Building general resilience in preparation for unexpected risks

Applying Complex Systems Thinking to Disaster Risk Reduction

THESIS SUBMITTED BY

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"Because resilience may not be obvious without a whole-system view, people often sacrifice resilience for stability, or for productivity, or for some other more immediately recognizable system property."

Donella Meadows
MIT scholar and book author, 1941-2001
p. 77, Thinking in Systems: A primer (2008)

Abstract

This thesis investigates the application of Complex Systems Thinking (CST) to Disaster Risk Reduction (DRR) strategies in order to build resilience in preparation for unexpected risks.

The increasing uncertainty and hyper-connectivity in world networks means that the exposure to unexpected risks is rising. National and international DRR strategies have been shown to be insufficient to move countries, states, communities and individuals to prepare in a more responsible way.

Complex Systems Thinking offers a holistic understanding of a disaster in time and space, while appreciating the uncertainty involved in risk management. However, its operationalisation is encountering numerous difficulties because of the reductionist model on which DRR strategies are formulated. This thesis argues that these efforts need to be complemented with systemic methods that may overcome the hierarchical structures in which current DRR strategies are conceived and implemented. This requires systems to develop the ability to be ambidextrous, that is, to keep current DRR structures in place while extending their range to include unexpected events for which no prescribed actions exist. The question arises, how should this be done?

The portfolio of papers and commentary that comprises the substance of the thesis addresses these thematic questions in an integrated way. Taken together, they advance the core argument of the thesis, which is that CST

offers an alternative approach to moving from a reductionist to an ambidextrous mindset; this will enable DRR practitioners to 'think outside the box' and to take better account of the complex systemic conditions in which disasters develop.

Paper 1 shows how disasters are characterised by interacting systems that need to develop the capability to adapt and to be flexible beyond predefined frameworks and regulations in order to be better prepared to face uncertainty. Paper 2 highlights that disaster risk reduction operates at the interface between knowable and unknown risks and, for this reason, reductionist and systemic approaches to disaster risk reduction need to be integrated. In Paper 3, these concepts are juxtaposed with the concept of resilience in the Australian context and three scales of enquiry are presented: (1) members of the public from two South Australian councils, (2) the Australian Red Cross and (3) the South Australian Government organisations that are responsible for DRR.

The concept of resilience is further explored in a conceptual framework in Paper 4, where the overall methodology adopted in this thesis is illustrated. Current DRR strategies are overbalanced towards mitigation of identified risks, but neglect to take into account that disasters are largely unexpected events.

'What is preventing communities and institutions from developing a culture of safety and resilience?' Paper 5 addresses this question on an international level and suggests that interdependencies between strategic priorities need to be taken into consideration, if international targets are to be met.

Paper 6 provides an overview of the South Australian DRR context and an integrated cross-scale perspective of potential and systemic constraints that act as barriers to change. Finally, Paper 7 summarises the state of the art of DRR at the South Australian level and suggests possible ways forward.

The final chapter includes key insights and recommendations, while introducing future research steps.

Keywords: Disaster Risk Reduction (DRR), prevention, mitigation, System of Systems (SoS), Complex Systems Thinking (CST)

Preamble

Foreword

This thesis is about resilience and disaster risk reduction. It concerns itself with strategy and common good, risk management and long-term thinking. It offers disaster risk reduction practitioners and academics a new way of seeing the phases of preparation before a disaster is perceived. In particular, it challenges the way uncertainty is tackled in western societies and proposes a new way of thinking rooted in complexity and systems theories.

But how did it all start?

Figure 1.1. Particular of coat of arms of Lizzano. Authorised by Benito Mussolini in 1929.

Resilience has been a background theme for a long time. I originally come from Lizzano, a small town in Southern Italy. Lizzano's coat of arms is an oak tree and among its branches, it reads 'Fracta et ligata refloret', which, translated from the Latin, means 'broken and tied it flourishes'. Legend says that during a storm, the most majestic oak in town was violently struck by the fury of the wind, which caused the two main branches to drop. During the storm the castle, being the safest refuge, had opened its doors to all the people living around the town.

After the storm, the community did not give up on the broken tree and decided to tie the branches to the trunk. Their efforts were rewarded when finally the oak, almost magically, flourished more beautifully than before. The tree became a symbol of resilience. Those in the community had taken care of one another and of their valued tree. The story offers a profound metaphor for the care of human beings for their environment (back then people knew that they were highly dependent on the resources of the land, being primarily farmers).

The message conveyed in this story is powerful: "broken and connected, it now flourishes". I have often contemplated these words and sensed their profound and open meaning, which pervades this thesis.

About the author

My background has influenced the development of this thesis, representing at times strength and at times risk of bias. For this reason, I declare it to the reader here as a matter of transparency.

I have worked in a number of corporate businesses across Italy, Germany, France and Australia, mainly in project and risk management related positions. In 2010, I authored the book 'Risk Management in Complex Projects. An exploratory study to managing unknown unknowns in uncertain environments' published by LAP. I hold a Bachelor degree in Logistics and Production Engineering from the Politecnico di Torino / Free University of Bolzano (Italy) and a Master in Business Engineering from the Karlsruhe Institute of Technology (KIT, Germany).

I am co-founder and board member of the *Sferracavalli| International Festival of Sustainable Imagination* (Italy), Co-Chair of the South Australian Covenanting Committee (reconciliation between Australian First and Second Peoples), board member of the National Voluntary Service Strategic Reference Group of the Australian Red Cross and a volunteer in Emergency Services for the Australian Red Cross.

In the latter role as an Emergency Services volunteer for the Australian Red Cross in South Australia, I have been activated multiple times during heat waves and bush fires between 2012 and 2015, both at the headquarters of the Australian Red Cross, in relief centres and out in the field, to provide support to disaster survivors.

Acknowledgments

When starting to read a book or a thesis, I normally read the acknowledgements because they give me an indication of what it takes to put together the document that I am about to read. It is in that spirit and with gratitude that I write the following.

I acknowledge the financial support of the University of Adelaide through the Adelaide Scholarship International (ASI). In addition, the Australian Commonwealth Government and the South Australian Fire and Emergency Service Commission (SAFECOM) provided financial support (Grant no. NDRP-1213-33) and generous advice during the PhD journey.

Research participants supported this study by volunteering their time and contributing their insights and expertise. I wish to thank: the community members and staff of Community Safety at the City of Onkaparinga; the community members and staff of Emergency Management at the Adelaide City Council; the Australian Red Cross – Emergency Services; the SA Police; the SA Metropolitan Fire Services; the SA Country Fire Services; Safework SA; the SA Department of Environment and Water; the State Emergency Services; Primary Industries and Regional SA; the SA Department of Health and the Department for Planning, Transport and Infrastructure. Thank you.

I am thankful to both my supervisors for believing in me, in my research and stakeholder engagement skills.

I am thankful to my principal supervisor, Professor Vernon Ireland, for initiating me into Complex Systems Thinking and giving me the freedom to explore its application to Disaster Risk Reduction.

My deep gratitude goes to my co-supervisor, Dr. Barry Elsey, for supporting and encouraging me in developing my own critical thinking, for believing in me while questioning my assumptions, thus helping me to sharpen them. I shall always treasure your teachings about life and academia.

I also thank Professor Kristine Gebbie for coffee-time progress checks and wise advice on focus group facilitation.

Thanks to Dr. Robyn Groves, who helped me to express my thoughts in English and assisted with proofreading this thesis. During the last 3 years, I spent long hours sitting at a desk without having any back problems. The merit is Ms. Michelle Langman's – thanks for your wise advice and fun pilates classes.

I thank my family in Italy and Australia for their support and enthusiasm for my research topics. Your positivity and warm attitude helped me endure in the journey and feel at home in this far away country.

Thanks to all the friends that supported me by asking clever questions, proofreading my writing, listening to my complex thoughts, and continuing to be my friend.

Finally, thanks to Rowan who supported me in every possible way, including by solving mysterious formatting issues, cooking, cleaning, proof-reading, listening, and cheering me up. You helped me see this PhD as part of a much bigger journey, that is, life. Thank you.

To the people living in the uncertainty of today

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Abbreviations

ARC Australian Red Cross

CEDIM Centre for Disaster Management and Risk Reduction Technology

CFS Country Fire Services

CST Complex Systems Thinking

DEWNR Department of Environment, Water and Natural Resources

DPTI Department of Transport, Planning and Infrastructure

DRR Disaster Risk Reduction

GAR Global Assessment Report

HFA Hyogo Framework for Action 2005-2015

HL Hazard Leader

KIT Karlsruhe Institute of Technology

MFS Metropolitan Fire Services

NERAG National Emergency Risk Assessment Guidelines

NSDR National Strategy for Disaster Resilience

OECD Organisation for Economic Co-Operation and Development

OSCE Organisation for Security and Co-operation in Europe

SAFECOM South Australian Fire and Emergency Service Commission

SA South Australia (n)

SAPOL South Australian Police

SEMP State Emergency Management Plan

SES State Emergency Services

SMAG State Mitigation Advisory Group

SoS System of Systems

SoSS System of Subsystems

UN United Nations

UNISDR United Nations Office for Disaster Risk Reduction

ZERMC Zone Emergency Risk Management Committee

1 Introduction

This thesis comprises seven publications preceded by an introductory chapter and followed by a conclusion chapter.

The purpose of this introductory chapter is to provide an overview of the overarching foundational elements of this thesis. Starting from my motivation and the problem scenario, I proceed to address key concepts, philosophical and methodological underpinnings of this thesis. Finally,

key concepts, central arguments and knowledge contributions per chapter and publication are summarised in Table 6.

1.1 Motivation

In 2009, I was writing a paper on disaster risk communication as part of a class at the KIT in Germany, when an earthquake killed over 300 people in Italy. Many people died as a consequence of being crashed by collapsing infrastructure. Incident analysis revealed a number of concurrent causes contributing to the exacerbation of the disaster consequences.

The most disturbing details emerged with phone interceptions recorded in the direct aftermath of the incident, where the underlying system of corruption emerged (Massari 2014). This led me to reflect on the complexity of addressing such rooted and systemic risks within the current DRR capacity.

Moreover, in 2010, I was writing my master's thesis on complex risk management in business projects, when the Eyjafjallajökull volcano suddenly erupted in Iceland. European skies were covered with ash to the extent that air traffic was congested for a week. A number of side effects characterised that strategic decision, including significant economic losses, e.g. for the tourism industry, congestion of essential services such as medical flights and many more effects that were not recorded.

The most interesting aspect of the incident was the lack of appropriate strategic instruments and policies to manage the scope of the disaster. The uncertainty of those days was reflected in the fact that decisions to ban and allow air traffic were made on the basis of the same amount of information. Decisions could not be made based on statistical data,

because it was the first incident on that scale. In the absence of enough relevant information, authorities decided that the precautionary principle, also known as the 'better safe than sorry' principle had to be applied.

The incident had an impact on far more people and systems than those that had been prepared to face the risk. In other words, it was a systemic emergency (Cavallo 2010).

Disasters like these show that risks can be divided into at least two families: risks that can be identified and at least theoretically prepared for and risks that cannot be identified until at least after the disaster. It can be assumed that they exist, but there are normally no solid knowledge bases on which to tackle them in the way disaster risks are 'catered for'.

The distinction between these two types of risks that often cannot be distinguished clearly, represented the first milestone of this PhD thesis and the beginning of an iterative experiment, which is reported in the following chapters.

1.2 Novel uncertainties

Disasters are no longer extra-ordinary events. They are increasingly part of daily news: missing planes, destructive floods, nuclear incidents, earthquakes, financial crises, are examples of the disasters that the public has become familiar with over recent years.

Disasters that affect far away countries can also ultimately have an effect on our home countries. For example, the World Trade Centre terrorist attack shocked the entire world and had significant consequences on airport safety measures in the majority of the countries; the tsunami in

2004 is considered the greatest disaster in Scandinavia, because the number of Scandinavian people hit by it was unprecedented and the list could continue with nuclear and environmental disasters.

Why are disasters so newsworthy these days?

A changing climate means the possibility of disaster events with new higher frequencies and intensities, as events such as the 'Super Typhoon Haiyan' in the Philippines in 2013 have shown. The typhoon, characterised by unprecedented wind strength and storm surges, affected over 16 M people and killed 6.300.

As the number and intensity of natural and human-made disasters increases, the world is confronted with new questions concerning civil protection and disaster risk reduction strategies.

