Information Knowledge Systems Management 10 (2011) 175–188
DOI 10.3233/IKS-2012-0192
IOS Press

Chapter 10

How to watch the right butterfly: Some guidelines for the design of emergency response organizations

Tim Haslett*

Abstract: This paper proposes a methodology for the assessment and redesign of emergency response organizations. The paper takes a multi-methodology approach and discusses a series of well-established theoretical frameworks to provide accessible and easy to understand processes for practicing managers. The paper begins by highlighting the non-linear and catastrophic nature of civil emergencies as the basis for organizational design. The methodology proposed to sequential. The first stage uses Pepper's World Hypotheses as a means for assessing organizational responsiveness. The second stage applies Checkland's CATWOE and stakeholder analysis as a means to applying the "wisdom of crowds" to organizational design. The third stage involves scenario planning using qualitative System Dynamics and causal loop diagrams. The fourth stage applies elements of Stafford Beer's Viable Systems Model to the process of environmental scanning. The fifth and final stage is a discussion of the need to build organizational learning into the adaptive capabilities of the organization.

Keywords: Emergency organizations, catastrophic shifts, Pepper's World Hypotheses, System Dynamics, Stafford Beer

1. Introduction

> "In the modern world we are faced with innumerable and multifaceted difficulties and issues which cannot be captured in the minds of a few experts and solved with the aid of some super-method. We are faced with "messes", sets of interacting problems, which ran from the technical and the organizational to the social and political, and embrace concerns about the environment, the framework of society, the role of corporations and the motivation of individuals" (Flood and Jackson, 1991 pg xi).

Flood and Jackson argue that management science must address the diversity of the messes confronting managers by developing a rich variety of methodologies appropriate to the problem situation. They cite examples of the application of such methodologies:

- Optimizing the number and arrangement of supermarket checkout points to reduce waiting time
- Designing a petrochemical plant
- Pollution control for authorities
- Structuring an organization for an environment of rapid technological and market change
- Decision-making on police resources location in dealing with vice in the major city

*Corresponding author. E-mail: thaslett@bigpond.net.au.

– Assisting in industrial disputes
– Helping debate among adherents of different doctrinal positions in the Anglican Church

This approach, known as Total Systems Intervention (Flood, 1994, 1995, 2003; Jackson, 1999, 2006; Mingers, 1996; Mingers, and Brocklesby, 1997; Munro, and Mingers, 2002) is designed to address "messes' a term coined by Russell L. Ackoff (1974) who described messes: "[Situations where]. . . every problem interacts with other problems and is therefore part of a set of interrelated problems, a system of problems. . . . I choose to call such a system a mess." or "wicked problems", a term coined by C. West Churchman (1967) to describe situations that have incomplete, contradictory, and changing requirements that are often difficult to recognize.

(For a more detailed definition see: http://en.wikipedia.org/wiki/Wicked_problem).

This paper addresses a special class of wicked problem: one where the problem or system state undergoes a large and rapid transition with disastrous consequences. The widespread and devastating effects of natural disasters have been widely documented: insurance risk (Doherty, 1997), ecosystems (Scheffer, 2001), impact of climate change (Ling et al. 2007), discuss instances of catastrophic and chaotic events. In addition, there is increasing emphasis on the means for managing (Cappola, 2011; Perry, 2007; Steinberg and Cruz, 2004) and mitigating such events (Godschalk, 2003).

These events are catastrophic, in that the changes in the behaviour of system are massive and rapid and the system begins to operate under completely different conditions. These events are chaotic, in that the type and extent of the change was not predictable and the change was brought about by relatively small change(s) in some part of the system. This is variously described as "sensitivity to initial conditions" or more popularly the "butterfly effect" (Lorenz, 1963) or tipping points (Scheffer, 2010) There is a substantial literature of both catastrophic and chaotic behaviours largely aligned with complexity theory, self-organization and agent based modelling. This body of knowledge represents a powerful theory base for understanding the dynamics not only of physical systems, but also the dynamics of large, complex social political and organizational systems. Scheffer et al. (2009). Dakos (2009), Drake and Griffen, (2010) suggest that there may be generic early warning signals for such catastrophes most particularly slower recovery from perturbations, increased autocorrelation and increased variance (Scheffer et al., 2009).

We know from our knowledge of non-linear dynamics, catastrophe and chaos theory that systems can move to new system states in completely unpredictable ways (Zeeman, 1976; Hampton Turner, 1981) This paper brings some elements of existing knowledge to bear on this seemingly intractable problem. In doing this, the paper uses a set of well-known approaches to organizational design. The choice is not prescriptive but indicative of the multi-disciplinary approaches necessary to deal with non-linear changes in an organization's environment (Midgley, Richardson and Gregory, 2006).

While much of this is relatively theoretical and inaccessible for people concerned with the day-to-day running of large organizations, it does indicate that there are warning signs that may alert managers to catastrophic shifts in the system. The challenge for academics and scientists is to find ways to articulate these theories into practical methodologies for the management and structure of organizations. Such methodologies must have a number of attributes in that they must be:

1. Well based in sound theory
2. Articulated into easily understood language
3. Capable of designing of new organizational structures and strategies.

