

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.

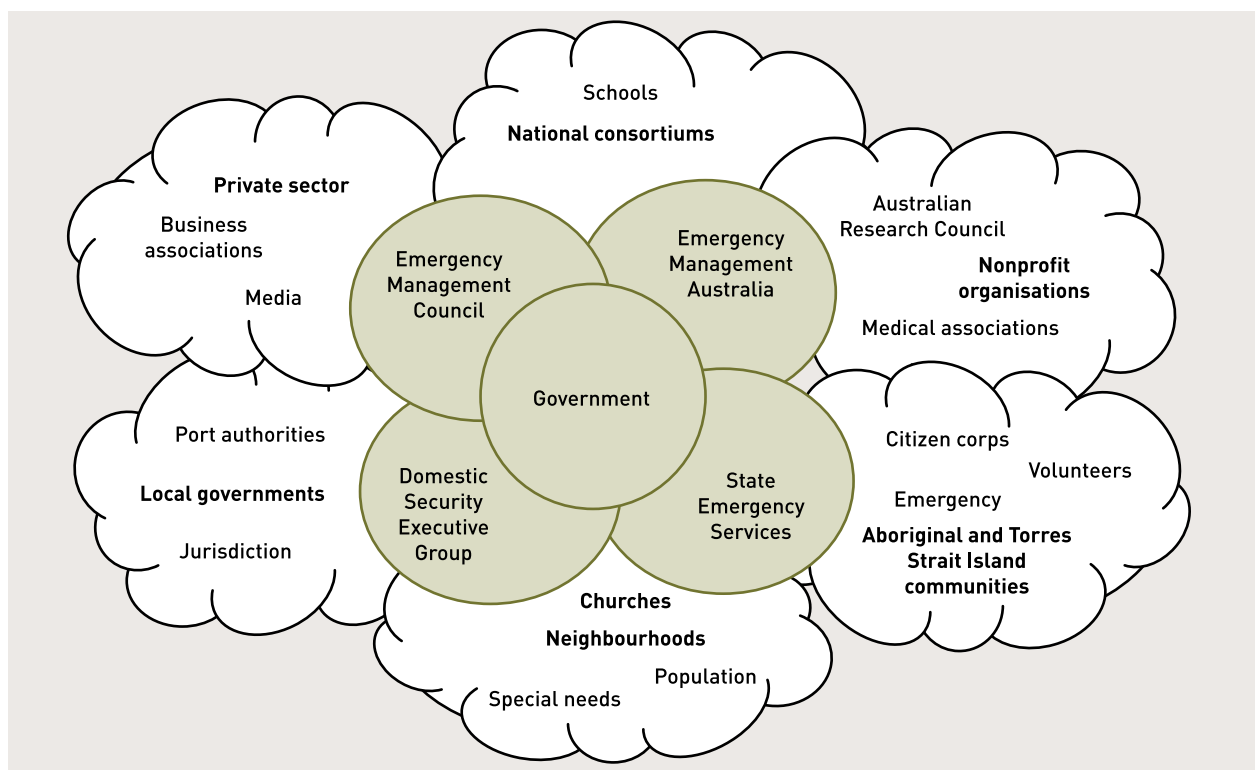
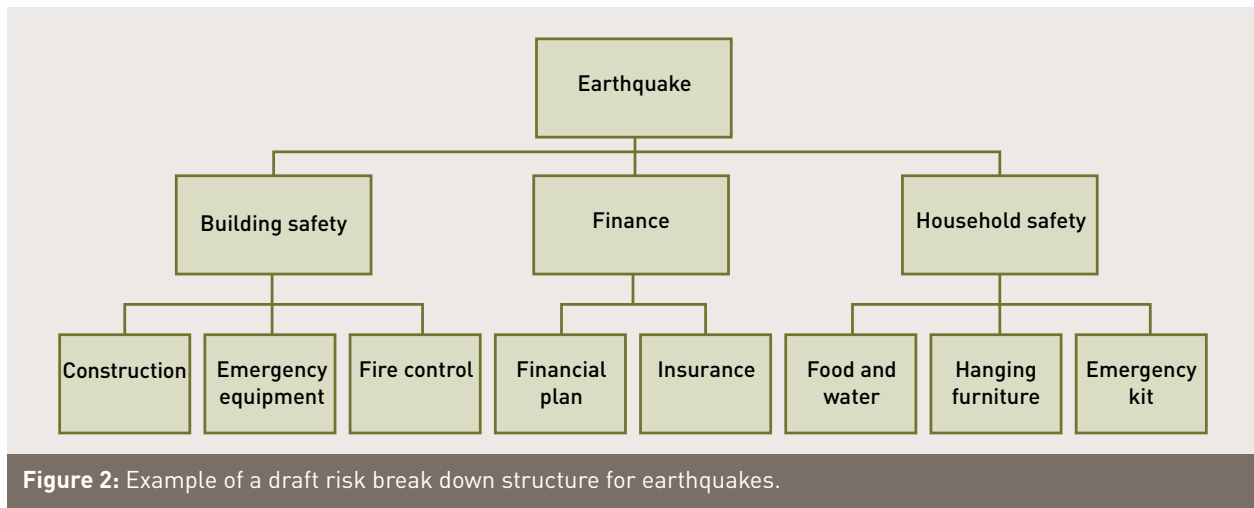


Figure 1: Map of generic emergency management System of Systems.