The destructive consequences of disasters call for more resilient societies, but how can resilience be built in the face of rising novel uncertainties?

This is the core research question of this thesis.

1.3 What does it mean for Disaster Risk Reduction?

The United Nations Office for Disaster Risk Reduction (UNISDR), which coordinates international DRR strategic thinking, defines DRR as 'the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters'. However, it also acknowledges that 'DRR involves every part of society, every part of

government, and every part of the professional and private sector' (http://www.unisdr.org/who-we-are/what-is-drr).

International DRR strategies such as the Hyogo Framework for Action (HFA, United Nations 2005) or more recently, the Sendai Framework (UNISDR 2015) and national strategies such as the Australian National Strategy for Disaster Resilience (COAG 2011), highlight above all, the importance of assessing risks and preparing for them (Childs et al. 2013).

In Australia, the National Strategy for Disaster Resilience (COAG 2011) has encouraged research beyond the borders of individual organisations, to focus on the empowerment of communities in order to increase their resilience in response to disasters. This strategic goal was formulated in response to bushfires, cyclones and floods that have recently intensified in Australia due to climate change (Steffen 2013). The intent of the National Strategy is to promote collaboration between disaster management practitioners and local communities to build disaster resilience.

Current disaster preparedness strategies often focus on building resilience for known disaster risks. However, disasters are characterised by interdependent and systemic risks that can trigger cascading effects (Lorenz, Battiston & Schweitzer 2009), which are hard to predict. The 'unexpected' is already part of the life of many communities. For this reason, there is an urgent need to investigate ways to prepare for what we are not able to predict or to communicate.

There is another important factor that needs to be considered. Even when disasters are predicted and risks have been identified, survivors report the unexpected nature of their experience facing the disaster and its

consequences. In other words, even consequences of known risks are experienced as *unexpected*. For example, in South Australia, the risk per antonomasia, is bush fire. The unexpected nature of the experience even of 'prepared survivors', that is people who followed institutional preparedness steps, emerges in national and local newspapers (e.g. http://www.adelaidenow.com.au/news/south-australia/bushfire-at-cherryville-in-mount-lofty-ranges/story-e6frea83-1226638759006 with reference to the Cherryville fires in South Australia; The Saturday Age on 13 October 2013 with reference to the NSW fires; The Advertiser on 6 and 7 January 2015 with reference to the Samson Flat fires in South Australia).

Despite survivors' conscious preparation for bushfires, there are sides of the disaster that top-down approaches cannot prepare for sufficiently (Cornell 2015). Is there an alternative that can better prepare people affected by disasters? Attention turns to the central concept of the thesis.

1.4 Complex Systems Thinking

Over the last sixty years, scholars and practitioners have become increasingly aware of the complexity and uncertainty that influence and cause rapid changes in the world. Resilience has been linked to the existence and development of community resources to face 'change, uncertainty, unpredictability, and surprise' (p. 402, Magis 2010).

In disasters as much as in many other sectors, changes often happen in a nonlinear way as a consequence of 'plural causality' (Gilpin & Murphy 2008). This means that a cause can lead to several effects and vice versa, multiple effects can be linked to a number of causes (Fink 1986 in Gilpin & Murphy 2008).

A complex adaptive system is 'a system comprised of a large number of entities that display a high level of interactivity. The nature of this interactivity is mostly nonlinear, containing manifest feedback loops' (p. 7, Cilliers et al. 2001). Therefore, systems thinking is often seen in contrast to the Cartesian paradigm, which is based on the assumption that 'the behaviour of the whole can be understood entirely from the properties of its parts' (p.5, Merali & Allen 2011). On the contrary, complexity science scholars focus primarily on the interactions and relationships between the parts and how these influence the identity of the system being studied (Cilliers et al. 2001).

Table 1.1. Characteristics of a complex adaptive system (adapted from Cavallo 2010).

Characteristics of a complex system	
Large amount	Great number of interacting entities
Nonlinearity of interactions	The system can evolve as a consequence of small perturbations[1], while showing resilience under significant stress as a result of self-organisation
Dynamic system	Continuous evolution of the system
Irreversible evolution	The system cannot be reset to a previous configuration or blocked in a status
Cause-effect relation	An understanding of the cause-effect relationship is possible only in hindsight
Unpredictability	Unforeseeable evolution/development of the system
Incompressibility	The whole differs from the sum of the interacting entities. Interdependencies cannot be simplified in a reductionist manner.
Emergence	Unexpected upcoming event, which has never been experienced before

Like complexity science Ramalingam et al. 2008), Complex Systems Thinking is a collection of ideas from a range of disciplines. In particular, this thesis has been influenced by cybernetics (von Foerster & Poerksen 2001), sociology (Beck 2011; Morin 2007), chaos theory (Prigogine 1996; Weick 2005), complex adaptive systems in the natural sciences (Walker & Salt 2012; Folke 2006; Carpenter et al. 2012; Holling & Gunderson 2002), systems thinking (Meadows 2008; Midgley 2003; Jamshidi 2008; Snowden & Boone 2007; Allen et al. 2011) and semiotics (Peirce 1931-1958 in Eco &

[1] The butterfly flapping its wings and potentially causing a storm is the most famous example by Edward Lorenz (Ramalingam et al. 2008).

Sebeok 1984). Taken together, these theories have helped build the theoretical framework of this thesis.

In this thesis, DRR is addressed as a System of Systems (Boardman & Sauser 2008), that is, as an integrated network of independent, but interdependent autonomous complex systems that contribute towards the achievement of a common purpose (Keating 2009). In the case of DRR, building community resilience, increasing community safety and reducing disaster risks are examples of common purposes.

Table 1.2. Characteristics of Systems of Systems (Maier 1998; Boardman and Sauser 2008).

General System of Systems characteristics	
Autonomy	The ability of a system as part of SoS to make independent choices. This includes managerial and operational independence while accomplishing the purpose of SoS.
Belonging	Constituent systems have the right and ability to choose to belong to SoS. The choice is based on their own needs, beliefs, or fulfilment.
Connectivity	The ability to stay connected to other constituent systems.
Diversity	Evidence of visible heterogeneity.
Emergence	Formation of new properties as a result of developmental or evolutionary process.

Communities, government and non-governmental organisations, schools, religious institutions are examples of complex systems belonging to the DRR System of Systems.

Complex adaptive systems operate in different stability levels (Walker & Salt 2012). For example, different communities operate in different operating spaces. The figure below can help elucidate this example. A community can be considered as a system moving in a basin in an n-dimensional[1] space.

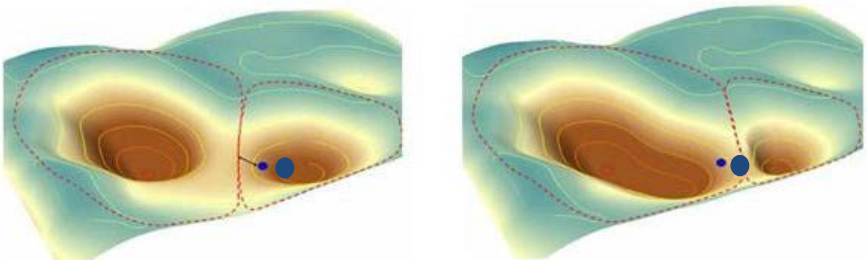


Figure 1.2. Stability levels and thresholds (Walker et al. 2004).

The concentric yellow lines represent the states within a stability level, in which the system orbits presently (Figure 1.2). Possible states within the same basin are characterised by functions and feedbacks. When a disaster occurs, the system (the blue ball) crosses the threshold (red-dotted line) of a stability level and moves into a new basin, that is, into a new stability level. The new stability level can have a different shape, that is, it can be characterised by new functions and feedbacks. In that case, the system behaviour is bound to change, to adapt to new external conditions[2]. For example, the long term displacement of a community after a disaster can cause a change of stability level by forcing the community to adopt new functions, hence to adapt to new routines.

[1] Dimensions can refer, for example, to community connectedness degree, availability of green spaces, number of vulnerable people (Walker & Salt 2012).

[2] The example of the cattle ranchers in Zimbabwe can help clarify this social-ecological theory. A heavy drought killed significant numbers of their cattle. After trying to protect their cattle, they noticed that other wild animals were surviving much better and without much effort. So, they decided to join forces with their neighbours and open a safari park, which proved to be very successful (Cumming 1999 in Walker & Salt 2006).

Hence, the underlying assumption is that communities are complex adaptive systems in which 'properties and patterns at higher levels emerge from localised interactions and selection processes acting at lower scales and may feed back to influence the subsequent development of those interactions' (Levin 1998 in Olsson et al. 2004).

For this reason, the application of Complex Systems Thinking with its feedback logics meets the need of 'continuous testing, learning and developing knowledge and understanding' that according to Carpenter & Gunderson (2001) is necessary to cope with change and uncertainty.

A final remark needs to be made. For many years, Complex Systems Thinking has been seen as an alternative to reductionist thinking and determinism. However, this thesis found that organisations, strategies, systems should be organised following the principle of *ambidexterity*, that is to say, by developing a strategic and organisational ability to apply both reductionism and CST (Cavallo 2014 b). Therefore, this thesis values the significant achievements of reductionist approaches by seeking solutions that complement them, rather than replacing them.

1.5 Research background

This section aims to provide a brief overview of the research activities undertaken during the last three years.

This thesis started with a preliminary phase of research that consisted of a context analysis to better understand needs and agendas of local, state, national and international institutions. A literature review also constituted an important activity during this time and throughout the

duration of the PhD. Ethical approval was granted in December 2012 (H-2012-176).

Within the first six months of the PhD, a grant proposal, written based on the corresponding PhD research proposal, was submitted to and project funding successfully approved by the Australian Commonwealth and the South Australian Government for the period 2012-2014.

In the first instance, stakeholder engagement occurred by using the snowball method to conduct personal meetings. Moreover, an open lecture was organised to attract stakeholders, to gather feedback and to engage the wider community in the conversation on the application of CST to DRR. The open lecture was entitled 'Experts in Complex Project Management: Getting ready for the Unexpected'. Similarly engaged international and national presenters, who had been contacted during the first year of the PhD, were invited to deliver a presentation on their research at their universities before the research project involved in this thesis was to be presented. Each presentation was recorded professionally and uploaded on YouTube[1] in order to reach a higher number of stakeholders in other Australian states and nations. The component of the video regarding the presentation of this thesis has been watched over 500 times, so demonstrating that this method allowed the involvement of scholars and practitioners who would otherwise been difficult to find. Some of these 'viewers' made contact to ask further questions and their comments provided important information to advance the arguments of this thesis.

[1] http://blogs.adelaide.edu.au/ecic/2013/03/06/video-experts-in-complex-project-management/

The following phase involved nine focus group discussions conducted on three levels, or scales, as they are called in the publications that follow after social-ecological literature (Walker & Salt, 2012): community members from two councils (one metro and one peri-urban); the Australian Red Cross Emergency Services, as the biggest non-governmental organisation in South Australia involved in disaster preparedness and prevention, and finally, the group of the government organisations called Hazard Leaders that are responsible for disaster prevention and mitigation of the highest rated risks in South Australia.

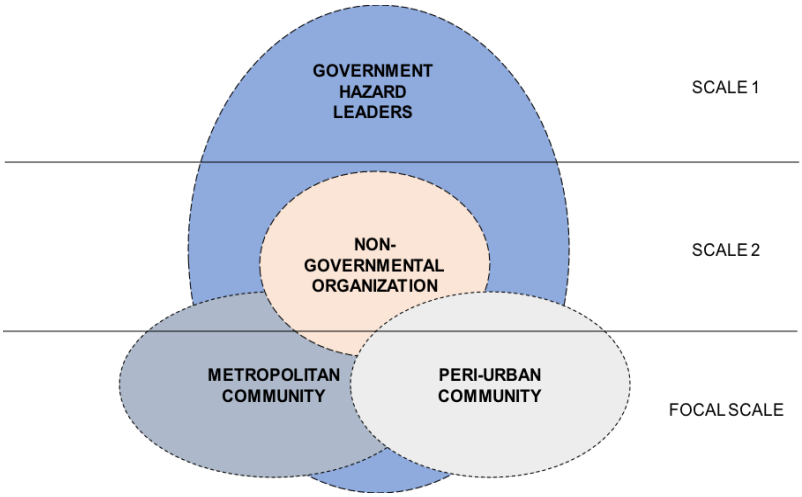


Figure 1.3. Three scales involved in focus group discussions (Cavallo 2015a).