(Stephens and Haslett, 2003)

In Australia, the Victorian bushfires of 2009 represented such a catastrophic and chaotic event. Bushfires are triggered by butterfly effects such as a cigarette butt thrown from a car, a lightening strike, a windborne ember from a fire, a spark from a power tool or fallen power lines. By 2009, climate change drought meant that the immediate conditions in rural Victoria, particularly the fuel load and the weather conditions, were so extreme that the bush fire reached an unprecedented ferocity creating a firestorm that raged for six weeks. These conditions, including winds of 120 km per hour, temperatures in excess of 45C and fire-fronts travelling at 100 km per hour resulted in the loss of 373 lives, horrific wildlife and stock losses and insurmountable ecological degradation. It became clear in the subsequent Royal Commission that the exigent fire fighting services were not equipped in theory or in practice to deal with such a situation. For a commentary on the associated politics of disaster see Olson (2000).

Numerous other examples abound: on a global scale the most spectacular being the GFC and the BP oil spill in the Mexican Gulf, but there are numerous and less widely published examples of smaller local events in business and government.

Both chaos and catastrophe theory indicate that many systems can move from stability to "far from equilibrium" states quickly and unpredictably. The catastrophe models discussed by Guastello (1995, 2009, 2011) indicate that in many cases a very limited number of factors can lead to rapid changes in system state. In more complex system models, such as the swallowtail and mushroom models, more complex sets of causational variables lead to a wider range of possible system states. In chaotic systems, changes in one variable can move the system into a chaotic state. The answer to the famous question: "If a butterfly flaps its wings in Brazil, do you get tornadoes in Texas?" is "Yes, but you need to be watching the right butterfly".

The key question that arises from this situation is: How can we prepare organizations to deal with situations where the environmental conditions are beyond anything previously experienced (i.e. where the "once in a hundred years scenarios" begin to occur on a regular basis)? Part of the answer involves developing an understanding of the nature of non-linear, catastrophic and chaotic events. The key to controlling, managing or influencing them lies in understanding the structure and causation of these events and then designing structures and process with sufficient requisite variety (Ashby, 1956) that are capable of mitigating them.

This paper proposes a number of general models and some simple processes that will enable organizations to improve their preparedness for such situations. This model has five components, the first two of which have a diagnosis and design focus, while the remaining three have a planning and engagement focus. The five components are:

1. Diagnosis of organizational fitness
2. Stakeholder engagement
3. Scenario planning
4. Organization design
5. Evaluation and learning

The necessary first step is to understand the need for a shift from a "closed system" view of organizations, where internally generated rules and procedures predominate, to an "open systems" view, where the capability for rapid and flexible responses predominates. It is proposed that using Pepper's (1942) World Hypotheses as a form of organizational analysis provides a simple and effective means for understanding the ability of an organization to respond to a rapidly changing environment.

Table 1
Pepper's World Hypotheses

	Root metaphor	Paradigm	Organizational class
Formism	Classification	Similarity and simple causality	Type I
Mechanism	Machine process	Processes, delays and feedback	Type II
Organicism	Organism	Co-ordinated activities	Type III
Contextualism	Context specificity	Environment influences context	Type IV

2. Diagnosis of organizational fitness and Pepper's World Hypotheses

Pepper (1942) provides a system of frames for modes of thought that can be used as a useful window on an organization. He identified a "root metaphor" corresponding to each of four hypotheses (See Table 1). These root metaphors provide a useful framework for an initial diagnosis of organizational fitness. Pepper's four world hypotheses and corresponding root metaphors are:

Formist Metaphor: This is a taxonomic or classification approach to understanding. Giving everything a label within a system of labels provides the sense of structural fullness that counts as understanding in this worldview.

Mechanist Metaphor: People operating out of this worldview explain things by cause and effect relationships of parts within a whole.

Organicist Metaphor: This is a systems approach to understanding, focusing on organic wholes that are more than the sums of their interacting parts. It is a view of forests instead of trees.

Contextualist Metaphor: This approach to understanding is embedded in the particular historical and contextual circumstances that make this situation unique. It is a relativistic way of seeing the world.

http://paei.wikidot.com/pepper-stephen-four-world-hypotheses

It is proposed that these four will hypotheses be used to benchmark organizations as Type I, II, III, and IV to indicate the response capability of an organization so that an assessment of organizational flexibility and responsiveness can be made by examining the extent that organizational structures and processes reflect each of the four hypotheses.

In reality, most organizations will have elements of each one of these four hypotheses present in their structures and processes. However, one is likely to be the dominant metaphor within the organization.

Type I Organizations (predominantly formist) will be preoccupied with distinctions and classifications of various phenomena, an example is the apartheid system in South Africa which functioned primarily on formism with classification being based on skin colour. Such systems deal with very high degree of certainty and predictability and function in highly stable (and repressive) environments.

Type II Organizations (predominantly mechanistic) will have machine driven capabilities and be characterized by high levels of predictability but unlike formist organizations have an ongoing dynamic function. Such organizations are also characterized by long-term planning activities. Prime example examples of such organizations are transport systems where stability and predictability of ongoing systems are highly desirable attributes.

