening in such systems (Adams et al. 2014; von Bertalanffy 1972). A key concept in approaches to address organizations (systems) and their associated issues is *problem formulation*. Problem formulation provides a portal into complex system understanding and is essential in the eventual development of solutions that might bring about positive change for complex system problems (Dery 1984; Lynn 1980; Warfield 1976).

There is wide acknowledgement of the importance of problem formulation—ranging from ideas of defining problems to developing effective solutions. First, this phase is intrinsically linked to how human beings view the world. Quade's (1980) work suggests that a major element of problem formulation relates to being "dissatisfied with current or projected state of affairs" (Quade 1980, p. 23). To enable successful succeeding steps for problem resolution, the analyst must attempt to bring as much clarity as possible to the situation under study (Warfield 1976). Such efforts, according to Quade (1980) involve "identify[ing] the problem to be studied and define its scope in such a way that he has some hope of finding an acceptable and implementable solution with the economic, political, technological, and other constraints that exist, including limitations imposed by the policy makers' span of control and the time available for decision" (p. 23). Consequently, how the analyst views the situation has a major implication on problem formulation. Thus, the centrality of problem formulation in addressing complex systems problems continues to be pervasive.

Problem formulation is subject to multiple perspectives and the variability generated from those perspectives. Therefore, problem formulation is not simply "a descriptive definition [of situations], for it does not merely describe but also chooses certain aspects of reality as being relevant for action in order achieve certain goals" (Dery 1984, p. 35). The subjective nature of problem formulation is also supported by Vennix's (1996) arguments that suggests "people [may] hold different views on (a) whether there is a problem, and if they agree there is, (b) what the problem is" (Vennix 1996, p. 13) and the fact that problems "arise from a problem area or nexus of problems rather than a well-define problem" (Quade and Miser 1985, p. 17). This is also echoed by Dery's (1984) supposition that "problems are not objective entities in their own right" (p. 65), which is consistent with the call for problem formulation to address a plurality of objectives held by involved stakeholders (Rittel and Webber 1973). Therefore, problem formulation is not privileged by singular perspectives or approaches.

However, problem formulation is recognized as being closely coupled to overall systems success. This has been recognized from some of the earliest works on problems, as evidenced by Wellington's (1887) suggestion that "the correct solution of any problem depends primarily on a true understanding of what the problem really is, and wherein its difficulty, we may profitably pause upon the threshold of our subject to consider first, in a more general way, its real nature—the causes which impede sound practice; conditions on which success or failure depends; directions in which error is most feared. Thus we shall more fully attain that great prerequisite for success in any work—a clear mental perspective, saving us from confusing the obvious with the important and the obscure and remote with the unimportant" (Wellington 1887, p. 1). Table 1 provides a breath of concepts associated with problem formulation in systems-based methodological approaches. Consequently, the problem formulation phase "has subsequently been considered the most critical stage in policy analysis" (Dery 1984, p. 2) and is "probably the single most important routine, since it determines in large part…the subsequent course of action" (Mintzberg et al. 1976, p. 274).

We can add *pathologies* to the list of concepts of problem formulation in complex systems since they describe systemic issues that limit system performance (Beer 1984; Keating and Katina 2012; Ríos 2012). However, ambiguity remains concerning how we identify pathological conditions acting to limit growth, performance, sustainability and viability of complex systems. Dery's (1984) proclamation: "whether we seize, set, define, discover, or formulate a problem, we are not certain of precisely what we are doing; nor is it obvious that we understand the object of such pursuits" (p. 14) remains intact. This is especially so since there continues to be a "lack of clarity as to what problem definition is or how to do it" (Crownover 2005, p. 30). The focus of this chapter attempts to bridge this gap by discussing how systems theory might be used to enhance problem formulation for complex systems (Katina 2015).

The reminder of this chapter is organized as follows: Sect. 2 explores the concepts of systems theory (a set of laws, principles, and theorems) to articulate an emerging comprehensive set of principles relevant to any natural or manmade system. This provides a conceptual foundation that captures the keys to understanding system behavior and performance. Section 3 derives a set of pathologies, drawn from the conceptual foundations of systems theory, which act to inhibit system performance or produce aberrant behavior. These pathologies provide sources of issues that can feed more robust problem formulation from a systems perspective. In Sect. 4, the implications of pathologies for practitioners faced with the task of formulating complex system problems are discussed. The concluding section discusses potential future research to advance the problem formulation stage for systems based approaches.

Table 1 Concepts of problem formulation

		Concepts related to problem formulation for complex systems								
Authors	Domain	Multiple views of the problem	Define/formulate/frame the problem	Problem as objective entity	Problem as constructive or interpretive entity	Rich pictures	Context/contextual Integrity	Problem setting	Frame the context	Problems as pathological conditions
Beer (1984), Ríos (2012)	Management cybernetics	X	X							X
Bergvall-Karebon (2002)	Systems analysis	X			X	X	X			
Bowen (1998)	Systems analysis		X							
Checkland (1985)	Systems analysis	X			X	X	X			
Crownover (2005)	Engineering management	X	X	X	X	X	X	X	X	
Dery (1984)	Policy analysis		X	X						X
Farr and Buede (2003)	Systems engineering		X							
Gibson et al. (2007)	Systems analysis						X			
Hitchins (2003)	Systems engineering		X					X		
Keating et al. (2001b, 2003)	Systems engineering/SoSE		X				X			
Quade and Miser (1985)	Systems analysis				X		X			
Schön (1983)	Systems analysis				X		X	X	X	
Vennix (1996)	Systems analysis	X								

2 Foundations of Systems Theory

The term *systems theory* does not have a single common or accepted definition. It is frequently attributed to Anatol Rapoport, Norbert Weiner, Karl Ludwig von Bertalanffy and Ross Ashby (Klir 1972; Laszlo and Krippner 1998) and emerged in the 1940s as an attempt to provide an alternative to reductionism. Reductionism is closely aligned with the scientific method, which holds that a complex organism is nothing but the sum of its parts, and therefore they can be reduced to constituent elements to explain the performance of the whole (Hammond 2002; von Bertalanffy 1968). As doubts regarding the classical scientific approach of isolating constituent elements became clear in different fields, researchers became more interested in notions of 'organization' of wholes rather than parts (von Bertalanffy 1972). They kept re-discovering the Aristotelian dictum of the whole being greater than the sun of its parts in biology, psychology, sociology, and physics (von Bertalanffy 1968; Laszlo 1996). This set in motion a different level of thinking, based in understanding systems behavior/performance not being explained from traditional reductionist thinking.

The argument for systems theory started in 1920's when von Bertalanffy stated: "*Since the fundamental character of the living thing is its organization, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena. This investigation gives us no information about the coordination or parts and processes*" (*as cited in* von Bertalanffy 1972, p. 410). The proposed solution to this issue in biology was to "discover the laws of biological systems (at all levels of organization)" to gain knowledge about the complete picture that includes coordination of parts and processes (von Bertalanffy 1972, p. 410). In terms of systems and understanding, the purpose of systems theory emerged as a platform for uniting different disciplines through inductive discovery of universally applicable models, principles and laws that help explain 'system' phenomena (Heylighen and Joslyn 1992; Laszlo 1996; Laszlo and Krippner 1998; von Bertalanffy 1950).

The argument was that such models, principles, and laws provided a natural link between different and diverse systems. This was the basis for commonality among different disciplines, which could be found using systems theory and leveraged to enhance our understanding of the natural world. This is illustrated in Kenneth Boulding's letter to von Bertalanffy where he writes: "I seem to have come to much the same conclusion as you have reached, though approaching it from the direction of economics and the social sciences rather than from biology—that there is a body of what I have been calling 'general empirical theory,' or 'general system theory' in your excellent terminology, which is of wide applicability in many different disciplines. I am sure there are many people all over the world who have come to essentially the same position that we have, but we are widely scattered and do not know each other, so difficult is it to cross the boundaries of the disciplines" (as cited in von Bertalanffy 1968, p. 14). Thus, the struggle to find a commonality across the disciplines was fully ignited.

The founders of systems theory foresaw this emerging theoretical field as a necessary and sufficient platform for transcending the boundaries of the classical sciences (von Bertalanffy 1968, 1972). Thus, the notion of systems theory was not limited to living organisms. It transcended machines, physicochemicals, organizations, and social systems (Stichweh 2011). The foundation of the *Society for General Systems Research* (since renamed, *International Society for the Systems Sciences*) in 1954 provides further clarification on the need of systems theory. The original bylaws stated that the aims of general systems theory:

1. To investigate the isomorphy of concepts, laws, and models from various fields, and to help in useful transfers from one field to another
2. To encourage development of adequate theoretical models in the fields which lack them
3. To minimize the duplication of theoretical efforts in different fields
4. To promote the unity of science of through improving communications among specialists (Adams et al. 2014; Hammond 2002; von Bertalanffy 1972).

In postulating general systems theory, von Bertalanffy's objective was to bridge the gap that exists in different disciplines via the discovery of principles and laws common across disciplines. von Bertalanffy (1968) proclaims "…there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or 'forces' between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general" (p. 32). Rather than promoting and creating bubbles of knowledge without a sense on holistic understanding, proponents of systems theory suggested that there is a need for a discipline that can bridge the gap created by compartmentalization of reductionist thinking (Laszlo 1996). More explicitly, Hammond (2002) notes that the traditional scientific method and its reductionist mindset are in fact "rooted in the mechanistic worldview we inherited from the scientific revolution of the seventeenth century…we needed a more ecological or systemic world, based on an understanding of our fundamental interconnectedness and interdependence, with each other and with all of life" (p. 430). Thus, systems theory was clearly focused on the discovery of a universally applicable body of knowledge that would be transportable across multiple domains of inquiry.

Consequently, there are pronounced differences between reductionist and systems approaches along the lines of 'substance' and 'organization' (Laszlo 1996). These differences can also elaborate upon by examining systems theory through three related concepts, including systems science, systems technology, and systems philosophy (Strijbos 2010; von Bertalanffy 1972). This current discourse is primarily focused on 'systems science' which deals with knowledge of the connected 'wholes'—complexity as opposed to a focus on detailed and isolated system elements. von Bertalanffy (1972) suggests that systems science deals with the "scientific exploration and theory of 'systems' in various sciences (e.g., physics, biology, psychology, social sciences), and general systems theory as the doctrine of principles applying to all (or defined subclasses of) systems" (p. 414). Therefore, the basis for the trajectory of systems theory was set by the early works. Their focus was on finding commonality across disciplines through a set of universals that would define the function, performance, and behavior of all systems, natural or manmade.

While an accepted general systems theory has yet to emerge (Adams 2012; Adams et al. 2014; Gaines 1977; Monod 1974), the aspect of systems theory describing isomorphic concepts, laws, principles, and theorems applicable to different systems are becoming increasingly evident (Adams et al. 2014; Clemson 1984; Flood and Carson 1993; Stichweh 2011; Strijbos 2010; von Bertalanffy 1968; Weinberg 1975). Thus, the current state of systems theory can only provide a set of concepts, laws, principles, and theorems from different discipline to describe different system structures and their behaviors. Additionally, as suggested by Strijbos (2010), systems theory can be used to gain "insights of one discipline" based on related theories (p. 453). In this instance, Strijbos's work supports the notion that systems theory is about how different theoretical perspectives can be transported from one field to another to address a wide array issues in distinctive disciplines. In this respect, system phenomena and their related issues are not constrained to individual fields, but rather are transdisciplinary in their existence in multiple fields. Certainly, this was the case as exemplified by control engineering which has roots in cybernetics (Jackson 2003; Strijbos 2010; von Bertalanffy 1968) and broad applicability to other disciplines. It is from this perspective that this current exploration adopts the following formal definition of systems theory: "…a unified group of specific propositions which are brought together to aid in understanding systems, thereby invoking improved explanatory power and interpretation with major implications for systems practitioners" (Adams et al. 2014, p. 113).

Drawing on six major sectors and forty-two individual fields of science, Adams et al. (2014, pp. 117–119), proposed thirty constituent propositions—inclusive of laws, principles, and theorems—as a collective of systems theory clustered around seven axioms. The axioms included centrality, context, design, goal, information, operational, and viability. Table 2 is provided to capture an expanded view of laws, principles, and theorems pertinent to systems theory. This table significantly expands those included in Adams et al. (2014) to include a wider array of principles not included in that work.

Up to this point in this chapter, we have articulated need and provided a formal definition of systems theory. However, it would be an oversight to assume that the concepts in Table 2, the collection of 45 concepts, exist as the 'complete and definitive' set of concepts, laws, and principles that can define systems theory. Nonetheless, the provided concepts are sufficiently representative of systems theory to provide a solidly grounded basis for development of systems pathologies. From this systems theoretic starting point, the following section focuses on how systems theory can be used to inform problem formulation.

Table 2 Contemporary concepts of systems theory

Concepts of systems theory and proponents	Concept descriptions
Law of complementarity (Bohr 1928; Mehra 1987; Murdoch and Murdoch 1989)	Any two different perspectives or models about a system will reveal truths about that systems are neither entirely independent nor entirely compatible
Law of requisite hierarchy (Aulin 1982; Aulin-Ahmavaara 1979; Klir 1991)	The weaker in average are the regulatory abilities and the larger the uncertainties of available regulators, the more hierarchy is needed in the organization of regulation and control to attain the same result, if possible at all
Law of requisite parsimony (Miller 1956; Simon 1974; Warfield 1995)	Human short-term brain activity (memory) is incapable of dealing or recalling more than seven plus or minus two items
Law of requisite saliency (Boulding 1966; Hester and Adams 2014; Warfield 1999)	The factors that will be considered in a system design are seldom of equal importance. Instead, there is an underlying logic awaiting discovery in each system design that will reveal the saliency of these factors
Law of requisite variety (Ashby 1956; Clemson 1984; Flood and Carson 1993)	The control achieved by a given regulatory sub-system over a given system is limited by: (1) the variety of the regulator and (2) the channel capacity between the regulator and the system
Principle of balance of tensions (Keating 2009; Keating et al. 2010)	To relieve tensions in complex systems, a metasystem structure must be used to create the right balance between: (1) the autonomy of subsystems and the integration of the system as a whole, (2) purposeful design and self-organization, and (3) focus on maintaining stability and pursuing change. Moreover, there is no 'right' or 'wrong' balance of tensions, rather a 'shifting' balance based on the needs on the system
Principle of basins of stability (Bateson 1972; Nicolis and Prigogine 1975)	Complex systems have basins of stability which are separated by the thresholds of instability or phases of transition. When acted upon, systems will tend to move into another state (basin) of stability. Thus, a system 'parked' on a ridge will 'roll downhill'
Principle of buffering (Skyttner 2005; Wildavsky 1988)	Stability of systems is enhanced by maintaining a surplus. However, an unused reserve cannot help the system. Whether we are talking about petroleum or wheat reserves or excess capacity to store food or water in the body, the surplus serves to buffer the system against an unexpected increase in demand

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Principle of circular causality (von Foerster Mead and Teuber 1953; Korzybski 1994)	Any effect becomes a causative factor for future effects, influencing them in a manner particularly subtle, variable, flexible, and of an endless number of possibilities
Principle of darkness (Ashby 1956; Beer 1979; Cilliers 1998)	Each element in the system is ignorant of the behavior of the system as a whole, it responds only to information that is available to it locally. This point is vitally important. If each element 'knew' what was happening to the system as a whole, all of the complexity would have to be present in that element
Principle of emergence (Aristotle 2002; Checkland 1993; Guckenheimer and Ottino 2008)	Whole entities exhibit properties which are meaningful only when attributed to the whole, not its parts—e.g. the smell of ammonia cannot be deduced from the individual elements, only coming about from their interaction. Every model of a system exhibits properties as a whole entity which derive from the interaction of components, but cannot be reduced to individual components
Principle of equifinality (Paritsis 2000; von Bertalanffy 1968)	If a steady state is reached in an open system, it is independent of the initial conditions, and determined only by the system parameters (i.e. rates of reaction and transport). Hence, taking different paths, the same final state may be reached from different initial conditions
Principle of eudemony (Beer 1978; Kant 1991; Li 2013)	Well-being in complex systems involves more than financial profitability. It involves a sense of well-being and happiness which might involve the right balance in terms of material, technical, physical, social, nutritional, cognitive, spiritual, and environmental aspects
Principle of events of low probability (Machol and Miles 1973; Machol et al. 1965)	No system can be all things to subsystems and entities—including people, all of the time. More specifically, the critical fundamental missions of a system should not be jeopardized to accommodate or maximize events of low probability in individual subsystems or entities
Principle of feedback (Adams et al. 2014; Skyttner 2005; Wiener 1948)	All purposeful behavior may be considered to require negative feed-back. If a goal is to be attained, some signals from the goal are necessary at some time to direct the behavior
Principle of hierarchy (Checkland 1993; Clemson 1984; Pattee 1973)	Complex natural phenomena are organized in hierarchies with each level made up of several integral systems. In a hierarchy, levels are said to denote emergent properties of an organization

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Principle of holism (Ackoff 1971; Smuts 1926)	A system has holistic properties possessed by none of its parts. Each of the system parts has properties not possessed by the system as a whole. More specific, it is very important to recognize that the whole is not something additional to the parts: it is the parts in a definite structural arrangement and with mutual activities that constitute the whole
Principle of homeorhesis (Margulis 1999; Waddington 1957)	This concept encompasses dynamical systems which return to a trajectory, even if disturbed in development. In homeorrhesis, systems return to a particular path of a trajectory while in homeostasis systems return to a particular state
Principle of homeostasis (Becvar and Becvar 1999; Cannon 1929; von Bertalanffy 1968)	The property of an open system to regulate its internal environment so as to maintain a stable condition, by means of multiple dynamic equilibrium adjustments controlled by interrelated regulation feedback mechanisms
Principle of least effort (Ferrero 1894; Zipf 1949)	To attain a specific goal, all complex systems will naturally choose the path of least resistance. For instance, in choosing between adapting to its environment or adapting the environment, a system will select the alternative that requires the least expenditure of resources (effort)
Principle of minimal critical specification (Adams et al. 2014; Cherns 1976, 1987)	There are two aspects of this principle, positive and negative. The positive aspect of the principle suggests a need for identifying what is essential for design while the negative aspect suggests that no more should be specified than is absolutely essential for design of complex systems
Principle of multifinality (Buckley 1967; Skyttner 1996)	This principle suggests that complex organizations with similar histories and conditions can have outcomes that vary widely. Thus, we can't draw premature conclusions regarding outcome expectations for different organizations that appear to be operating under similar conditions
Principle of omnivory (Watt and Craig 1988; Wildavsky 1988)	This principle suggests that stability in a complex system is achieved by having a greater number of different resources and of pathways for their flow to the main system components (i.e., modification of internal structures to enable intake of different inputs [resources]. In other words: spread the risks or 'don't put all your eggs in one basket'.

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Principle of pareto (Beer 1979; Pareto 1897)	In any large complex system, it appears that eighty percent of the outputs or objectives will be produced by only twenty percent of the system means. For example, the case where eighty percent of the shares are held by twenty percent of the shareholders or twenty percent of the sizes (coats, trousers, and shoes) fit eighty percent of the customers
Principle of redundancy of potential command (Clemson 1984; McCulloch 1965)	Effective action is achieved by an adequate concatenation of information. In a management structure, the potential to act effectively belongs to that subset of management that first acquires the proper information. In other words, power resides where information resides
Principle of redundancy of resources (Clemson 1984; Pahl et al. 2011; Shannon and Weaver 1949; Watt and Craig 1988)	Generally, maintenance of smooth internal operations and continuous progress toward overall complex system goals requires redundancy of critical resources. Such resources include, but are not limited to, human, information, or material resources that can be accessed as backup or fail-safe to support achievement of system goals when necessary. Redundancies act to increase the reliability of a system
Principle of relaxation time (Beer 1978; Iberal 1972)	It is a characteristic of our society that its institutions (systems)…have a longer relaxation time [recovery time] on average than the mean time interval between massive external perturbations
Principle of resilience (Holling 1973; Katina and Hester 2013; Martin-Breen and Anderies 2011)	Complex systems exhibit the ability to withstand, recover from, and reorganize in response to disturbances. This might be characterized by defensive characteristics such as deterrence, system defensive properties such as physical barriers, capacity, time to repair, availability of warning systems, or critical time
Principle of satisfying (Simon 1956; Skyttner 2005)	This is the decision-making process whereby one chooses an option that is, while perhaps not the best, good enough. In essence, satisfying is attaining a certain minimum quality level for the decision, enough to solve the problem but not necessarily more

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Principle of self-organization (Adams et al. 2014; Ashby 1962)	Complex systems organize themselves lacking outside intervention; they exhibit emergent global structure and behavior out of interactions of local and seemingly independent components [systems, elements or parts]
Principle of sub-optimization (Ackoff 1977; Heylighen 1992; Hitch 1953)	If each subsystem, regarded separately, is made to operate with maximum efficiency, the system as a whole will not operate with utmost efficiency. More critically, independent improvement of a particular subsystem may actually worsen the overall performance of the whole
Principle of transcendence (Capra 1982; Krippendorff 1986; White and Krippner 1977)	Complex systems seem to organize and radiate information in other dimensions beyond physical space-time and mental boundaries of learning, development, and evolution. In such instances material structures are no longer considered the primary reality. God is seen as the source of all being and particularly as the source of evolutionary force, exemplified by that which 'transcends' our capability to fully comprehend, existing beyond scientific explanation
Principle of viability (Beer 1979, 1981; Clemson 1984)	To maintain viability, there must be effective organizational balance maintained along two dimensions: (1) Autonomy of organizational units verses integration of the system as a whole and (2) Stability of operations versus adaptation to changing conditions
Theorem of incompleteness (Clemson 1984; Kleene 2002; Gödel 1962)	Typically referred to as Gödel's theorem of incompleteness, this theorem suggests that an effective framework for complex systems cannot be both effective and complete. There are always situations that cannot be adequately addressed within the current frame of understanding of complex systems, which must be resolved at a higher level of understanding
Theorem of information redundancy (Hester and Adams 2014; Shannon and Weaver 1949)	Errors in information transmission can be protected against (to any level of confidence required) by increasing the redundancy in the messages. Redundancy of the messages is required due to 'noise' and thus extra channel capacity might be required to ensure that the message reaches the intended destination

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Theorem of morphogenesis (Becvar and Becvar 1999; Krippendorff 1986)	The ability of complex systems to maintain stability in the context of change conditioned by a morphocatalysis (i.e., conditioned by system contact or co-presence of another system). System-enhancing behavior such as growth, creativity, innovation and change are allowed to remain functional based on other systems. However, it also connotes change in the context of stability inasmuch as stability is required in order for the system to be able to change and to maintain itself in the face of external change
Theorem of purposive behaviorism (Keating et al. 2010; Rosenblueth et al. 1943; Tolman 1948)	Complex system purpose must be ascertained through rigorous examination of what the system is producing (e.g., behavior, performance, outputs/outcomes), not what it was intended to produce. Thus, system purpose is directly related to 'results' and not attributed to 'intended' purpose or desires regardless of the 'well-intended meaning' of design
Theorem of recursive system (Beer 1978; Krippendorff 1986)	If a viable system contains a viable system, then the organizational structure must be recursive; in a recursive organizational structure, any viable system contains, and is contained in, a viable system. Thus, the fundamental laws governing the processes, functions, and structure at one level are also present at the next higher level
Theory of communication (Shannon 1948a, b; Weaver 1948)	This theory deals with information especially the process in which a message is coded, transmitted, and decoded. More precisely, transference of meaning between systems by conveying of information, which is done in the bits of information (binary digit). This process aids in control of systems and it is necessary for survivability in changing environments
Theory of control (Aizermann 1975; Checkland and Scholes 1990; Skyttner 2005)	The process and means by which a whole system retains its identity and/or performance under changing circumstances. This is might involve moving the system toward a predefined goal involving continuous comparison of current states to future goals through information processing, programing, decision, and communication

(continued)

Table 2 (continued)

Concepts of systems theory and proponents	Concept descriptions
Theory of dynamic equilibrium (D'Alembert 1743; Hester and Adams 2014; von Bertalanffy 1968)	For a system to be in a state of equilibrium, all subsystems must be in a floating (not steady or stable) state characterized by invisible movements and preparedness for maintain equilibrium in the midst of change. Moreover, this suggests that systems will stay in their initial condition until some form of interaction is made with them
Theory of punctuated equilibrium (Calida and Katina 2012; Eldredge and Gould 1972; Gould and Eldredge 1977)	The theory suggests that most systems exhibit little net evolutionary change for most of their geological history, remaining in an extended state of stasis (i.e., a period or state of inactivity or equilibrium). However, when such a significant evolutionary change occurs in such systems, it is generally restricted to rare and rapid change that occurs, on a geologic time scale, through a process of cladogenesis (i.e., the process by which a species splits into two distinct species rather than one species gradually transforming into another)
Theory of sociotechnical systems (Cherns 1976, 1987; Keating et al. 2001b)	At the core of this theory is the notion that the design and performance of complex systems can be improved, and indeed can only work satisfactorily, if the 'social' and the 'technical' are brought together and treated as interdependent aspects of a work system. This 'joint optimization' of the technical and social subsystems, that constitute a total work system with neither subsystem being superior to another, is necessary for successful design and operation of a complex sociotechnical system
Theory of system boundary (Bowler 1981; Mitroff 1998; Warfield 1976)	Every system has a set of boundaries that indicates some degree of differentiation between what is included and excluded in the system. Boundary is critical since, too narrow or too broad a boundary gives a false impression of the system of interest—resulting in pursuit of solutions to the wrong 'system' problem. Boundary identification is necessary to have a minimum description required to distinguish a system from its environment
Theory of system environment (Laszlo 1996; Weinberg 1975)	This theory is the basis for suggesting that every system operates in an environment which is always outside the control of the system and yet it (the environment) can influence system processes and behavior. Moreover, since systems do not control the environment, they can only adapt to changes in the environment

3 Systems Theory-Based Pathologies

Etymologically, the term *pathology* has been used in relation to understanding observed symptoms and determining causes of disease and death through dissection of living systems (Bynum and Porter 1997; Long 1965; van den Tweel and Taylor 2010). Moreover, the term 'pathology' is also intrinsically related to understanding structural and functional morphological changes which tend to focus on disease etiology, pathogenesis, cell morphologic changes, and the consequences of those changes (Kumar et al. 2010). In recent times, there has also been a focus on understanding pathologies beyond animate systems (Barnard 1946; Beer 1984; Dery 1984; Keating and Katina 2012; Ríos 2012). Table 3 is drawn to indicate differing perspectives on *pathology* in different domains.