In the same period of the focus group discussions, collaboration with the Risk and Crisis Research Centre at the Mid Sweden University in Östersund in Sweden provided a six week opportunity to conduct interviews with the counterparts of scale 2 and 1 (Figure 1.3) in Mid Sweden. While only one publication (Cavallo 2015a) alludes to this experience, significant insights on resilience emerged from the contrast between South Australia, Mid Sweden and Southern Italy. These were used to stimulate discussion in the focus groups that followed later in 2013 in South Australia.

Stakeholder engagement continued throughout the duration of the PhD. In particular, publications were circulated as soon as they became available.

Data analysis and dissemination were conducted in parallel since the very beginning of the thesis to ensure timely and adequate feedback.

As explained in section 1.4, feedback is an important element in CST. As the thesis progressed in the spirit of abductive reasoning (Cavallo & Ireland 2014), theories were regularly verified against assumptions arising from the continuous exchange of ideas with stakeholders and paper reviewers.

1.6 Applications of main findings to DRR

Taking all the publications together, the applications of the leading ideas and findings arising from the research are highlighted below. These range from the local to the international level in focus and scope.

1.6.1 Locally

- Identify potential for community members to take the lead on resilience building activities in a way that is most appropriate for their community taking into account the strengths and weaknesses of the community and individuals. The principle of 'guided self-organisation' (Helbing 2013) should be observed.
- Put in place strategies that are flexible enough to accommodate new community routines, which, for example, are no longer centred in their neighbourhood as it used to. More research is

needed to investigate how to influence these routines with reference to resilience.

- Create emotional hooks that community members value; in other words, understand their agenda and purposes and integrate resilience building processes based on what community members are already doing, thereby integrating top-down with bottom-up approaches to DRR
- Identify influencers/leverage points within the community and among the systems that have an impact on resilience by including systems beyond the obvious DRR sector or *System of Subsystems* (Cavallo 2014a)

1.6.2 In Australia

- Design feedback policies that provide the possibility to adjust to dynamic environment and community routines on a regular and flexible basis
- Build capacity of the DRR sector to 'think complex' in order to build capacity and capability to prepare organisations and communities to face unexpected risks
- Create a basis for overarching ambidextrous policies that tackle both traditional risk management methods and CST to aim to build specified and general resilience, that is resilience to known and resilience to any risks, including unknown risks
- Train executives of all public sectors (not only DRR) to think in an ambidextrous way, that is to be able to 'think reductionist and complex' depending on the problem to be addressed
- Enhance research in general resilience alongside specified resilience

1.6.3 Internationally

- Capture needs on international level (e.g. World Bank, OECD, UNISDR) that can be only met by applying CST to DRR strategies
- Enhance research on general resilience and the integration of reductionist and CST approaches in DRR
- Educate and train to at least acknowledge complexity
- Implement ambidexterity by integrating teams of experts for reductionist and CST in DRR strategies
- Coordinate ambidextrous projects and programmes to encourage asset based community disaster risk reduction

1.7 Notes on methodology

This thesis seeks to offer a way towards a better understanding of how communities, non-governmental and government organisations perceive the problem and handle it in an interdependent way.

To this end, qualitative studies are needed in disaster risk reduction to reconcile findings from social disciplines to more technical knowledge on disasters. The ultimate goal is to make knowledge available and relevant to DRR practitioners, so that community resilience can be supported and enhanced.

Many approaches to risks are based on historical information. However, as it has been shown in the publications included, disasters are increasingly posing new threats that have never occurred before (e.g. Typhoon Haiyan in the Philippines recorded 'unprecedented wind strength and storm surge' in Cavallo & Ireland 2014).

Statistical studies need to be complemented with studies providing indications on system's general adaptation abilities, because the space in which communities and individuals operate is dynamic.

1.7.1 **Philosophical foundations**

Table 3 presents the philosophical foundations of this thesis, which find expression through the various publications included.

Table 3. Philosophical foundations.

Philosophical foundations			
Ontology	Relativism	Guba & Lincoln 1994	Rejection of naïve realist ontologies; local constructed realities.
Epistemology	Social Constructionism	Schwandt 1994 and Crotty 1998	The society shapes the way we see the world; therefore, reality can be criticised to be improved. A collective generation of meaning is implied.
Theoretical Perspective	Interpretivism	Neuman 2004; Crotty 1998; Bryman 2012	Verstehen vs. Erklären: goal is to understand rather than explaining. The research is successful if the researcher manages to provide an accurate imitation of the Weltanschauung of the people being studied.
Methodology	Soft-Systems Methodology	Checkland & Poulter 2006; Midgley 1997	In their everyday life, people act following different purposes; their worldview needs to be taken into consideration in order to arrive to an approach, which can work for most people.
	Social-ecological systems	Walker & Salt 2012; Holling & Gunderson 2002; Flach 2012	The two extremes of resilience building are in specified and general. Transformability needs to be investigated to better understand how to support communities to prepare for disasters.
Methods	Preliminary interviews; Focus groups; Local, national and international reports; feedback from publications; participation to public hearing	Miles & Huberman 1994; Denzin 1994; McMurray 2004; Bryman 2012; Berg 2001	Stakeholders' worldviews need to be investigated in an integrated way. What collective meaning of resilience building emerges out of their integrated worldviews?

1.7.2 Social constructionism and constructivism

Constructivism and constructionism are often used interchangeably (e.g. Bryman 2012). However, the distinction between these two concepts was very helpful to inform the angle of analysis taken in this research thesis.

The following table illustrates the differences between social constructionism and constructivism (Schwandt 1994).

Table 1.4. Difference between social constructionism and constructivism.

Social constructionism	Constructivism
Society shapes the way we see the world	Every individual has a unique experience
Society provides a view of the world	Everyone has the right to see the world in their own way
Society can be criticised	Nobody can be criticized for their views

In this thesis, the epistemological position reflects predominantly a social constructionist perspective, which acknowledges that concepts such as resilience or risk are heavily influenced by a worldview that is influenced by society. Instead of being about individuals making meanings (constructivist posture), social constructionism is about the 'collective generation of meaning as shaped by convention of language and other social processes' (Schwandt 1994).

However, this epistemological perspective is functional to the analysis in the sense that the thesis took into consideration that there are aspects of life which we learn in a social constructionist way and others that we

learn in a constructivist way. For example, we learn how to write in a social constructionist way, but we learn to grief in a constructivist way.

As clarified earlier, research in DRR needs to rely on an inter-epistemological approach, implying that neither positivists nor hermeneutists can claim to own the entire truth. Building knowledge needs both sides and, more often, several complementary perspectives, which, considered together, can provide a holistic picture of a possible reality.

1.7.3 **Merit in interpretivism**

Nietzsche had noticed that there are no facts, only interpretations (Prigogine 1996). The interpretive approach is often adopted with a constructionist view of the reality. In opposition to the Cartesian spirit of researching in order to explain the external world (*erklären*), the interpretive approach is about understanding (*verstehen*) the worldview (*Weltanschauung*) of research participants and representing how they see the world, feel about it and act (Miles & Huberman 1994; Crotty 1998; Neuman 2004).

The validity of a study depends on the ability of the researcher to have captured the inner worldview of the research participants (Neuman 2004). Accordingly, a theory can be classified according to:

- The level of social reality that the theory explains
- The direction of reasoning. This thesis uses abductive reasoning, which is more appropriate for complex systems (Flach 2012; Kerr 2013)

- The forms of explanation that it employs
- The overall framework of assumptions and concepts in which the theory is embedded

Based on Neuman's (2004) considerations, the following table summarises the steps taken towards theory formation in this thesis.

Table 1.5. Theory formation explained following Neuman's (2004) model.

THEORY FORMATION		
Level of theory	**Micro-level**	SA resilience building processes
	Meso-level	Comparisons of resilience barriers and catalysts
	Macro-level	Specified and general resilience in international Disaster Risk Reduction
Direction of reasoning	Abductive	
Explanation	Interpretive	
Abstraction	Theoretical Framework; Middle-range theory	

Denzin (1994) states that in qualitative research 'Trustworthiness consists of four components: credibility, transferability, dependability and confirmability (these are the constructionist equivalents of internal and external validity, reliability and objectivity; Lincoln and Guba 1985)'. The trustworthiness of this thesis is discussed below by addressing its four components.

Credibility refers to the fact that research participants are the best positioned to judge the merit of the research. Findings were presented

and discussed with research participants. Published papers were circulated to all participants directly or indirectly through council and comments were invited. Participants considered findings credible and thus decided to endorse a subsequent research project (please refer to final chapter for further information).

If results can be generalised or transferred to other contexts, they are transferable. This thesis shows transferability, since it addresses DRR at local, state, national and international level. Moreover, the sense-making framework presented in this thesis has been used also to develop strategic organisational thinking at the Australian Red Cross and can be used to foster innovative and entrepreneurial thinking.

Dependability refers to the ability of the researcher to take into account the dynamic context in which the study takes place. This thesis is dependable because it addresses changes on global scales while considering constraints and barriers to transformation in DRR strategic thinking. One of the main arguments presented is the need for DRR strategies to adapt to dynamic systems that are not always predictable.

Confirmability refers to the extent to which other researchers would arrive at similar conclusions. The confirmability was tested by always having a second person taking notes and by comparing understandings and interpretations of what was being said (Krueger & Casey 2014).

Finally, the validity and merit of this research was also confirmed by the critical peer-review process undertaken as part of the publication of the seven papers included in this thesis.

1.7.4 Limitations of study

This thesis presents a number of limitations.

First, the need to integrate interdisciplinary knowledge into DRR meant that it was necessary to touch on sociological topics without having a full grasp of them. For this reason, concepts such as social capital were explored only with reference to risk management implications rather than from a sociological point of view.

Second, the ambition of this thesis, to have a direct practical influence on DRR in South Australia, required an adjustment of concepts and ideas to the current language and narrative (Meadows 2008) used in DRR in Australia. Every publication was shared with DRR government agencies and the Australian Red Cross, in order to allow direct feedback loops. This means that academic language had to accommodate for a looser, less technical jargon, which coincides more with the sector of application rather than with the theories, being applied (Weick 2005). For this reason, some concepts had to be sacrificed for ease of communication. One example is the social-ecological theories at the basis of this thesis: concepts such as stability levels, thresholds, basins of attraction, all of which had to be avoided. This leads to the third point.

Third, every publication represents iterations in the exploration of the topic. This is the nature of abductive reasoning (Sebeok & Umiker-Sebeok 1984). For this reason, some of the underlying fundamental concepts may seem repetitive, when reading one publication after the

other. However, the sequence of the publications shows the evolution of these concepts and theories, which were also important to introduce the dynamic context of enquiry.

Fourth, this thesis has been conducted in the Adelaide area, where 70% of the South Australian population lives. For this reason, while this thesis addresses DRR in South Australia, it should be noted that large parts of the state were outside the scope of this thesis.

Fifth, the number of participants involved at the community level is low compared to the South Australian population. For this reason, while data saturation was achieved[1], community views were not considered as representative of the entire State. Rather, they were considered as contributions to the understanding of the problem being studied.

Finally, I would like to acknowledge that the necessity to express ideas in writing led to represent findings primarily in a linear reductionist way: 'Words and sentences must, by necessity, come only one at a time in linear, logical order. Systems happen all at once. They are connected not just in one direction, but in many directions simultaneously' (p. 5, Meadows 2008). The choice of writing this thesis by publication allowed more flexibility and a decent amount of theory iterations (Eco & Sebeok 1984; Snowden & Boone 2007).

However, and in spite of these limitations, the spirit of the research was to explore leading ideas, bringing together such important constructs as

[1]Please refer to Cavallo 2015a in Chapter 7.

DRR and CST in order to find ways and means of finding new approaches to a complex problem.