Type III Organizations (predominantly organic) are characterized by a holistic and integrated approach to the operations, particularly in relation to the internal functioning of the company. This means there will be a high level of coordination and synergy between various elements within the company and an absence of isolated operational silos. Computer-integrated manufacturing systems are typical of this type of organization.

Type IV Organizations (predominantly contextual) are those that are capable of adaptation in response to environmental change through an environmental scanning capability and mechanisms capable of operationalizing environmental and competitive information. Most organizations that operate in a competitive market environment will have elements of this within their organizational structures. Retail chains are an example of organizational structures that have elements of contextualism and mechanism. A marketing department that is capable of significant adaptation of the product range in response to customer demand is a contextual element while the physical structures, often retail outlets and the logistics chains, are highly mechanistic.

In a further step towards applying Pepper's hypotheses to practical areas of management, Barton, Stephens and Haslett (2009) related Pepper's hypotheses to contemporary approaches in systems thinking. Traditional, objectivist approaches to systems thinking relate to Pepper's first and second hypotheses, while contemporary constructivist approaches relate to the third and fourth.

In situations where the external environment is relatively stable, the first two systems, formism and mechanism are adequate. However, in situations of environmental instability the coordination of the organic organization and the adaptive capabilities of the contextual organization are necessary for effective operations. However, if organizations are to deal with situations characterized by highly unpredictable instability, such as extreme bushfires, flooding earthquakes or widespread urban rioting then the capabilities of the organic and contextual organizations are required.

There are two specific problems for organizations that charged with responsibility for responding to such natural disasters. The first is how to respond to situations that may be, in the worst-case scenario, beyond the organization's capability control and the second is how to build preventative measures that have the capability to mitigate the worst-case scenarios (McEntire, 2001). In the first case, it is a question of a coordinated response capability whereas in the second it is a case of environmental scanning and extensive scenario planning. These capabilities are inherent in both the organic and contextual organizations.

Pepper's World hypotheses provide a framework for managers to evaluate the relative capability of their organizations to respond to extreme events. Organizations that are charged with coordinating the response to natural and civil disasters and whose major response capabilities fall into the Type I and Type II categories will have the capability limited by the extent of the scenarios that they have currently classified and by a machine driven response capability. This means that the response of the organization is limited by its past experience and its capability is limited by its current rules and procedures.

This simple model enables managers to examine and understand the functioning and limitations of their organization. An organization whose root metaphor is formism will deal with situations according to its prevailing taxonomy and respond to situations that appear to be similar in similar ways. Causes of variation will become less important because the classification system is designed to pick up regularity rather than variation. At the other end of the continuum, analysis of situations will depend entirely on context, in which case an organization will have significant redundancy to deal with a wide range of different situations. Applying this simple analysis allows managers to gauge where the organization sits on the root metaphor continuum and whether the positioning of the organization provides the capability for appropriate responses.

3. CATWOE and stakeholder engagement

The initial discussion in this paper suggested that emergency response organizations are faced with external environments that are capable of making technically catastrophic shifts in the system states.

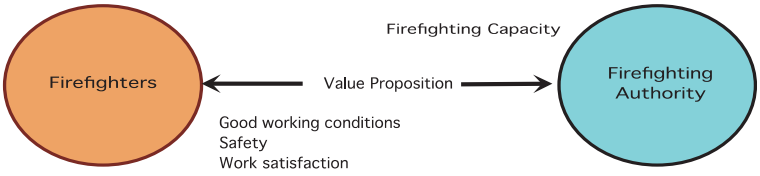

Fig. 1. Two-way value proposition for fire authority and workers.

It was further suggested that the potential for such shifts, if not the exact nature of the shift, may be predictable. While it may be technically difficult to collect the data that is indicative of such catastrophe shifts, it may be possible to construct human systems that have some potential to provide this capacity. Recent work on the wisdom of crowds (Surowiecki, 2004; Oinas-Kukkonen, 2008) suggests that dispersed, independent and expert information systems may provide accurate predictive information for organizations. Checkland (1981,1990, 2000) designed CATWOE, a stakeholder analysis methodology that provides a means for gathering that specific information.

CATWOE is a descriptive framework that is useful as a framing exercise and providing a perspective for the formulation of the Root Definition or purpose of the organization and for identifying the groups or individuals who will provide the "crowd wisdom" that may provide useful as a predictive mechanism for catastrophic environmental shifts. The elements of a CATWOE analysis define these elements:

- Clients – those who benefit (or suffer) from the operations of the organization such as customers
- Actors – the individuals, groups, institutions and agencies who perform the functions of the organization
- Transformations – the processes that transform inputs to outputs
- Weltanschauung or world-view is the bigger picture into which the situation fits and incorporates the way the organization views the world
- Owners – the people who have ultimate say over the project who provide the resources and who can pull the plug
- Environment – the broader constraints that act on the situation. These may be ethical limits, the laws, financial constraints or limited resources

The final stage of the CATWOE analysis is to establish the Value Propositions that constitute the two-way exchange of value between the organization on one hand and the clients and owners on the other. These value propositions are indicative of the relationships that must be maintained to keep the organization viable. This stage in the analysis can ensure that someone has responsibility for managing and maintaining the exchange of value.

This process is then expanded to include all key stakeholders, both internal and external. During this process, the organization will need to make a number of "boundary calls" on who to include and who to exclude.