Emerging research indicates that the term *pathology* can be viewed as a condition that acts to reduce system performance. Recent research demonstrates that *pathology* can also be described as deviation in application of concepts of systems theory (Katina 2015; Keating and Katina 2012). This is the case inasmuch as pathology is "expressed as the lack of use of principles (i.e., not recognizing utility of systems theory) or direct violation of a principle (i.e., ignoring or inappropriate application of systems theory)" (Katina 2015, p. 10) with deep implications for system performance and viability.

To develop pathologies based on systems theory an inductive process, synonymous with the grounded theory method of qualitative research (Glaser and Strauss 1967; Leedy and Ormrod 2010; Saldaña 2013; Strauss and Corbin 1990) was undertaken. Multiple sources of data elaborating several concepts of systems theory were collected and coded as 'text data' for a possible pathologies based on Katina's

Table 3 Selected schools of thoughts about system pathology

Source domain	Underling concepts	Examples
Medicine	A significant area of focus for current medicine and a critical element of causal study of disease, diagnosis, prevention, and treatment	– Disease
Management theory (Barnard 1946)	Organizational structural issues that can affect performance and growth of the organization	– Communication-relevant pathology – Position-relevant pathology
Policy analysis (Dery 1984)	Discrepancies between current system performance, growth, sustainability, or viability and the cherished 'ideal' system	– Social issues
Management cybernetics (Beer 1984; Keating and Katina 2012; Ríos 2012)	Deviations, inadequacies, and ineffectiveness in subsystems functions of the Viable System Model (VSM)	– Structural pathology – Functional pathology – Information and communication pathology

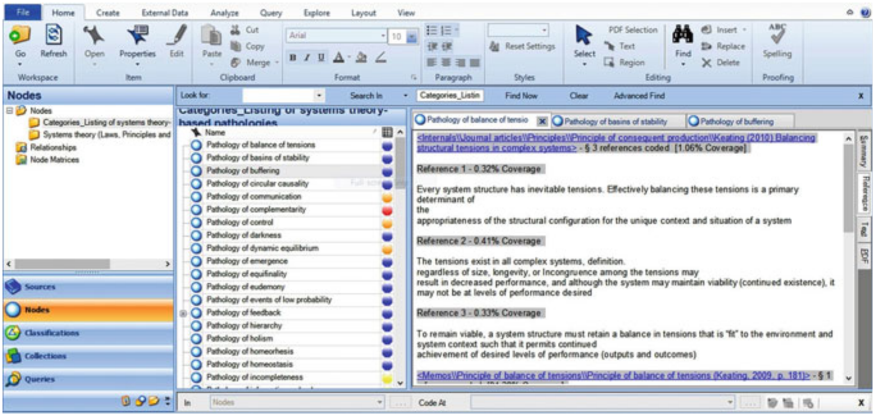

Fig. 1 A screenshot from NVivo® 10 as used in this research

(2015) notion of inadequacy in application of systems theory—or more precisely, a lack of use of, or violation of, laws, principles, and theorems that define systems theory. The pathologies were developed by reflecting on the meaning of concepts of systems theory in relation to complex problem formulation in terms of pathologies. Each systems theory concept was viewed as 'data' and was imported and coded as distinctive 'text units' and analyzed for meaning related to complex system problem formulation using the NVivo® 10 software package. Figure 1 provides an illustration of the NVivo® 10 interface used in this research. The left side of this figure represents the 'text units' from different authors that were coded for various pathological conditions related to concepts of systems theory.

The inductive approach undertaken in this research is recommended for researchers pursuing qualitative based approaches to research (Auerbach and Silverstein 2003; Boyatzis 1998; Butler-Kisber 2010; deSantis and Ugarriza 2000; Saldaña 2013). In this approach, the researcher extracts "significant statements" (Butler-Kisber 2010, p. 50) from data, "formulating meanings" (Butler-Kisber 2010, p. 61) about them through the researcher's interpretation, and clustering meanings into coherent 'categories' with written descriptions supported by the text data. It is noteworthy that most of the 'text units' are imported into NVivo as 'memos', since it is not possible to import some more extensive data sources such as textbooks. The memo entries also included "analytic memos" which are defined as "not just as a significant word or phrase you applied to a datum, but as a prompt or trigger for written reflection on the deeper and complex meanings it evokes" (Saldaña 2013, p. 42). More specifically, Mason (2002) notes that analytic memos enable "thinking critically about what you [the researcher] are doing and why, confronting and often challenging your own assumptions, and recognizing the extent to which your thoughts, actions and decisions shape how you research and what you see" (p. 5). Table 4 is provided to illustrate emerging systems theory-based pathologies (STBP) developed from the 45 concepts of systems theory, following the grounded theory inductive approach identified above.

Table 4 Articulation of systems theory-based pathologies

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of complementarity	This pathology occurs when an organization decides to ignore alternative perspectives or models that are not entirely compatible with established missions, goals, or objectives. An organization in such a situation mistakenly assumes that there is only one 'right' perspective despite the ambiguity, complexity, interdependency, and uncertainty involved in complex systems	Law of complementarity (Bohr 1928; Clemson 1984; Krippendorff 1986; Mehra 1987; Murdoch and Murdoch 1989; Skyttner 2005)
Pathology of requisite hierarchy	This pathology occurs when an organization assumes or takes on increasing responsibilities but fails to create appropriate levels of hierarchy to regulate and control the system as a whole. More specifically, Klir (1991) notes that "in the context of social systems, a relationship between the production capacity of a human society and the degree of hierarchy associated with the organization of the society that is needed for efficient regulation" (p. 211). Each production level requires a corresponding degree of hierarchy to maintain production and efficiency	Law of requisite hierarchy (Aulin 1982; Aulin-Ahmavaara 1979; Klir 1991)
Pathology of requisite parsimony	This pathology occurs when the human element of a system assumes more than what can be reasonably be handled. This pathology might be exhibited in terms of lack of accuracy (Miller 1956) in any activity related to performing work in a complex system, especially when such activities involve more than seven plus or minus two functions, missions, or objectives. Attempts to be beyond this scope "prelude sound reasoning" (Warfield 1999, p. 25)	Law of requisite parsimony (Miller 1956; Simon 1974; Warfield 1995)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of requisite saliency	This occurs when an organization assumes that all aspects of the system, be it design, execution, etc. are of equal importance, failing to distinguish varying levels of importance (priority). Warfield (1999) suggests that this thinking contributes to poor intellectual productivity and is attributed to spurious saliency (i.e., emphasizing the wrong elements, out of proportion to what they deserve), unproductive emulation (i.e., behaving like those who help create rather than resolve problems), and cultural lag (i.e., not using a common established knowledge base)	Law of requisite saliency (Boulding 1966; Hester and Adams 2014; Warfield 1999)
Pathology of requisite variety	This pathology occurs when the regulatory system of an organization—including management team and its tools as well as regulatory procedures, has insufficient capacity to effectively deal with issues at hand. In essence, this is a situation where a system is overwhelmed by the variety of its subsystems and/or environment	Law of requisite variety (Ashby 1956; Clemson 1984; Flood and Carson 1993; Skyttner 2005)
Pathology of balance of tensions	The presence of this pathology is indicated by lack of a system structure that balances tensions between (1) independence of subsystems and missions of the whole, (2) structured design and self-organization, and (3) maintaining stability and allowing for change commensurate with unpredictability in the system/environment. Failure to retain this balance creates the right conditions for poor levels performance stemming from a mismatch of balance of the system with the operational setting within which it exists	Principle of balance of tensions (Keating 2009; Keating et al. 2010)
Pathology of basins of stability	This pathology occurs when an organization fails to recognize, or even consider, the different possible configurations of systems and their contribution to current levels (desirable or undesirable basin) of stability. Also, that significant effort is required to guide the system from one 'basin' to another. This is why it is very difficult to for organizations to quit undesirable habits that work to maintain current basins of stability (Clemson 1984)	Principle of basins of stability (Bateson 1972; Hester and Adams 2014; Nicholis and Prigogine 1975)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of buffering	The pathology of buffering entails operating with no slack. In this case slack refers to "capacity in excess of immediate needs" (Wildavsky 1988, p. 116). Unlike the pathology of redundancy of resources (i.e., not having the *same* kind resource in case of failure), this pathology simply addresses a need for 'surplus' in case of unexpected increase in demand while being aware that an used surplus could actually harm efficiency of the system	Principle of buffering (Skyttner 2005; Wildavsky 1988)
Pathology of circular causality	This occurs when we operate in complex system settings using a traditional (linear) mode of thinking where A causes B and B cause C without recognizing that C could as well contribute to the formation of A. An organization experiencing this pathology fails to recognize that B might be caused by subtle, variable, flexible and a potentially endless number of possibilities including A	Principle of circular causality (von Foerster et al. 1953; Korzybski 1994)
Pathology of darkness	When we operate complex systems under the assumption that we know everything there is to know about their behaviors, we are in a position to experience this pathology. In fact, Clemson (1984) suggests that effective management of complex systems does not require knowing all there is to know about such systems, but rather knowing the "crucial aspects of the system and to actually avoid knowing about (hopefully) irrelevant details" (p. 204)	Principle of darkness (Ashby 1956; Beer 1979; Cilliers 1998; Clemson 1984; Skyttner 2005)
Pathology of emergence	This pathology occurs when management assumes behaviors of wholes (i.e. system) can be directly inferred by the properties of the parts (i.e., subsystems or elements), independent of their interaction. In this situation, there is failure to recognize that the integrated system (whole) will exhibit behavior that is different from those of individual subsystems, only being realized from the interaction of the subsystems/elements. The result is a failure to recognize system behavior existing (emerging) beyond the individual subsystems/elements	Principle of emergence (Aristotle 2002; Checkland 1993; Guckenheimer and Ottino 2008; Heylighen 1989)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of equifinality	This pathology occurs in a complex system setting when we assume that there is only one path to arriving a final desired state (i.e., mission achievement). In such a case, an organization fails to explore and recognize other viable alternatives and measures that would still result in achievement of the same desired mission and objectives	Principle of equifinality (Cummings and Worley 2005; Katina et al. 2014b; Paritsis 2000; von Bertalanffy 1968)
Pathology of eudemony	This pathology is exhibited when we fail to recognize the importance of concepts that are desirable and yet not easily quantifiable. More specifically, this pathology occurs when more value is placed in singular system aspects (e.g., financial profitability) without a more balanced (holistic) consideration or accounting for happiness which might involve material, technical, physical, social, nutritional, cognitive, spiritual, and environment aspects of complex systems	Principle of eudemony (Beer 1978; Kant 1991; Li 2013)
Pathology of events of low probability	This pathology is endemic in situations wherever we operate under the assumption that well-designed complex systems must serve all subsystems and entities (including people) without differentiation. In essence, this pathology requires operating under the assumption that the "system must be able to store and process every conceivable intelligence input' in spite of the fact that the resulting system is too complex to be workable" (Machol and Miles 1973, p. 39). Under this operational mode, critical missions can be jeopardized as a result of providing support to events of low probability with equal priority	Principle of events of low probability (Machol and Miles 1973; Machol et al. 1965)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of feedback	This pathology entails failure to use system output/outcome results (i.e., scanning for success or failure in anticipated behavior or performance) to make modifications necessary to continue to meet behavior/performance expectations. This might occur when an organization lacks mechanisms for single loop learning (i.e., detection and correction of error within existing system configuration) and double loop learning (i.e., detection and correction of error by modifying fundamental aspects of the system) (Argyris and Schön 1978)	Principle of feedback (Adams et al. 2014; Luhmann 2013; Skyttner 2005; Wiener 1948)
Pathology of hierarchy	This pathology suggests a lack of understanding that complex systems are organized in hierarchies. These hierarchies are necessary to provide regulatory structure that provides 'organization' essential to generate desired system performance/behavior. Insufficient or ineffective hierarchy fails to provide the level of regulatory controls necessary to reduce uncertainty in the face of turbulent and emergent system conditions	Principle of hierarchy (Checkland 1993; Clemson 1984; Pattee 1973; Simon 1973)
Pathology of holism	This pathology occurs when management assumes that behaviors of an integrated system are possessed in parts of the systems (i.e., subsystems). This pathology is different from the pathology of emergence in that it suggests that understanding of a system cannot be maintained past a particular point of reduction. The concern is that understanding is diminished as a system is 'abstracted' from the whole. In this situation, there are "no clear role definitions or divisions of responsibilities" since there are no clear difference between the whole and the part (Clemson 1984). In effect, understanding beyond the level of the whole will always be flawed—regardless of the precautions taken, and failure to recognize this limitation creates the conditions for this pathology	Principle of holism (Ackoff 1971; Skyttner 1996; Smuts 1926)

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Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of homeorhesis	This pathology entails failure to place mechanisms in place that enable a system to return to its desired trajectory (i.e., path) following environmental disturbances. These disturbances are inevitable in complex systems and the ability to invoke mechanisms that return a system to its trajectory is an essential aspect of system design and development. Without an effective set of these mechanisms a system may be delayed in returning to intended trajectory, and may not be able to return at all	Principle of homeorhesis (Adams et al. 2014; Margulis 1999; Waddington 1957)
Pathology of homeostasis	This pathology is evidenced by failure to develop internal mechanisms that ensure the system can retain its internal steady state stability in the face of disruptions from external forces. Failure to maintain steady state could be attributed to weak regulatory systems such as feedback mechanisms (Becvar and Becvar 1999) that respond to deviations in performance or behavior	Principle of homeostasis (Becvar and Becvar 1999; Cannon 1929; von Bertalanffy 1968)
Pathology of least effort	Failure related to this pathology results in a system that does not move forward via a path of least resistance, but instead pursues the desired path, goal, or mission by means that are inefficient. Therefore, resources are potentially 'expended' on activities that are not necessary to secure system performance. Expending least energy is desirable only to the extent that it produces desired levels of performance. Least energy is undesirable, and directed efforts must be undertaken to expend energy (beyond least energy) necessary to assure continued achievement of system performance. Critical system evaluation is needed to ensure that systems do not simply follow least resistance paths that are inconsistent with maintaining system performance levels	Principle of least effort (Ferrero 1894; Krippendorff 1986; Zipf 1949)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of minimal critical specification	This is a pathological condition where specific and minute detail (e.g., instructions) is provided on every aspect of a complex system. Included in this pathology is lack of focus on the major essential elements. Moreover, this pathology creates the right conditions for poor creativity, an essential element for dealing with complexity (Stacey 1996)	Principle of minimal critical specification (Adams et al. 2014; Cherns 1976, 1987)
Pathology of multifinality	This pathology tells us that experience can be treacherous. In complex systems, this involves the tendency to draw premature conclusions regarding system situations that appear to be operating under conditions with similarity to prior situations. This is failure to recognize important 'distinctions' simply because we have dealt with 'similar' situations in the past, achieving positive results using a particular approach. Therefore, the error occurs as we anticipate the 'same' results using the same approach even though outcomes can vary widely based on the sometimes subtle situational differences	Principle of multifinality (Adams et al. 2014; Buckley 1967; Skyttner 1996)
Pathology of internal diversification	This pathology occurs when internal structures (i.e., pathways) of a system cannot be modified to increase their input diversity required to maintain system stability. A system that exhibits this pathology might rely on a single pathway to process inputs. When this occurs, the system loses its ability to withstand any decline in the specific area of specialization making it susceptible to the most limited perturbations	Principle of omnivory (Watt and Craig 1988; Wildavsky 1988)
Pathology of pareto	This is the pathological condition steaming from the assumed 'causal-interrelationship' evident in simple systems. This creates the right conditions for operating under assumptions of linearity where there is a failure to distinguish (prioritize) the impacts of efforts. Instead, the focus of efforts is not necessarily directed in proportion	Principle of Pareto (Beer 1979; Clemson 1984; Pareto 1897)

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Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
	to yielding higher levels of desired results. This is failure to recognize that "attempts to increase productivity (i.e., more of some desired output) are frequently counter productive" (Clemson 1984, p. 206) due to inherent messiness and rich interconnectedness within a system as well as the inherent inequalities for impact of different activities on system performance	
Pathology of redundancy of potential command	This pathological condition might occur in situations where entities of an organization do not have the 'freedom' to seize opportunities (e.g., novel events, crucial facts, trends) that can aid in making more informed system decisions. This is the case where entities must adhere to the 'chain of command' such that entities are not empowered to take any actions beyond that those explicitly prescribed. In effect, decision and the ability to engage decisive action are separated from the locus of understanding and execution	Principle of redundancy of potential command (Adams et al. 2014; Clemson 1984; McCulloch 1965)
Pathology of redundancy of resources	This is a condition in which the organization is designed and operated with resource margins that place the organization at risk should resource allocations be insufficient to deal with inevitable emergent conditions. Thus, organizations subject to this pathology operate without consideration for extra critical resources—including human, which might be required to increase system reliability and redundancy necessary to buttress performance in the wake of unforeseen circumstances. Under such a situation, management might not seize new opportunities due to lack of extra managerial and resources capability (Clemson 1984)	Principle of redundancy of resources (Clemson 1984; Pahl et al 2011; Shannon and Weaver 1949; Watt and Craig 1988; von Bertalanffy 1968)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of relaxation time	This pathology occurs when an organization experiences too many changes at the same time. Therefore, the conditions are set to render the organization incapable of processing or assimilating all the rapid changes. Regardless of the cause of such changes, the organization has to be designed such that the relation time (i.e., recovery time) is shorter than the mean time between disturbances. Otherwise, the impact of changes, or the consequences stemming from interaction of multiple changes, cannot be determined with any degree of confidence	Principle of relaxation time (Beer 1978; Clemson 1984; Iberal 1972)
Pathology of resilience	An organization exhibiting this pathology might be described as inflexible, brittle, and hard. Such organizations, when they experience disturbances that change their stability, lack the capability to quickly recover to previous configurations or performance levels. This pathology also suggests that the organization has deficiencies across multiple measures of resilient systems (Gheorghe and Katina 2014)	Principle of resilience (Holling 1973; Katina and Hester 2013; Martin-Breen and Anderies 2011)
Pathology of satisficing	When the principle of satisficing (good enough) is ignored, the principle of optimization (one best) becomes the norm. Optimization can result in significant effort (and resources) being expended in unnecessary pursuit of locating the best solution. However, this invokes a failure mode that does not appreciate shortened time horizons for decision-making, scarcity of information, or limitations to information processing capability	Principle of satisficing (Hester and Adams 2014; Simon 1956; Skyttner 2005)
Pathology of self-organization	It can be said that this pathology exists in an organization structure where little to no autonomy is given to entities (i.e., subsystems). In such a case, there is limited opportunity to self-organize. As a consequence, the surrender of autonomy introduces limitations on independence and freedom of decision, action, and interpretation.	Principle of self-organization (Adams et al. 2014; Ashby 1962; Clemson 1984)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
	These limitations curtail the individual identity and creativity of system members. However, entities of an organization may also err on the side of too much self-organization, resulting in unconstrained runaway independence which "denies the complex web of interdependent relationships sustaining it [the organization] and that results in the diminishment and even the downfall of the centered organism" (Thompson and Cuff 2012, p. 148)	
Pathology of sub-optimization	This pathology elaborates on several other pathologies including emergence, holism, and satisficing. It suggests that independent improvement of subsystems does not always improve the performance of the integrated system whole. In fact it can worsen the performance the integrated system whole. It is evidenced by sacrifice of global system level unity for individual member local interests	Principle of sub-optimization (Ackoff 1977; Heylighen 1992; Hitch 1953)
Pathology of transcendence	This pathology can be experienced if we operate under a particular assumption. This assumption is that stability and viability of complex systems can only be achieved within the confines of reality as defined and understood within the objective realm of scientific or physical laws. In such a case, belief in God and accompanying activities such as praying are ignored since science and human understanding have taken precedence. In effect, this suggests a lack of acceptance that there are correspondences in natural and manmade systems for which understanding lies beyond rational, scientific, or determinate explanation. Instead, explanation exists at the metaphysical level and must be taken on 'faith'	Principle of transcendence (Capra 1982; Krippendorff 1986; White and Krippner 1977)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of viability	Any organization experiencing this pathology is heading toward becoming unviable (questioned continued existence). This is the case since it lacks the right balance along the dimensions of autonomy and adaptability. Its entities (i.e., subsystems) might have too much autonomy such that insufficient attention if paid to system-level concerns and/or the organization is incapable of adapting at a rate that is commensurate with the rate of environmental change	Principle of viability (Adams et al. 2014; Beer 1979, 1981; Clemson 1984)
Pathology of incompleteness	An organization suffering from this pathology will assume that all issues affecting performance can be understood and therefore solvable within their current frame of operations. However, this thinking can limit the organization since situations can arise out of system operations that are unresolvable within the current frame of understanding. This pathology is characterized by an organization's "repeated failures to solve a problem or a persistently frustrating situation" (Clemson 1984, p. 208). Think of healthcare, terrorism, and intractable conflicts that defy resolution within the frame of reference within which they exist	Theorem of incompleteness (Clemson 1984; Kleene 2002; Gödel 1962)
Pathology of information redundancy	This is the pathological condition in which an organization takes limited efforts in protecting against 'noise' in information transmission. The organization might have a limited transmission set for information, a limited capacity of transmitters, or simply view redundancy applications as a 'waste' (Hester and Adams 2014, p. 71) of scarce resources. Regardless of the reason, the result is insufficient redundancy to ensure that information is received as necessary to support decision, action, and interpretation	Theorem of information redundancy (Clemson 1984; Hester and Adams 2014; Shannon and Weaver 1949)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of morphogenesis	This is a condition in which an organization fails to remain stable, while simultaneously continuing to grow, due to an increasing presence of a morphocatalyst influencing the system. This might be attributed to, for instance, a morphocatalyst (e.g., consultants) that is frequently allowed to provide new information without giving the organization a chance to assimilate the information. The opposite is true for an organization that operates a closed system, *wishing to remain internally focused*, incapable of maintaining stability in the face of external changes, or a morphocatalyst, which is denied and for which a system response is not mounted	Theorem of morphogenesis (Becvar and Becvar 1999; Krippendorff 1986; von Bertalanffy 1968)
Pathology of purpose behaviorism	An organization that clings to the idea of 'this is what we are *supposed* to produce' suffers from the pathology of system purposeful behavior. This is in contrast to the focus on what is actually produced. Evidence of this pathology is apparent when the organization focuses on 'intended' results (i.e., behavior, performance, and output/outcome designed) as opposed to 'actual' results (i.e. behavior, performance, and output/outcomes of the system achieved)	Theorem of purposive behaviorism (Beer 1979; Keating et al. 2001b, 2010; Rosenblueth et al. 1943; Tolman 1948)
Pathology of recursiveness	This pathology exists when an organization (system) is not capable of defining itself such that it is both contained within a higher level structure (viable system) and also contains lower level structures (viable systems). Any attempts to exist as an independent system, without appreciation of the system within which the system is embedded, as well as the systems that are embedded within the system, presents potential difficulties. The result presents difficulties and potential system collapse since the governing laws, processes, functions, and structure might create insurmountable dysfunctions within the system	Theorem of recursive system (Beer 1978; Krippendorff 1986; Smith 1994)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of communication	This pathology exists when an organization lacks ability for transference of objects, energy, or information and ideas. This transference occurs from one point to another, according to the 'intent' of the sender. However, the pathology also encompasses difficulties or inability to process, store, and retrieve information. These issues contribute to instability of an organization	Theory of communication (Checkland 1999; Shannon 1948a, b; Skyttner 2005; Weaver 1948)
Pathology of control	A system exhibiting the control pathology will lack sufficient regulatory capacity that preserves 'identity' (maintenance of unity, uniqueness, and continuity) such that any change in the environment will not have a common reference point against which consistent interpretation can be guided. A system with this pathology might tend to shift its interpretation of 'predefined' missions and goals. This might be evident concerning the dimensions of ineffectiveness (i.e., the extent to which organization is unable to consistently achieve its intended mission/goals), inefficiency (i.e., the extent to which organization is unable to utilize resources efficiently) and inefficacy (i.e., the extent to which an organization is unable to effectively contribute to the higher-level system purpose to produce desired effects)	Theory of control (Adams et al. 2014; Aizermann 1975; Checkland and Scholes 1990; Skyttner 2005)
Pathology of dynamic equilibrium	This is the operating mode characterizing organization systems that are believed to be in state of equilibrium, yet some of their entities (subsystems) are known to be the state disequilibrium. Because of the constant interactions among the subsystems in complex systems, one cannot predict the effects of the seemingly isolated subsystem (in disequilibrium) on the dynamic of the larger system of which it is a constituent system. The result is experienced as a larger system unable to invoke sufficient controls to maintain a state of dynamic equilibrium	Theory of dynamic equilibrium (D'Alembert 1743; Hester and Adams 2014; von Bertalanffy 1968)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of punctuated equilibrium	This is a pathology that suggests that an organization will maintain a relative stability over the course of its life time while accounting for known perturbations. The long periods of stasis (i.e., relative calmness) creates a false sense of feeling safe to the point of dismissing 'black swans' events of low probability but high consequences (Taleb 2010) or 'x-events' events rare and unthinkable (Casti 2012) as simply 'fictional' and improbable. The pathology is manifest as a system not preparing for effective response in the face of discontinuities	Theory of punctuated equilibrium (Calida and Katina 2012; Eldredge and Gould 1972; Gould and Eldredge 1977)
Pathology of sociotechnicality	This pathology occurs when an organization fails to recognize the need for a joint optimization of both social systems (i.e., soft/human aspect) and technical systems (i.e., technology in the workplace) as well as their interaction. This is core to viability of the organization. This pathology might be evidenced by an organization showing preference for either the technical or social systems. Thus, the enabling or constraining impacts of either the social, technical, or both systems are not fully realized	Theory of sociotechnical systems (Cherns 1976, 1987; Clegg 2000; Jordan 1963; Keating et al. 2001b; Klein 1994)
Pathology of system boundary	This is a pathological condition describing operating an organization without explicit lines of demarcation defining what is part of the organization (system) and in effect what is not part of the organization (i.e., its environment which is separated from the system by the boundary conditions). The pathology is evidenced by discordance stemming from either pursuing too narrow, or wide, a scope of system objectives or interests without adequate definition of the criteria by which what is included or excluded from the system can be determined. The inability to define, recognize, and purposefully redefine system boundaries are characteristic of this pathology	Theory of system boundary (Bowler 1981; Forrester 1994; Mitroff 1998; Troncale 1977; Warfield 1976)

(continued)

Table 4 (continued)

Systems theory-based pathology	Pathology description	Supporting systems theory and proponents
Pathology of environment	As a result of pathology of system boundary (i.e., having fuzzy knowledge on what is part/not part of the system), an organization might experience the pathology of environment. This pathology is evidenced as a failure to recognize the influence that the environment has on the system of interest. To a higher degree, this might occur when issues that are outside the control of the system are confused and treated as if they are under control of the system. Also, to a somewhat lesser degree this might exist when issues that are under control of a system are assumed to be outside the control of the system and therefore left to be influenced by the environment	Theory of system environment (Keating 2010; Laszlo 1996; Umpleby et al. 1990; von Bertalanffy 1968; Weinberg 1975)

4 Implications for Problem Formulation in Complex Systems

The inductively developed STBPs have implications in design, execution, and evolution of newly designed or operating systems. More specifically, within the concept of problem formulation for complex systems, these pathologies might offer several utilities.