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 31000¹, 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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References

- Aldrich, DP 2012, *Building Resilience. Social Capital in Post-Disaster Recovery*, The University of Chicago Press, Chicago.
- Arbon P, Gebbie K, Cusack L, Perera S & Verdonk S 2012, *Developing a model and tool to measure community disaster resilience*, Torrens Resilience Institute, Adelaide.
- Australian Emergency Management Institute 2012, 'Attorney-General's Department Disasters Database', Attorney-General's Department, Canberra. At: www.disasters.ema.gov.au/Default.aspx.
- Boardman J & Sauser B 2008, *Systems Thinking. Coping with 21st Century Problems*, CRC Press, Broken Sound Parkway, NW.
- Bosch OJH, Nguyen NC & Maeno T 2013, 'Managing Complex Issues through Evolutionary Learning Laboratories', *Systems Research and Behavioural Science*.
- Cavallo A 2010, *Risk Management in Complex Projects. An exploratory study to managing unknown unknowns in uncertain environments*, Lambert Academic Publishing, Saarbruecken.
- Cavallo A & Ireland V 2012, 'SoS in Disasters: Why Following the Manual Can Be a Mistake', *IEEE International Conference on System of Systems Engineering*, Genoa.
- Cavallo A & Ireland V 2014, *Preparing for complex interdependent risks: A systems approach to building disaster resilience. International Journal of Disaster Risk Reduction (2014)*, <http://dx.doi.org/10.16/j.jdr.2014.05.001>.
- Checkland P & Poulter J 2006, *Learning for Action: A Short Definitive Account of Soft Systems Methodology, and Its Use Practitioners, Teachers and Students* John Wiley & Sons.
- Climate Council of Australia 2014, *Angry Summer 2013/2014*. At: www.climatecouncil.org.au/uploads/ff37af7492b4b698420c1aebdaed54a0.pdf.
- COAG 2011, *National Strategy for Disaster Resilience. Building the resilience of our nation to disasters*, Commonwealth of Australia.
- Comes T & Cavallo A 2013, 'Designing decision support systems at the interface between complex and complicated domains', *19th Americas Conference on Information Systems AMCIS2013 Chicago, Illinois, USA*.
- Flach JF 2012, 'Complexity: learning to muddle through', *Cognition, Technology and Work*, vol. 14, no. 3, pp. 187-197.
- Gilpin DR & Murphy PJ 2008, *Crisis Management in a Complex World*, Oxford University Press, New York.
- Helbing D 2013, 'Globally networked risks and how to respond', *Nature*, vol. 497, no. 7447.
- IPCC 2014, *Oppenheimer M, Campos M, Warren R, Birkmann J, Luber G, O'Neill B & Takahashi K 2014, 'Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change'*, in M Brklacich & S Semenov (eds), vol. 1, *Intergovernmental Panel on Climate Change (IPCC)*, Stanford, CA, pp. 13-19.
- Loch CH, DeMeyer, A & Pich MT 2006, *Managing the unknown. A new approach to Managing High Uncertainty and Risk in Projects*, Wiley, Hoboken.
- Maani K & Cavana RY 2007, *Systems thinking, Systems Dynamics: Managing Change and Complexity*, 2 edn, Pearson Education New Zealand, Auckland.
- Magis K 2010, 'Community Resilience: An Indicator of Social Sustainability', *Society & Natural Resources*, vol. 23, no. 5, 2010/04/05, pp. 401-416.
- Meadows D 2002, 'Dancing With Systems', *The Systems Thinker*, vol. 13, no. 2.
- Moberg F & Simonsen SH 2011, 'What is resilience?'. At: www.stockholmresilience.org/21/research/what-is-resilience.html.
- Morin E 2007, 'Le vie della complessità', *La sfida della complessità*, Bruno Mondadori, Milano, pp. 25-36.
- Park J, Seager TP, Rao PSC, Convertino M & Linkov I 2013, 'Integrating risk and resilience approaches to catastrophe management in engineering systems', *Risk Analysis*, vol. 33, no. 3, pp. 356-367.
- Resilience Alliance 2010, 'Assessing resilience in social-ecological systems: Workbook for practitioners. Version 2.0'. At: www.resalliance.org/index.php/resilience_assessment.
- Snowden D & Boone MJ 2007, 'A Leader's Framework for Decision Making: Wise executives tailor their approach to fit the complexity of the circumstances they face', *Harvard Business Review*, November.
- South Australian Fire and Emergency Services Commission 2012, *Prevention and Preparedness. Hazard Leaders*, Adelaide. At: www.safecom.sa.gov.au/site/emergency_management/prevention_and_preparedness.jsp.
- Walker B & Salt D 2012, *Resilience practice. Building Capacity to Absorb Disturbance and Maintain Function. How can landscapes and communities adapt and transform in a changing world?*, Island Press, Washington, DC.
- Williams T 2002, *Modelling Complex Projects*, John Wiley & Sons, Ltd, Chichester.
- Zolli A & Healy AM 2012, *Resilience. Why Things Bounce Back*, *Headline Business Plus*, London.

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