Once a comprehensive map of stakeholders and value propositions has been constructed, the organization can formulate the Root Definition or purpose of the organization that will encompass each of the value statements. This exercise defines the scope of the management task in terms of managing both internal and environmental dynamics and plays an important part in establishing the context for a Type IV organization,

More importantly, it identifies the group of people who may form the predictive capability for the organization. Such a group, armed with the theoretical knowledge of tipping points or catastrophe shifts, may be able to identify palpable warning signs and causal connections in the system's behaviour. Their

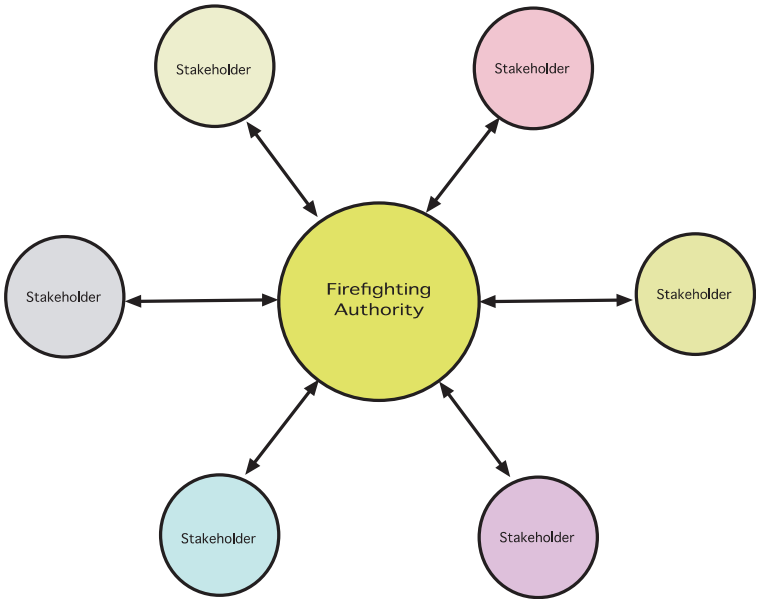

Fig. 2. Multiple stakeholders and value propositions.

role and function will be described later in the paper in terms of System 4 in Stafford Beer's Viable Systems model (Beer, 1971). The tool for harnessing this "crowd wisdom" is primarily qualitative System Dynamics modelling.

4. Scenario planning and system dynamics

Once the context of the management task has been defined, it is then possible to use System Dynamics (SD) modelling (Forrester, 1961, 1969,1971; Sterman, 2000) to begin defining the elements that may constitute which parts of the organization have the potential for non-linear or catastrophic change (Randolf, 2002; Cooke, 2003: Cooke and Rohleder, 2006). Causal loop diagrams (CLDs) are a simple and robust tool for capturing critical dynamic (Wolstenholme and Coyle, 1983; Wolstenholme, 1999) and represent the qualitative methodology of SD. The CLD shown below sets out the dynamics of changes in the workforce. It shows the impact of long-term vacancies and the delays in filling positions. Over time, this situation develops into a "rookies and pros" archetype where the combination of long training times and long lead times in recruitment trigger a decline in the capability of the organization. Such a decline has the potential to adversely affect the organizations ability to respond in times of crisis.

After stakeholders have built the CLD, they postulate a reference mode or "Behaviour over time" (BOT) graph that is a free hand sketch of the expected behaviour of the system in question.

In this case, it is suggested that once experienced staff decline to a critical level, there is a non-linear change in organizational capability. The final stage of this process can involve building a computer simulation model to quantify and understand the critical threshold in the system.

The goal at this stage in the process is to engage stakeholders in building contestable scenarios to identify which part of the organization's environment have the potential for non-linear or catastrophic change.

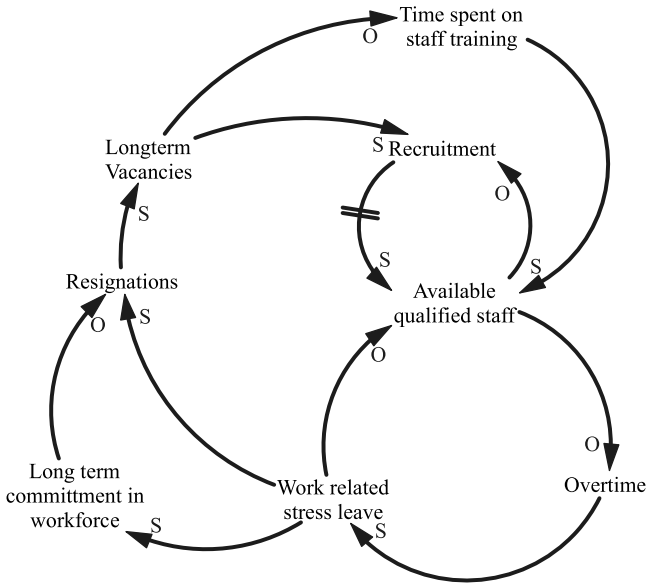

Fig. 3. CLD demonstrating dynamics of fire-fighting resources.