1.8 Format of thesis and contributions to knowledge

Three international conference papers, three journal articles and one book chapter are presented in this thesis. These are reported chronologically below. The first five publications have already been published, whereas the last two have been accepted for publication and are currently in press. All publications have been peer-reviewed.

a) Cavallo, A and Ireland, V (2012). *SoS in Disasters: Why following the manual can be a mistake.* Proceedings of IEEE 7th International Conference on System of Systems Engineering, July 16-19; pp.161-166, Genoa, Italy. DOI: 10.1109/SYSoSE.2012.6384163 ISBN: 978-1-4673-2974-3

b) Comes, T and Cavallo, A (2013). *Designing decision support systems at the interface between complex and complicated domains*. Proceedings of Americas Conference on Information Systems AMCIS2013, 15-17 August, Chicago, Illinois, USA. http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1367&context=amcis2013

c) Cavallo, A (2014a). *Integrating disaster preparedness and resilience: a complex approach using System of Systems*. Australian Journal of Emergency Management, vol. 29, issue 3, pp. 46-51. ISSN: 1324-1540 https://ajem.infoservices.com.au/items/AJEM-29-03-10

d) Cavallo, A & Ireland, V (2014). *Preparing for Complex Interdependent Risks: A System Of Systems Approach to Building Disaster Resilience*. Prepared for the Global Assessment Report on Disaster Risk Reduction 2015, United Nations Office for Disaster Risk

Reduction (UNISDR). Geneva, Switzerland. Published in International Journal of Disaster Risk Reduction, vol. 9 C, pp. 181-193. DOI: 10.1016/j.ijdrr.2014.05.001

e) Cavallo, A (2014b), 'Complex systems thinking: an integral feature of disaster preparedness for unexpected interdependent risks', paper presented at 5th International Disaster and Risk Conference Davos 2014 (IDRC) Davos, Switzerland, 24 - 29 Aug 2014, pp. 139-142. https://idrc.info/fileadmin/user_upload/idrc/documents/IDRC14_ExtendedAbstracts.pdf

f) Cavallo, A (2015a), 'Let's get ready for the Unexpected: A Cross-Scale Study to Support Communities, NGOs and Government to Build Disaster Resilience', The "State of DRR at the Local Level". A 2015 Report on the Patterns of Disaster Risk Reduction Actions at Local Level, United Nations Office for Disaster Risk Reduction (UNISDR), Geneva, Switzerland (in press).

g) Cavallo, A (2015b), 'Complex Systems Thinking in preparation for unexpected risks: A cross-scale study on building general resilience in South Australia', in CN Madu & C-H Kuei (eds), Handbook of Disaster Risk Reduction and Management, World Scientific Press & Imperial College Press, London (in press).

Every publication is preceded by a statement of authorship indicating the work undertaken by the authors.

The following table provides a summary of key concepts, main arguments and knowledge contributions per chapter and publication. Finally, Chapter 9 provides an overview of research findings and future research steps.

Table 6. Key concepts, central arguments and knowledge contributions per chapter and publication.

Chapter / Publication	Key concepts	Central argument	Knowledge contribution	How they fit within thesis
Chapter 2 (a) Cavallo & Ireland 2012	System of systems (SoS); creative disobedience; risk interconnectedness in independent and interdependent systems	Disaster management can benefit from a System of Systems approach	Disasters should be considered as System of Systems A System of Systems perspective of the 2011 Great East Japan earthquake	Paper 1 shows how disasters are characterised by interacting systems that need to develop the capability to adapt and to be flexible beyond predefined frameworks and regulations in order to be better prepared to face uncertainty.
Chapter 3 (b) Comes & Cavallo 2013	Decision theory, emergency and risk management, complexity science, systems theory	Epistemological pluralism and adequate ad-hoc approaches need to be integrated in the design of decision support systems for crisis and emergency management	Formulation of a research agenda to integrate complicated and complex approaches to DRR	Paper 2 highlights that disaster risk reduction operates at the interface between knowable and unknown risks and for this reason, reductionist and systemic approaches to disaster risk reduction need to be integrated.
Chapter 4 (c) Cavallo 2014a	Community resilience, disaster planning and preparation, complex risk management; System of Systems (SoS) vs. System of Subsystems (SoSS); Soft Systems methods	Building resilience is a complex task. The integration of general resilience thinking will contribute to the strategic direction outlined in the Australian National Strategy for Disaster Resilience (COAG 2011)	Exploration of 'resilience' within a preparedness context. Conceptual exploration of approach to support communities in building their own resilience Holistic systemic view of DRR in the Australian context	In Paper 3, these concepts are juxtaposed with the concept of resilience in the Australian context and three scales of enquiry are presented: (1) members of the public from two South Australian councils, (2) the Australian Red Cross and (3) the South Australian Government organisations that are responsible for DRR.

Chapter / Publication	Key concepts	Central argument	Knowledge contribution	How they fit within thesis
Chapter 5 (d) Cavallo & Ireland 2014	System of Systems, Complex Systems Thinking, adaptive cycle, abductive reasoning	Current DRR strategies are overbalanced towards mitigation of identified risks, but neglect to take into account that disasters are largely unexpected events.	Building resilience requires an understanding of the dynamic and uncertain context in which communities are operating. Focusing on general resilience can help increase capability to face complex risks.	The concept of resilience is further explored in a conceptual framework in Paper 4, where the overall methodology adopted in this thesis is illustrated.
Chapter 6 (e) Cavallo 2014 b	Ambidexterity; exploitation and exploration of information, specified and general resilience	Interdependencies between strategic priorities need to be taken into consideration, if international targets are to be met.	Ambidexterity should be pursued by encouraging approaches based on reductionist and Complex Systems Thinking to prepare equally for known and unknown risks; therefore, building specified and general resilience.	'What is preventing communities and institutions from developing a culture of safety and resilience?' Paper 5 addresses this question on an international level.
Chapter 7 (f) Cavallo 2015a	Exploratory research, sense-making, Complex Systems Thinking, systemic barriers, innovation	The DRR sector is organised hierarchically. This hierarchical structure clashes with the systemic nature of unexpected interdependent risks and resilience.	Barriers to application of CST in South Australia; limitations of current DRR organisational structures in South Australia (focus on higher scales' perspectives)	Paper 6 provides an overview of the South Australian DRR context and an integrated cross-scale perspective of potential and systemic constraints that act as barriers to change.
Chapter 8 (g) Cavallo 2015b	Complex Systems Thinking, bonding, bridging and linking social capital, transformability, cross-scale analysis	DRR strategies that focus on preparation for unexpected systemic risks need to rely on a platform of enquiry, which is equally 'networked' and which focuses on relationships between systems and individuals within the SoS.	Challenges the DRR sector has to face in South Australia in order to build capacity for exploration and better prepare for the consequences of complex interconnected risks (focus on focal scale perspective)	Paper 7 summarises the state of the art of DRR at the South Australian level and suggests possible ways forward.

1.9 Summary

This chapter has both introduced and provided an overview of the main thought lines of the research that comprise the thesis. This was done by introducing Disaster Risk Reduction (DRR) and Complex Systems Thinking (CST) and by explaining why CST can help overcome problematic aspects in current DRR strategies.

The research background and the philosophical foundations were discussed to provide the reader with the general frame of this thesis. Applications and main contributions to knowledge were presented as general statements and in conjunction with the publications that constitute this thesis and that follow this chapter.

The main argument is based on the observation that every disaster involves unexpected components of risks that communities and organisations are not prepared to face. However, the DRR literature has focused predominantly on preparing for specific risks (Carpenter et al. 2012; Berkes & Ross 2012), for example, floods, bush fires, landslides. Therefore, there is a strong need to better understand what can be done to build resilience in preparation for unexpected risks.

2

Beyond plans: disasters as SoS

Preface to paper

The purpose of this paper was to explore the leading idea that runs through the entire thesis, that is, the understanding of a disaster as a System of Systems (SoS). The IEEE System of Systems Engineering (SoSE) conference provided an opportunity to validate this assumption within a community of international experts in the field.

The discussion following the presentation provided important feedback, which was further explored in private conversations during the entire conference and beyond.

The endorsement of such experts' opinion enabled the validation of the very first assumption of this thesis, that is, that disasters can be comprehended and conceptualised as System of Systems.

This paper focused on disaster response after the Great East Japan earthquake. However, I realised that the international discourse highlighted the need to think of DRR holistically, moving the attention from response towards the phases preceding a disaster.

Statement of Authorship

Title of Paper	SoS in Disasters: Why following the manual can be a mistake
Publication Status	⊙ Published, ○ Accepted for Publication, ○ Submitted for Publication, ○ Publication style
Publication Details	Cavallo, A and Ireland, V (2012). SoS in Disasters: Why following the manual can be a mistake. Proceedings of IEEE 7th International Conference on System of Systems Engineering, July 16-19; pp.161-166, Genoa, Italy. DOI: 10.1109/SYSoSE.2012.6384163 ISBN: 978-1-4673-2974-3

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	Antonella Cavallo		
Contribution to the Paper	Conceptualised work, wrote and reviewed manuscript, acted as corresponding author and presented work at the 7th International Conference on System of Systems Engineering in Genoa, Italy in 2012.		
Signature		Date	13/4/2015

Name of Co-Author	Vernon Ireland		
Contribution to the Paper	Supervised development of work.		
Signature		Date	15 April 2015

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Cavallo, A. & Ireland, V. (2012) SoS in Disasters: Why Following the Manual Can Be a Mistake. In *Proceedings of IEEE 7th International Conference on System of Systems Engineering, July 16-19, Genoa, Italy*. *IEEE, pp. 161-166*

NOTE:
This publication is included between pages 56-62 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

http://dx.doi.org/10.1109/SYSoSE.2012.6384163

3

At the interface between complex and complicated

Preface to paper

It was clear to me that current DRR practices have had a significant impact on the level of preparedness of communities and individuals to face disasters. Therefore, it was not my intention to dismiss the theoretical bases that underlie current risk management and DRR practices. Instead, I had to work on the integration of approaches. One approach seemed to be based on a Cartesian reductionist paradigm, whereas the one I was most interested to explore, was based on systems thinking.

Therefore, in July 2012, after participating to the IEEE SoSE conference in Genoa, Italy, I went to the Karlsruhe Institute of Technology (KIT) in Germany, where the Centre for Disaster Management and Risk Reduction Technology (CEDIM) is based. In particular, I organised a meeting with Dr. Tina Comes[1], who at that time, was Head of the Interdisciplinary Research Unit on Risk Management at the KIT and an expert on distributed scenario-based multi-criteria decision support. I explained that I wanted to study how *complex* and *complicated* approaches could be integrated in a DRR theoretical framework. This article constitutes part of our conversation that continued in 2013, when she spent a month in Adelaide.

[1] Dr. Tina Comes is currently Associate Professor at the Centre for Integrated Emergency Management at the University of Agder, Norway.

Statement of Authorship

Title of Paper	Designing decision support systems at the interface between complex and complicated domains
Publication Status	● Published, ○ Accepted for Publication, ○ Submitted for Publication, ○ Publication style
Publication Details	Comes, T and Cavallo, A (2013). Designing decision support systems at the interface between complex and complicated domains. Proceedings of Americas Conference on Information Systems AMCIS2013, 15-17 August, Chicago, Illinois, USA.

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	Antonella Cavallo		
Contribution to the Paper	Conceptualised work (need to integrate complex and complicated domains) and initiated collaboration; wrote and reviewed manuscript (50 %)		
Signature		Date	12/4/2015

Name of Co-Author	Tina Comes		
Contribution to the Paper	wrote and reviewed manuscript (50%); acted as corresponding author and presented at the Americas Conference on Information Systems in Chicago, IL, USA.		
Signature		Date	12/4/2015

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Comes, T. & Cavallo, A. (2013). Designing decision support systems at the interface between complex and complicated domains. In *Proceedings of Americas Conference on Information Systems AMCIS2013, August 15-17, Chicago, Illinois, USA.*

NOTE:
This publication is included between pages 66-72 in the print copy of the thesis held in the University of Adelaide Library.

4

Integrating disaster preparedness and resilience

Preface to paper

In 2013, while I was a visiting research fellow at the Risk and Crisis Research Centre at the Mid Sweden University, I prepared a poster (included in the appendix) to visualise current problematic aspects in DRR

in Australia and propose a first conceptualisation of an integrated framework to address identifiable and unknown risks.

The poster attracted questions from a large number of government representatives and academics. The editor in chief of the Australian Journal for Emergency Management asked me to write an article to explain the ideas outlined in the poster.

This article is the result of the effort that followed.