First, the articulated pathologies form a nexus of deep systemic issues that will affect performance of a complex system. Similar to human health, treating the underlying conditions, as opposed to superficial symptomatic manifestations, is necessary to treat a disease (aberrant system condition). Therefore, there is a need to examine the 'deep' systemic issues affecting the system. Unlike symptoms which might be eliminated with little effort on surface at a different point in time and place, the pathological conditions represent deep fundamental systemic issues that might not be obvious from the surface. This implies, for a practitioner, that there is a need to go beyond the superficial issues and examine the core system issues encompassing structure (e.g., hierarchies) and culture (e.g., policy) of an organization, internal elements (e.g., individual worldviews; resources), and organizational operating environment (e.g., other systems). Figure 2 is drawn to illustrate the relationship between systems theory and problem formulation.

Second, these pathologies are derived from systems theory. Undoubtedly, systems theory forms the foundation for thinking in terms of 'systems' (Adams et al. 2014; Hammond 2002; Strijbos 2010; von Bertalanffy 1972; Warfield 1976) and the derived pathologies (Beer 1984; Katina 2015; Keating and Katina 2012; Ríos 2012). For a practitioner tasked with problem 'framing' in complex systems, there is a need to be familiar with systems theory and its tenets along the dimensions of philosophical (the nature of values and beliefs informing a worldview), epistemology (the nature of knowledge and knowing), ontology (the nature of reality), and methodology (guiding frameworks for exploration of systems and their

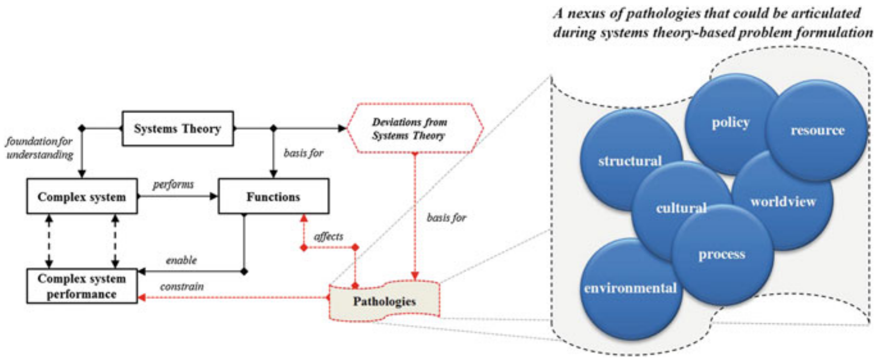

Fig. 2 Systems theory with respect to problem formulation

problems) (Flood and Carson 1993). Systemic intervention cannot be expected without systemic thinking which requires understanding 'systems.'

Third, the proposed approach to problem formulation supplements contemporary problem formulation methods and tools. Rather than seeing the proposed pathological assessment as a replacement approach in lieu of other methods and tools (e.g., needs analysis, Fishbone diagraming, SWOT analysis; requirements analysis, rich picture), the practitioner should be able to realize the place and the utility of identification of pathologies in problem formation. These are not meant to replace other problem formulation methods, but rather act as a complementary perspective for more robust problem formulation for complex systems. In all likelihood, the level of utility of these approaches will vary based on the problem domain, system of interest, and the context of application.

Fourth, the developed pathologies, especially their assessment in an organization, form the basis for design and development of problem formulation and ultimately improvement in a complex system. The role and importance of problem formulation is widely acknowledged as a key aspect in systems-based methodologies. However, there has always been ambiguity associated with how to engage in problem formulation (Crownover 2005; Dery 1984, Rein and White 1977). This ambiguity is reduced by articulation of pathologies based on inadequacies associated with applications of systems theory. The pathologies exist as violations of systems theory (i.e., laws, principles, and theorems) and can form the basis for identification of circumstances, trends, and patterns acting to limit system performance. These pathologies can then be used in conjunction with a selected systems-based methodology to support development of systemic strategies to increase the likelihood of achieving expected performance, growth, and viability.

Finally, it is essential to recognize that a STBP does not have one 'correct' interpretation. Even if there is agreement on the 'existence' of a pathology, the interpretations concerning the source and meaning will not necessarily be congruent among different observers. Thus, in a truly holistic systems thinking fashion, the idea of a pathology in complex systems must embrace a systems theoretic principle of complementarity. In this view, different perspectives will emerge, revealing insights about the system from different points of view.

5 Proposed Research Directions

Systems theory is taken as the basis for holistic 'systems' understanding (Adams et al. 2014). It would, thus, make sense to attempt using systems theory in different aspects complex system governance (Keating 2014; Keating et al. 2014), including problem formulation. In this research, systems theory is undertaken as the basis for more robust problem formulation with emphasis on articulation of STBPs (Katina

2015). More specifically, the current state of research applies an emerging systems theory-based pathologies construct (Katina 2015) to articulate pathologies. These pathologies are based on the inadequate applications of the principles, laws, and concepts of systems theory. More specifically, the pathologies exist as the direct violation of concepts of systems theory. Encompassing laws, principles, and theorems, the 45 articulated pathologies are inductively built from the 'systems' body of knowledge. In light of current state of research, these pathologies are presented as a first generation glimpse of what promises to be an evolving inquiry. In light of this inquiry, we offer three critical insights.

First, the articulated list of pathologies is not provided as an exhaustive list of all pathologies that might exist in systems theory. They are provided as sufficient set of systems theory-based pathologies, based on the current understanding of concepts of systems theory (Adams et al. 2014; Clemson 1984; Krippendorff 1986; Skyttner 2005; von Bertalanffy 1968). Therefore, other pathologies could be developed based on further exploration and elaboration of concepts from systems theory. However, this does not preclude fruitful explorations and application to current applications looking for more robust approaches for problem formulation.

Second, to stay true to the nature of complex systems and complex problem formulation—especially considering the continued existence of ambiguity, complexity, emergence, interdependence, and uncertainty, these pathologies cannot be assumed to exist in isolation. They influence and are influenced by other pathologies. Therefore, it might prove fruitful to engage in research elaborating to how pathologies are related and to 'cluster' pathologies rather than viewing them as single isolated issues. This approach might serve to further refine to 'meta-pathologies.' However, again this limitation does not preclude utilization of the pathologies in their present form. We can conclude that the pathologies, their understanding, and evolution will progress as they are applied in problem formulation scenarios.

Finally, it's important to recognize that present research is theoretical in nature, although the linkage to practice has been provided. This implies that applications of the research might enhance our understanding of the nature of these pathologies and serve to provide 'face validation' of these pathological conditions as well as their utility in problem formulation endeavors. In relation to these ideas, research dedicated to 'measuring' pathologies must be undertaken on an organizational level. This might include measuring the 'degree of existence of pathology' as well as the 'degree of consequence of pathology' using an ordinal scale. Such measures could then be used to indicate the relative importance of pathologies and might assist in prioritization and strategic allocation of resources to address the pathologies.

Glossary

Ambiguity	increasing lack of clarity and situational understanding
Complexity	large numbers of richly interdependent and dynamically interacting systems with behavior difficult to predict
Emergence	inability to deduce behavior, structure, or performance from constituent elements
Interdependence	mutual influence among complex systems through which the state of a system influences and is influenced by, the state of interconnected systems
Management cybernetics	the science of effective organization, places emphasis on communication and control of systems
Metasystem	a governing structure with a set of interrelated higher level functions; it provides for integration of autonomous complex systems to achieve functionality (or goals and missions) beyond constituent systems
Problem formulation	arguably the most important stage of systems-based methodologies intended for discovery of circumstances, trends, patterns, and issues acting to limit complex system performance
Sustainability	evolving for future existence and thus is the capacity to endure over time
Systems pathology	a circumstance, factor, or pattern that acts to limit system performance, or lessen systems viability, such that the likelihood of a system achieving performance expectations is reduced
Systems theory	a unified group of specific propositions which are brought together to aid in understanding systems, thereby invoking improved explanatory power and interpretation with major implications for systems practitioners; provides a set of universals that can define function, performance, and behavior of all systems, natural or manmade

Systems theory-based pathology (STBP)	a pathology (see systems pathology) stemming from deviation in applications of systems theory and expressed as the lack of use of fundamental concepts of systems theory (i.e., laws, principles, and theorems) or direct violation of fundamental concepts of systems theory (e.g., ignoring a systems theoretic law)
Uncertainty	incompleteness in understanding, predicting, or controlling
Viability	continued present existence

References

Ackoff RL (1971) Towards a system of systems concepts. Manage Sci 17(11):661–671. doi:10.1287/mnsc.17.11.661

Ackoff RL (1977) Optimization + objectivity = optout. Eur J Oper Res 1(1):1–7. doi:10.1016/S0377-2217(77)81003-5

Adams KM (2012) Systems theory: a formal construct for understanding systems. Int J Syst Syst Eng 3(3/4):209–224. doi:10.1504/IJSSE.2012.052684

Adams KM, Hester PT, Bradley JM, Meyers TJ, Keating CB (2014) Systems theory as the foundation for understanding systems. Sys Eng 17(1):112–123. doi:10.1002/sys.21255

Aizermann MA (1975) Fuzzy sets, fuzzy proofs and some unresolved problems in the theory of automata control. Presented at the special interest discussion session on fuzzy automata and decision processes, 6th IFAC World Congress, Boston

Argyris C, Schön D (1978) Organizational learning: a theory of action perspective. Addison-Wesley, Reading, MA

Aristotle (2002) Metaphysics: Book H—Form and Being at Work, 2nd edn. (trans: Sachs J). Green Lion Press, Santa Fe

Ashby WR (1956) An introduction to cybernetics. Chapman & Hall, London

Ashby WR (1962) Principles of the self-organizing system. In: von Foerster H, Zopf G (eds) Principles of self-organization. Pergamon Press, New York, pp. 255–278

Auerbach CF, Silverstein LB (2003) Qualitative data: an introduction to coding and analysis. New York University Press, New York

Aulin A (1982). The cybernetic laws of social progress: toward a critical social philosophy of Marxism, 1st edn. New York: NY: Pergamon Press

Aulin-Ahmavaara AY (1979) The law of requisite hierarchy. Kybernetes 8(4):259–266. doi:10.1108/eb005528

Barnard CI (1946) Functions and pathology of status systems in formal organizations. In: Whyte WF (ed) Industry and Society. McGraw-Hill, New York, pp 46–83

Bateson G (1972) Steps to an ecology of mind. Jason Aronson Inc, New York

Becvar DS, Becvar RJ (1999) Systems theory and family therapy: a primer, 2nd edn. University Press of America, Lanham

Beer S (1978) Platform for change. Wiley, Chichester

Beer S (1979) The heart of the enterprise. Wiley, New York

Beer S (1981) Brain of the firm: the managerial cybernetics of organization. Wiley, Chichester

Beer S (1984) The viable system model: its provenance, development, methodology and pathology. J Oper Res Soc 35(1):7–25. doi:10.2307/2581927

Bergvall-Kareborn B (2002) Enriching the model-building phase of soft systems methodology. Syst Res Behav Sci 19(1):27–49

Bohr N (1928) The quantum postulate and the recent development of atomic theory. Nature 121 (3050):580–590

Boulding KE (1966) The impact of social sciences. Rutgers University Press, New Brunswick

Bowen K (1998) Some thoughts on multimethodology. Syst Pract Action Res 11(2):169–177

Bowler D (1981) General systems thinking. North Holland, New York

Boyatzis RE (1998) Transforming qualitative information: Thematic analysis and code development. Sage, Thousand Oaks

Buckley W (1967) Sociology and modern systems theory. Prentice-Hall, Englewood Cliffs

Butler-Kisber L (2010). Qualitative inquiry: thematic, narrative, and arts-informed perspectives. Sage, London

Bynum WF, Porter R (1997) Companion encyclopedia of the history of medicine, 1st edn. Routledge, New York

Calida BY, Katina PF (2012) Regional industries as critical infrastructures: a tale of two modern cities. Int J Crit Infrastruct 8(1):74–90. doi:10.1504/IJCIS.2012.046555

Cannon WB (1929) Organization for physiological homeostasis. Physiol Rev 9(3):399–431

Capra F (1982) The turning point: Science, society, and the rising culture. Simon and Schuster, New York

Casti J (2012) X-Events: complexity overload and the collapse of everything. William Morrow, New York

Checkland PB (1985) Formulating problems for systems analysis. In: Miser HS, Quade ES (eds) Handbook of systems analysis: overview of uses, procedures, applications, and practice. Elsevier Science Publishing Co., Inc, New York, pp. 152–170

Checkland PB (1993) Systems thinking, systems practice. Wiley, New York

Checkland PB (1999) Systems thinking, systems practice. Wiley, New York

Checkland PB, Scholes J (1990) Soft systems methodology in action. Wiley, Chichester. Retrieved from http://www.amazon.com/dp/0471986054

Cherns A (1976) The principles of sociotechnical design. Hum Relat 29(8):783–792. doi:10.1177/001872677602900806

Cherns A (1987) Principles of sociotechnical design revisited. Hum Relat 40(3):153–161

Cilliers P (1998) Complexity and postmodernism: understand complex systems. Routledge, New York

Clegg CW (2000) Sociotechnical principles for system design. Appl Ergonomics 31(5):463–477

Clemson B (1984) Cybernetics: a new management tool. Abacus Press, Tunbridge Wells

Crownover MWB (2005) Complex system contextual framework (CSCF): a grounded-theory construction for the articulation of system context in addressing complex systems problems. Dissertation, Old Dominion University, Norfolk

Cummings TG, Worley CG (2005) Organization development and change, 8th edn. Cengage Learning, Mason

D’Alembert J (1743) Traité de dynamique. David l’Ainé, Paris

Dery D (1984) Problem definition in policy analysis. University Press of Kansas, Lawrence

DeSantis L, Ugarriza DN (2000) The concept of theme as used in qualitative nursing research. West J Nurs Res 22(3):351–372

Eldredge N, Gould SJ (1972) Punctuated equilibria: an alternative to phyletic gradualism. In Schopf TJM (ed) Models in paleobiology. Freeman Cooper, San Francisco, pp. 82–115

Farr J, Buede D (2003) Systems engineering and engineering management: keys to the efficient development of products and services. Eng Manag J 15(3):3–11

Ferrero G (1894) L’inertie mentale et la loi du moindre effort. Revue Philosophique de La France et de l’Étranger, T. 37:169–182

Flood RL, Carson ER (1993) Dealing with complexity: an introduction to the theory and application of systems science. Plenum Press, New York

Forrester JW (1994) System dynamics, systems thinking and soft OR. Syst Dyn Rev 10 (2):245–256

Gaines BR (1977) Progress in general systems research. In: Klir GJ (ed) Applied general systems research: recent development and trends. Plenum Press, New York, pp 3–28
Gheorghe AV, Katina PF (2014) Editorial: resiliency and engineering systems—research trends and challenges. Int J Crit Infrastruct 10(3/4):193–199
Gibson JE, Scherer WT, Gibson WF (2007) How to do systems analysis. Wiley-Interscience, Hoboken
Glaser BG, Strauss AL (1967) The discovery of grounded theory: strategies for qualitative research. Aldine de Gruyter, New York
Gödel K (1962) On formally undecidable propositions. Basic Books, New York
Gould SJ, Eldredge N (1977) Punctuated equilibria: the tempo and mode of evolution reconsidered. Paleobiology 3(2):115–151
Guckenheimer J, Ottino JM (2008) Foundations for complex systems research in the physical sciences and engineering. Northwestern University: National Science Foundation, Evanston
Hammond D (2002) Exploring the genealogy of systems thinking. Syst Res Behav Sci 19(5):429–439. doi:10.1002/sres.499
Hester PT, Adams KM (2014) Systemic thinking: fundamentals for understanding problems and messes. Springer, Berlin
Heylighen F (1989) Self-organization, emergence and the architecture of complexity. Presented at the proceedings of the 1st European conference on system science (AFCET), pp. 23–32. Retrieved from http://cleamc11.vub.ac.be/papers/SelfArchCom.pdf
Heylighen F (1992) Principles of systems and cybernetics: an evolutionary perspective. In: Trappl R (ed) Cybernetics and systems. World Scientific, Singapore, pp 3–10
Heylighen F, Joslyn C (1992) What is systems theory? In: Heylighen F, Joslyn C, Turchin V (eds) Cambridge dictionary of philosophy. Principia Cybernetica Web, Brussels. Retrieved from http://pespmc1.vub.ac.be/SYSTHEOR.html
Hitch C (1953) Sub-optimization in operations problems. Oper Res 1(3):87–99. doi:10.1287/opre.1.3.87
Hitchins DK (2003) Advanced systems: thinking, engineering, and management. Artech House Publishers, Norwood
Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4(1):1–23. doi:10.1146/annurev.es.04.110173.000245
Iberal A (1972) Towards a general science of viable systems. McGraw-Hill, New York
Jackson MC (2003) Systems thinking: creative holism for managers. Wiley, Chichester
Jordan N (1963) Allocation of functions between man and machines in automated systems. J Appl Psychol 47(3):161–165. doi:10.1037/h0043729
Kant I (1991). The metaphysics of morals (trans: Gregor MJ). Cambridge University Press, Cambridge
Katina PF (2015) Emerging systems theory-based pathologies for governance of complex systems. Int J Syst Syst Eng 6(1/2):144–159. doi:10.1504/IJSSE.2015.068806
Katina PF, Hester PT (2013) Systemic determination of infrastructure criticality. Int J Crit Infrastruct 9(3):211–225. doi:10.1504/IJCIS.2013.054980
Katina PF, Despotou G, Calida BY, Kholodkov T, Keating CB (2014a) Sustainability of systems of systems. Int J Syst Syst Eng 5(2):93–113. doi:10.1504/IJSSE.2014.064833
Katina PF, Keating CB, Jaradat RM (2014b) System requirements engineering in complex situations. Requirements Eng 19(1):45–62. doi:10.1007/s00766-012-0157-0
Katina PF, Pinto CA, Bradley JM, Hester PT (2014c) Interdependency-induced risk with applications to healthcare. Int J Crit Infrastruct Prot 7(1):12–26. doi:10.1016/j.ijcip.2014.01.005
Keating CB (2009) Emergence in system of systems. In: Jamshidi M (ed) System of systems engineering. Wiley, Hoboken, pp. 169–190
Keating CB (2010) Balancing structural tensions in complex systems. Presented at the proceedings of the American society for engineering management, ASEM Press, Huntsville, pp. 1–8
Keating CB (2014) Governance implications for meeting challenges in the system of systems engineering field. In: 2014 9th international conference on system of systems engineering (SOSE), IEEE, Adelaide, pp. 154–159. doi:10.1109/SYSOSE

Keating CB, Katina PF (2012) Prevalence of pathologies in systems of systems. Int J Syst Syst Eng 3(3/4):243–267. doi:10.1504/IJSSE.2012.052688

Keating CB, Jacobs D, Sousa-Poza AA, Pyne JC (2001a) Advancing sociotechnical systems theory. Proceedings of the 22nd american society for engineering management, national conference. ASEM Press, Huntsville, pp 336–341

Keating CB, Kauffmann P, Dryer D (2001b) A framework for systemic analysis of complex issues. J Manag Dev 20(9):772–784

Keating CB, Rogers R, Unal R, Dryer D, Sousa-Poza AA, Safford R, Peterson W, Rabadi G (2003) System of systems engineering. Eng Manag J 15(3):35–44

Keating CB, Calida BY, Sousa-Poza AA, Kovacic SF (2010) Systems thinking. In: Merino D, Farr J (eds) The engineering management handbook. ASEM Press, Huntsville, pp 91–139

Keating CB, Katina PF, Bradley JM (2014) Complex system governance: concept, challenges, and emerging research. Int J Syst Syst Eng 5(3):263–288

Kleene SC (2002) Mathematical logic. Dover Publications, Mineola

Klein L (1994) Sociotechnical/organizational design. In: Karwowski W, Salvendy G (eds) Organization and management of advanced manufacturing. Wiley, New York, pp. 197–222

Klir GJ (1972) Preview: the polyphonic GST. In: Klir GJ (ed) Trends in general systems theory. Wiley, New York, pp. 1–16

Klir GJ (1991) Facets of systems science. Kluwer Academic/Plenum Publishers, New York

Korzybski A (1994) Science and sanity: an introduction to non-Aristotelian systems and general semantics. Wiley, New York

Krippendorff K (1986) A dictionary of cybernetics. The American Society for Cybernetics, Norfolk. Retrieved from http://repository.upenn.edu/asc_papers/224

Kumar V, Abbas AK, Fausto N, Aster J (2010) Robbins and cotran: pathologic basis of disease, 8th edn. Saunders, Philadelphia

Laszlo E (1996) The systems view of the world: a holistic vision for our time. Hampton Press, Cresskill

Laszlo A, Krippner S (1998) Systems theories: their origins, foundations, and development. In: Jordan JS (ed) Systems theories and a priori aspects of perception. Elsevier Science, Amsterdam, pp 47–74

Leedy PD, Ormrod JE (2010) Practical research: planning and design, 9th edn. Pearson, Upper Saddle River

Li J (2013) The visible hand: from struggling survival to viable sustainability. Presented at the 56th annual proceedings of ISSS, international society for the systems sciences, pp. 1–19. Retrieved from http://journals.isss.org/index.php/proceedings56th/article/view/1959

Long, E. (1965). A history of pathology. *Annals of Internal Medicine*, *63*(4), 741. doi:10.7326/0003-4819-63-4-741_4

Luhmann N (2013) Introduction to systems theory (trans: Gilgen P). Polity, Malden

Lynn LE (1980) The user's perspective. In: Majone G, Quade ES (eds) Pitfalls of analysis, vol 8. Wiley, New York, pp. 89–115

Machol RE (ed) (1965) System engineering handbook. McGraw-Hill, New York

Machol RE, Miles RF (1973). The engineering of large-scale systems. In: Miles RF (ed) Systems concepts: lectures on contemporary approaches to systems. Wiley, New York, pp. 33–50

Margulis L (1999) Symbiotic planet: a new look at evolution, 1st edn. Basic, New York

Martin-Breen P, Anderies JM (2011) Resilience: a literature review. The Rockefeller Foundation, New York. Retrieved from http://www.rockefellerfoundation.org/blog/resilience-literature-review

Mason J (2002) Qualitative researching, 2 edn. Sage, London

McCulloch WS (1965) Embodiments of mind. MIT Press, Cambridge

Mehra J (1987) Niels Bohr's discussions with Albert Einstein, Werner Heisenberg, and Erwin Schrödinger: the origins of the principles of uncertainty and complementarity. Found Phys 17 (5):461–506. doi:10.1007/BF01559698