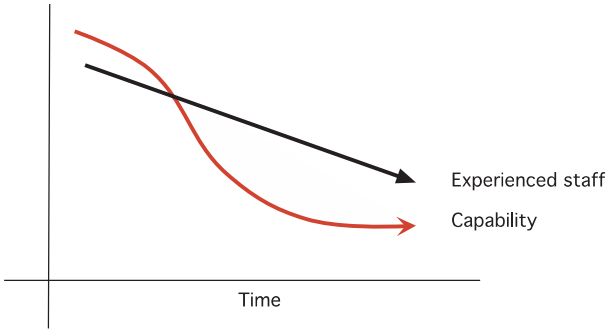

Fig. 4. Linear decline in staff triggers non-linear decline in capability.

5. Organization design, the Viable Systems Model and requisite variety

Following Chandler's (1962) view that structure follows strategy, the next stage in the process is to apply Stafford Beer's (1971) Viable Systems Model (VSM) to the design of the organization. The VSM is based upon the organic metaphor of the management system being the brain of the organization. The VSM consists of five interrelated components (Stephens and Haslett, 2011)

- System 5: The brains trust or senior brain functionality. The part of the organization that ultimately determines the strategic policies that the organization will follow.
- System 4: The engine room of the Brain. The Intelligence, the gathering of information through the connection of the muscles and organs with the outside world that looks at planning, forecasting and predictive strategy for the organization.
- System 3: The floor or base of the Brain. A system that controls the complexity of the muscles and organs in System 1 and maximizes the inner functionality of the organization.

- System 2: The system that oversees the muscles and organs, a system that stabilizes their interaction. Identified as the sympathetic nervous system, it coordinates or calms down any fluctuation or inconsistency in the operating system of the organization.
- System 1: The muscles and organs. The parts of the organization that actually do things. They provide for the fundamental activities of the system. They can be described as the operations that make the organization tick.

The elements that are the most importance in building Type IV Organizations are Systems 4 and System 1. These are the two systems within the VSM that have direct contact with the external environment through the operating system and through the intelligence gathering system. Systems 4 and, to a lesser extent, System 1are responsible for the flow of information into the organization to ensure it is maintaining its value propositions. Establishing strong Systems 4 and System 1 organizational capability must be supported by communication networks and operational competencies. This can be achieved by apply the law of requisite variety.

Closely linked to the idea of the VSM is the Conant/Ashby Law of Requisite (Conant, 1981) variety that states that required autonomous systems need to acquire an internal model of their environment to persist and achieve stability or dynamic equilibrium. Or put more simply, the organizations structure and capability must reflect the variety in the environment. For example, if a bushfire can travel at 60km per hour, then emergency warning and evacuation systems must be capable or responding in the shortest time that fires are likely to reach populated areas.

The organizational implications of this are that organizations need to build sufficient redundancy around key environmental factors that have the potential for non-linear change. However, this means that there will always be excess capacity and capability during non-emergency periods. The challenge therefore becomes one of maintaining a capability without incurring the excess costs of extended periods of downtime.

6. Organizational learning and adaptation

The literature on fitness landscapes (Kauffman, 1989a, 1989b, 1993; Holland, 1989, Dooley, 1997) provides a useful metaphor for understanding the impact of the forces of natural selection in biology. Here, evolution selects the fittest through "test" on the fitness landscape. Such process can take millennia, time periods that most organizations do not enjoy. It is therefore necessary for organizations to speed up that process of adaptation on their respective fitness landscape. This process can be achieved by applying the principles of organizational learning. Fundamental to organizational learning are the processes of hypothesis creation and testing shown as a spiral process in Fig. 5 (Kolb, 1984; Senge, 1990).

This process implies that the organization will be actively involved in the construction and testing of causal hypotheses about the nature and effectiveness of the organization's interaction with the environment. Once such processes are well established within the organization structure, the organization has the potential to be proactive, rather than reactive, in relation to environmental change (Stephens and Haslett, 2004).

A structured and deliberate approach to organizational learning allows an organization to learn from its successes as well as its mistakes and also to be deliberate about the way in that it incorporates the learning from that process into its formal structures.

The need for such learning is clear. In the wake of the Ash Wednesday Victorian Bushfires of 16 February 1983 it was found:

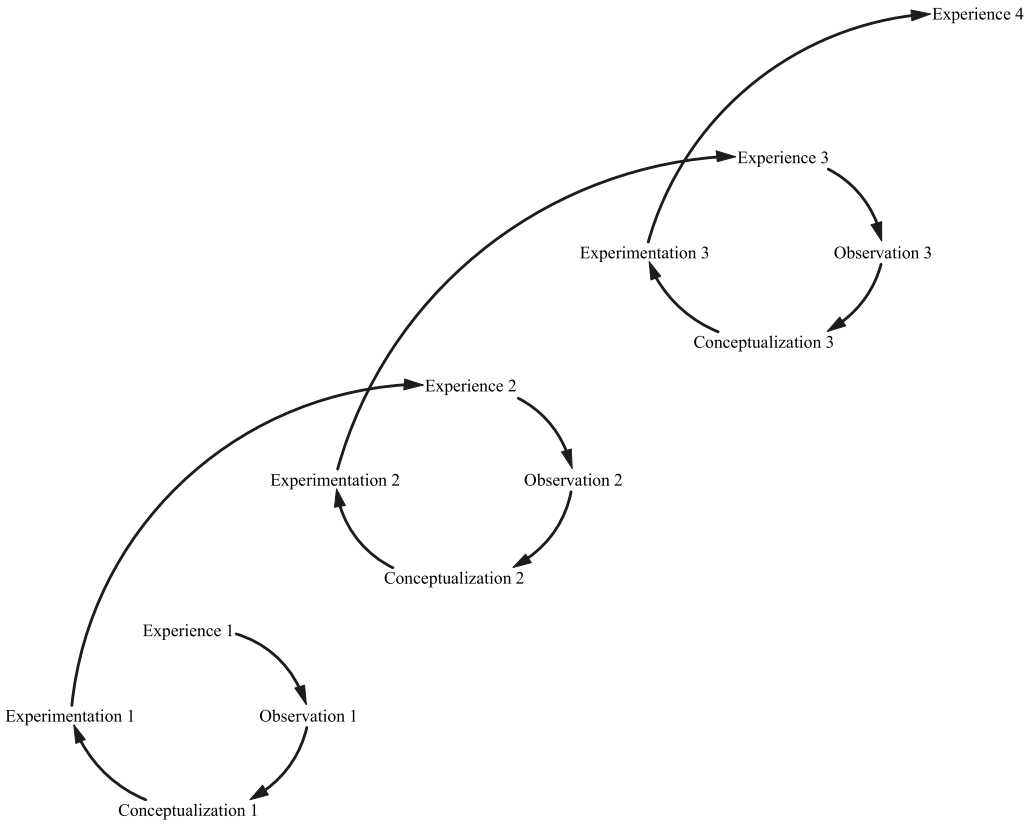

Fig. 5. Learning spiral after kolb.

"Many of the Victorian fires were thought to have been caused by sparks between short-circuiting power lines, and tree branches connecting with power lines

http://en.wikipedia.org/wiki/Ash_Wednesday_fires

In 2009, in the wake of the Black Saturday Bush fires, it was found "The majority of the fires were ignited by fallen or clashing power lines, or were deliberately lit."

http://en.wikipedia.org/wiki/Black_Saturday_bushfires

7. Conclusion

This paper has argued the case for a multi-method approach to the design and operation of emergency services organizations. Such approaches have been proved useful in situations that are characterized by complex sets of interactions in the physical environment and complex relationships between stakeholder groups. Such a requirement is common for most organizations, but in the case of emergency services organizations the physical environment has one special characteristic: the capability for rapid and disastrous change, often on an unprecedented scale. It has also argued that designing such a multi-method approach must be based on sound theory and presented in a language accessible to managers.

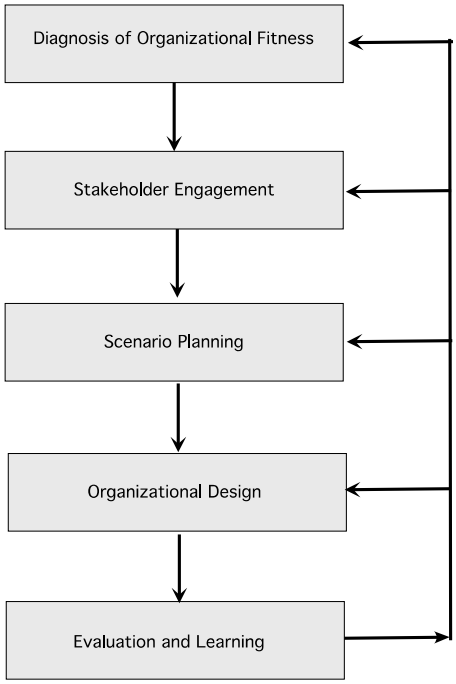

Fig. 6. Pattern of feedback and learning.

The complex interactions between stakeholders and the environment need to be analyzed, understood and, most importantly, managed within a framework, of the potential for catastrophic and non-linear change.

The starting point for such an approach is an understanding of the extent to which the existing organizational structures are capable of responding to such rapid changes in the environment. A simple four-stage model is proposed to form the basis for such organizational analysis. The model is designed to provide a framework for a major analysis of the organization without going into the specific detail of capabilities. This stage of the process focuses on the internal capability of the organization.

The next stage addresses the relationship between the organization and its external environment but most importantly shifts the focus to the information flows about the environment. Given the potential for subtle shifts in the state of the environment to trigger catastrophic changes, it is important that widespread and well-connected information networks support the organizational capability. Designing such networks requires thoroughgoing stakeholder analysis.

Once the appropriate organizational structure is in place and the relationships with external stakeholders and information networks are established, it is then possible to begin planning potential disaster scenarios. The role of the external stakeholders in this process cannot be underestimated as are involved from it broadens the expertise place well beyond that within the organization.

With the scenarios in mind it is possible to fine-tune the structure of the organization taking into account the need for the organization to have sufficient redundancy to cope with the multiplicity of scenarios that have been developed.

The final stage of this organizational is providing structures and processes that ensure that the learning from the successes and failures of the organization's operations can be built into learning cycles for organizational improvement. The capability for organizational learning and change provides the fundamental basis to support the other stages of the development.