Statement of Authorship

Title of Paper	Integrating disaster preparedness and resilience: a complex approach using System of Systems
Publication Status	⊙ Published, ○ Accepted for Publication, ○ Submitted for Publication, ○ Publication style
Publication Details	Cavallo, A (2014a). Integrating disaster preparedness and resilience: a complex approach using System of Systems. Australian Journal of Emergency Management, vol. 29, issue 3, pp. 46-51. https://ajem.infoservices.com.au/items/AJEM-29-03-10

Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	Antonella Cavallo		
Contribution to the Paper	Conceptualised work, wrote and reviewed manuscript and acted as corresponding author.		
Signature		Date	13/4/2015

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Name of Co-Author			
Contribution to the Paper			
Signature		Date	

Integrating disaster preparedness and resilience: a complex approach using System of Systems

Antonella Cavallo, University of Adelaide, discusses a 'System of Systems' approach to building resilience. ®

ABSTRACT

The number of natural and human-made disasters has increased in recent times as a result of many factors, including climate change (IPCC 2014, Climate Council of Australia 2014) and increased interconnectivity of potential risk factors (Helbing 2013). The nature of disaster events has made institutional organisations around the world aware that new disaster prevention strategies are required. In this context, international and national standards have been changed to focus more on community resilience as well as disaster management. In Australia, the *National Strategy for Disaster Resilience* (COAG 2011) has embraced this change and pushed for 'shared responsibilities' between government, emergency services, communities and individuals. The Strategy does not provide a definition of resilience; hence, it gives space to a conceptual exploration of an approach to support communities in building their own resilience.

This article contributes to the conceptual conversation around community resilience in Australia by discussing new ways of thinking. Particularly, it focuses on the balance between specified and general resilience, that is, the ability of a community to prepare for known and unknown risks. This distinction is taken further to discuss a complementary conceptual approach to current command-control strategies in support of general community resilience building based on systems thinking. The integration of *ad hoc* traditional approaches and systemic methods is considered as the key to increased community resilience.

It should be noted that this article concentrates on the 'front-end of disaster management' emphasising planning and preparation and not on responding to disaster events. Current disaster preparedness strategies could effectively be complemented by incorporating this new approach to general resilience to build community resilience before disasters happen.

Introduction

The *National Strategy for Disaster Resilience* (COAG 2011) was released in 2011. The Queensland floods had just occurred. The nation was in shock, authorities included. How was it possible that some parts of the country well known for drought problems were now suffering severe consequences of flooding? For many people, that was the first real sign of climate change; the first signs that the 'impossible' can happen. This national experience and the increasing number of disasters worldwide were a warning signal to many. The costs of the disaster response made it clear that better preparation for disasters was needed. International standards and agreements, such as the United Nations *Hyogo Framework for Action* (HFA), played an important role in the development of a discourse that is inclusive of those organisations, community groups and people who are traditionally left out of the disaster-planning phase. In recent years, the intensity and increasing frequency of disaster events have triggered a review of the traditional disaster management framework: prevention, preparedness, response and recovery (PPRR). The introduction of 'disaster resilience' into disaster management has introduced a new way of thinking about disaster mitigation, which does not replace the traditional command-control approach, but it is complementary to it.

The traditional approach refers to the delivery of expert services to recipient communities. A proposed complementary approach would see the role of

communities reviewed at the national level to involve community members in an active collaboration to prepare for disasters. This would contribute to 'community resilience' defined as the engagement of community resources by its members to face 'uncertainty, unpredictability, surprise and change' (Magis 2010). Similarly, the Stockholm Resilience Centre states that:

> *'Resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop'*
>
> (Moberg & Simonsen 2011).

More commonly, resilience is referred to as the ability of a community to 'bounce back' after something bad happens (Zolli & Healy 2012). Despite efforts to define exactly what resilience is, there seems to be a common understanding that resilience cannot be confined to a closed framework. So far, no 'recipe solution' has been identified to build or increase resilience in a community. Instead, common characteristics of resilient communities have been identified and discussed in government documents, such as the *National Strategy for Disaster Resilience.*

The focus of this article is on the need for emergency management organisations and the wider community to share a vision and a common approach towards building resilience to unexpected disaster events. Current approaches to disaster prevention focus on the risks that can be identified and managed. They focus on specific risks that are known or can be known. However, there are a number of risks that are not identified, which the wider community might therefore not be prepared for. Additionally, it has been acknowledged that many risks cannot be predicted but that there is potential to prepare for them (Cavallo 2010, Gilpin & Murphy 2008, Loch, DeMeyer & Pich 2006, Meadows 2002), therefore unknown risks can be managed to some degree. There is also a need for disaster management to have a more holistic approach, which goes beyond individual organisations to create a 'shared responsibility' involving not only emergency management organisations and institutions, but also communities and individuals (Cavallo 2010, COAG 2011). Based on this, it is argued that the emergency management sector needs to invest in strategies that build general resilience in the community. This refers to the capacity of the community to prepare for unknown shocks (Walker & Salt 2012). In addition, a new perspective is required that incorporates 'System of Systems' (SoS) thinking. This is a complex holistic approach that recognises the contribution of stakeholders across the wider community to prepare for disaster events.

Disaster resilience in a complex System of Systems (SoS)

Systems theory represents an opportunity for a global vision of disasters and their overall management. Disaster prevention is often organised on the assumption that it can be broken down into a series of work packages, which are addressed individually by emergency services agencies. However, when a disaster occurs, any number of different organisations and individuals emerge to help. These are independent and at the same time interdependent. This way of thinking could be built into the planning and prevention phase, that is, before disaster events. In short, disasters need to be considered as a whole, because they are greater than the sum of their component parts (Cavallo & Ireland 2012). In this sense, a disaster is the expression of the interactions between different systems such as emergency services organisations, weather, community, environment, isolated members of the community and other factors. For this reason, disasters have to be approached holistically in terms of space, for example inter-organisational relations, and time, such as the system's historical context (Meadows 2002). It might not be possible initially to describe the whole system in an exhaustive way. However, an awareness that other parts of the system exist and that there is a portion of uncertainty involved in the strategy is fundamental. Indeed, this can contribute to constructing a more thoughtful risk management plan and increase the system's resilience.

System of Systems offers certain elements, which particularly apply to the disaster prevention discourse. They are autonomous, that is they decide to belong to a System of Systems such as the emergency or to maintain connection with the other systems in the same SoS. They are heterogeneous and contribute to the evolution of the SoS towards unpredictable states or conditions (Boardman & Sauser 2008). An example of this is the market, populated with independent, but interdependent competitors. Equally, before, during and after disasters, independent systems operate, while at the same time being interdependent.

Organisations, community groups, councils and others can be represented as both independent and interdependent systems within a whole system. On one hand, some parts of the system are connected to one another in a hierarchical way, for example, government and its agencies (green in Figure 1). On the other hand, other parts of the system operate in an autonomous way and collaborate informally (white in Figure 1).

This model represents the core emergency management agencies, which are connected to different levels of government hierarchically and are typified by a command-control mindset. Other agencies comprise the periphery of this model suggesting their relative autonomy and flexibility in the way they operate.

Resilience is complex and dynamic

Resilience is a dynamic system property, which can change over time depending on system conditions. In this sense, resilience can be defined as the distance between current system conditions and the system 'critical threshold' (Resilience Alliance 2010). The difference between system and SoS is shown in Table 1. Systems, problems or projects are complex

'if their future is uncertain' (Flach 2012). For example, community resilience is complex because it is not possible to precisely define the elements needed to make a community resilient. Even if the time at which the threshold will be reached is unknown, knowing that there is a threshold can support building resilience in a system (Resilience Alliance 2010). This is very important, because when applied to disaster resilience, it proposes that even if we do not know the nature and timing of a disaster event, raising awareness about the possibility of an unexpected event will reduce the likelihood of crossing the 'critical threshold', that is to say that it will increase the system's resilience.

Disaster preparedness and disaster resilience

An important aspect of this analysis is the distinction between specified and general community resilience in disaster prevention. This distinction is often driven by disaster preparation and response nexus; therefore it is commonplace to think in terms of specified rather than general resilience (Walker & Salt 2012). Systems practitioners need to complement command-control strategies by investing in general resilience before disasters occur.

Disaster preparedness is about preparing communities and response systems to face the risks that have been identified in a certain area. Once the risks are identified, a risk management plan can be put into place to prepare the population to face those risks. The assumption behind such an approach is that once the hazard is identified, the technical sectors of response can be broken down into packages of actions, plans, instructions, etc. which can be addressed independently. Once all the packages have been addressed, it is assumed that the 'boxes have been ticked' because the sum of those completed packages gives the impression that the risk has been dealt with in its entirety (Park *et al.* 2013). For example, after identifying the hazard of an earthquake, different organisations prepare to address a range of risks like structural instability of buildings, impacts on social, administrative and financial structures, and urgent household needs. For each group of risks, further risk areas are identified and action plans are formulated accordingly. For example, a householder may consider their access to essential goods, such as food and water. Supermarkets, pharmacies, etc. might not be accessible in the wake of a disaster. One recommendation is to store enough water and non-perishable food in the house suitable for at least three days (see Figure 2).

Figure 2 shows that disaster preparedness follows a pyramid-shape structure where risks are identified one by one and linear action plans are elaborated on the basis of the identified risks.

Disaster preparedness can be seen as a System of Subsystems. The hazard is broken down into a series of independent joint actions, that is to say a reductionist approach is used. Providers mitigate the identified risks in specific top-down programs, while the community members are clients. The causal relationships behind such an approach are linear, e.g. cause 1 has effects 1, 2, 3. Networked effects are hardly ever considered.

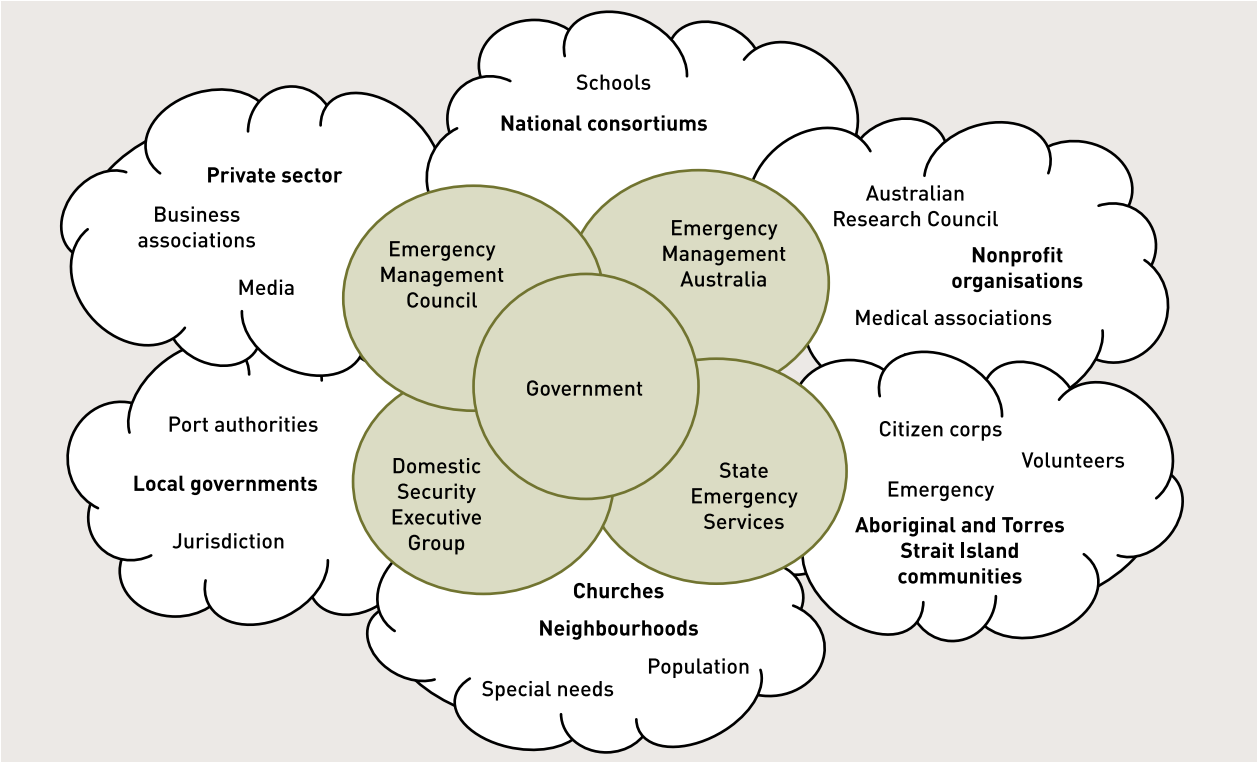


Figure 1: Map of generic emergency management System of Systems.