Miller GA (1956) The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol Rev 63(2):81–97. doi:10.1037/h0043158
Mintzberg H, Raisinghani D, Théorêt A (1976) The structure of the "unstructured" decision processes. Adm Sci Q 21(2):246–275
Mitroff II (1998) Smart thinking for crazy times: the art of solving the right problems. Berrett-Koehler Publishers, San Francisco
Monod J (1974) On chance and necessity. In: Ayala FJ, Dobzhansky T (eds) Studies in the philosophy of biology. Macmillan Press, London, pp 357–375
Murdoch DR, Murdoch D (1989) Niels Bohr's philosophy of physics. Cambridge University Press, Cambridge
Nicolis G, Prigogine I (1975) Self-organization in non equilibrium systems. Wiley, New York
Pahl G, Beitz W, Feldhusen J, Grote KH (2011) Engineering design: a systematic approach, 3rd edn. (trans: Wallace K). Springer, Berlin
Pareto V (1897) Cours d'économie politique professé à l'Université de Lausanne. University of Luzerne, Luzerne
Paritsis N (2000) Models of intelligence and behavior. In: Paritsis N (ed) Systems and intelligence. Lector Publishing Company, Iraklio, pp 65–80
Pattee HH (1973) Hierarchy theory: the challenge of complex systems. Braziller, New York
Quade ES (1980) Pitfalls in formulation and modeling. In: Majone G, Quade ES (eds) Pitfalls of analysis, vol 8. Wiley-Interscience, Chichester, pp 23–43
Quade ES, Miser HJ (1985) The context, nature, and use of systems analysis. In: Misser HS, Quade ES (eds) Handbook of systems analysis: overview of uses, procedures, applications, and practice. Elsevier Science Publishing Co., Inc, New York, pp 1–32
Rein M, White SH (1977) Can policy research help policy? national affairs. Washington, DC. Retrieved from http://www.nationalaffairs.com/public_interest/detail/can-policy-research-help-policy
Ríos JP (2012) Design and diagnosis for sustainable organizations: the viable system method. Springer, Berlin
Rittel HWJ, Webber MM (1973) Dilemmas in a general theory of planning. Policy Sci 4(2):155–169. doi:10.1007/BF01405730
Rosenblueth A, Wiener N, Bigelow J (1943) Behavior, purpose and teleology. Philos Sci 10 (1):18–24
Saldaña J (2013) The coding manual for qualitative researchers, 2nd edn. SAGE Publications Ltd, Thousand Oaks
Schön D (1983) The reflective practitioner: how professionals think in action. Temple Smith, London
Shannon CE (1948a) A mathematical theory of communication: part 1. Bell Syst Tech J 27 (3):379–423
Shannon CE (1948b) A mathematical theory of communication: part 2. Bell Syst Tech J 27 (4):623–656
Shannon CE, Weaver W (1949) The mathematical theory of communication. University of Illinois Press, Champaign
Simon HA (1956) Rational choice and the structure of the environment. Psychol Rev 63(2):129–138
Simon HA (1973) The organization of complex systems. In: Pattee HH (ed) Hierarchy theory. Braziller, New York, pp. 1–27
Simon HA (1974) How big is a chunk? Science 183(4124):482–488
Skyttner L (1996) General systems theory: an introduction. Macmillan Press, New York
Skyttner L (2005) General systems theory: problems, perspectives, practice, 2nd edn. World Scientific Publishing Co., Pte. Ltd, Singapore
Smith C (1994) A recursive introduction to the theory of computation. Springer Science & Business Media, New York
Smuts J (1926) Holism and evolution. Greenwood Press, New York

Stacey R (1996) Complexity and creativity in organizations, 1st edn. Berrett-Koehler Publishers, San Francisco
Stichweh R (2011) Systems theory. In: Badie B, Berg-Schlosser D, Morlino L (eds) International encyclopedia of political science, vol 8. SAGE, New York, pp 2579–2588
Strauss AL, Corbin JM (1990) Basics of qualitative research: grounded theory procedures and techniques. Sage Publications, Newbury Park
Strijbos S (2010) Systems thinking. In: Frodeman R, Klein JT, Mitcham C (eds) The oxford handbook of interdisciplinarity. Oxford University Press, New York, pp 453–470
Taleb NN (2010) The black swan: the impact of the highly improbable. Random House Trade Paperbacks Edition, New York
Thompson CL, Cuff JM (2012) God and nature: a theologian and a scientist conversing on the divine promise of possibility. A&C Black, New York
Tolman EC (1948) Cognitive maps in rats and men. Psychol Rev 55(4):189–208
Troncale L (1977) Linkage propositions between fifty principal systems concepts. In: Klir GJ (ed) Applied general systems research: recent development and trends. Plenum Press, New York, pp. 29–52
Umpleby S, Heylighen F, Hu J (1990) The ASC glossary. Retrieved 25 Oct 2014, from ftp://ftp.vub.ac.be/pub/papers/Principia_Cybernetica/Nodes/Cybernetics_glossary.txt
van den Tweel JG, Taylor CR (2010) A brief history of pathology. Virchows Archiv 457(1):3–10. doi:10.1007/s00428-010-0934-4
Vennix J (1996) Group model building: facilitating team learning using system dynamics, 1st edn. Wiley, Chichester
von Bertalanffy L (1950) An outline of general system theory. Br J Philos Sci 1(2):134–165. doi:10.1093/bjps/I.2.134
von Bertalanffy L (1968) General system theory: foundations, developments, applications. George Braziller, New York
von Bertalanffy L (1972) The history and status of general systems theory. Acad Manag J 15 (4):407–426. doi:10.2307/255139
von Foerster H, Mead M, Teuber HL (1953) Cybernetics: circular causal and feedback mechanisms in biological and social systems. Josiah Macy, Jr Foundation, New York
Waddington CH (1957) The strategy of genes: a discussion of some aspects of theoretical biology. Allen and Unwin, London
Warfield JN (1976). Societal systems: planning, policy and complexity. Wiley-Interscience, New York
Warfield JN (1995) Spreadthink: explaining ineffective groups. Syst Res 12(1):5–14. doi:10.1002/sres.3850120104
Warfield JN (1999) Twenty laws of complexity: science applicable in organizations. Syst Res Behav Sci 16(1):3–40. doi:10.1002/(SICI)1099-1743(199901/02)16:1<3::AID-SRES241>3.0.CO;2-F
Watt K, Craig P (1988) Surprise, ecological stability theory. In: Holling CAS (ed)The anatomy of surprise. Wiley, New York
Weaver W (1948) Science and complexity. Am Sci 36(4):536–544
Weinberg GM (1975) An introduction to general systems thinking. Wiley-Interscience, New York
Wellington AM (1887) The economic theory of the location of railways. Wiley, New York
White JW, Krippner S (eds) (1977) Future science: life energies and the physics of paranormal phenomena. Anchor Books, USA
Wiener N (1948) Cybernetics: or control and communication in the animal and the machine. MIT Press, Cambridge
Wildavsky A (1988) Searching for safety. Transaction Publishers, New Brunswick
Zipf GK (1949) Human behavior and the principle of least effort, vol xi. Addison-Wesley Press, Oxford

Soft Social Systems and Shocks: An Experiment with an Agent Based Model

Leena Ilmola and Nikita Strelkovsky

> The word reality can never mean anything more than the mental model of the user of that word.
>
> Meadows 2005, p 132.

Abstract In this chapter, we will elaborate on the challenge of uncertainty emerging from increasing complexity and how to deal with that in decision making. We will present an example of a decision making tool that supports the analysis of the potential futures and provides a decision maker with an idea of the proper actions to be taken.

Keywords Agent based models · System shocks · Uncertainty

1 Introduction

Emerging uncertainties of global systems present a challenge to decision making. Plenty of studies have been conducted, and models have been built leveraging operations research and economics to support decision making in complex environments. Two of the features that have a great impact on the nature of dealing with uncertainty are still missing. First the models are frequently missing the main source of uncertainty; a reaction of a social system to a disruptive event or a shock. The feedback of the social system is often pushing our well planned operations out of their trajectories and we are facing the second of the decision making challenges to be elaborated in this chapter; the situation in which we do not know what we do not know; ontological uncertainty. We present a decision support application to meet both of these challenges, an Agent-Based Model designed for dealing with uncertainty.

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1.1 Complexity Increases Surprises

Uncertainty is a real challenge to planning and decision making. This situation is not unknown to policy and business planners, but nowadays uncertainty is more dominant than it used to be. The phenomenon seems to remain with us (OECD 2014a) and to shape our environment (World Economic Forum 2015). Let us elaborate three different shock examples that well illustrate the nature of uncertainty: Internet failure; fast growth of ISIS; and power of one fund management company.

We have studied the resilience of national economies by stress testing the national system with low probability, high impact shocks. One of the most popular among various audiences is the potential collapse of the internet. According to OECD (2014b) there are close to 700 million people in the OECD countries that use wireless internet. We know from our case studies (IIASA, Seven Shocks and Finland) that the main functions of life, such as electricity markets and distribution systems rely on the Internet. What happens if the internet fails?

The first reactions are that search engines, social media and e-mail fails to work. In the developed countries such as Finland, the payment is based on digital systems, one of the first real problems is that you cannot use your card for payments. Moreover, the ATM network (if it is logically separated from the Internet and still operates) will soon be empty of cash. The distribution system is based on wireless communications and delivery vans do not know what or where to deliver. People may survive the no money, no food, no social media situation, but soon mobile communications will not be available. Even the national broadcasting companies are in trouble because the major part of their news material is distributed via the internet. Communications are transferring to mobile phones, and that will cause the collapse of the mobile phone network. We do not have landlines left, and messaging pigeons are slow to train.

According to our studies the worst is still to come. Even if most of the energy production is not connected to the internet, the distribution, electricity markets and network maintenance are. In this situation, a relatively small technical problem may collapse the entire energy distribution system. If we do not have electricity, we do not have electric heating, gasoline pumps will not be working, trains will not operate and please, do not use your toilet because you cannot flush it.

We can pretty well anticipate the development described above, but the true uncertainty lies in the social system. The reaction of the social system defines the damages in this situation. Either people are calmly waiting for the return to normal and keep themselves and neighbours alive with the contents of melting freezers and warm with blankets. The other alternative reaction of the social system is to rob and riot.

The example above was technological by its nature. The recent geopolitical developments, endogenous to the social system, have the power to shake the economic, technological and even environmental systems. ISIS was difficult to find on Google before 2012, the acronym ISIS in 2013 referred to the software systems.

Even if the Islamist movement had been recognized three years ago, not many political scientists or futurologists would have anticipated that large areas of Iraq, Syria and Yemen would be invaded in less than a year. Even rarer are those experts that would have predicted the nature of the ISIS practices. The speed of development and magnitude of ISIS achievements have been too much for our anticipation systems.

The reaction of the social system is so far two fold. The ISIS rule, the new Islamist Kalifat, has attracted Islamist youth and thousands of young persons have joined the ISIS troops. If this is surprising, the reactions of political systems have been even harder to predict. The traditional superpowers US and Russia plus the new powers such as China and EU have been very passive, they are reluctant to join in this conflict. The rule of Saddam Hussein was criticized strongly, but now even more brutal acts such as robbing, burning, raping, torturing, killing and enslaving people is only followed with despise.

The third example does not illustrate chaos—at least not yet. Have you heard about Blackrock? If not, pay some attention to this phenomenon now. Blackrock is the world's most powerful fund management company. According to the Economist[1] (December 7, 2014), the assets that this company is managing are 15,000,000,000,000 dollars. Just for comparison; the budget of the Federal Government of United States is app. 5 trillion dollars, three times smaller than the assets Blackrock is managing. Blackrock owns a stake in almost every listed company not just in America but globally. (Op. cit) Already in 2009 over 70 % of investment decisions were made automatically by computers. The software the Blackrock is using is called Alladin.

The role of the social system is, in this case, different than in the cases described above. Blackrock is perceived to be one of the winners of the investment market. Their expertise is appreciated, and their actions are closely watched. In principle, all try to imitate the investment behaviour of Blackrock, and they try to do it fast because early reactions generate an advantage in the investment market. What so ever the company does, the others will follow. So the power of this one company is higher than its gigantic assets.

The true danger here is a failure, either technological or human caused. Sudden change in the observed behaviour of Blackrock's Alladin may lead other automatized fund management systems to react within seconds, and to a sudden drop in the values of the assets around the world. Collaterals lose their value, the balance sheets of banks collapse and chaos in the financial market will lead to the deep recession in the real economy that is dependent on financial systems functionality.

Strategists have to make their strategic choices. Decision makers have to make their decisions, even if they know that their perception of the future will prove, with a high probability, to be inaccurate in the course of time. A recent example of an

[1]http://www.economist.com/news/leaders/21591174-25-years-blackrock-has-become-worlds-biggest-investor-its-dominance-problem.

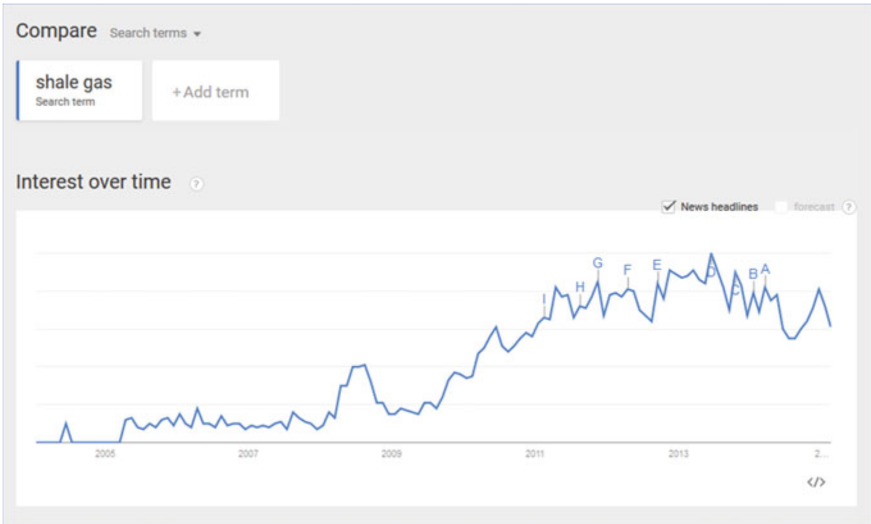

Fig. 1 Shale gas trends http://www.google.com/trends/explore#q=shale%20gas

unexpected nature of social systems feedback that is shaking a global energy (and defense) industry was a reaction to the Tsunami that hit Japan in March 2011. The tsunami caused the Fukushima Daiichi nuclear power plant accident, and that triggered policy changes in the German energy policy. The German Parliament made a decision to shut down about 40 % of the country's nuclear reactors immediately and to phase out the remaining ones by 2022.

The emerging role of shale gas presents another kind of surprise within the field of energy. New technologies such as slick-water fracturing made this source of energy a commercially feasible form of energy and the recent studies show that there are over 50 analyzed high potential shale gas basins around the world. The Google search engine tells us that ten years ago, shale gas was not on the top of the agenda as a concept. Now we know that it has changed both the current market dynamics (pricing, energy trade flows) and the projections of the structure of the future energy markets and emissions (Figs. 1 and 2).

As the DOE of the US stated in their report of the Energy Production (2014)[2] that even with this information there are many uncertainties that shape the demand projections; such as social unrest in the Middle East and North Africa, the political energy choices of the Japanese government and consumer preferences and technological breakthroughs. All of these uncertainties are emerging from the social system.

[2] http://www.eia.gov/forecasts/aeo/pdf/0383%282014%29.pdf.

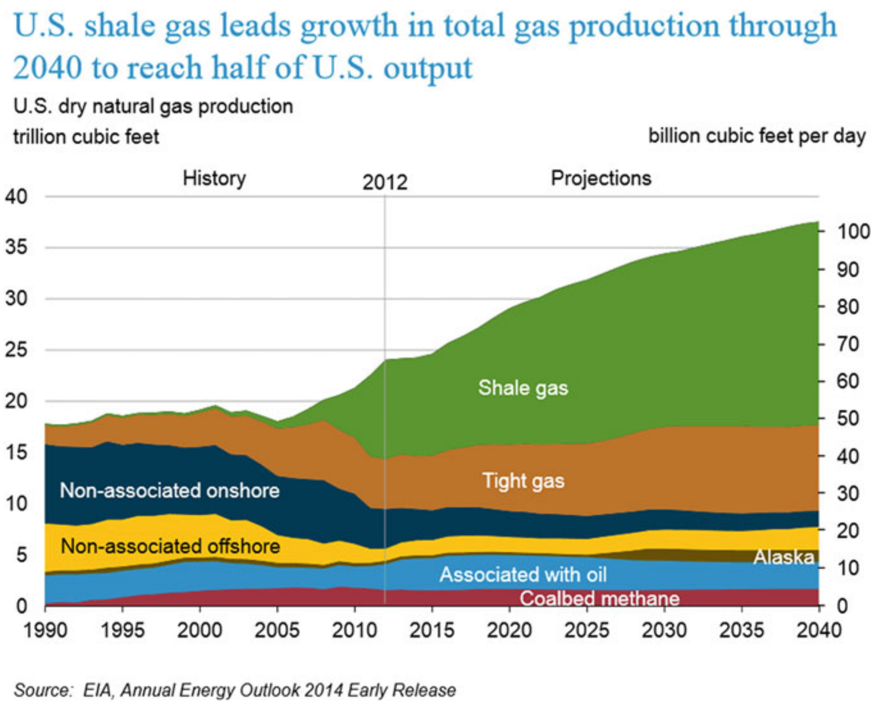

Fig. 2 Shale gas production. http://www.eia.gov/pressroom/presentations/sieminski_01222014.pdf

When the reality brings sudden surprises as in this example, what should be the appropriate tools to meet the increasing information requirements and support planning and decision making?

The global social environment is so complex that it would be unrealistic to hope that we will ever have sufficient information to reduce uncertainty (Anderson 1999; Courtney 2003). Therefore; traditional planning methods will not be effective as in the past. Within our research community (the Global X Network) we are dedicating our research for studying uncertainties.

We have classified uncertainty by assessing the probability of potential outcomes. The theory of science speaks about epistemological and ontological uncertainties. Epistemological uncertainty is dealing with the “known unknowns” covering the area where we can apply probability as a tool for assessment. When we are speaking with decision makers, we divide epistemological uncertainty into metro-train uncertainty (we know that train is coming, but we do not know if it is on time exactly), and the coconut uncertainty (it is possible that the coconut can drop onto our head, but this probability is very small). Ontological uncertainty is dealing with “unknown unknowns”, issues that we do not even know that they do exist (Lane and Maxfield 2005; Walton 2008).

2 Social System as a Source of Surprises

Here are a few words about social systems. The main purpose of the social system (SS) is to distinguish itself from the other systems (Berger and Luckmann 1966), from its environment. For this purpose the social system is building, maintaining and defending its identity (Luhmann 1995). To exist, the social system develops shared perception of identity and the idea about the nature of its environment (Anderson 1999). Identity of a nation is developing during centuries, whereas the Blackrock brand has built it in less than ten years.[3]

The identity formation process is intersubjective and is based on the communications between people that establish a nation or a new company. After a while newcomers accept the rules and perceptions as they are, and the longer the institution has existed, the harder it is for participants of an institution to challenge the dominating perception (Stacey 1995).

An example that is related to our previous comment on shale gas. One of the basic assumptions of energy supply has been something that is called ‘peak oil’, the concept that refers to the moment when we have reached the maximum limit of the reserves of oil. This perception was presented in the 1950’s (Deffeyes 2002), and it was launched to the public in early 2000. The process started as an autopoietic intersubjective process (Nicolis and Prigogine 1977) among experts, and it reached the public early in 2000, when the Association for the Study of Peak Oil and Gas re-launched the term. Even if the predictions have not been proven to be true (mainly due the unconventional sources of oil such as shale gas and other fossil fuels), the perception of scarcity of energy available has shaped energy policies and the price formation. Typically for this kind of process, the shared perception at its beginning is vague. As it develops over time and institutionalized, it forms the social construction of reality for those that operate in the community. Especially if the process gets support and is not challenged during the institutionalization period. In time, people and politicians forget how the concept was birthed, and all of us perceive the framework as the reality that is impossible to change. Only those people that initiated the concept may remember how the process was started long ago.

In the Complex Adaptive Systems (CAS) theory, the same phenomenon have been described as organizations schemata (Anderson 1999). Schemata consist of identity, internal rules and recipes, the perception of the external environment and rules of coevolving in this environment. The same issue is called in Cognitive theory: a set of shared mental models (Hodgkinson et al. 1999; Hodgkinson 2003). These mental models do not define only the rules of co-operation within an organization but filter the observations of the external environment (Ilmola and Kuusi 2013). In principle, an organization (when seeking for efficiency) will focus its attention on those issues that it perceives essential for its operations. In the world

[3]www.blackrock.com: The company started with a different brand, Blackstone in 1988 and reached its current structure in 2005–2006.

corporate market, competitors, customers' needs and technologies relevant to the business are in focus. Luhmann calls this choice as indication and distinction rules, Ansoff (1979, 1984) speaks about filters, and Weick (1984, 2001) sensemaking process.

The common denominator of all the frameworks presented above is that a social system has a tendency to support its identity (decrease uncertainty) by seeking for information that is confirming its current perceptions. This process will stabilize the social system (nation, expert community or an organization of a company) and increase its efficiency. Typical features of social systems is that this process will continue until the social system is too rigid to adapt to its environment, and a small trigger can push the organization from its development trajectory (Folke 2006).

To optimize its fit to the environment, the social system has to import energy. This energy can be either resource (people, money) or information. To start an effective sensemaking process, where an organization will truly reconsider its perceptions, a trigger for this process has to be strong. A surprise, shock or extreme event will cause tension between current perception, and the new information acquired. According to Weick (1984, 2001) the impact of disturbing information depends on the strength of the conflict between existing dominating mental models and the external information "signal of change".

Social systems prefer stability, and as we have seen, the reason for this is efficiency. To save energy, every system favors a situation where the environment is highly predictable. Moreover, the system (like the government) does not have a need to put resources (to have one more meeting about worrying market uncertainties) into disruptions. In these cases social system, a nation, expert community or a company, tries to stabilize the situation by either doing its utmost to remove disturbing dynamics (that can be either internal or external) or neglect it (avoid noticing disruptive signals of change or reduce their impact by claiming that they are not important).

So far, all the features of a social system we have described increases their predictability. Surprises emerge from situations where the existing perceptions of reality are challenged, or we feel that we do not have enough information about the situation. In the society or an expert community level, uncertainty may lead people to unpredictable mass behavior. When we think that something is going on, but we do not have the information, we have a tendency to look at what others are doing. Other-directedness is strong especially in the situations where people are afraid, angry or emotionally aroused. In these situations, they are susceptible to psychological suggestion and easy to manipulate (Brudermann and Fenzl 2010; Schachter and Singer 1962). This is how riots emerge. As we have seen, even people that in normal conditions are rational and well behaving, some people are breaking windows and stealing (The Observer, Sunday, May 11, 2014 about the UK August 2011 riots).

According to the recent research made about resilience (Ilmola and Casti 2013; Ikonen 2013; Kouvo 2014; Mayer et al. 1995; Sztompka 1998; Zhang and Wang 2010) it seems that the social systems that have a strong trust are less prone to the disruptive mass behavior. Trust can be defined as the willingness of a party to be vulnerable to the actions of another party based on the expectations that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party (Ikonen 2013; Mayer et al. 1995; Zhang and Wang 2010). This trust can be a trust to peers, authorities or institutions. As Kouvo (2014) in his recent studies have proved, it seems that trust in institutions predicts trust in another member of a social system as well.

As we stated above, trust includes a perception of someone's behavior about the future. The trust concept can be used regarding future expectations in a wider sense as well. The financial system and investment theorists are speaking about trust as a trust in the future (Benhabib et al. 2014; Brooks 2014; Nofsinger 2005; Simon 1979). When an investor is expecting smaller returns from a specific field (as a reaction to Alladin behavior shift), he will be motivated to decrease his investments to the enterprises operating in the field.

There is a specific field of trust studies that use the concept of social mood (Casti 2012; Casti and Ilmola 2010; Hall et al. 2013). In these studies, social mood is defined as an endogenous feature of a system. Social mood is emerging in the social system via herding behavior, and it defines the nature of the feedback loop, the reaction of the social system to the change in environment. This is the hard part of the social mood framework because it claims that the recession does not cause negative social mood, but vice versa; negative social mood causes recession. Social mood cannot predict the behavior of a social system as such (and never a behavior of an individual), but the mood makes some reactions more likely than other types (Casti 2012).

Let us return to the examples presented at the beginning of the chapter, what will be the impact of social mood on the feedback loops of the social system on an Internet collapse, ISIS expansion and failures of a fund management giant? According to social mood theory (Lampert et al. 2010; Casti 2012; Prechter and Parker 2007), if the mood is positive (=expectations are positive) people will try to adapt and improvise in order to help others. Young men prefer to study instead of go to war. People will not loose their trust in the financial markets so fast without additional consideration. If the mood is negative, the Internet collapse will cause riots, young men who lost their faith in the future will join the ISIS troops, everyone panics when financial markets suddenly show surprising behavior.

Shocks are needed. According to Complex Adaptive Systems theory, a social system—even if it tries to increase stability—is the most flexible and capable in adaptation when it is in the state of self-organization (Anderson 1999; Ackoff 1974; Stacey 1995). This state is reached when a shock has changed the situation so much that previous rules and regulations are not valid anymore. In this situation, social systems are inventing new ways to cope with change, and improving its resilience. So to avoid too deep a stabilization every social system needs shocks, external energy shots that kick-off change processes. However, the shock can as well push the social system to chaos (riots, panics, wars) if there are no constraints, such as trust and positive social mood.

3 Agent-Based Modelling and Social System

One of the methodological experiments where we study uncertainty with the model that integrates both the economic system and social system dynamics is an Agent-Based Model (ABM) of the national economy. Agent-based modelling can be used as a laboratory for different what-if analyses for policy makers. It is especially suitable for prognostics, such as exploring the consequences of decisions that have a time delay or other complex dynamics. The development of the agent based model makes the assumptions related to the topic of interest explicit and explores their consequences. It also allows testing different assumptions and thus goes one step beyond merely challenging existing assumptions (Gilbert 2008).

3.1 Creating an Agent Based Model

There are three distinguishing characteristics of ABM that make it useful for uncertainty analysis.

1. it models the behaviour of agents,
2. system level behaviour emerges from agent level behaviour, and
3. the model is useful for studying shocks that go beyond the scope econometric models.

The ABM models the agents and their interaction. All this requires knowledge about agents' behaviour rules. The value of an ABM application is in combining our existing knowledge of individual agents' behaviour to produce integrated knowledge. There is no need for formulation of assumptions about system level behaviour (even if for validation purposes it is useful to have data about the historical behaviour) in different situations. Here we return to the decision makers' problem, how to know what is the most efficient policy in the situation that we have not experienced before. It is much easier to imagine how individual agents such as families or companies will behave in a new situation than to make propositions about the behaviour of a society or national economy as a whole. Emergent outcomes can be observed in the system, in our case at the national level by simulating the interactions between agents.

It is essential to recognise three major constraints that are built into the agent-based modelling. The model does not produce knowledge about the behaviour of individuals for that simple reason that the modeller defined the behaviour rules when the model was built. ABM is also not useful for making predictions of outcomes under a large number of various simultaneous assumptions. The ABM is useful in the situations where we *compare* consequences of different policies or study dynamics that is triggered by a strong shock. Simulations by ABM provides us with understanding of the systems dynamics and indirect effects of policies/shocks.