Rapidly changing environmental and climatic conditions will pose increasing great challenges full emergency services organizations. The increasing complexity of these challenges will require increasingly complex and multidisciplinary approaches to the design and development of these organizations.

References

Ashby, W. R. (1956). *An Introduction to Cybernetics.* London: UK, Chapman and Hall.

Barton, J.A, Stephens, J.R. and Haslett, T.R. (2009). Action Research: Its Foundations in Open Systems Thinking and Relationship to the Scientific Method. *Systemic Practice and Action Research* (*SPAR*). Volume 22, Number 6.

Beer, S. (1971). *Brain of the Firm.* Great Britain: John Wiley and Sons.

Coppola, D. P. (2001) The Management of Disasters *Introduction to International Disaster Management* (*Second Edition*), 2011, pp. 1–35.

Checkland, P. B. *Systems Thinking, Systems Practice*, John Wiley and Sons Ltd. 1981.

Checkland, P. B. and Scholes, J. *Soft Systems Methodology in Action*, John Wiley and Sons Ltd. 1990.

Checkland, P. B. (2000). Soft Systems Methodology: A thirty year retrospective. *Systems Research and Behavioral Science*, 17, 11–58.

Conant, R. (1981) *Mechanisms of Intelligence: Ross Ashby's papers and Writings* Intersystems Publications.

Doherty, N, A. (1997) Innovations in Managing Catastrophic Risk *The Journal of Risk Insurance*, Vol 64, No 4, pp. 713–718.

Drake, J. M. and Griffen, B. D. (2010) Early warning signals of extinction in deteriorating environments *Nature* 467, 456–459.

Cooke, D. L. (2003) A system dynamics analysis of the Westray mine disaster *System Dynamics Review* Volume 19, Issue 2, 139–166.

Cooke, D. L. and Rohleder, T. R. (2006) Learning from incidents: from normal accidents to high reliability *System Dynamics Review* Volume 22, Issue 3, Autumn (Fall), 213–239.

Chandler, Alfred Dupont. (1962) *Strategy and Structure: Chapters in the History of the Industrial Enterprise.* Cambridge: M.I.T. Press,

Dakos, V., van Nes, E. H., Donangelo, R., Fort, H. and Marten Scheffer, M. (2009) Spatial correlation as leading indicator of catastrophic shifts. *Theoretical Ecology* Volume 3, Number 3, 163–174.

Dooley, K. J. (1997) A Complex Adaptive Systems Model of Organizational Change, *Nonlinear Dynamics, Psychology, and the Life Sciences*, Vol. 1(1): 69–97.

Flood, R. L. (1994) I keep six honest serving men: They taught me all I knew, *System Dynamics Review* Volume 10, Issue 2–3, 231–243.

Flood, L. and Jackson, M. (1991) *Creative Problem Solving: Total Systems Intervention.* John Wiley and Sons.

Flood, R. L. (1995) *Total Systems Intervention* (*TSI*)*: A Reconstitution* The Journal of the Operational Research Society Vol. 46, No. 2, 174–191.

Flood, R. (2003) *Total Systems Intervention: Local Systemic Intervention* Systemic Practice And Action Research Volume 4, Number 3, 197–213.

Forrester, J. (1961) *Industrial dynamics.* Waltham, MA: Pegasus Communications.

Forrester, J. (1969) *Urban Dynamics.* Pegasus Communications.

Forrester, J. (1971) *World Dynamics.* Wright-Allen Press.

Godschalk D. R. (2003) Urban Hazard Mitigation: Creating Resilient Cities *Natural Hazards Review* 4:3 136–144.

Guastello, S.J. (1995) *Chaos, Catastrophe and Human Affairs. Applications of Nonlinear Dynamics to Work, Organisations and Social Evolution* Lawrence Erbaum Associates, Mahwah, New Jersey.

Guastello, S.J. (1995) *Chaos, catastrophe, and human affairs: Applications of nonlinear dynamics to work, organizations, and social evolution.* Lawrence Erlbaum Associates.

Guastello, S.J., Koopmans, M. and Pincus, D. (eds), (2009). *Chaos and Complexity in Psychology: The Theory of Nonlinear Dynamical Systems.* New York: Cambridge University Press.

Guastello, S.J. and Gregson, R. A. M. (eds), (2011). *Nonlinear Dynamical Systems Analysis Using Real Data*. Boca Raton, FL: CRC Press.

Holland, J. (1989). Using Classifier Systems to Study Adaptive Non Linear Networks *Lectures in the Sciences of Complexity*, (ed Stein, D.): Addison Wesley Longman, pp. 463–499.

Holland, J (1995) *Hidden Order* Addison-Wesley, Redding, Massachusetts.

Kauffman, S.A. (1989). Principles of Adaptation in Complex Systems. *Lectures in the Sciences of Complexity*, (ed. Stein, D.): Addison Wesley Longman pp. 527–618.

Kauffman, S.A. (1989) Adaptation on Rugged Fitness Landscapes. *Lectures in the Sciences of Complexity,* (ed. Stein, D.): Addison Wesley Longman pp. 619–712.

Kauffman, S.A. (1993). *At home in the universe. The search for the laws of complexity.* Oxford University Press.