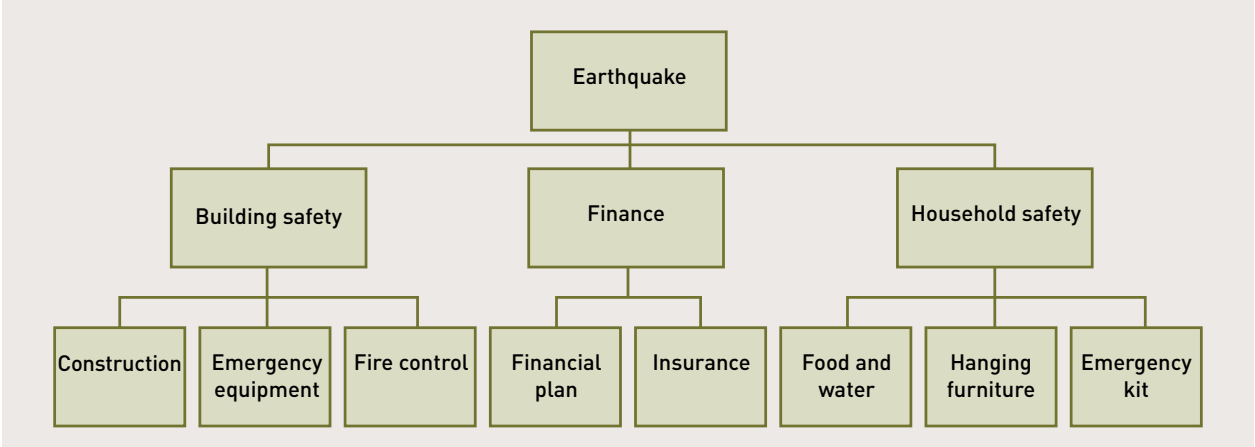


Figure 2: Example of a draft risk break down structure for earthquakes.

Many organisations consider the practice of analysing networked risks 'too complex'. Because some practices are already in use, strategies can be selected by analysing the needs and responding to those (Snowden & Boone 2007).

Contrary to mainstream projects and disaster preparedness, complex projects such as building resilience to disaster cannot be broken down into subsystems (Flach 2012) because, in the process, the interactions characterising the system would be lost. Disaster preparedness involves complex responses. Traditional reductionist approaches are a viable strategy to break down problems. However, building resilience is more complex because it requires the reconnection of elements broken down over time or are yet to be established (for example, institutions are much more aware of the synergies between community activities and events and disaster resilience building processes).

Building disaster resilience complements disaster preparedness programs because it is based both on bottom-up and top-down approaches; on inductive and deductive thinking. It starts from the system components and goes to the top to create an overall perspective of the system, e.g. from the community members up to the governmental perspective and from there, back to community members to obtain feedback and continue building resilience. These aspects of disaster preparedness and disaster resilience are illustrated in Table 1.

Disaster management has long been studied from the perspective of emergency management institutions, organisations and agencies as service providers and affected community members as clients; passive receivers. As a consequence, affected communities have been considered as separate from disaster management activities. In the last decade, things have changed and several studies have shown the potential intrinsic value in involving communities to increase the effectiveness of disaster preparedness (Aldrich 2012).

The *National Strategy for Disaster Resilience* highlights the importance of building relationships throughout 'communities of interest' and 'communities of practice'. The main aspect found to have a direct influence on the resilience of a community is the degree of connectedness between its members (Arbon *et al.* 2012). In essence, people who know other people are likely to be more resilient than isolated members of the community. In this context, organisations involved in disaster preparedness are left with the question of what it means in practice to support communities to build their resilience to disasters and to the unexpected. Ideally, the mechanisms that underpin planned collaboration between government and non-government organisations and the wider community would both respond effectively to major disaster events and also increase the capacity for long-term community resilience.

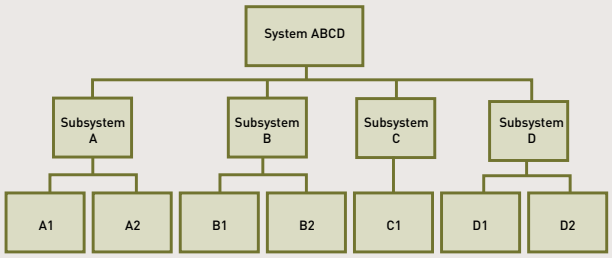
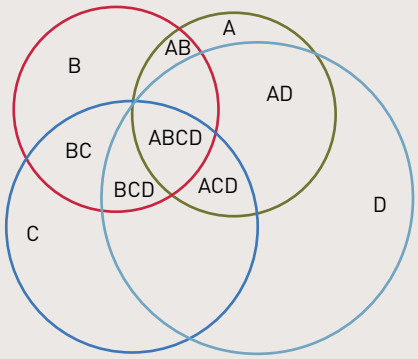
Some would say that the resilience of a system depends to a great extent on the social capital of people in a community (Aldrich 2012) and on the ability of the system, involving all of the organisations and players, to manage identified risks. Disaster prevention and mitigation are influenced by risk management plans. These are formulated after risk identification, evaluation and analysis. In turn, they inform risk mitigation and monitoring strategies. This procedure, embraced by international standards such as ISO 31000[1], is based on the ability of an organisation to identify its risks and manage them. However, it does not take into consideration those risks, which are unforeseen or often of a multi-causal nature (Comes & Cavallo 2013). This paper argues for a non-linear approach to risk assessment so that multi-causality is likely to be better understood and approached.

Correspondences with communities

This discussion builds on Soft Systems Methodology (Checkland & Poulter 2006) and on the more recent concept of the Evolutionary Learning Laboratories (Bosch, Nguyen & Maeno 2013). Both acknowledge the importance of going beyond the superficial symptoms to address 'the basis of the iceberg' to use a metaphor by Maani and Cavana (2007).

1 ISO 31000 - Risk management www.iso.org/iso/home/standards/iso31000.htm and ISO/TR 31004:2013 for Risk management - Guidance for the implementation of ISO 31000.

Table 1. Two complementary ways of thinking about disaster preparedness and disaster resilience.

Specified resilience	General resilience
Disaster preparedness thinking	Disaster resilience thinking
Reductionist thinking	Inductive, deductive and abductive thinking
	
System of subsystems (SoSS)	System of Systems (SoS)
Identified risks	Unforeseen, unanticipated risks or unprepared community
Linear thinking	System thinking
Sense and respond	Probe, sense and respond
Mitigate negative events	Keep safe operating space

They argue that a systemic approach can help organisations to find a paradigm for collaboration in addressing multi-faceted, complex problems involving a large number of stakeholders.

Building resilience within specific groups poses such a challenge. In terms of stakeholders, there are multiple organisations working in disaster prevention. While the methods of analysis detailed above are different, both suggest that building community resilience to disasters is best addressed by involving all stakeholders. In order to achieve this, the world-views of the stakeholders and of the agencies need to be taken into equal account. Ultimately, while this approach does not necessarily guarantee a definitive solution, it does offer a 'desirable and feasible' way forward for all parties. Translated into practical terms, this means starting a conversation at the community level and taking it up to an intermediary agency and finally to the level of government agencies. A key point of difference with previous approaches to disaster mitigation is that the relationship between emergency services organisations and other stakeholders would operate very differently. Currently the information on disaster prevention is 'pushed down' to the community. However, there is no information on the existing capability of the community to play a collaborative role in mitigating risks. A key focus here is on how best to support members of the public to collaborate more actively in building resilience within their communities, based on their specific worldviews as well as their current and potential capabilities. Building resilience in the community is a process which needs to go from the parts to the whole and from the whole back to the parts (Morin 2007). For this reason, the search for a paradigm to support the wider community to build resilience needs to start with them. In more 'complex' terms, their self-organisation is at the centre of this study.

Conclusion

This conceptual paper presents a new approach to building community resilience by drawing on complexity theories and 'complex risk management' (Cavallo 2010).

Disasters are complex Systems of Systems. In disasters some elements of risk cannot be predicted or prepared for. This is also due to the complexity of which many risks are the expression. Risks that can be addressed in traditional ways are also mixed with systemic risks, which require new approaches. Current strategies focus on structured programs that acknowledge the presence of the former but often neglect the co-existence of conditions that have an influence on further risks. Disaster preparedness can help the construction of deployment action plans for risks which can be identified, but it cannot cover those situations that have not been planned for and which have systemic cascading effects. Therefore, in order to achieve both, disaster preparedness needs to be integrated with strategies to build community resilience in a sustainable way. While disaster preparedness can be approached with reductionist approaches, building resilience is a complex project, which is characterised by much uncertainty.

Many aspects are significant in building resilience. However, most studies point to the degree of connection of community members within and beyond their living area as the most important factor positively influencing general community resilience. By drawing on the specific needs, characteristics and capabilities of

particular communities and their environments, disaster preparedness allows individuals different ways of building and contributing social capital. The connections individuals develop within and outside the community can help them recover more quickly from a disaster or an unexpected event (Aldrich 2012).

Further study in South Australia is exploring ways to support populations in increasing resilience to unexpected events. The holistic view taken in this paper (Cavello & Ireland 2014) proposes the involvement of all potential players in disaster prevention and risk mitigation, including both specialist organisations and community members, to better provide disaster preparedness and to build community resilience.

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About the author

Antonella Cavallo is a PhD candidate at the University of Adelaide. Her research involves collaboration with community members, government organisations and NGOs, nationally and internationally. She is one of the contributors to the United Nations Global Assessment Report on Disaster Risk Reduction 2015 (GAR 15).

5

Preparing for complex interdependent risks

Preface to paper

The United Nations Office for Disaster Risk Reduction (UNISDR) issued a call for input papers to be integrated into the United Nations Global Assessment Report 2015 (GAR15), a report on disaster risk reduction which provides biennial advice on the progress made by nations towards the achievement of the priorities outlined in the Hyogo Framework for Action, that is, the United Nations International Strategy for Disaster Risk Reduction[1].

The article that follows was selected by the Organisation for Economic Co-operation and Development (OECD) in the Thematic Research Area 16 'Interconnected, inter-dependent risk' to be integrated in GAR15.

This article condenses some of the ideas presented in the last paper and presents the theoretical and methodological skeleton of this thesis, while showing the international relevance of the proposed arguments.

[1] This strategy has now been replaced with the Sendai framework launched in March 2015 at the World Conference on Disaster Risk Reduction. The Sendai framework will be in force between 2015-2030.

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Author Contributions

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Name of Principal Author (Candidate)	Antonella Cavallo		
Contribution to the Paper	Conceptualised work, wrote and reviewed manuscript, acted as corresponding author and presented work at the United Nations Global Risk Forum in Davos, Switzerland (International Disaster and Risk Conference 2014).		
Signature		Date	21 July 2014

Name of Co-Author	Vernon Ireland		
Contribution to the Paper	Supervised development of work		
Signature		Date	21 July 2014

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6

CST in international strategies

Preface to paper

After collecting data in South Australia, the trip to Sweden and several trips to Southern Italy, I was ready to review the specified/general resilience framework and to take it to an international DRR audience of experts.

The International Disaster Risk Conference in Davos, Switzerland provided a good opportunity to gather feedback from experts who had seen this concept at its embryonic stage. Moreover, the presentation of the following paper once again stimulated rich conversations that confirmed the need for a change of paradigm, or to be more precise, for the integration of new epistemological approaches to risks on an international level.

A stream on the unexpected nature of future risks due, for example, to the coupling effects of availability of natural resources[1] helped to sharpen my ideas from practice through to the ontology of DRR.

In this short paper, I reflected on the clash between current strategies and the difficulties these may face in practice because of the lack of integration of perspectives.

[1] Dr. Hannes Kunz, Institute for Integrated Economic Research.

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7

Let's get ready for the unexpected

Preface to paper

This paper provides an overview of the Australian and South Australian DRR context. International and national experts had confirmed the need for CST in DRR strategies, while acknowledging the existence of significant barriers to the integration of CST in current DRR strategies.

Focus group discussions with community members, the Australian Red Cross and representatives of the Hazard Leaders in South Australia helped to gain an integrated perspective on the factors blocking the application of CST to DRR and general resilience.

This article was selected by the United Nations Office for Disaster Risk Reduction (UNISDR) to be published in *The "State of DRR at the Local Level". A 2015 Report on the Patterns of Disaster Risk Reduction Actions at Local Level*.

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8

Building general resilience in South Australia

Preface to paper

This book chapter reviews the conceptualisation of the specified and general resilience framework and provides an overview of the backbone theories formed in this thesis. Furthermore, it discusses barriers to general resilience by emphasising community members' perspectives in South Australia.