3.1.1 Modelling Process

The first step in creating an agent based model is to define its purpose. The research questions and objectives of the modelling exercise need to be clear. The purpose determines what to include in the model and what to leave out. The ABM model is only able to answer questions it is designed to address. In practice, the definition of the purpose can be part of an iterative process and the purpose may change during the modelling.

After it is relatively clear what question the model should address, the agents, their connections and their behaviour need to be defined. To ensure that the model user and modeller have a shared understanding of the purpose, the definition process can be done in a series of participatory modelling sessions. The structure of the model is drafted jointly with the modellers and the model users. The definition process is guided by two criteria: the research question and data availability. The first relates to the purpose of the model—what is it that the model should do, and what can be left out. The other criterion are more pragmatic: is it possible to get reliable data about agents and their choices? The agents and the definition of the rules that determine their behaviour should have an impact on the system as a whole, and the systems behaviour should have an impact on the agents. The definition process is often iterative, first we build the first version of the model, run simulations, analyse the results and then improve the model so that it can address the research question as well as possible.

Efficient modelling requires elaboration of systems boundaries. The building of the comprehensive model is a time consuming and expensive exercise. Every new feature will increase the cost of the model. Optimization of the cost-output ratio is one of the key project criteria. What should be included in the model and what part of the phenomenon studied could be presented in the scenario that is input into the model. The answer depends again on the purpose of the model and the time available for building the project. As we know from our experience you can improve your model for ever, but seldom will you have enough money for it.

The structure of the model is in our case defined by state charts, which describe the life cycle of each agent as a set of states and rules for the transition between states. This means that each month each person can make a choice depending on his or her situation. For example, an employed person might want to quit or continue working, and an unemployed person might try to apply for a job or stay unemployed. Three kinds of rules are described by these actions:

1. Simple rules: the agent is a child until he is 18.
2. Probabilistic rules: an agent becomes a student with a probability of 74 %, and the time to graduation is taken from a specified distribution.
3. Code rules: a willingness to have a job based on a set of conditions and variables, it is represented as code.

Once the model structure and agent behaviour is defined, it is time for data acquisition and to do the actual modelling. If the data is not available (as it often happens when modelling social systems behaviour) we turn to experts and rely on their expert judgement. However, to ensure model transparency it is important to be clear about what assumptions are based on statistics or “facts” such as legislation, and which are expert estimates. The modelling is in the most cases done with a specific software, in our case with software tools called Anylogic.

The resulting model should be the best approximation of reality that can be made to answer the research questions. The model can be validated by comparing the results of the simulation to the observed, historical behaviour of outcomes. If the model results seem to not make sense, it could be that the model structure is incomplete, reflecting an incomplete understanding of the system or data sources are not the best ones. However, if the logic and structure of the model holds under critical scrutiny, then the outcome might be an example of unexpected emergent behaviour.

When the model is validated, we are ready for simulation. In most of the cases, two different simulation strategies are applied. The model can be used for sensitivity analysis and identification of optimal solution space. According to this strategy, the model is used for the massive amount of simulation runs with stochastic data. The second option that we have chosen in the Dream Valley model is to build specific scenarios that will be used as input to the simulation.

Agent based models that we present here allows us to examine the impact of external shocks in the system. The ways we use a model is fourfold:

1. Experimenting with different scenarios: if this event happens or a policy is implemented, what is the outcome
2. Decision maker toolkit: a decision maker can change parameters during simulation and see what happens (observation of the dynamics of the system change)
3. Pattern identification: run a large number of different scenarios and identify some typical reaction patterns (and anomalies)
4. Increasing resilience: Define a shock scenario and think how to repair the system in a crisis, then test the response

An ABM simulation process of a specific scenario consists of five steps:

1. Scenario building: A Scenario describes what is happening, what is the external shock in question or why and which kinds of policies should be tested. Due to the complexity and data availability constraint, it is often more efficient to include a large part of the behaviour to be studied into a scenario, not to include all to the behaviour rules of agents. A Scenario is needed as well to describe the developments that are outside of the model.
2. Input to the model simulation: The model is quantitative, and scenarios are in most of the cases qualitative by their nature. The scenario we wish to simulate has to be translated into a format that is possible to use as input to the model. If the aim is to model impact of a sudden collapse of the export market, we have to

manipulate the export demand of the industries that have been described in the scenario. In our model, the input is in practice an excel sheet or several sheets.

3. Simulation run: we run two simulations, one with the business-as-usual data (where the behaviour obeys the current trends) and then another with the scenario input data.
4. Simulation results are reported both in the model user interface (dashboard) and exported as data time series. In the reporting tables, we provide analysis phase with graph presentations that show both the business-as-usual results and scenario results.
5. Analysis and Conclusions: This phase requires time and often some additional simulations where the sensitivity of the model is tested. As stated earlier, if the outcome of the simulation seems to be unexpected, the case may be either a problem with the model or data or handicap of our existing mental models and perceptions. If the latter case is valid, the model can address something novel, and it should be studied more thoroughly with additional simulation runs.

4 A Case Example: Using Agent Based Modelling in Foresight

4.1 Background of the Project

Dream Valley (DV) model is a generic national economy and society model that we can use as a laboratory to test potential future shocks and stress test both the national economy and social system. The DV model is based on input-output tables of the national economy, but it integrates both population statistics, consumption statistics and social mood into the same framework. The model we use consists of different companies (with a sector specific production function), public sector (in our model as one agent) and individuals. It is evident, that, for instance, if we model the Korean economy and it's social systems, we cannot apply 45 million agents, so we use a scaling factor, but even in a scaled application the number of individual agents that have their own behaviour rules, we have more than 350,000 agents.

The existing Dream Valley model simulates behavior of economic agents: public sector (municipalities and government), economic sectors (63 sectors to which a real company structure is applied), and households (individuals, their age, education, jobs/retirement and consumption patterns) in an open economy. The existing DV model operates with monetary flows, is demand driven and shocks are exogenous by their nature (e.g., they may be radical changes in resources inflows; export income, foreign capital, returns on investments and outflows; outflows; payments of imports, payments of foreign capital, investments and borrowing of foreign capital). The main data source is the National Input-Output tables. We also use population statistics (such as population size, birth/death rates, migration), municipal/state statistics (expenditures and purchases, tax rates, unemployment benefits and

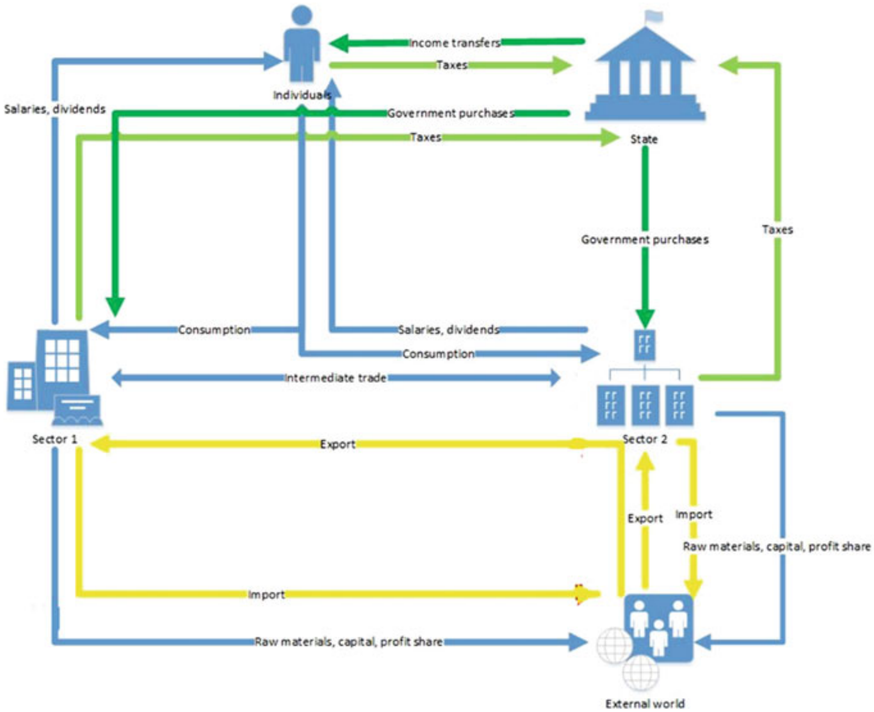

Fig. 3 The model describes the flows between main agents within the national economy and the connections (exports and imports only) to the external world

pensions), household consumption structure, company structure per sector and inverse matrixes (as an addition to standard IO tables) to derive intermediate consumption.

Our model (Fig. 3)—as most of the ABM tools—are not built for forecasting purposes, but has been designed for studying national socio-economic dynamics. It is essential to understand the impact of the social system's reactions to public policies and economic transactions. The Dream Valley model is designed for shock testing. The scenarios we can use it for are typically such as "What happens to demographic structure if the social mood is heavily negative for 10 years?" or "What is the impact of a rumor of poisoned Chinese food?"

4.2 *Structure of the Model*

For foresight purposes, the DV model has been customized so that it will represent the most important key functions of the national economy, and that requires some country specific adjustments to the generic DV model. The most recent extension to the DV is a social layer: influence of social attitudes, expectations about the future and impact of these expectations on consumer behavior, as well as corporate and financial sector investment behavior.

4.3 Individuals

The model is attributed so that every individual is defined by age, gender, education, social state, job, type of employment, income, consumption structure, savings/investment rate, family status, number of children and social mood. The scaling factor is 1000; so one person represents the behavior of 1000 persons with similar attributes (this parameter can be changed in range 100–10,000). The increase of the scaling factor shortens the running time of the model remarkably.

As shown in Fig. 4, the individual enters into the model when he is born, or when he immigrates to the country or at the model initialization (according to population data), goes to school and when he is 18 (if he is male) he goes to the military service (the probability of 97 %). After the military service or if the individual is female, they go to college or university (probability 0.8) or immediately look for a job (probability 0.2). Those who get more education will study for six years (probability based on statistics) and if they wish they may have a part time job as well. After graduation, a person seeks a job. A person can choose to be an

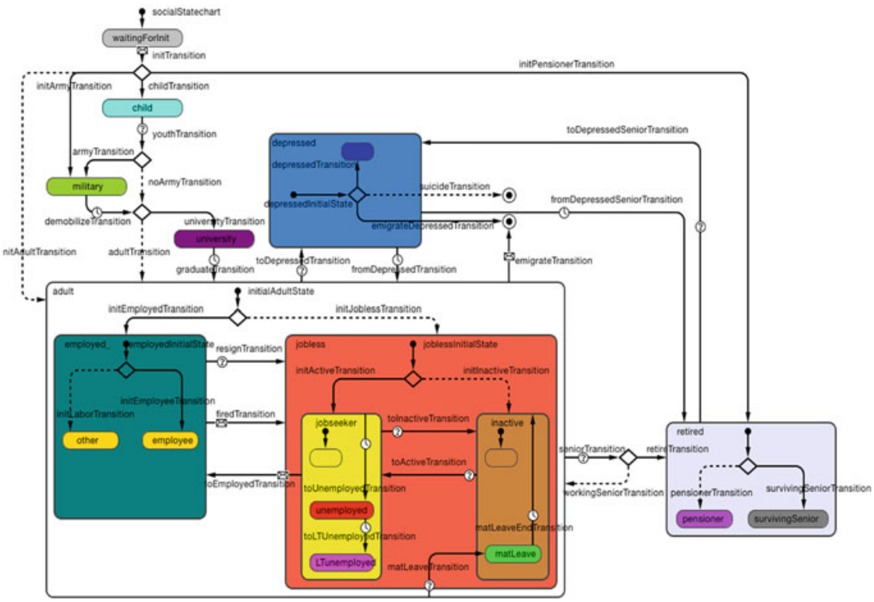

Fig. 4 The behavior options of the individuals are described as a state chart

entrepreneur or to look for a job as an employee. If he does not get a job, he can either start a company of his own or be unemployed. An adult person can decide to be inactive, or if he is sick (with a probability based on statistics) he can stay at home.

A person who has a job can decide to get married and have children. A female person can either decide to stay at home with children until the youngest of them reaches a certain age or continue to work.

If an employed person gets fired, he can either look for another job or decide to be an entrepreneur or become passive. A person as well can emigrate or retire (if he is over 65). When a person is over 60 he can retire, and if his pension is not high enough, or he does not get any support from children, he can look for a second life job either full time or part time until he is ready to retire (with statistics based probability, probability of complete retirement increases by age up to 75 years).

An individual is consuming according to the income statistics a share of their income, which is distributed among the sectors according to the Input-Output table.

4.4 Social System

In the latest version of the Dream Valley model, we have included some features of the social systems in the model. As described earlier in the social systems theoretical part of the chapter, expectations about the future have an impact on behavior. We call this element social mood. Use of social mood theory involves taking a non-deterministic view of social behavior: Given a pattern of social mood changes over a specific time frame determine periods when the mood is positive or negative (optimistic or pessimistic) about the future on that timescale. We then outline the possible *types* of events that might occur during these periods and employ the social mood as a way of "biasing" what is more or less likely to occur. The social mood allows us to assign relative likelihoods, that is, an ordering, to the various possibilities from most plausible to highly unlikely.

The notion of social mood offers a coherent framework for anticipating the way social events will unfold. It is based on the assumption that human behavior changes as a result of forces inside the human system itself (the endogenous nature of human systems).

Expectations about the future have an impact on the behavior of individual agents by changing the probability of certain behavior (such as education activity (Sipsma et al. 2015), job seeking (Stephens 2004; Berlew and Hall 1966), getting married (Harknett and Kuperberg 2011), having new children (Sobotka et al. 2011) and consumption (Carroll et al. 2006; Kurz et al. 2015; Stillwagon 2015; Bachman et al. 2015; Abraham and Harrington 2015; Black et al 2015), emigration (Bauman et al. 2015; Docquier et al. 2014) or a suicide (Granados and Tapia 2005; Nordt et al. 2015; Piérard and Grootendorst 2014). In the business as usual situation expectations do not have any impact on behavior (social mood is not positive or negative).

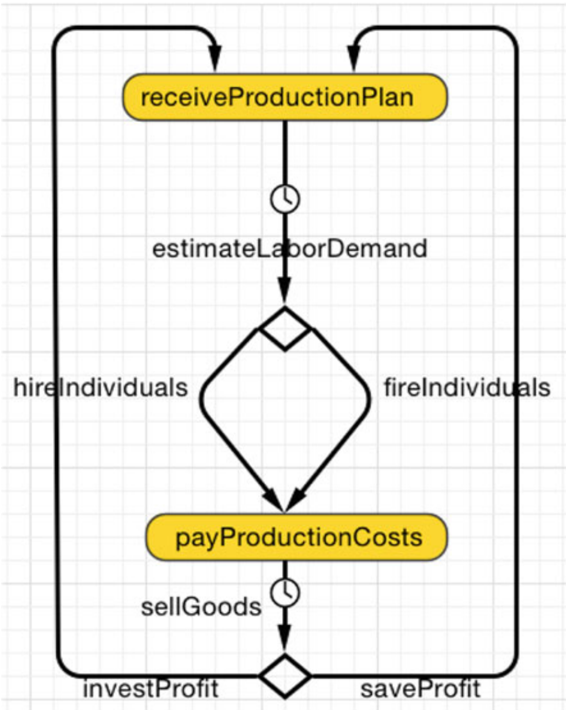

Fig. 5 Demand is defining the amount of production volume. Production plan (based on IO table) defines the amount of raw materials and intermediate products needed for production of the demanded amount of products/services

4.4.1 Economic Sectors

Economy is demand driven. Companies are following the production function of the sector (Input-Output statistics), and productivity will change when the scenario defines so. Companies buy raw materials and intermediate products (components, services) and decide to recruit more people if the demand is higher than the previous period or dismiss people if the demand is lower than earlier. Capital formation, profit rate and labor/production ratio values come from the current IO table. Productivity follows the statistical coefficient (Fig. 5).

Companies can decide how they use the profit, either to invest it and thus improve the productivity of the sector or distribute it as dividends. Companies pay taxes on their profits to the government (according to the corporate tax rate).

4.5 Government

The government can tax individuals and companies. Government expenditures (from IO tables and budget statistics available) cover the Government consumption (such as education, hospitals, infrastructure building), income transfers (pensions, unemployment compensation) and direct subsidies to companies (these are marked as taxes fewer subsidies in the IO table).

A government budget is balanced via debt (increase of sovereign debt or payments of the existing debt). The amount of debt can be automatically constrained according to the predefined rules. The government expenditure behavior can be manipulated according to the different policy scenarios that define the structure of government expenditure (investments on education, health care cost, pensions and other income transfers) and the structure of tax income (shifts between income tax, structure of the corporate tax, value added tax).

4.6 Time Steps

The base year of the model was defined according to the statistics available in 2011. The model covers 24 years altogether; four past years (2008–2011) and twenty years to come (2012–2032). The time step in the model is one month, at the end of the month every agent makes changes in its behavior (such as to recruit more labor or to have a child).

4.7 Scenarios

The ABM supported scenario modelling used in the case study consisted of seven phases. The qualitative scenario building phase produced a set of scenario stories. Scenario stories were interpreted as quantitative data and then the simulations of the changed input data were run. The results were exported as time series and analysis was based on a comparison of the base line results to the scenario results. As an outcome, the process provided the research team with insight for the policy recommendations (Figs. 6 and 7). The model interface allows to set and combine different types of economic scenarios: export, import and government expenditures changes.

4.8 Simulation

In this scenario we are testing different expectations for the future: positive social mood describes a situation where social system relies on the future, and they perceive the current situation as quite a positive one. The behavior rules applied for the positive social mood in comparison to the business-as-usual (BAU) situation are:

+ Individuals reached the retirement age are 20 % less probable to retire (they continue to participate in the labor market)
+ Passive individuals (excluding women on maternity leave) are 20 % more probable to change their state to jobseekers
+ Jobseekers are 20 % less probable to change their state to passive

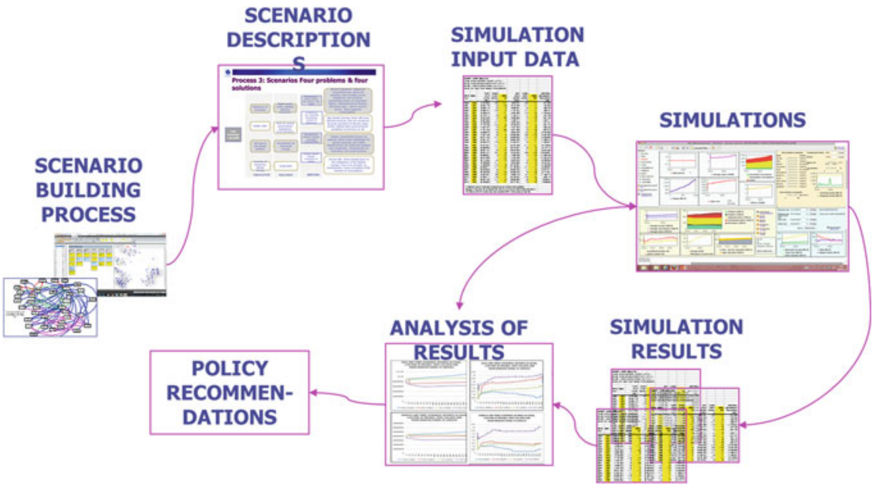

Fig. 6 7 Phase modeling

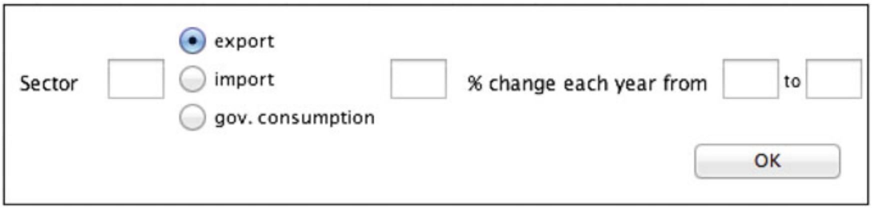

Fig. 7 Model interface

+ Individuals reached 18 years (or after finishing the military service if they are male) are 20 % more probable to join a University
+ Birth rate will increase by 20 % (as a flow variable)

When the expectations area negative; social mood (SM) is negative, the behavior rules compared to the business-as-usual (BAU) behavior are

− Individuals reached the retirement age are 20 % more probable to retire (they continue to participate in the labor market)
− Passive individuals (excluding women on maternity leave) are 20 % more probable to be passive
− Jobseekers are 20 % more probable to change their state to passive
− Individuals reached 18 years (or after finishing the military service if the are male) are 20 % less probable to join a University
− Birth rate will increase by 20 % (as a flow variable)

Export will develop according to BAU scenario (+5 % per year) for each sector, so in this analysis the economy maintains its current sector structure.

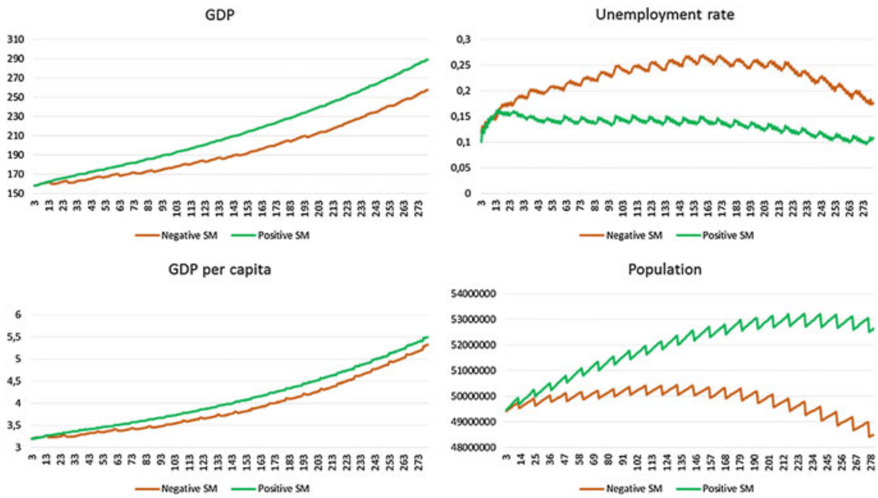

Fig. 8 Social system's perceptions about the future are in this simulation either negative (negative SM) or positive (positive SM). *Source* Simulation 20150319

Social mood has in this simulation a significant impact on GDP, when the social system has a positive perception about the future; the GDP is 12 % higher than in the period of the negative social mood (Fig. 8). GDP per capita shows the same trend, even if the difference is not as high due to the strong impact of the negative expectations on the amount of population (the outcome is 8 % smaller than in the scenario of the positive social mood). If the impact of social mood is as anticipated in this simulation, the impact of social mood on population is high, the difference is more than 8 %. Unemployment rate is reacting most radically; the difference is at its highest in the 13th year of the simulation, when social mood is positive, unemployment is 43 % lower than in the case of negative social mood. The development trajectory of the unemployment in the negative social mood scenario is bending when the population is decreasing.

The results of this simulation indicate that a 40 % change in the social expectations has a relative smaller impact on GDP and population. Social mood has the largest impact on the unemployment rate until interdependency with population development is decreasing the supply of labor.

4.8.1 Limitations of Social Mood Simulations

Due to the lack of data, we have not been able to include the detailed consumption patterns to the model. Some of the dynamic effects are thus not visible in the domestic demand. The second, and perhaps more severe limitation of this simulation model is emerging of the simple input-output table based production function of the model and thus does not show the impact of future expectations on companies' investment behavior.

5 Conclusions

The motto of this chapter, citation of Donella Meadows, stated that reality is a mental model. The citation describes something very essential about the nature of the social systems and our slogan fits even better in our attempt to capture the emergent nature of a complex adaptive social system by using ABM.

The aim of our research is to develop tools for decision makers that have to make decisions in the complex environment. To advance, we have to admit, that we cannot provide decision makers with sufficient information or insight so that they could make fact based reaching decisions. After we surrender to uncertainty, some alternative opportunities are opening. Our ABM experiment does not try to predict what will happen in the future. The only role of this study was to generate some insight about the role of the feedback loops of the social system as drivers of uncertainty.

As stated earlier, the ABM simulation is always a prisoner of the mental models of researchers. All that we can do is to use the body of the scientific knowledge about social systems as a basis for behavior rules, and accept simultaneoulsy that even this knowledge is not sufficient to represent reality.

After all of these severe limitations, why bother? The ABM work is very resource intensive and it takes a lot of time. We believe that it is essential to provide decision makers with an opportunity to experiment and experience the dynamics. As we see, the dynamics are difficult to capture in the traditional outcome graphs (such as in the picture x), but when a decision maker has an opportunity to follow the dashboard during several simulations, we hope that he will capture something essential about the dynamics and how the system evolves. That may have a power to change the mental models of the impact of the social system of the decision maker himself.