Kolb, D. (1984) *Experiential Learning*, Prentice-Hall, Englewood Cliffs, NJ.

Lorenz, E. N. (1963). "Deterministic Nonperiodic Flow". *Journal of the Atmospheric Sciences* 20: 130–141.

Ling, S. D., C. R. Johnson, C. R., S. D. Frusher, S. D.,and K. R. Ridgway, K. R. (2009) Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift *Proceedings of the National Academy of Sciences of the United States of America*.

McEntire, A. (2001) Triggering agents, vulnerabilities and disaster reduction: towards a holistic paradigm, *Disaster Prevention and Management*, Vol. 10 Iss: 3, pp. 189–196.

Midgley G., Richardson K., Gregory W. (ed.) (2006) Systems Thinking and Complexity Science: Insights for Action, Boston: ISCE Press.

Oinas-Kukkonen, H. (2008). Network analysis and crowds of people as sources of new organisational knowledge. In: A. Koohang et al. (eds): *Knowledge Management: Theoretical Foundation*. Informing Science Press, Santa Rosa, CA, US, pp. 173–189.

Olson, R. S. (2000) Toward a Politics of Disaster: Losses, Values, Agendas, and Blame *International Journal of Mass Emergencies and Disasters,* 18(2), 265–287.

Perry, M. (2007) "Natural disaster management planning: A study of logistics managers responding to the tsunami", International Journal of Physical Distribution and Logistics Management, Vol. 37 Iss: 5, pp. 409–433.

Rinaldi, S. M. (2004) Modeling and Simulating Critical Infrastructures and Their Interdependencies *Proceedings of the 37th Annual Hawaii International Conference on System Sciences* Big Island, Hawaii.

Rudolph, J. W. (2002) Disaster dynamics: Understanding the role of quantity in organizational collapse *Administrative Science Quarterly* Vol. 47, No. 1, pp. 1–30.

Scheffer, M., Bascompte, J., Brock, W. A., Brovkin, V., Carpenter, S. R., Dakos, V., Held, H., van Nes, E. H., Rietkerk, M. and Sugihara, G. (2009) Early-warning signals for critical transitions *Nature* 461, 53–59.

Scheffer, M. (2010) Foreseeing tipping points. *Nature*, vol 467, pp 411 ff.

Scheffer, M., Carpenter, S., Foley, J. A., Folke, C. and Walker, B. (2001) Catastrophic shifts in ecosystems *Nature*, Vol 413, 11 October 2001.

Senge, P. (1990) *The Fifth Discipline: The Art and Practice of the Learning Organization*, Doubleday Currency, New York.

Steinberg, L. J. and Cruz A. M. (2004) When Natural and Technological Disasters Collide: Lessons from the Turkey Earthquake of August 17, 1999 *Natural Hazards Review* 5, 121 ff.

Stephens, J. and Haslett, T. (2003). Demystifying Beer – do you want fries with that? Published in proceedings: *Systems in Management 9th Annual conference of the Australia and New Zealand Systems Society* (ANZSYS). Published by ANZSYS, Melbourne: Australia, Monash University.

Stephens, J. and Haslett, T. (2011 forthcoming) *"An Application of Stafford Beer's Viable Systems Model to the Strategic Planning process"* Systemic Practice and Action Research.

Sterman, J. D. (2000) *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Irwin/McGraw-Hill.

Stephens, J. and Haslett, T. (2004) Action Learning as a Mindset: The Evolution of PICCO *Systemic Practice and Action Research* Volume 15, Number 6, 485–507.

Surowiecki, J. (2004) *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*, Doubleday.

Thom, R., Zeeman, C. and Postle, D. The Cusp of Catastrophe in *Maps of the Mind* Charles Hampden-Turner. Collier Books, 1981.

Varian, H. R. (2007) Catastrophe theory and the business cycle. *Economic Inquiry* Volume 17, Issue 1, January 1979, pp. 14–28.

Wolstenholme, E. and Coyle, R. (1983) The development of system dynamics as a methodology for system description and qualitative analysis *The Journal of the Operational Research* . . . Vol. 34, No. 7.

Wolstenholme, E. (1999) Qualitative vs quantitative modelling: the evolving balance. *The Journal of the Operational Research* Vol. 50, No. 4, Apr., pp. 422–428.

Ying Su, Xiaodong Huang and Zhanming Jin (2009) Modeling Emergency Service Centers with Simulation and System Dynamics, *11th International Conference on Computer Modelling and Simulation*, Cambridge.

Zeeman, E. C. (1976) "Catastrophe Theory" *Scientific American* pp. 65–70.

Author Bio

Dr. Tim Haslett has over 30 years experience teaching in post-graduate and doctoral Management programs at Monash University including as the Director of the Business Action Research Centre. He played a major role in the development and delivery of the Master of Organizational Systems and in the PhD program that developed from it. He also has extensive consulting experience in systems based approaches to change management, managing technological change and strategic management. He has published over 70 refereed conference and journal articles. He is a director of Linchpin Consulting and Ponte Consulting and currently holds an Adjunct appointment at the University of Queensland and will soon be taking up an adjunct position with the newly established Centre for Innovation and Excellence in Prevention a State-funded centre researching the effectiveness of preventative health programs.