Findings from previous publications are used to address the central questions of this thesis from an abstract and general perspective to the local level, where policies and practices are implemented. What can be done to build general resilience in South Australia? What is already contributing to building general community resilience? How can these practices be fostered by government in the spirit of guided self-organisation?

This book chapter has been peer-reviewed and accepted for publication in the form presented here.

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9 Conclusion

The purpose of this chapter is to summarise main arguments and to provide concluding remarks and insights arising from the research reported in this thesis. Based on a summary of the arguments presented, practical, policy, strategic and theory-building implications of the findings are discussed. Finally, the originality of the knowledge contributions and future research are presented.

9.1 Summary of thesis arguments

This thesis makes a knowledge contribution to disaster risk reduction (DRR) strategic thinking.

In a disaster, risks connect beyond the boundaries of individual emergency management organisations. These organisations depend on each other as well as on governments, communities, partner institutions and individuals, all of which are subject to evolving environmental conditions. Disaster resilience thus depends on the entire interconnected system and not simply on individual organisations.

The uncertainty posed by natural and human-made disasters arises from both known risks and a range of unforeseeable risks, some of which may be novel, not having been observed before. These interconnected risks may evolve over short time periods and may feed into one another. In a network of multiple causes and effects, such risks may not be foreseeable at the disaster preparedness level, and may only be observed at the time of disaster response. This creates a higher level of complexity and requires new approaches from individual organizations and their members to make decisions outside predefined frameworks and hierarchical command-control structures, while still operating in the ethos of their organisations.

This thesis advocates for DRR strategies to go beyond linear approaches to risk management. This is necessary in order to better address complex interdependent risks where such risks may be novel or unforeseen and which may connect in a cascading manner. The resulting causal network needs to be addressed in turn with a networked approach in order to enrich existing linear approaches, so recognising the need for an interconnected holistic approach to deal appropriately with interconnected risk factors.

The social-ecological distinction between specified and general resilience is used to assess strengths in current disaster risk reduction strategies and

to suggest potential for improvement. Specified resilience refers to known risks, whereas general resilience refers to unknown risks. DRR strategies should address both in order to prepare the wider community for both predicted and unexpected risks.

Approaches to building specified resilience tend to be top-down and aim to mitigate already identified risks. As the result, specified resilience has been observed to be increasing over time (Childs et al. 2013). Continuing challenges remain, however, due to the unpredictability of future disasters and difficulties in ensuring that the wider community has access to risk specific information.

All-hazard approaches have contributed to increased levels of general resilience in the community. However, the importance of 'all-hazard' approaches in areas exposed to significant specific risks has been underestimated and approaches to building general resilience have been under researched.

General resilience thinking may help to reach out to parts of the wider community, currently difficult to involve in disaster risk reduction activities. This may be achieved by exploiting network effects and bottom-up approaches within and beyond a community.

Unexpected cascading effects and their causes can normally be identified only retrospectively. However, applying System of Systems (SoS) logics allows a better understanding of network effects, even across unrelated systems, before the disaster happens. These network effects can be used a priori to prepare the community to face disaster risks – allowing better management of unknown risks.

While this thesis has been carried out mainly in South Australia, these insights are relevant and applicable to other countries, as demonstrated in the publications and the sections that follow.

9.2 Practical implications of findings

In recent years, there has been an intensification of standards, strategies, guidelines and regulations in the attempt to make systems safer and more reliable. However, practice has shown that regulations are insufficient (e.g. Great East Japan disaster or L'Aquila earthquake) and that it should not be assumed that regulations would be respected unconditionally. Systemic causes of disasters (e.g. corruption or, more often, in general, conflicting interests) need to be addressed in a systemic way, that is, by empowering communities to act beyond government hierarchies.

The DRR cycle, i.e. Prevention, Preparedness, Response and Recovery, neglects to take into account the systemic conditions at the basis of community resilience. Therefore, using the proposed specified-general resilience framework can be helpful to introduce the missing basic component of resilience, which is general resilience. This way of thinking complements the traditional generalised DRR thinking by acknowledging and exploiting contextual knowledge and specific community routines to implement localised strategies for community resilience. Therefore, while knowledge transfer is important and should be endorsed, it is also important to remember that good practices cannot be just 'copy-pasted', but need to be transposed in a way that makes most sense to the community (Fuhrer 2015).

This leads to risk communication. Communities are increasingly diverse. Hence, DRR communication and strategies need to factor this in and to

use diverse communications channels and strategies to maximise communication effectiveness.

This can be done by activating members of the wider community, as international and national strategies have recognised. However, this recognition in principle has failed to translate into practice in most countries due to lack of supporting policies; hence, government organisations are not incentivised to develop long-term strategic partnerships with the community.

In South Australia, government agencies involved in the study have indicated that 'lack of money and political will' are the most significant deterrent factors to the application of CST to DRR in the State (Cavallo 2015a). However, while these are important factors, the potential to use CST within current frameworks and strategies exists to an extent. An example provided within the Zone Emergency Risk Management Committees (ZERMC) showed the capacity for initiative of community members and the facilitating role of government to provide guidance and resources for communities to develop their own strategies and collaborations, based on their needs and strengths (Cavallo 2015b). In other words, current guidelines do allow space for doing things in a different way, that is, to integrate reductionist thinking and CST. However, it is difficult for government officials to shift their thinking, when Commonwealth funding following a disaster depends only on whether or not the risk assessments that have been conducted meet national guidelines (Cavallo & Ireland 2014). This raises a problem of compliance that needs to be tackled with new incentives and policies, if gaps in the process of building resilience are to be addressed.

To this end, long-term political and management commitment are essential to advance resilience-building practices and to adequately prepare communities to face the unexpected. Lack of commitment is often due to a lack of management understanding of systemic risks, whose cascading effects can undermine the resilience of economies, societies and ecosystems, so leading to major societal changes. For this reason, politicians and government managers would benefit from national education programs on CST tools and methods that would help them to better understand systemic synergies and dynamics, so leading to the implementable change on every level.

Furthermore, CST education programs can help shift thinking towards ambidexterity in a sector that is largely populated by military and paramilitary organisations whose practices are based on top-down, command-control logics. These can help building specified resilience in the phases preceding a disaster and are the most adequate strategy when responding to a disaster. However, a more systemic, bottom-up approach is also needed to fully exploit networks and cascading effects useful to build general resilience alongside specified resilience. Adequate CST education programs can support a shift towards ambidextrous thinking.

9.3 Policy implications

'The greatest challenge of general resilience is to design and implement concrete policies and actions' (p. 3255, Carpenter et al. 2012). This issue stems from the difficulty of designing indicators that accurately represent progress and change in an interconnected System of Systems. How can concrete policies and actions be linked unequivocally to the capability levels of the wider community to face the unexpected? Drivers of general

resilience have been identified, for example, in social capital, trust, modularity and adaptability (Carpenter et al. 2012; Walker et al. 2012). However, the positive correlation between these factors and the ability of a community to face unexpected risks can hardly be quantified in detail. Many scholars, practitioners and community members recognise the effectiveness and the importance of general resilience policies. However, the lack of CST prevents the development of monitoring tools that work in a different way from those used in traditional risk management.

Therefore, most DRR strategies, policies and actions are still designed on a top-down basis, so neglecting the systemic nature of risks and of the mechanisms needed to build general resilience. This represents a significant limitation of most of the existing international and national strategies and consequent policies (Cavallo & Ireland 2014).

In the spirit of systems thinking, policies should be designed based on feedbacks (Meadows 2008) according to the 'probe, sense and respond' approach (Snowden & Boone 2007; Cavallo 2014a). This would allow checking on effectiveness and the scope of policies and concrete actions on a more regular basis and adapting them to increase their effectiveness in different contexts. For example, the 'meet your neighbour campaign' in South Australia was not as effective as expected because it neglected to take into account that social capital resides no longer predominantly within the neighbourhood (Cavallo 2015b). Further examples include the Indian labourers who moved back into a cyclone prone area because their first concern was the risk of starvation (Cavallo & Ireland 2014). Policies should take into account system dynamics at the base of community routines and design concrete actions based on feedbacks (Cavallo 2015b). Guidelines such as the National Emergency Risk Assessment Guidelines

(NERAG) in Australia allow a generalised assessment of risks, but neglect to provide an indication of the 'pulse' of the system in terms, for example, of general resilience and system dynamics[1]. New community routines indicate that these concepts and resulting policies should refer to social networks rather than to neighbourhoods alone.

Enhancing CST at the policy-making level will support the design of feedback and networked policies by providing a new lens to analyse and influence targeted systems.

DRR policies should develop ambidextrous frameworks that allow tackling foreseeable risks while empowering and supporting communities to prepare for all types of risks, including the unexpected. However, the existing predominant hierarchical organisational structure in the DRR sector influences the way of thinking in DRR (Weick 2005). For example, efforts to develop integrated strategic planning have been made in South Australia by, for example, conducting inter-agency risk assessments. These, however, have not translated into inter-agency strategies to tackle assessed risks, nor they have translated into a genuine all-hazard interdisciplinary approach to build community resilience. This may also be due to power and control exercised primarily by a limited number of agencies with a central role in disaster response. For this reason, Carpenter and colleagues claim that 'policies for general resilience must overcome budget limitations, […] barriers in politics and the structure of existing agencies and institutions' (p. 3251, 2012).

[1] One of the guiding principles of the United Nations International Strategy for Disaster Reduction outlined in the Sendai Framework reads: 'While the drivers of disaster risk may be local, national, regional or global in scope, disaster risks have local and specific characteristics that must be understood for the determination of measures to reduce disaster risk' (p. 8, UNISDR 2015).

9.4 Strategic implications

The complexity and the uncertainty involved in disaster risks need to be tackled with approaches that are fundamentally different from those used to address foreseeable risks. CST can help DRR strategies to consider new strategies that are open-ended and that depend on community and system dynamics.

DRR strategies should encourage ambidextrous thinking to also build general resilience. For this to happen, a number of aspects need to be addressed.

Monitoring and evaluation are based on indicators that are adequate for specified resilience, but cannot measure the systemic effectiveness of general resilience programs. Without being able to quantify the cost-benefit of general resilience programs, these are often dismissed. More research is needed to study new monitoring and evaluation tools for general resilience.

The phases preceding a disaster, that is, prevention and preparedness, are predominantly seen by DRR practitioners as 'preparation to respond', thus discouraging systemic and general resilience thinking in mitigation strategies. This could be shifted by reviewing the concept of resilience in international and national strategies.

Resilience is often considered as a goal rather than a dynamic system property. Consequently, actions taken are based on short-term plans and are rarely connected to a longer-term strategic plan. The conceptualisation of resilience needs to be reviewed to include its systemic understanding in space and time.

Strategy, policy and risk management guidelines should be consistent and share the same strategic vision. A more coherent funding allocation is needed that is bound to specified and general resilience programs.

'Lack of money' and, to an extent, 'lack of political will' (Cavallo 2015a) can be overcome by optimising resources and encouraging creative solutions and long-term cross-scale collaborations.

Further, disasters have shown repeatedly that regulations and strategies are often not respected and are even consciously disregarded (Cavallo & Ireland 2012). For example, conflicting interests and corruption are constant systemic disaster risks. Current DRR methods do not allow addressing these risks without incurring in diplomatic obstacles. However, CST with its bottom-up approaches and non-hierarchical thinking represents a significant opportunity to finally tackle systemic and latent causes of disaster risks. In this way, it will be possible to have a deeper understanding of why strategies are not having the desired outcomes and how systemic conditions leading to those unintended outcomes can be influenced in an advantageous way, thus enabling resilience.

Finally, a shift of narrative in DRR is needed in order to allow a more holistic understanding of resilience. So far, DRR has been primarily linked to knowledge of risks. However, this thesis has shown the equal importance of knowledge of community and system dynamics. This missing component needs to be integrated into the DRR discourse, if communities are to be more generally resilient.

9.5 Theory-building implications

'The disaster management literature is definitely about specified resilience —to an earthquake, fire, flood, or landslides' (p. 17, Berkes & Ross 2012). This thesis breaks with the specified resilience rhetoric associated with disaster risk reduction and management practices to introduce the missing half, that is, general resilience.

This thesis challenges the general acceptance that decisions should be made taking into account only the available information (Cavallo 2010). It shows that increasing complexity and uncertainty require preparation for unexpected risks on all scales, from community to government and the entire System of Systems. They also require making sense of situations based on unknown and unmeasurable risks (Taleb 2007).