References

Abraham R, Harrington CW (2015) Consumption patterns in the aftermath of the financial crisis: the case of baby boomers. Mod Econ 6(02):245

Ackoff RL (1974) The systems revolution. Long Range Plan 7(6):2–20

Anderson P (1999) Complexity theory and organization science. Organ Sci 10(3):216–232

Ansoff HI (1979) Strategic management. Macmillan, London

Ansoff HI (1984, 1990) Implanting strategic management, Prentice Hall International, New Jersey

Bachmann R, Berg TO, Sims ER (2015) Inflation expectations and readiness to spend: cross-sectional evidence. Am Econ J Econ Policy 7(1):1–35

Baumann R, Sevec J, Sanzari F (2015) The relationship between net migration and unemployment: the role of expectations. East Econ J 41:443–458. doi:10.1057/eej.2014.44

Benhabib J, Evans GW, Honkapohja S (2014) Liquidity traps and expectation dynamics: fiscal stimulus or fiscal austerity? J Econ Dyn Control 45:220–238

Berger PR, Luckmann T (1966) The social construction of reality. Doubleday, New York

Berlew DE, Hall DT (1966) The socialization of managers: effects of expectations on performance. Adm Sci Q 1966:207–223

Black A, McMillan D, McMillan FJ (2015) Cointegration between stock prices, dividends, output and consumption: Evidence and forecasting ability for 29 markets. Rev Acc Finance 14:1

Brooks C (2014) Introductory econometrics for finance. Cambridge University Press, Cambridge

Brudermann T, Fenzl T (2010) Agent-based modelling: a new approach in viral marketing research. Gabler, Germany

Carroll C, Christopher D, Slacalek J (2006) Sticky expectations and consumption dynamics. Johns Hopkins University, Baltimore

Casti JL (2012) X-events, the collapse of everything. Harper Collins, New York

Casti, Ilmola (2010) An era of uncertainty: How to anticipate endogenous risks and threats? In: Decisions in a Complex World: Building Foresight Capabilities, Building Foresight Capabilities National Security Coordination Secretariat, Singapore pp.119−144. http://www.iiasa.ac.at/search/publication.php?authors=Ilmola,L

Courtney H (2003) Decision-driven scenarios for assessing four levels of uncertainty. Strateg Leadersh 31(1):14–22

Deffeyes KS (2002) Hubbert's peak: the impending world oil shortage. Princeton University Press, Princeton. (ISBN 0-691-09086-6)

Docquier F, Ozden Ç, Peri G (2014) The labour market effects of immigration and emigration in OECD countries. Econ J 124(579):1106–1145

Energy Production (2014) Department of Defense (DOE) Annual Energy Management Report Fiscal Year 2013. http://www.acq.osd.mil/ie/energy/energymgmt_report/FY%202013%20AEMR.pdf

Folke C (2006) The emergence of a perspective for social-ecological systems analyses. Glob Environ Change 16:253–267

Gilbert N (2008) Agent-based models (No. 153). Sage, Thousand Oaks

Granados J, Tapia A (2005) Increasing mortality during the expansions of the US economy, 1900–1996. Int J Epidemiol 34(6):1194–1202

Hall AM, Lampert M, Di Cesare S (2013) Using stock market indexes to anticipate elevated public health risk: a socionomic view of epidemic disease. Available at SSRN 2234003

Harknett K, Kuperberg A (2011) Education, labor markets and the retreat from marriage. Soc Forces 90(1):41–63

Hodgkinson GP (2003) The interface of cognitive and industrial, work and organizational psychology. J Occup Organ Psychol 76(1):1–25

Hodgkinson GP, Bow NJ, Maule AJ, Glaister KW, Pearman AD (1999) Breaking the frame; an analysis of strategic cognition and decision making under uncertainty. Strateg Manag J 20 (10):977

Holling CS (1993) Resilience and stability of ecological systems. Annual review of ecology and systematics Vol. 4 (1973), pp. 1−23. http://www.jstor.org/stable/2096802

Holling CS (2001) Understanding the complexity of economic, ecological and social systems. Ecosystems 4:390–405

Ikonen M (2013) Trust development and dynamics at the dyadic level a narrative approach to studying processes of interpersonal trust in leader-follower relationships, Itä-Suomen yliopisto

Ilmola L, Casti J (2013) A case study of uncertainty: Seven Shocks and Finland., Int J Innov Supply Chain Manag 7(2)

Ilmola L, Kuusi O (2013) Information filters as one of the means of managing strategic fit in a complex environment. Foresight 15(2):132–151

Kouvo A (2014) Luottamuksen lähtee, Vertaileva tutkimus yleistynyttä luottamusta synnyttävistä mekanismeistat. Annalis Universitatis Turkuensis, Turku

Kurz M et al (2015) Monetary Policy with Diverse Private Expectations. No. def022. Università Cattolica del Sacro Cuore, Dipartimenti e Istituti di Scienze Economiche (DISCE)

Lampert M, Wilson E (2009) Melody and mood: An update on the socionomics of popular music. The Socionomist

Lambert et al. (2010) Journal of personality and social psychology towards a greater understanding of the emotional dynamics of the mortality salience manipulation: Revisiting the "Affect Free"

Claim of Terror Management Research. https://pages.wustl.edu/files/pages/imce/lambert/affect_free_claim-in_press_jpsp.pdf
Lane DA, Maxfield RR (2005) Ontological uncertainty and innovation. J Evol Econ 15(1):3–50
Luhmann N (1995) Social systems. Stanford University Press, Stanford
Mayer R, Davis J, Schoorman D (1995) An integrative model of organizational trust. Acad Manag Rev 20(3):709–734
Meadows D, Randers J, Meadows D (2004) Limits to growth: the 30-year update. Chelsea Green Publishing, White River Junction
Nicolis G, Prigogine I (1977) Self-organization in nonequilibrium systems, vol 191977. Wiley, New York
Nofsinger JR (2005) Social mood and financial economics. J Behav Finance 6(3):144–160
Nordt C et al (2015) Modelling suicide and unemployment: a longitudinal analysis covering 63 countries, 2000–11. Lancet Psychiatry. (http://www.thelancet.com/journals/lanpsy/article/PIIS2215-0366(14)00118-7/references)
OECD (2014a) Risk Management and Corporate Governance, OECD Paris
OECD (2014b) Perspectives on Global Development 2014 boosting productivity to meet the middle-income challenge, OECD Development Centre Paris
Piérard E, Grootendorst P (2014) Do downturns cause desperation? The effect of economic conditions on suicide rates in Canada. Appl Econ 46(10):1081–1092
Prechter R, Parker W (2007) The financial/economic dichotomy in social behavioral dynamics: the socionomic perspective J Behav. Finance 8(2):84–108 Summer 2007
Prechter R, Deepak G, Parker W, Lampert M (2012) Social mood, stock market performance and US presidential elections: a socionomic perspective on voting results. SAGE Open, Thousand Oaks
Raynor K (2015) Book review: determined to succeed? performance versus choice in educational attainment. Teach Sociol 43(1):70–72
Schachter S, Singer JE (1962) Cognitive, social, and physiological determinants of emotional states. Psychol Rev 69:379–399
Simon HA (1979) Rational decision making in business organizations. Am Econ Rev 69:493–513
Sipsma HL et al (2015) The impact of future expectations on adolescent sexual risk behavior. J Youth Adolesc 44(1):170–183
Sobotka et al. (2011) United Nations Department of economic and social affairs population division expert Paper No. 2013/8 Pathways to Low Fertility: European Perspectives Tomáš Sobotka. http://www.un.org/en/development/desa/population/publications/pdf/expert/2013-8_Sobotka_Expert-Paper.pdf
Stacey RD (1995) The science of complexity: an alternative perspective for strategic change processes. Strateg Manag J 16(6):477–495
Stephens M Jr (2004) Job loss expectations, realizations, and household consumption behavior. Rev Econ Stat 86(1):253–269
Stillwagon JR (2015) Testing the expectations hypothesis with survey forecasts: the impacts of consumer sentiment and the zero lower bound in an I (2) CVAR. J Int Finan Markets Inst Money 35(2015):85–101
Sztompka P (1998) Trust, distrust and two paradoxes of democracy. Eur J Soc Theor 1(1):19–32
Walton JS (2008) Scanning beyond the horizon; exploring the ontological and epistemological basis for scenario planning. Adv Dev Hum Resour 10:147–165
Weick KE (1984) Toward a model of organizations as interpretation systems ACAD MANAGE REV April 1, 1984 9(2):284−295. doi:10.5465/AMR.1984.4277657
Weick KE (1995) Sensemaking in organizations. Sage, Thousand Oaks
Weick KE (2001) Making sense of the organization. Blackwell Publishers, Oxford
World Economic Forum (2015) Global risks report 2015 http://www.weforum.org/reports/global-risks-report-2015
Zhang Q, Wang E (2010) Local political trust: the antecedents and effects on earthquake victims' choice for allocation of resources. Soc Behav Pers 38(7):929–939

System Failure? Why Humanitarian Assistance Can't Meet Its Objectives Without Systems Thinking—and Why It Finds It so Hard to Use It

Simon Levine

Abstract Thinking in terms of systems is surely as old as any other kind of intelligent contemplation, but even if the creation of 'systems thinking' as a separate intellectual discipline is much more recent, academic approaches to analysing 'soft systems' have been around for at least two generations. The fact has to be faced, though, that the impact of more structured approaches to systems thinking have been extremely limited, with most of the world stubbornly continuing to address the obvious failings of the various systems that we need by tinkering with a few of the components, despite the evidence of decades that such approaches inevitably disappoint. Systems theorists have perhaps not helped as much as they could, being seen too easily as creating as esoteric jargon that seeks to describe in opaque terms what was already abundantly clear to everyone anyway—but not really offering a way forward that anyone connected with the problem could actually find helpful. (More recently complexity theorists seem to be repeating the same path.) This chapter describes a system (emergency response to droughts in the Horn of Africa) that was clearly not functioning well in the eyes of those who were working in it. It tells the tale of a diagnosis that did not start with system theory, but which found itself forced into understanding the problems in system terms, and which tried to find a system solution to avoid future repeated failures. It is presented here a story of both hope and disappointment with lessons that are hopefully of wider applicability than just for the humanitarian system that it describes. There was, and remains, hope, because so many of the practitioners found the use of system thinking (without any system jargon or intellectualisation) to be a refreshing take on an old problem and they saw that it offered a different way to do something about long standing failures. It is also a tale of disappointment because ultimately the initiative did not succeed in establishing the processes that were needed. And it

The chapter draws on the experience of the Pastoral Areas Coordination, Analysis and Policy Support (PACAPS) initiative of the USAID programme, Regional Enhanced Livelihoods in Pastoral Areas (RELPA).

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is hopefully instructive because systems thinking itself reveals why the initiative was so likely to fail: it is a sad truth that institutional diagnosis tends to be reserved for problems and is rarely used ex ante in assessing the institutional (or system) feasibility of proffered solutions. Some details about the livelihoods of livestock herders in the Ethiopia, Kenya and Somalia are necessary to understand the story, as are some technical details about how emergency aid actually works. These details have been kept to a minimum in order not to distract attention from the system lessons at the story's heart. Those who are interested in the more specific application of systems thinking to emergency response in arid areas or to the livelihood systems of the Horn of Africa should read Levine et al. (System failure? Revisiting the problems of timely response to crises in the Horn of Africa. Humanitarian Practice Network, Overseas Development Institute, 2011).

Keywords Humanitarian · Systems thinking · Horn of Africa

1 The Problem: Humanitarian Response to Drought in the Horn of Africa

Humanitarian response to repeated famines in pastoral areas in the Horn of Africa has consistently been late, despite an enormous investment in early warning. Although mass human fatalities have become rarer, interventions to protect and support people's livelihoods have consistently arrived too late to achieve their intended impact. This is striking because food security crises in the pastoral areas of the Horn are so regular, and because droughts in pastoral areas are the slowest-onset crises imaginable.

Attempts to improve early response have usually focused on 'capacity building' individual agencies, or on introducing new tools for achieving certain specific tasks. Millions of pounds have been spent on improving early warning, establishing livelihood 'baselines' to analyse the impact of droughts and other shocks, on running training courses for contingency planning and on a whole range of initiatives for being able to respond in a more appropriate way. (Millions of pounds have recently been spent just on rolling out the latest tool to ensure that response meets needs on time, the 'Integrated Phase Classification'.) Whatever the quality or necessity of such approaches, the problem of late and inappropriate response remains seemingly intractable, as seen most recently in the late responses to the 2011 famine in Somalia, which did not get off the ground for over a year after warnings were being given of impending crisis.

This chapter shows how an attempt to improve the timeliness of responses by international agencies found three ideas for moving forward which came from a growing and unexpected recognition that the roots of the problems were the failure by a multitude of experts and agencies to appreciate that they were working as part of systems. The three separate but interlinked new ways of thinking related to three kinds of system within which emergency response had to be seen. We proposed a new framework for thinking about programming and contingency planning, that saw interventions as affecting parts of livelihoods as a system; a new way of thinking about (and improving) preparedness, that understood how agencies worked as the operations of a system; and a new conceptual framework for thinking about emergency action that did not see interventions as implemented by an agency, but rather looked at the role of each agency in providing a response by the system as a whole.

Our initial analysis of the recent food security crises identified several areas of concern. Early warning (EW) of impending crisis had come several months before action was taken: the problem was thus not that EW reports were lacking, but that they were not triggering response. It was taking several months, though, from funding appeals being issued to the start of on-the-ground implementation of activities. We found that previous late responses had brought attention to the need for better contingency planning, but the contingency plans which aid agencies were compiling in ever-increasing quantities were also disconnected from action, and like the EW reports made very little reference to how or when action would be initiated. We found that so much contingency planning was being done that it was actually becoming a burden.

Our initial diagnosis was that this was due to technical weaknesses. For example, Early warning bulletins reported on rains or on harvest failures, but agencies (central and local government, UN, NGOs, donors) did not know how to turn this information into livelihood outcomes, resulting in inaction. Instead, they waited for humanitarian indicators (e.g. emaciated children) to tell them that a crisis had already arrived, making the expensive EW systems redundant. Contingency plans were entirely generic, and lacked any of the details that people needed to know how to use them—such as how anyone would know when they should be triggered, an indication of how long it would take from the time one indicator or threshold was reached until action would be needed, or how proposed contingency responses related to the overall problems that people faced. If contingency plans weren't helping people prepare for action, we wondered, what was the point of a contingency plan at all?

Our initial technical diagnosis identified areas of analysis that needed to be improved. This diagnosis seemed logical and, if it did not make the solution easy, at least it made the problem clear. Only later did we discover that we had fallen into the common trap of being drawn to the 'clear' problem, when the real issues were in fact far hazier.

There appeared to be a long list of problems, covering everything from the need for everyone to undertake their own assessments (using their own approaches), the politicisation and lack of transparency in EW, a general lack of funding for preparedness, the ways in which operating agencies are held to account by donors (which do not include a responsibility to achieve any impact, leading to a 'better to be late but with good paperwork' situation), poor information flows between the 'field' and decision-making centres in capitals and widespread weaknesses in analytical capacity around livelihoods, especially around predications and knowing what to do.

Multiple attempts to solve some of these problems individually had not really brought about much change: gradually it became clear that this was because we were really dealing with multiple symptoms with a common cause. The real problems that had to be tackled lay in how agencies worked together and communicated (with each other and internally); and what individuals and agencies were 'rewarded' by the system for providing. In other words, we started looking at the ability of the system to respond, rather than the capacity of individual agencies or individual people.

We found that previous attempts to improve early response had not applied such 'system diagnoses' or tried to improve late response by using 'system solutions'. Our emerging diagnosis might, therefore, go some way to explaining why previous efforts, which tended to focus on capacity-building of individuals or individual agencies, had brought only temporary improvement.

We weren't thinking academically about 'systems theory'. For us, thinking about a system simply meant looking at how different people and organisations had to work together in order to achieve anything at all, no matter how well they performed. Early warning could never save lives, and nor could donors—on their own. There was complete mutual dependence between the early warning systems, governments, donors, the private sector and implementing agencies in order to achieve their objectives. Instead of looking at people's (and organisations') performance from the standpoint of their own agencies, we were able to use a system perspective to analyse how behaviour that is competent in their own terms was not contributing to achieving the goals which collectively all the actors in the 'system' claimed they were working towards.

We were able to take this analysis a bit further. Some problems resulted because different actors did not really share the same objectives, although they appeared to; and other problems arose because different actors were only thinking about different parts of the system. (A theorist might say that they did not agree on which elements contribute to a single system.) The failure of a technically competent early warning was a good example of this. Early warning did not trigger response because (broadly) its users did not trust its predictions enough to make spending decisions involving millions of dollars. But the providers of EW continued to provide the same reports, without engaging with their clients (government, donors, aid agencies) to find out what they needed to provide to make earlier responses possible, just as their clients did not sit down with them to tell them what they really needed. Such behaviour only made sense if it didn't really see its role as 'providing the information that will permit early response' at all. In practice, it could be seen to be operating to a mandate of 'providing technically sound information, giving the best possible predictions of up-coming events that could affect food security'. This means that in its actual performance, it did not see itself in the same system as the aid responders at all. Once this was appreciated, it was easy to see that the multitude of capacity building programmes for early warning and, worse, the huge number of projects to establish more and more early warning systems, were not addressing the real problem at all and were almost inevitably going to be a waste of everyone's money: but more seriously, they would continue to distract attention so that progress on responding in time to save people's lives would not happen. Similarly, the interaction between donors and international agencies was poor because, while each side was frustrated with the tardiness and lack of coordination of the other, neither had established platforms for addressing these problems proactively. In system terms, the donors were working as part of a system that includes taxpayers and their own governments, to whom they were accountable. NGOs, on the other hand, tended to see the donor as an external source of funds into 'their system'.

Although this very different diagnosis gave us hope that a new way forward could be found, it also brought with it yet one more challenge—and one that probably explains much of the reluctance of previous attempts to fix late response by thinking in terms of systems. Organisations are managed, so there are mechanisms for enforcing a change in their performance. Systems are often not managed: no one is in charge of (even if, in theory, governments are supposed to be responsibility for systems within their own countries). This makes improving systems much harder than building the capacity of individual agencies. However, if we were right that there could be real change only by thinking of individual agencies improving their own work, there was no choice except to accept the challenge.

2 New Ways of Thinking

We broke down the failure of the early response system into three components, each of which was itself a different system problem.

1. Early response was not happening because *it was never planned*. In reality, there were no early response strategies at all, only individual projects for activities that would happen when they happened. (There was no such thing as a deadline by which time a project had to start or be abandoned.) This was because of a complete disconnect between agencies' thinking about their interventions and the livelihoods of the people they wanted to help. The livelihoods that agencies were trying to help were also a system, one in which time was a critical dimension, but this was not being given attention. (Again, we could perhaps say that the problem was that agencies did not include the livelihood systems of the people they wanted to help as being inside their own aid system.) As we understood system thinking better, we understood that focusing narrowly on one's own discrete and self-contained activities, without reference to the real world, is a classic symptom of system problems.
2. Early response projects were always late because the decisions to implement them were being made late. Decision-makers made what they thought were correct decisions and were then frustrated by their inability to get moving quickly enough, because their agencies were not prepared. They had focused

only on their own actions and were not seeing themselves as only a part of a response that their agencies delivered as an organisation or ‘system’ made of many components (including financial procedures, logistics and purchasing processes, management decisions making, human resource demands, etc.)

3. Agencies constantly blamed each other (NGOs blamed government, central government blamed local government, donors blamed early warning, and everyone blamed the donors) for the late response. But no one had a plan for getting people to work together in a different way, to try and diagnose how the system as a whole could function better.

What we had to offer were two tools for seeing and doing things differently—for contingency planning for livelihoods interventions and for preparedness. Neither was meant to be a *technical* improvement on what people had been doing before, but rather giving actors a different way of seeing what they needed to do. We wanted contingency planning to relate to livelihoods and crises as a dynamic system, and we wanted preparedness to be about the system readiness of the various components that work together in agencies. Crucially, the two tools linked together. We wanted to avoid the use of any technical or abstract systems language, and so we called our approach to contingency planning ‘crisis calendar analysis’, and our way of seeing preparedness as ‘preparedness auditing’.

2.1 Tool 1: Crisis Calendar Analysis: Livelihoods as a Dynamic System

Contingency planning was unrelated to real action because planning took place for purely abstract ‘shocks’ and not for actual possible situations. It had not helped response to be on time because it had not indicated **when** action would be needed. The conclusion was simple: get people to stop writing plans and to start thinking about what was coming and when it was likely to arrive.

We helped people to draw up a ‘crisis calendar’, detailing a likely scenario on an actual calendar, and using very specific, even quantified, estimates of as many parameters as possible. Any crisis with a fairly predictable course—even conflict in many cases—can be planned for with a crisis calendar. The parameters whose movements were predicted over time depended on what was important to livelihoods and the nature of the crisis. In our context, we often included pasture condition and water availability; livestock condition, mortality and price; grain prices; milk availability and breeding; and factors associated with pastoralists’ migration patterns, including conflict. Later work included planning for the management of drug stocks in rural health centres by looking at exactly when different roads were likely to be cut off by floods.

Starting with a normal seasonal calendar focused attention on the fact that not all change is due to a crisis, since the seasonality of food price or milk yields is always important. It was also instructive in revealing knowledge gaps—in our case, few people working on pastoralism knew just how much cattle or food prices tended to fluctuate seasonally (which should be surprising). The calendars quickly revealed limited understanding about pastoralists' own strategies in the face of crises—for instance no one was sure exactly when pastoralists would want to sell livestock in the face of a drought and when they preferred not to. The planners then estimated what each of the important livelihood parameters would look like month by month or week by week in the scenario they were planning for. The exercise could be conducted by scientists, politicians, NGO staff and farmers or pastoralists: the interaction of all would be the most fruitful arrangement. Indeed, the ability of the exercise to involve everyone as equals, answering the same questions and discussing the same reality in a single framework, may be the tool's most significant contribution.

There was a tendency for people to hesitate about making detailed forecasts because they could not be sure about their predictions. We believe that this is a fundamental mistake. A forecast does not have to be correct to be useful. Vague descriptions keep planning generic and ensure that the response system does not engage sensibly with the livelihood system it is designed to support. Being specific about the nature, size and timing of any impact of crisis played two critical roles. First, by moving away from very generalised and vague conclusions, we could see how details matter to planning and so come up with much more appropriate response plans. Second, it changed the nature of the contingency plan from something that would be implemented blindly into a document that gave a basis for monitoring—were things deteriorating in the way expected, did the crisis seem as bad as or worse than feared? People's fear of being locked into a set plan made them reluctant to move beyond general predictions, and ironically this fear then made it much harder to be flexible.

Crisis calendar analysis provided a framework within which to plan strategies and specific responses, but on its own it does not choose them. Which interventions are actually appropriate and which are justified as humanitarian responses in any situation still needs to be assessed. The first principle of crisis calendar analysis is that the timing of livelihood protection interventions should depend on the livelihood calendar. An obvious example: seeds have to be distributed before it is due to rain. This may sound obvious, but it is not how current humanitarian response is timetabled. Currently, humanitarian response is triggered by humanitarian indicators, which do not, of course, always go off in time to meet the livelihood calendar's requirements. Ensuring access to seed only when child malnutrition reaches a certain threshold may not help farmers plant on time. Using the principle that a livelihood calendar should be used to schedule events makes it a straightforward matter to show on the crisis calendar when different livelihood protection strategies would be appropriate—their 'windows of opportunity'. Thus, a livestock feeding intervention would make sense only from the time that animals are in danger from lack of fodder to the time when their survival is ensured from pasture. **Feeding outside this 'window' would make no sense**. Similarly, supporting offtake through livestock marketing makes sense from the time livestock prices fall considerably (due to lack of demand, poor body condition and sometimes because traders are waiting for prices to collapse) until the animals are no longer marketable

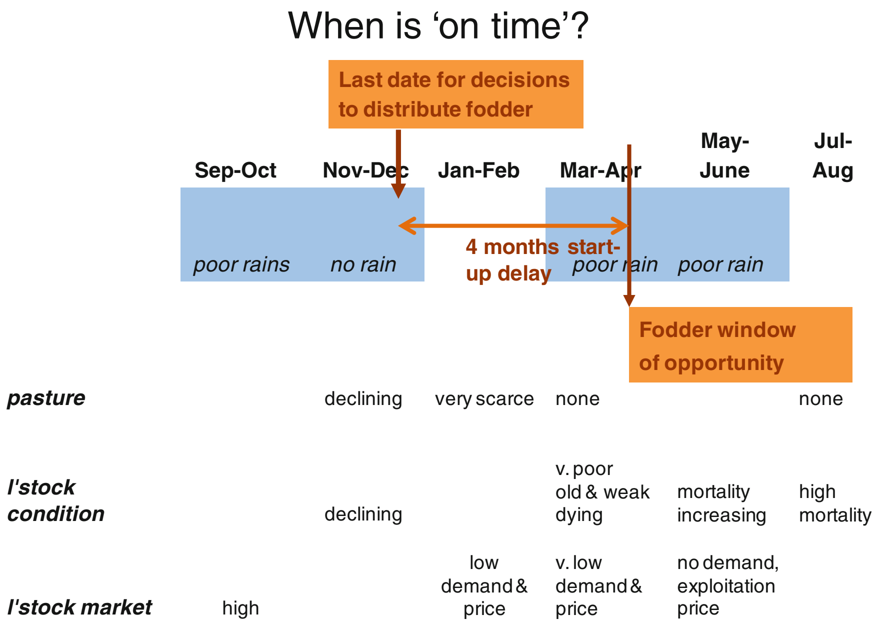

Fig. 1 Crisis calendar

—and certainly when they are too weak to reach the market and be transported long distances. (In one of the exercises we ran, this was from the beginning of March until June at the latest, see Fig. 1.)

The windows of opportunity for each intervention cannot be known for certain several months in advance, but they can be estimated and these estimates can be progressively modified as the crisis develops (or is averted). That, in short, is the essence of contingency planning and early warning—not treating them as stand-alone activities to be perfected (as so often had been the case) but putting them right at the heart of a response system. The range of appropriate interventions in any given context was small enough to make it relatively easy to have target dates for activities backed up by sound logic. Planning could then be based on the simple fact that, unless we were able to meet the windows of opportunity, it would be better not to implement the interventions at all. This moved discussions away from the fruitless search for the Holy Grail of the perfect indicator (one that could not be manipulated and which would always indicate on time the appropriate intervention.) By switching the attention to how livelihoods were changing, consensus tended be easy and speedy, regarding the problems to be addressed, the optimum times for intervention and on what needed doing.

The crisis calendar made it impossible to ignore a number of challenges to early response that had long been felt, but rarely discussed explicitly. Most fundamentally, in order to be on time, decisions to fund and implement an intervention often have to be taken before it is certain that a humanitarian situation will arise at all. Donors in particular are understandably reluctant to commit scarce humanitarian resources to a situation that may not materialise. This challenge cannot be addressed until the underlying logic of timely response is laid bare, showing that the choice is a stark one: work on the basis predictions or do not bother about early response at all. One major challenge is trying to shorten the time between decision making and the arrival of benefits on the ground—what we called the start-up timeline. These remained long (several months) principally because agencies had not thought about how long they are or why this should matter. This is why we introduced the idea of preparedness auditing.