To overcome uncertainty, much research has concentrated on isolated systems and, in the process, has idealised them and made them irrelevant to real life systems (Prigogine 1996). In this thesis, resilience is seen a system property relying on two legs, specified and general resilience, that is resilience to known and resilience to any risks, including the unexpected. These often overlap, so that building general resilience may contribute to building specified resilience and vice versa (Berkes & Ross 2012).

CST allows addressing community resilience from its roots, by creating systemic conditions that enable and foster community resilience independently from hierarchic power and will. This has major implications for DRR in countries where disaster consequences are exacerbated by corruption and conflicting interests that undermine the resilience of disaster survivors.

Moreover, the description of a disaster as a System of Systems (SoS) in time and space in opposition to a System of Subsystems (Cavallo & Ireland 2014), opens up to new DRR ontological and epistemological considerations leading, for example, to uncertainty considered as an ontological rather than as an epistemological issue (Cavallo 2015b). This represents a key change in the DRR narrative, which has primarily considered uncertainty as an epistemological issue.

For this reason, no attempt has been made in this thesis to reveal the unknown risks. Rather, the aim has been to understand what can be put in place to prepare for what, realistically, cannot be predicted, or prepared for. To this end, the emphasis is on a new way of thinking in DRR.

No formulas or scenarios were used in order to give space and freedom to the lived experience and expertise of participants. A significant effort was made to steer focus group discussions away from disaster response to focus on spaces and times preceding disasters. The decision not to use scenarios or formulas was also due to the strategy of using one unified narrative across the three scales (Cavallo 2015b). Members of the wider community could discuss complexity and uncertainty on the same theoretical basis as government officials. These officials, in turn, were given room to reflect on how current policies and strategies are affecting their own personal and professional communities and networks.

This methodology would have not been possible without drawing inspiration from several disciplines, primarily from complexity science and social-ecological systems. The framework for specified and general resilience was conceived out of the juxtaposition of concepts from the innovation, business, social-ecological and complex systems literature. This mix, and the use of abductive reasoning, led to the juxtaposition of

ideas leading to the generation of a new way of thinking (Weick 2005). The question of how DRR is organised was enriched by the question 'what is the DRR System of Systems?' (Cavallo & Ireland 2014).

The original interpretation of disasters as System of Systems composed of interdependent and autonomous systems, led to an understanding of cascading effects and interdependencies as challenges and opportunities. They represent a challenge for their potential to cause unexpected risks and opportunities, because their viral effects can be used for systemic preparedness and building general resilience.

9.6 Originality of contribution

Reduced to the essence of the thesis, the claim to originality lies in proposing a change of narrative in DRR by addressing the systemic causes of disaster, which need to be both anticipated and acted upon in a systemic way as an integral feature of DRR planning.

To facilitate an understanding on an operational level, it is useful to apply CST as a sense-making process for those with leadership and management responsibilities in DRR.

This thesis challenges the current understanding of resilience, which leans towards a reductionist comprehension. Future strategies and policies should be ambidextrous, thus going beyond planning for foreseeable risks to include preventive strategies in preparation for unexpected and systemic risks.

9.7 Future Research

Further research needs to be conducted in a number of areas.

Mastery of known knowledge and technical skills do not guarantee complete risk knowledge. What is needed is complex thinking abilities. However, DRR practitioners and government officials need support to 'shift thinking'. Therefore, research needs to focus on leadership development. This must shift from 'horizontal' (skills, competencies; taught known knowledge –called *complicated* in this thesis) to 'vertical' (thinking transformation; learnt not taught – *complex* in this thesis). Horizontal development, with its emphasis on known knowledge (technical skills), does not address the complex thinking abilities needed to prepare for a complex and uncertain environment. Vertical development addresses the gap by focusing on adaptive and complex thinking abilities. It does this through creating a learning environment designed to transform thinking around how participants make sense of their experiences[1].

Most DRR policies are based on hierarchical models of collaborations and are therefore bound to hierarchical and reductionist thinking. To this end, action research may be helpful to test CST education curricula and to build capacity for CST.

General resilience policies should allow systemic approaches and more frequent feedback loops. However, it is still unclear, how to monitor and evaluate general resilience, thus leading to general resilience being

[1] I have developed this particular research need in collaboration with Mr Andrew Stevens of the Executive Education Unit of the University of Adelaide.

neglected or considered as a side matter. Research can help to develop alternatives to the monitoring and evaluation tools that are currently based on specified resilience indicators. Advances in this area can positively influence the ability to design policies for general resilience.

Appendices

Appendix 1: Poster presented at the Australian and New Zealand Disaster and Emergency Management Conference, Brisbane, 28-31 May 2013.

Appendix 2: Ethical approval

Building Resilience with the Support of the Community: a Complex Approach

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Question

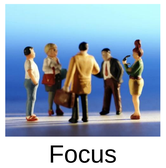
In following the Natural Disaster Resilience Strategy endorsed by the Council of Australian Governments in 2011, this poster illustrates a research methodology to build disaster resilience from community systems and building up to the governmental level of hazard leaders.

Hypothesis and background

- The ultimate goal of disaster preparedness is to mitigate the risk of physical, social and economic harm in the broader population. There are no preparedness programs or brochures, which fully prepare the population to mitigate every possible risk. Indeed, disasters always involve a portion of unpredicted or unidentified risks.
- This poster looks at ways of preparing for those unforeseen risks to which the population will inevitably be exposed in the case of a disaster.
- This study also addresses the risk that the population might not behave according to predefined emergency management plans, as was the case in the Italian cruise ship or the Fukushima disasters.
- A connected community is more likely to be able to thrive in an environment of unpredictability and surprise than one in which people do not know each other
- For this reason, in a systemic approach, the population is considered in the network of individual members. Starting from the community and proceeding towards hazard leaders, this study aims to support disaster preparedness agencies, such as the Australian Red Cross and local councils, to hand-tailor their approaches depending on the realistic potential of the community to apply disaster preparedness principles.

Procedure

Step 1



Focus groups with peri-urban and metro community

Step 2

Focus group with Australian Red Cross

Step 3

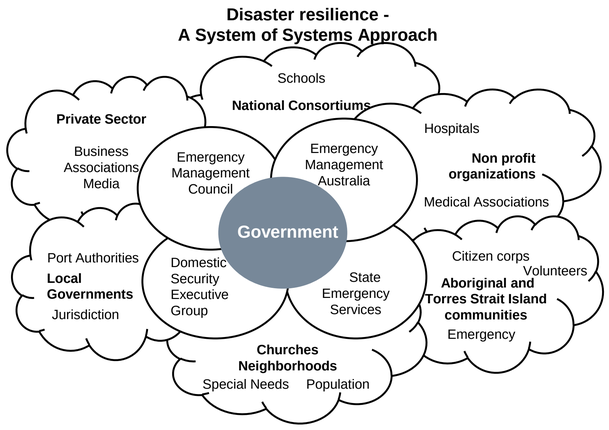
Interviews and focus group with Hazard Leaders in SA and Sweden

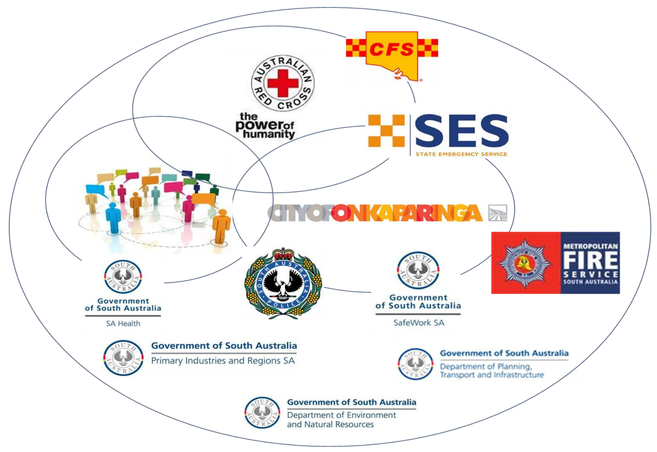
Step 4

Plenary session with all involved stakeholders in SA

Project overview

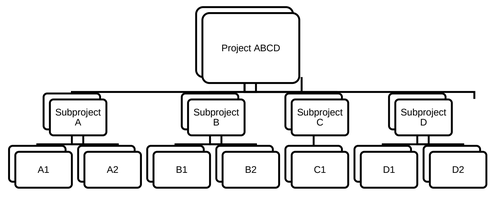
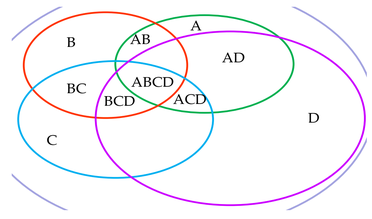
- A disaster is the expression of interactions between different systems such as emergency services, weather, community, environment, isolated members of the community, etc. For this reason, disasters have to be approached holistically in terms of space, e.g. inter-organisational relations, and in terms of time, e.g. the system's historical context.
- Organisations, community groups, councils can be represented as independent and interdependent systems. They have no formal hierarchical connection. Consequently, they are complex systems of systems.





Disaster preparedness and community resilience

- Disaster preparedness is about preparing the general public to face the risks that have been identified in a certain area. Once the risks are identified, a risk management plan can be put in place to prepare the population to face those risks.
- Resilience is a dynamic system property which can change over time depending on system conditions. In this sense, resilience can be defined as the distance between current system conditions and the system 'critical threshold'. Even if the time at which the threshold will be reached is unknown, knowing that there is a threshold can support building resilience in a system.

Disaster preparedness	Community resilience
Reductionist	Abductive
	
System of Subsystems (SoSS)	System of Systems (SoS)
Identified risks	Unforeseen, unanticipated risks or unprepared community
Linear thinking	System thinking
Sense and respond	Probe, sense and respond

Conclusion

- Disaster preparedness cannot cover those situations that have not been planned for and which have systemic cascading effects.
- Building resilience is complex as disasters are complex spatial and temporal systems of systems
- Complex bottom-up approaches are needed to develop plans tailored for each community profile

Poster presented at the 2013 Australian & New Zealand Disaster and Emergency Management Conference - Brisbane (QLD), 28-31 May 2013

Co-sponsored by

Australian Government
Attorney-General's Department

Government of South Australia
South Australian Fire and Emergency Services Commission

Work cited

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Resilience Alliance 2010

SOS draft adapted from SoS approach in the Washington State Military Department – Emergency Management Division (2009)

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17 December 2012

Dr B Elsey
Entrepreneurship Commercialisation and Innovation Centre

Dear Dr Elsey

PROJECT NO: H-2012-176
Managing uncertainty in disasters: a complex approach to improve community resilience through action learning

I write to advise you that on behalf of the Human Research Ethics Committee I have approved the above project. Please refer to the enclosed endorsement sheet for further details and conditions that may be applicable to this approval. Ethics approval is granted for a period of three years subject to satisfactory annual progress reporting. Ethics approval may be extended subject to submission of a satisfactory ethics renewal report prior to expiry.

The ethics expiry date for this project is: 31 December 2015

Where possible, participants taking part in the study should be given a copy of the Information Sheet and the signed Consent Form to retain.

Please note that any changes to the project which might affect its continued ethical acceptability will invalidate the project's approval. In such cases an amended protocol must be submitted to the Committee for further approval. It is a condition of approval that you immediately report anything which might warrant review of ethical approval including (a) serious or unexpected adverse effects on participants (b) proposed changes in the protocol; and (c) unforeseen events that might affect continued ethical acceptability of the project. It is also a condition of approval that you inform the Committee, giving reasons, if the project is discontinued before the expected date of completion.

A reporting form for the annual progress report, project completion and ethics renewal report is available from the website at http://www.adelaide.edu.au/ethics/human/guidelines/reporting/

Yours sincerely

Dr John Semmler
Acting Convenor
Human Research Ethics Committee

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Applicant: Dr B Elsey

School: Entrepreneurship Commercialisation and Innovation Centre

Project Title: ***Managing uncertainty in disasters: a complex approach to improve community resilience through action learning***

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

Project No: **H-2012-176** RM No: 0000015499

APPROVED for the period until: **31 December 2015**

It is noted that this project will be conducted by Antonella Cavallo, PhD candidate.

Refer also to the accompanying letter setting out requirements applying to approval.

Dr John Semmler
Acting Convenor
Human Research Ethics Committee

Date: 13 DEC 2012

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