2.2 Tool 2: Preparedness Auditing

The start-up months (or 'gestation period') are when resources are sourced, staff recruited and trained, purchases made and items transported. Although staff in most agencies could make reasonable estimates of the length of this start-up period, we found no cases where an agency had in fact tried to estimate this start-up period, and to use such an estimate in its planning. This is a critical failing. The failure of many livestock feeding initiatives to deliver any benefit at all in previous responses was a clear illustration of why. The typical start-up timeline for distributing fodder was 4–5 months. In Fig. 1, from a real crisis calendar, in order to start feeding in mid-April (i.e. in the only livelihood window of opportunity), then decisions to do this would have to be taken by mid-December. In practice, decisions were being taken when animals were seen to be dying, in May, with no thought to the fact that fodder would not suddenly arrive the day after deciding it ought to. A decision in May **inevitably** led to fodder delivery after the next rains had started (in September) when pasture had regenerated, guaranteeing that resources—time and money—were completely wasted.

Preparedness auditing used a Gantt chart to **quantify** an agency's state of preparedness. There was no technical innovation here—Gantt charts are hardly new. The change was in the approach, bringing preparedness into the response system and the relating it to the livelihoods of the people whose lives were to be supported. Agencies were simply not used to the idea of quantifying preparedness, or of holding people to account[1] for managing preparedness by reducing the start-up period on the chart.

The list of tasks that need to be completed before a project really 'starts' can be long. Preparedness auditing starts by getting agencies to think of all of these tasks, break them down into their constituent tasks and estimate how long each task will take, given the current systems, procedures and state of readiness of the agency.

[1]We ran a back-of-the-envelope calculation with agencies to estimate the value of livestock that died each day during a severe drought in their operational areas. We came to around $4.8 m per day. Every time a purchase request was delayed by someone who said 'I'm going to a meeting, I'll sign it tomorrow', this was the additional cost to the people affected by the drought. This caused some surprise.

As with contingency planning, it was important to move beyond generic stages (e.g. 'getting money from donors' or 'purchasing equipment') to get to all the detailed sub-tasks. A simple question was then asked about each sub-task: could it be done before a crisis arrived—which essentially meant, could it be done in the absence of a contract and funding? With a change in mentality, it quickly became clear that almost all the sub-tasks could have been well in advance. In all the cases where agency staff analysed their preparedness, it was found possible to reduce the start-up from 4–5 months to a few days or at most 2–3 weeks[2]—though most agency staff had felt that that they had been going as quickly as they could.

Why then is a delay of months still accepted? Why is preparedness auditing not being demanded as a precondition of funding, not included as a critical performance indicator in performance management and not being used as a key parameter in the evaluation of emergency programmes? Why does early warning not routinely include consideration of start-up delays in giving its warnings? The question is really, why do the various actors in the system not take responsibility for the outcomes delivered by the system that they are dedicated to serving?

2.3 Bringing It All Together

Several evaluations of humanitarian response in the Horn had shown that agencies were sometimes so late that their responses seemed ridiculous, as already illustrated. The crisis calendar helped us to understand how simple mistakes can make such lateness not just understandable, but inevitable. First, agencies often waited until it was clear that there is a crisis before deciding to intervene. They then decided to intervene in ways that sounded fine, but without reference to the windows of opportunity that were determined by the external constraints of the livelihoods themselves. We came to see that some interventions will never be provided adequately as emergency projects, because even if decisions about them are taken in response to predictions about a possible crisis, they can still never be on time. This is only a problem if we box off the emergency system: it is simple to see that interventions such as vaccination programmes (for both children and livestock) need to be permanent, though agencies in some countries still treat measles vaccinations as an emergency intervention in famines. Fodder is not something that can simply be delivered in response to a drought: permanent systems are needed to ensure fodder availability in times of stress in areas where these problems are recurrent. Crisis response then can consist in building on this, e.g. subsidising goods and services when crisis means that people cannot afford them.

[2]Considering the speed of response that is seen with 'sudden onset emergencies', such as earthquakes or typhoons, this timeline is not at all surprising.

2.4 System Solutions?

Since it was not possible to redesign an emergency response system from scratch, we had to work with the existing overall design and try to persuade the actors involved to make some necessary changes. Many such actors, who had been frustrated by the repeated failings of early response and the endlessly repeated cycle of humanitarian aid, were very interested. A small group in Nairobi, including staff from the government, donors, EW and NGOs, helped to lay out what needed to change and how a small pilot could contribute to that overall change.

The list of the changes needed was long and varied. Challenges included:

- Achieving local consensus about what the problems were, what had to be done and what strategies would be effective. This was very foreign to the standard practice whereby each agency (including government) thought up its own 'projects', found financing for them without reference to anything others were doing and used a description of the problem to justify them, without reference to the analysis and descriptions being given by others seeking to justify their own projects.
- Using the EW information to produce credible predictions with livelihood analysis and a clear calendar. Predictions needed to include their assumptions, for example related to migration, future rains and markets.
- Improving preparedness, at the level of agencies, across actors at the local level, nationally, etc.
- Designing and setting up funding mechanisms that could provide fast and flexible support.
- Ensuring that there were long-term initiatives that could ensure permanent access to the goods and services that were needed.

The 'system dimension' helped with the diagnosis but also provided the biggest challenge: none of the changes involved one single actor improving its own performance in isolation: necessary changes involved a coordinated and consensual shift in the way different actors worked with each other at different levels. When it is remembered that even getting one agency to change actually involved a complex maneuvering of many different departments (with different perspectives, objectives and working norms), the complexity became even more daunting. It was easy to see why it is so much more tempting for an implementing agency to worry instead about designing and running its own project. Since no individual or agency was being judged by their overall impact on future crises—i.e. on the system's ability to deliver—and since no individual or agency had the power to impose its management on the system, what was the incentive for anyone to worry about it?

2.5 Testing the System Cure

We had to test whether a system solution was feasible by piloting an initiative to effect system changes in one area. Our pilot worked at two levels: with individual agencies, to look at their preparedness and how to cut their response times; and to catalyse and facilitate change at system level. The two strands were related. The overall response was determined partly by the capacity of each element in the system. But the parallels were deeper: both strands looked to help people change how they worked together and how they defined their objectives. Both strands required tools that could establish a common language and a common framework within which people could analyse their work.

The preparedness audit tool had worked well in multiagency groups. Agency staff had usually been able to find ways *in principle* of reducing their start-up timeline preparedness from 4–5 months to 3–4 weeks. But their agencies as a whole had not done so. Why not? Quite simply, it was rare for staff members of different departments within a single agency to work together as a single team with a single shared objective (to deliver humanitarian assistance on time). We decided to offer 'preparedness clinics' to provide space for senior staff from any organisation to sit around a table, agree on shared objectives and agree how to achieve them. We would use crisis calendar analysis together with a preparedness calendar to help them analyse their own situation and its implications for response, and then facilitate their own discussion around ways to speed up response.

In an initial pilot the NGO involved almost immediately saw that there were no *technical* obstacles behind their problems of late response. It was an NGO that had invested enormously in preparedness and in team-building—and very successfully so. Staff had even prepared several 'contingency' concept notes for emergency interventions. However, these were in the desk drawer of one person and no one else knew they existed. They had not been shared with other programme staff or with support and administrative staff because the advantages of doing so had not been appreciated. Opportunities had been lost to prepare in advance draft budgets and recruitment plans, to start sourcing possible supplies or to make sure that the logistics department understood basic technical issues and specifications regarding likely purchases. There had been no reason for not sharing: it was the usual story of everyone being too busy doing 'their own job' to have the time to worry about 'other people's jobs'. Or, in other language, people saw themselves as working in different systems.

Participants quickly put to one side the 'technical' issues that we had planned to talk about: they largely ignored the facilitator because realised—before we did—that if they could just get their communication working, then all the 'technical' problems could be addressed very quickly. Simple changes in people's attitude to their work would make a huge difference. One example will suffice. When drilling wells, it was only after knowing the exact depth and flow rates of water from test drilling that the engineers knew what items would need purchasing. Programme staff could therefore only give the purchasing team the details at the very last minute. What they could have done, though, was to keep the logistics team informed about their progress so that they would know when the details would be coming through. This would have enabled the logistics or purchasing staff to arrange their work so that, when those details came in, they could be dealt with straight away. Why had no one thought of this?

These are the same questions that arise in every aspect of early response: why do donors not discuss their constraints with NGOs? Why do EW information users not tell EW providers what they need? No one felt that it was their job to manage the communication, because each team felt its responsibility ended with its own work. Unless the organisation as a whole at the highest level took responsibility for preparedness and response speed, things would never get better. And until senior management had a way of measuring preparedness, and holding their staff to account for improving it, that situation was not going to change.

In a parallel initiative, the small group wanted to see if a pilot could be created, in one, quite small, administrative area in Kenya, of a system in which agencies negotiated together what their responsibilities were, and what they needed from each other. Donors could clearly not promise specific funds for one area, but there was hope that everyone would work in good faith, being transparent about their overall constraints and policies. We chose to pilot in Kenya because of the level of interest shown, and because the then-administrative system included a structure, the District Steering Group (DSG), that brought together all actors concerned with food security and humanitarian issues.[3] Wajir District had reasonable security, and a reasonably well functioning DSG.

A series of meetings were held with a small group of actors (government, UN, donors and NGOs) involved in humanitarian work. A common vision of the problem and where solutions must come from was not hard to reach, but it took time. It took a whole year to bring on board the number of actors necessary to start a pilot in one District. The government Arid Lands Resource Management Project (ALRMP) felt the initiative had promise as a potential national approach and wanted to take ownership through its capacity-building project, the Drought Management Initiative (DMI), with technical support from our project. An initial joint visit with DMI to assess the opinions and perceptions of the various actors in the District elicited remarkably uniform views. Typical comments were:

- 'There is a lack of coordination'—though all who said this agreed that the DSG met every month and subcommittees met even more frequently.
- 'We had a meeting to talk about contingency planning but the DSG never did anything about it'—though all who said this agreed that they were members of the DSG.
- 'One of the main problems is the food aid, it is killing pastoralism'—though the recommendations from the DSG of which they were members always included the continuation of food aid.

[3]The District government based system of administration has since been replaced by decentralised County based local government. The principles of what follows, though, remain just as relevant.

- 'The DSG never discusses broader strategic issues about food security'—though they admitted that the DSG meetings have an open agenda, and all participate (or are invited) and could have raised strategic issues.

Even where a structure existed for everyone working in the field of food security to discuss issues together, to coordinate, to analyse early warning information and prepare together contingency plans for the District as whole; even where this structure had a direct and official line of communication to central government and other key decision-making forums; even here, the members of the structure were not using it. The degree of 'collegiality' among members was good—there were no problems of in-fighting, rivalries or politics. The Drought Management Officer (DMO) was respected and was doing his job. The problem was at the same time simple and yet hard to understand. The DSG was created by a World Bank funded State project (ALRMP), and so was seen as belonging to that project. The project which had created the position of the DMOs, was thus seen as responsible for the DSG. When people said 'the DSG hadn't …' they meant 'the DMO hadn't …'; everything was seen as 'his job' not theirs, **even when what was to be done was in their own interests**.

We are convinced that this problem is far from unique to Wajir, to Kenya or to drought management. Many projects establish structures, but systems do not work on their own. Training tends to focus on the activities that people have to complete which further reinforces the sense of **non**-ownership of the system as a whole—you are given your role as a cog in a bigger machine, and what you are taught is the limit of your responsibility. The fact that without the teeth to engage with others, you are only a wheel and not a cog, remains ignored.

Our diagnosis was widely accepted: when we suggested a meeting to look at a District-wide response strategy for a threatened drought, everyone was eager.

The promised workshop went ahead. The crisis calendar of the looming drought was analysed and members identified some useful strategic responses and immediate steps for preparedness that needed to be taken. We left with hope that the pilot could show a new way for the system as whole to work.

2.6 System Failure of System Solutions

The workshop had no follow up. What had been intended as a pilot 'system solution' was turned into yet another District-level capacity-building programme—even though our very diagnosis of the problem had said that such 'training' was not the way to get systems working properly. Even if such District-level training had been replicated across the country, this could not constitute the reforming of a national response system. The preparedness clinics fared little better. Many agencies had shown interest in the preparedness audit, and yet in only one case were the interested staff able to persuade their NGO as a whole to give it a try.

The reasons for our failures are perhaps the main lessons of our work. We did not believe that lack of appreciation of the product was the problem with the preparedness clinics. Rather, the very same system problems that were preventing early response made it so hard for the agency to organise to tackle its own 'system problems'. Everyone was busy, staff were over-stretched. Even where programme staff felt it was a priority, they had no forums for presenting the opportunities to their colleagues in other departments. Senior managers were too busy managing projects and contracts to have time to worry about something that they were not being held accountable for.

As for our District pilot, failure here was also due not to technical shortcomings but (as is more common) because of what is now called 'the political economy' of the solution itself. We failed to give as good an analysis of the difficulties of implementing our solution as we did of the problems we were addressing. Interest in our pilot grew to the extent that it derailed it. MPs are a significant fund-holder for development and humanitarian response in Kenya, and it was natural that the local MP became interested. However, he was also a Minister. For reasons that were never clear, there were political ramifications (for what was a regional and not a national programme) and we were told not to continue. Our withdrawal is also illustrative of the increasing risk-aversion in the sector. 'Changing the response system' was not a project deliverable or a contractual obligation. It was, though, considered to bring a degree of (political) risk. It made more sense, then, to focus on easily controllable deliverables (such as workshops and reports) rather than on bringing about change. . In attempting the pilot, we were fighting internally against the very system forces that we needed to change, such as the system rewards for agencies and individuals. We lost our fight. The irony of our failure is that it was good evidence that our diagnosis of the problems was correct.

Reference

Levine S, Crosskey A, Abdinoor M (2011) System failure? Revisiting the problems of timely response to crises in the Horn of Africa. Humanitarian Practice Network, Overseas Development Institute

Using First Nations Systems Thinking to Operationalize Sustainable Development

Ivan Taylor

Abstract In the following chapter, a systems thinking approach is described that reflects a Canadian First Nation's view of sustainable development. This approach is operationalized using a System Dynamics model, called Mini-World, developed by Harmut Bossel. The primary stocks in the Mini-World model were converted to represent the quality of The Land, The People and The Economy which is terminology to which the First Nation can relate. Bossel's concept of "orientors" is used to translate the stocks in the model into traditionally and culturally specific values in which the First Nation is particularly interested. It is hoped that this translation of the measures, from a classical System Dynamics model into concepts the First Nation can relate to, will lead to acceptance and use of this operationalization of their systems thinking.

Keywords Systems thinking · Sustainability · First nations · System dynamics

1 Introduction

In the following chapter, a systems thinking approach will be described that reflects the culture and traditions of a Canadian First Nation and how this can be incorporated into the traditional oral history concept of sustainable development that has been practiced by the First Nations people of Canada for millennia.

We will begin with a brief discussion of the history and current issues surrounding First Nations in Canada. It will be shown that assimilation of First Nations into Canadian culture has not been successful and has, in fact, done great harm over the years. One will be able to see why the First Nations might be somewhat guarded with respect to outside experts coming into their communities to solve the various challenges they face. They have been severely mistreated since European contact

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and, because of that, it is of paramount importance to gain the trust of the First Nation. The First Nations are proud of their culture and want to see it preserved and revitalized. Any attempt to support their economic development must recognize this fact and reflect First Nations culture and traditions in its approach.

In this chapter, we also hope to describe what great economic potential lies within the First Nations community and how once it is realized will put them on a more equal footing with the mainstream economy of Canada. So in the third section of the chapter, we will discuss the recently found $120 billion economic development opportunity in Northern Ontario called “The Ring of Fire”.

Only after these preliminary discussions can we feel confident enough to operationalize their systems thinking approach. This operationalization is based on an adaptation of Harmut Bossel’s Mini-World model (Bossel 2007) that was built to replicate Jay Forrester’s World2 System Dynamics model (Forrester 1971).

2 The First Nations of Canada[1]

In Canada, indigenous people, who are not Inuit, are referred to as First Nations. The First Nations have obtained the right to self-government and now have control over environmental protection and natural resources on their land. It is commonly understood that First Nations are able to negotiate directly with the Crown on a Nation-to-Nation basis. There are currently around 630 individual First Nations in Canada that represent a population of 850,000.

These people suffered greatly from colonization by the Europeans, even though the settlement of Canada was much less combative than what happened in the United States. There have been many efforts to assimilate the First Nations people into Canadian society. They have not been successful. The First Nations of Canada have retained much of their culture and have had a positive influence on Canadian culture in general.

Even though these attempts at assimilation were largely unsuccessful, the inter-generational effects are still being felt today which as a consequence have taken their toll on the health and welfare of the First Nations people. Many of the First Nations people live in communities with what could be considered Third-World conditions. They suffer from high levels of unemployment, incarceration, substance abuse, homelessness and poverty, and lower education levels. In terms of health, for men, where the average Canadian man can expect to live to 77 years of age, the average First Nations man will live to 69. Similarly, for women, the average Canadian woman can expect to live to 82, whereas the average First Nation woman would expect to live to 76. Suicide rates are also extremely high among young people in the First Nations; two times the sex-specific rate of Canadians and three times the age-specific rate. It is believed that this high suicide

[1]This section draws heavily on the article in Wikipedia on First Nations (2015).

rate has been caused by low self-esteem because their culture and traditions have been marginalized in Canadian society.

Recently, things have been looking up for First Nations people. In the 20th century, their population has increased tenfold and they are the fastest growing demographic in Canada. Since 1960, their population has grown by 161 % primarily because of reduced infant mortality rates. At present, approximately half of the population of the First Nations in Canada is under the age of 25.

The Supreme Court of Canada has upheld a number of legal cases regarding First Nations treaty rights recently. The First Nations' cultural heritage is inextricably connected to the land. Thomas King, the noted aboriginal author, is quoted as saying "if you understand nothing else about Native history, you have to understand the 'land thing'" (The Next Chapter 2014; King 2013). The First Nations rightly feel that Canadians have pushed them off their land. They are a proud people and we can see why First Nations feel suspicion with the Canadian's motives. They wish to solve their own problems by employing their own cultural and traditional ways. They feel strongly about the sacredness of the land and do not want to sacrifice it in the name of economic development.

2.1 Northern Ontario's Ring of Fire[2]

In 2007, a large amount of high grade minerals were found northeast of Thunder Bay, Ontario. These minerals included platinum, palladium, nickel and copper. This area of Ontario was later called "The Ring of Fire" and was equated by politicians as Ontario's equivalent to the "Oil Sands" in Alberta. In 2008, there was a find of 72 megatons of chromite. Chromite is smelted into ferrochrome and used in the production of stainless steel. It is planned to set up the smelting operation in Sudbury, Ontario. By 2012, there were over 30,000 claims made by 35 companies to mine for chromium, copper, zinc, platinum, vanadium and gold.

Negotiations with First Nations over land rights began in 2011. There are plans for income sharing with First Nations of the potential worth of the Ring of Fire which is estimated to be as much as $120 billion. Job creation and skills training are also expected to help First Nations in the area. Regional infrastructure would be greatly improved with all-weather roads, links to the power grid and access to high-speed broadband internet. It is believed that development will have a profound effect on the local First Nations communities.

However, there are also challenges the First Nations will have to overcome. There is a general low level of educational attainment in the First Nations. Most of the working age population in the communities have not completed high school.

[2]This section draws on information from the Wikipedia article on Northern Ontario Ring of Fire (2015).

One grand chief stated that “two or three years is not enough time for skills training to train locals for construction jobs”.

The First Nations are also obviously concerned about mining’s impact on their environment. The First Nations called for a Joint Environmental Assessment Review Panel to allow them to participate as an equal to the mining interests.

It is the intent of this chapter to demonstrate that the First Nations people are not interested in sitting on the sidelines as mainstream society continues to benefit from all that “mother earth” has to offer. They intend to find innovative and, more importantly, sustainable mechanisms to engage with people who share their vision. This is in the spirit of the First Nations people of today as well as for the generations to come. We believe that System Dynamics can play a role in this effort and can help in the operationalization of their values.

3 Systems Thinking

Systems thinking is both a worldview and a process in the sense that it informs one’s understanding regarding a system and can be used as an approach in problem solving (Edson 2008: 5). As described by Ackoff (1994), systems thinking emphasizes interconnectedness, causal complexity and the relation of parts to the whole, thereby challenging traditional linear thinking and simple causal explanations. In this sense, systems thinking “is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots” (Senge 1990: 68). Through the continued evolution of systems thinking a variety of different ways of being holistic have emerged that are rooted in different paradigms and metaphors.

First Nations people share an inherent cultural concept that “everything is connected”. This characterizes their framework and cultural worldview which encapsulates their traditions and values. The realization of the cultural worldview of the First Nations people was key in shaping the methodological approach associated with this work and allowed the translation of their traditional worldview and knowledge to be integrated within the systems dynamics approach.

4 A System Dynamics Approach

At first, we considered the possibility of adapting a classic approach like World2 by Forrester (1971). However, we decided that this type of approach would be too complicated a way to introduce System Dynamics. Fortunately, we found a simpler approach that had been built by Bossel (2007), called Mini-World, to replicate the results of the World2 model.

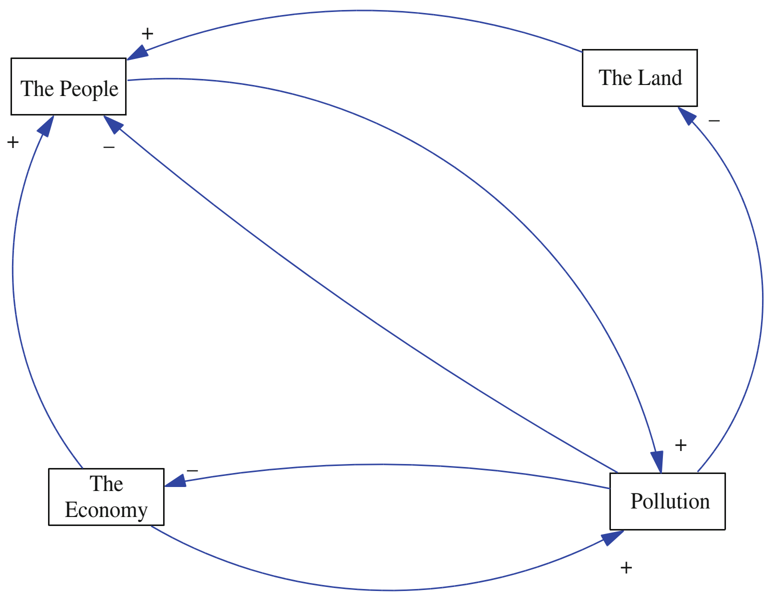

Fig. 1 Schematic of our adaptation of the Mini-World approach

It was relatively easy to adapt Mini-World to our needs. One of the first things that needed to be done was reflect the key values expressed by the First Nations with regards to sustainable development: The Land, The People and The Economy.

Figure 1 provides a simple schematic of our adaption of the Mini-World model. We can see the three stock variables for The Land, The People and The Economy. We have also included an important fourth stock variable representing the level of Pollution in the Land. As the level of Pollution goes up, the quality of The Land, The People and The Economy goes down. As the quality of The Land goes up, this has a positive effect on The People. As the number of people increases, this will increase the amount of Pollution. As The Economy increases, it is assumed that this will also increase the amount of Pollution. As The Economy increases, this will increase the attractiveness of the community and draw in more people.

Figure 2 shows the System Dynamics model, in the Vensim language (2015), which can be used to measure the impact of development proposals on the environment, society and the economy of a First Nation. The environment, society and the economy are shown in italics. The environment is affected by the level of pollution which in turn is affected by the rate of degeneration that causes the pollution level to increase and the rate of regeneration that causes the pollution level to decrease. Society increases based on the population increase rate which includes both births and immigration into the First Nation and decreases based on the population decrease rate which includes both deaths and emigration out of the First Nation. The economy will change based on the economic growth rate and a target level of consumption that is desired.

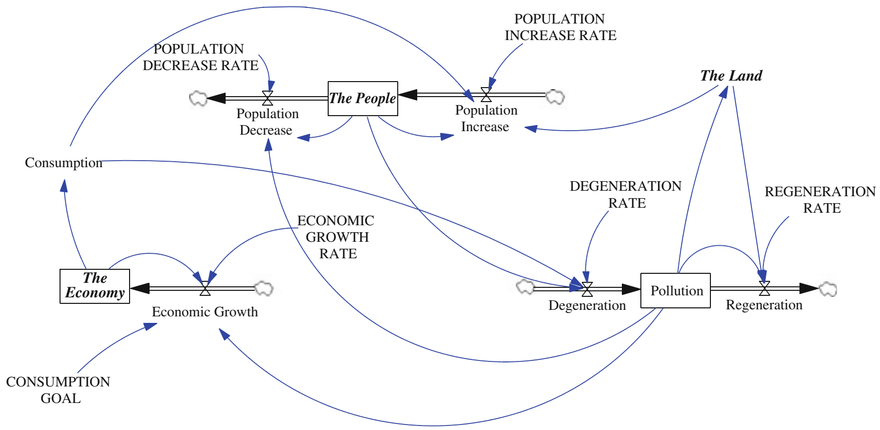

Fig. 2 The systems thinking approach in the Vensim Language

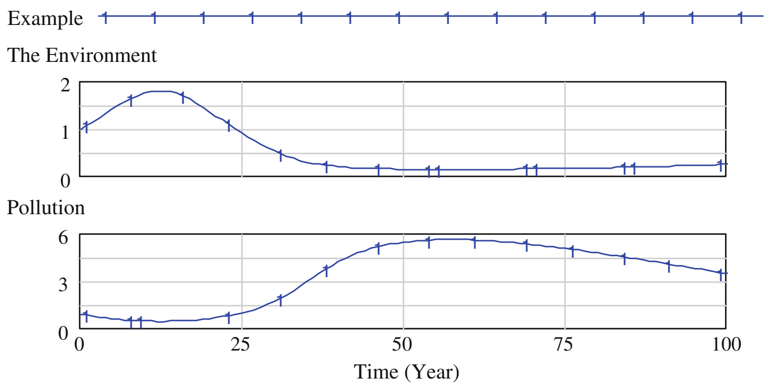

Fig. 3 The relationship between pollution and the environment

This System Dynamics model is quite simple but it attempts to produce expected future values of the quality of the environment, society and the economy for a First Nation. These future values are relative to the current values in the First Nation.

Figure 3 shows typical results that can be obtained from the System Dynamics model for the environment and the level of pollution. We can see that there is an inverse relationship between pollution and quality of the environment. As the pollution level decreases in the first 25 years, the quality of the environment is relatively good. However, as the level of pollution increases above its current level after 25 years, the quality of the environment becomes quite poor.

Figure 4 shows the relationship between society and the population increase and population decrease. We can see that in the first 10 or so years, the population

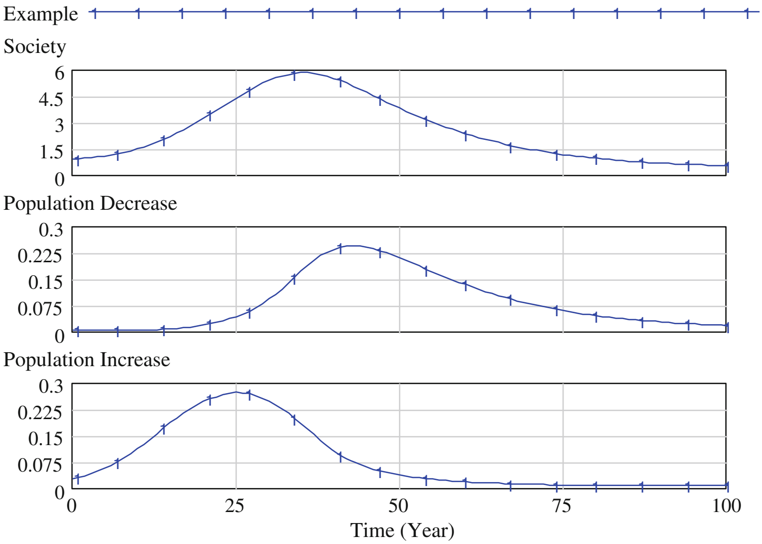

Fig. 4 Society as a function of population increase and population decrease

increase is greater than zero while the population decrease is approximately zero. So during this period of time, the value for society increases. The population decrease starts to get larger after the first 10 years. However, the population increase is still greater than the population decrease until about year 30. At this point, the value of society reaches its peak. After 30 years, the population decrease is greater than the population increase which causes the value of society to start to decrease. Both the population increase and the population decrease gradually approach zero and the value for society begins to stabilize. However, the value for society stabilizes at a lower level than it originally started.

Figure 5 shows the relationship between the economy and economic growth. We can see that economic growth is increasing in the first 30 years. Although, the rate of economic growth is decreasing for a while, it is still above zero until about 35 years into the future. So the economy peaks at year 35. Then economic growth drops below zero which causes the economy to falter and shrink for a few years. About year 65, economic growth returns to an above zero level and the economy begins to slowly recover. Notice that even with this dip in economic growth, the economy is always better than the current level.

Figure 6 shows a graph summarizing the impact of development on the environment, society and the economy over a 100 year period. We can see that all of the values for the environment, society and the economy start at 1.0 which represents the current values in the First Nation. In the first few years of development, all of these values are increasing. It does not appear that this level of development is

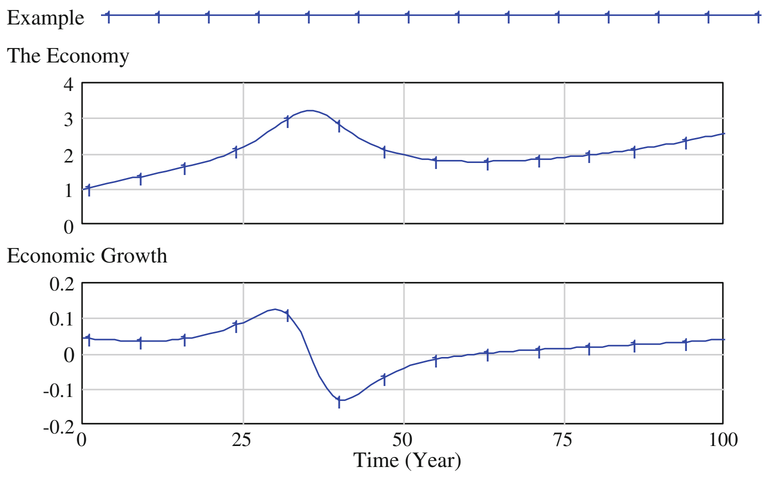

Fig. 5 The economy and economic growth

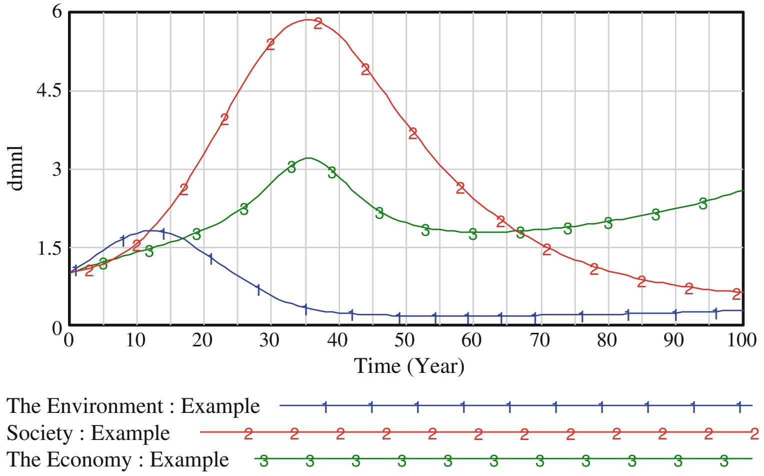

Fig. 6 Summary of the impact of development on the Environment, Society and the Economy

sustainable. It appears that the development will have a significant negative effect on the environment. Although, the value for society sees significant increases in the early years of development, the value begins to reverse after 35 years. Possibly, the high level for society is not sustainable because of the low quality of the environment. After 80 years, value for society is expected to be lower than the original level. The economy shows some ups and downs but it is always higher than the current level and is increasing at the end of the period under study.

4.1 Operationalizing Some Performance Measures of Interest to a First Nation

We will now introduce the concept of “orientors” developed by Bossel (2007) to evaluate the impact of the environment, society and the economy on performance measures in which First Nations are interested.

In the following discussion, we will denote the values from the System Dynamics model in *italics* and the performance measures produced for a First Nation in **bold**.

The performance measures will be calculated by translating the values produced by the Systems Dynamics model for *the environment*, *society* and *the economy*. Table 1 shows how this will be done.

The performance measures will be expressed on a percentage scale which is different from the values in the System Dynamics model which are relative to the current values.

The First Nation will specify the exact relationships between the System Dynamics model values for *the environment*, *society* and *the economy* and the performance measures. Then we will translate these relationships into Vensim Lookup functions (2015). These Lookup functions are simply x–y graphical plots with the System Dynamics model value on the x-axis and the performance measures on the y-axis.

For example, as described in Table 1, the quality of **The Land** is an increasing function of the quality of *the environment* in the System Dynamics model. Figure 7 shows an example of the relationship which can be translated into a Lookup function in Vensim (2015).

The quality of **Game** is also an increasing function of the quality of *the environment* in the System Dynamics model. Figure 8 shows an example of the relationship.

Table 1 Relationships between the *Environment*, *Society* and the *Economy* and the performance measures

Performance measure	Relationship with *the Environment*, *Society* and *the Economy*
Effect on **The Land**	Increases with greater values of the *Environment*
Effect of **Game**	Increases with greater values of the *Environment*
Effect on **Sacred Sites**	Decreases with greater values of the *Economy* Decreases with greater values of *Society* Increases with greater values of the *Environment*
Effect on **The People**	Increases as *Society* approaches an ideal value Decreases as *Society* moves away from an ideal value
Effect on **Infrastructure**	Increases with increasing values of the *Economy* Decreases with increasing values of *Society*
Effect on **Job Creation**	Increases with increasing values of the *Economy* Decreases with increasing values of *Society*

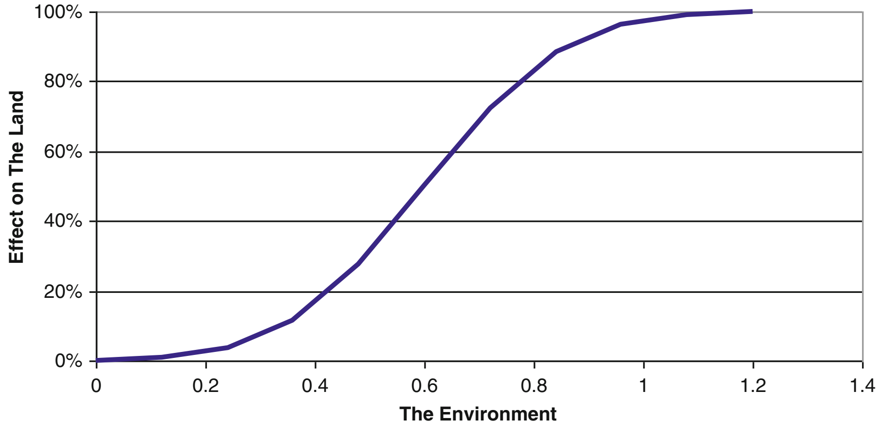

Fig. 7 An example of a lookup function representing the relationship between the *Environment* and the effect on **the land**

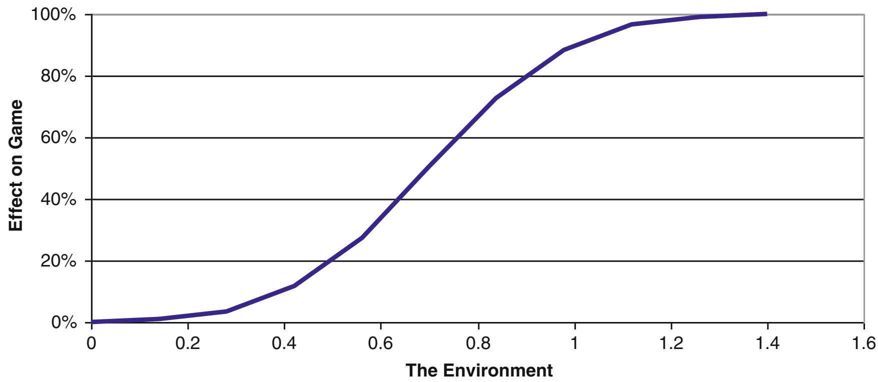

Fig. 8 The relationship between the *Environment* and the effect on **game**

We believe that the performance measure for **Sacred Sites** is a function of all three values in the System Dynamics model (*the economy*, s*ociety* and *the environment*).

If the value for *the economy* in the System Dynamics model increases and values for *society* and *the environment* stay constant, then it is assumed that more waste is created and the performance measure for **Sacred Sites** will decrease. If the value of *society* in the System Dynamics model increases and the values for *the economy* and *the environment* stay constant, then it is assumed that more waste is created and the performance measure for **Sacred Sites** will decrease. Finally, if the value for *the environment* in the System Dynamics model decreases, then it is assumed that *the environment* has less capability of handling the current amount of waste and the performance measure for **Sacred Sites** will decrease.

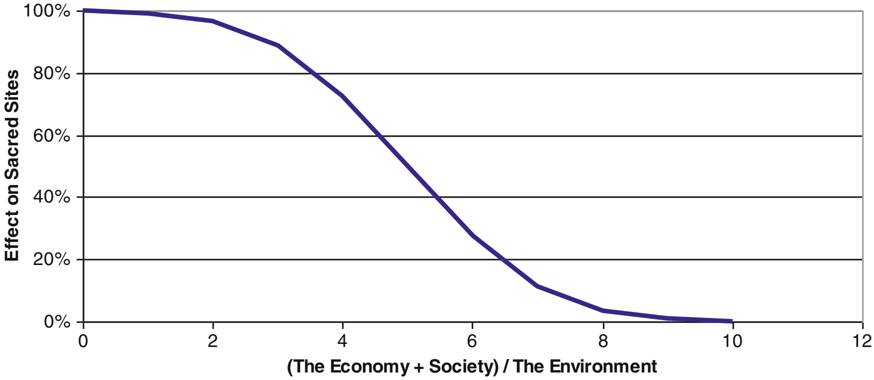

Fig. 9 The relationship between the *Economy*, *Society* and the *Environment* and **Sacred Sites**

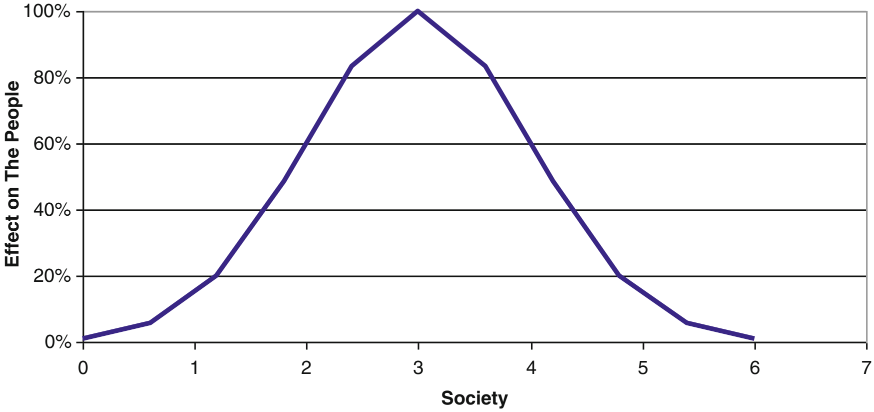

Fig. 10 The relationship between *Society* in the system dynamics model and **the people** performance measure

The performance measures for **Sacred Sites** is currently quite high, nearly 100 %. Figure 9 shows an example Lookup function for **Sacred Sites**.

Let us say that the ideal population is three times the current level in the First Nation. That is, the performance measure for **The People** is 100 % when the value of *society* in the System Dynamics model is 3.0. Figure 10 shows an example of the relationship between *society* in the System Dynamics model and **The People** performance measure.

With the measures of performance for **Infrastructure** and **Job Creation**, the relationship is based on the values of *the economy* and s*ociety* in the System Dynamics model. If the value for *the economy* in the System Dynamics model is increasing, while the value for *society* in the System Dynamics model stays constant, then the performance measures for **Infrastructure** and **Job Creation** would be increasing.

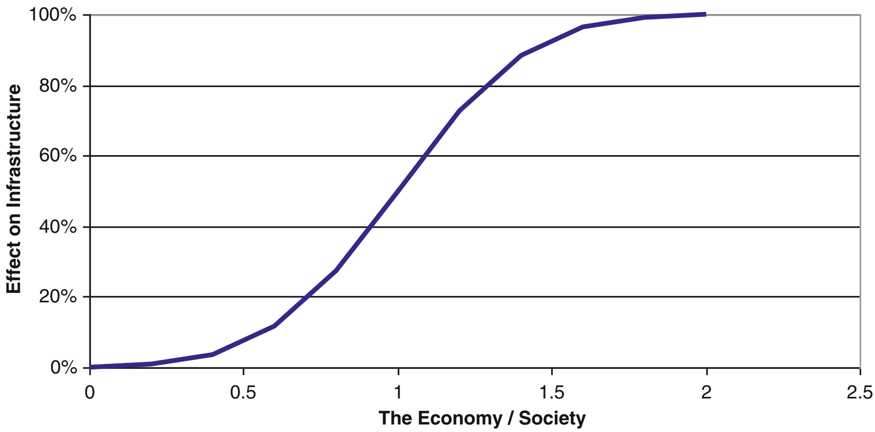

Fig. 11 The relationship between the *Economy*, *Society* and **infrastructure**

In contrast, if the value for s*ociety* in the System Dynamics model is increasing, while the value for *the economy* stays constant, then the performance measures for **Infrastructure** and **Job Creation** would be decreasing.

The performance measure for **Infrastructure** is currently mediocre. Figure 11 shows an example relationship.

The performance measure for **Job Creation** is currently very poor. Figure 12 shows an example relationship.

We hope that by using these orientors (Lookup functions in Vensim) we can translate the results of the System Dynamics model into traditional values in which the First Nations are interested.

4.2 Example Results for the Performance Measures

Figures 13, 14 and 15 are displays of the performance measures that were calculated from our example run of the System Dynamics model with our example Lookup functions.

The performance measures for **The Land** and **Game** are a function of *the environment* in the System Dynamics model. We have seen that because the quality of *the environment* is expected to become very poor with high levels of pollution, after 20 years of development, the performance measures for **The Land** and **Game** drop to nearly zero (see Fig. 13).

The performance measure for **Sacred Sites** is also a function of *the environment* although slightly more complicated. This performance measure shows basically the same behaviour as **The Land** and **Game** (see Fig. 13).

This impact of development on **The Land**, **Game** and **Sacred Sites** likely would not be acceptable to First Nations. Therefore, development options that do less

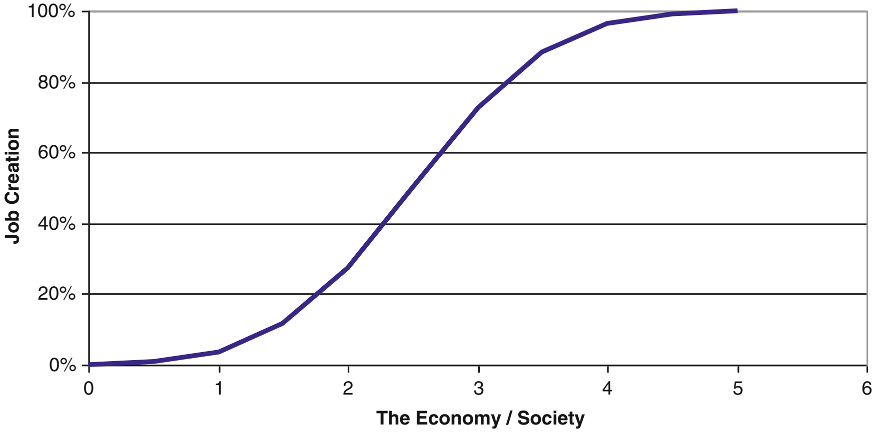

Fig. 12 The relationship between the *Economy*, *Society* and **job creation**

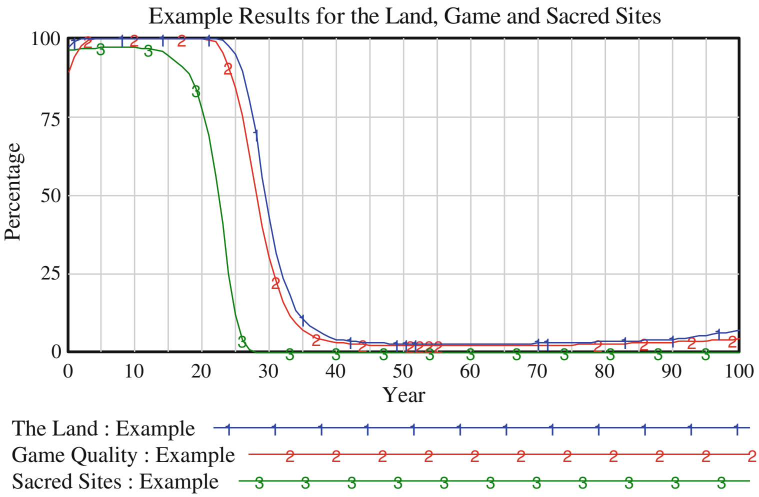

Fig. 13 Example results for **the land**, **game** and **Sacred Sites** performance measures

harm to *the environment* would need to be considered. This could be obtained by options that result in less degeneration or options that invest in more regeneration (see Fig. 2).

The **Job Creation** values start quite low because of the nature of the Lookup function's initial setting. However, as *the economy* picks up and the population drops off in later years, these values eventually increase to almost 100 % (see Fig. 14).

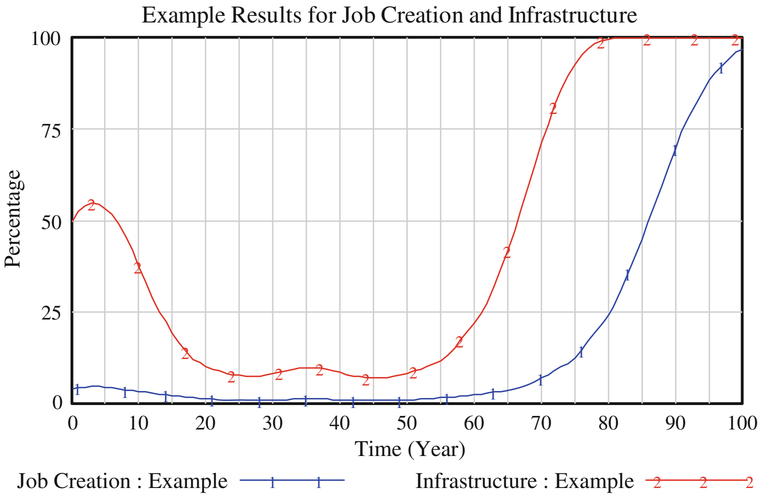

Fig. 14 Example results for **job creation** and **infrastructure**

The values for **Infrastructure** start off at a mediocre level because of the nature of the Lookup function's initial setting that is assumed. It declines rapidly because the rapidly increasing population expected in the community out paces *the economy*. However, in later years, *the economy* picks up and population drops off, so the value for **Infrastructure** begins to increase and quickly reaches 100 % (see Fig. 14).

The high values in later years for **Job Creation** and **Infrastructure** are somewhat deceiving. The high levels of **Job Creation** and **Infrastructure** are more a function of the reduced population in later years than they are a function of improvements in *the economy*.

Recall that the performance measure for **The People** is based on an ideal population. Examining the results from the System Dynamics model for *society* in Fig. 6, we can see that around year 20 the population is approaching the ideal value. However, for the next 15 years, the population greatly exceeds the ideal population. So the performance measure for **The People** approaches and settles at around 0 %. Then around year 35 (see Fig. 6), the population begins to decrease from the high level back down towards the ideal population. So the performance measure for **The People** approaches 100 % again. However, we can see from Fig. 6 that the population continues to decrease past the ideal value after year 55. So the performance measure for **The People** again approaches 0 %.

This result for the performance measure for **The People** is somewhat misleading. There is actually only one cycle, not two. This is a case of the classic problem, called "overshoot and collapse", found by Forrester (1971) in the early sustainable development System Dynamics models. The high rate of growth causes the

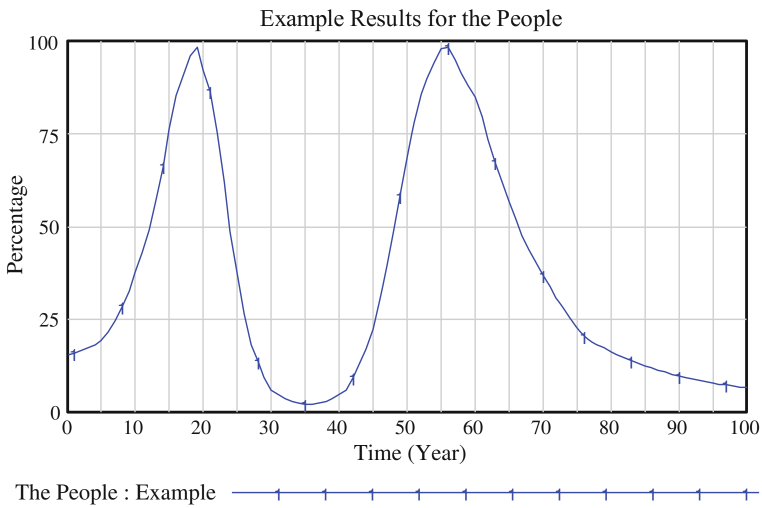

Fig. 15 Example results for **the people**

population to exceed (overshoot) the sustainable level and because this high level of population is not sustainable this results in a subsequent rapid decline (collapse). The two cycles shown in Fig. 15 are a result of the fact that the ideal population is approached twice once while on the ascent and once while on the decline.

5 Summary and Conclusions

The First Nations of Canada have an instinctive knowledge of systems thinking in their culture, traditions and values. They will apply this systems thinking approach to the issues surrounding their economic development. They believe that sustainable development requires a strong connection between the environment, society and the economy. First Nations describe their systems thinking approach to sustainable development using various traditional values. These values need to be considered and measured in any attempt to support their economic development.

Drawing upon the 'systems approach' rooted in the cultural heritage of the First Nations, we have attempted to operationalize the quality of the environment, society and the economy that the First Nations are interested in, using a classical System Dynamics model. Also we have developed a Lookup function approach to translate the results from the System Dynamics model into the performance measures representing traditional and cultural values.

We hope this adaptation of First Nations' intuitive systems thinking approach using their own terminology will lead to acceptance of our support in their sustainable development.

References

Ackoff R (1994) Systems thinking and thinking systems, system dynamics review. 10(2–3): 175–188

Bossel H (2007) Systems Zoo 3: simulation approaches, economy, society, development. Books on Demand GimbH, Norderstedt

Edson R (2008) Systems thinking applied: a primer. ASysT Institute http://www.anser.org/docs/systems_thinking_applied.pdf. Accessed 24 July 2015

First Nations, Wikipedia (2015) https://en.wikipedia.org/wiki/First_Nations. Accessed 2 March 2015

Forrester J (1971) World dynamics. MIT Press, Cambridge

King T (2013) The inconvenient indian: a curious account of native people in North America, Anchor Canada

Northern Ontario Ring of Fire (2015) http://en.wikipedia.org/wiki/Northern_Ontario_Ring_of_Fire. Accessed 13 March 2015

Senge P (1990) The fifth discipline. Currency doubleday, New York

The Next Chapter (2014) http://www.cbc.ca/radio/thenextchapter/shelagh-s-extended-conversation-with-thomas-king-and-leanne-simpson-encore-1.2842615, 28 Jan 2014. Accessed 4 March 2015

Vensim Home Page (2015) http://vensim.com/. Accessed 2 March 2015