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Complex Systems Thinking: An Integral Feature of Disaster Preparedness for Unexpected Interdependent Risks

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ABSTRACT: Recent disasters have shown a level of complexity and interconnectedness that are increasingly beyond the capability of current disaster management practices.

This study advocates the need for disaster preparedness strategies to go beyond linear risk management approaches to also address systemic risks. Linear thinking has proved adequate to deal with risks that can be identified a priori. However, the uncertainty increasingly posed by natural and human-made disasters arises from both known risks and a range of unforeseeable risks, some of which have not been observed before.

These interconnected risks unfold over short periods of time and interact with each other. In a network of multiple causes and effects, such risks may not be foreseeable at the disaster preparedness level, and may only be identified at the time of disaster response. The resulting higher level of complexity requires the integration of new thinking and decision-making at the disaster preparedness level.

Using complex system thinking and socio-ecological notions of resilience, this paper presents a conceptual framework to illustrate key differences between building specified and general resilience, that is, resilience to known and unknown risks.

Acknowledging and planning for uncertainty allows disaster risk reduction strategies to expand beyond risk mitigation paradigms to integrate policies that take into consideration systems' thresholds for maintaining a safe operating space – so allowing better preparation for unknown risks.

Keywords: unknown; preventive action; emerging and cascading risks; resilience framework; System of Systems.

1. INTRODUCTION

This paper addresses two of the Priorities of the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA). Priority 1 emphasizes the need for a 'strong institutional basis for implementation' and Priority 3 highlights the importance of creating a 'culture of safety and resilience at all levels'. This paper focuses on the interaction between these two priorities and the question addressed in the overall exploratory study is 'What is preventing communities and institutions from developing a culture of safety and resilience?' This paper proposes that Disaster Risk Management (DRM) would benefit from a complementary mode of thinking based on Complex Systems Thinking (CST) to more effectively address unexpected interdependent risks.

To answer this question the research draws on the socio-ecological distinction between specified and general resilience (Walker & Salt 2012). Specified resilience is the resilience to known risks, whereas general resilience is the resilience to unknown risks (Table 1). This second type of resilience can be considered as an all-hazard approach, since risks are unknown a priori.

This paper takes a social constructionist and interpretivist view (Crotty 1998), consciously different from the positive perspective taken by many authors (e.g. Khazai et al. 2013; Helbing 2013; Sornette et al. 2013; Cruz & Krausmann 2013). These perspectives

are equally important. However, risk management has provided mainly positivist approaches to risks (Haque & Etkin 2007; Cavallo & Ireland 2014) and this paper presents one possible way to complement this way of thinking.

1.1 Specified resilience

Current DRM practices are based principally on ISO 31000[1], a standard for risk management that involves risk identification and assessment. Following the direction given by HFA, many countries have implemented risk assessment practices and consolidated available information on risks. These practices have allowed capability development to deal with identified risk, that is, risks that are *complicated* (Cavallo & Ireland 2014). In other words, they have contributed to build specified resilience, that is, resilience to known risks.

The underlying assumption in the risk analysis is that causes and effects are connected in a linear way, so that by mitigating the causes, the identified risks will be mitigated or their magnitude reduced. Action plans define how risks will be managed. They normally follow a top-down approach; for example, the government communicates the risks that the community needs to prepare for. Risks are broken down into their components and responsibilities are distributed among a number of organisations. The sum of the actions corresponds to the overall DRM strategy. For example, in South Australia every key identified risk corresponds to the responsibility of a nominated government agency.

In systemic terms, the hierarchical system's configuration is called a 'System of Subsystems' (De Rosa et al. 2008), where every subsystem is dependent on the higher one in the hierarchy. In this case, the community is at the bottom of the hierarchy and risk communication and management occur in a standardized top-down manner.

1.2 General resilience

Disasters always contain elements of unexpected risks. Even well prepared people find that going through a disaster and managing the upcoming risks, triggers a plethora of unexpected risks and feelings of fear and anxiety.

In disasters, many risks are the result of multiple interacting risks arising, for example, from the environment, the disaster unfolding in unexpected ways and from varying degrees of personal and community resilience and preparedness. Modeling these interdependent risks is often either impossible or impractical (Cavallo & Ireland 2014). For the same reason, these risks are complex to anticipate in the sense that normally, the cause-effect nexus can only been understood in hindsight.

Top-down approaches to disaster risk reduction help by preparing resources with which to respond to the disaster. However, they may fail to identify the real needs of a household or a community and neglect relevant community strengths, which are equally important to response and resilience in the face of disasters.

General resilience is the ability of a community to respond in a flexible and adaptable way to unexpected emerging risks. It is a type of community capability, which cannot necessarily be taught or instructed, because it may well be based on inner values, daily individual and community routines, which are often unrelated to disaster management plans. For example, social capital is currently seen as one of the biggest drivers in building general resilience (Aldrich 2013). Some DRM programs include 'Meet your neighbors' as one of the instructions, without considering that a large number of community members work in a different place than the community in which they reside. For this reason, they are often away from home from 7 am until 7 pm on weekdays, which leaves little time and energy to have meaningful exchanges with their neighbors. When after-hours responsibilities in caring for families are taken into account, the connections between neighbors are further weakened.

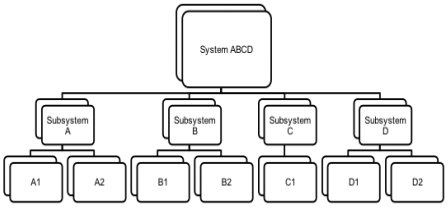
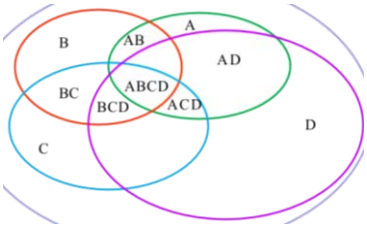
Table 1 summarizes the main differences between specified and general resilience and clarifies some of the concepts mentioned in this paper.

An important point of distinction between specified and general resilience is that disaster preparedness strategies, used to build specified resilience, normally focus on risk mitigation. On the contrary, general resilience building strategies focus predominantly on system's conditions and thresholds. The above example on community routines illustrates this.

Building general resilience involves more than the awareness of community's routines. It is about understanding system's leverage points in order to capitalize resources invested to build resilience.

[1] ISO 31000 - Risk management http://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. Differences between building resilience to known risks and unexpected interdependent risks (Cavallo & Ireland 2014, Snowden & Boone 2007; Williams 2002; Helbing 2013; Walker & Salt 2012).

SPECIFIED RESILIENCE	GENERAL RESILIENCE
Known / knowable risks	Unexpected interdependent risks
Complicated: cause-effect relationship can be established before the disaster	Complex: cause-effect relationship can only be established in hindsight
Reductionist thinking	Complex Systems Thinking
Top-down approaches	Bottom-up approaches and guided self-organization
	
Identified risks	Unforeseen, unanticipated risks or unprepared community
Linear thinking	System thinking
Exploitation of knowledge: Sense and respond	Exploration: Probe, sense and respond
Mitigate risk of negative events	Keep a safe operating space
General approach	Context specific
Written protocols	Flexible, adaptable frameworks
Standardized	Customized
Compliance and objective measurements	Dynamic identification of leverage points in the network

2. THE NEED FOR AMBIDEXTERITY IN DRM

Why is the distinction between specified and general resilience important?

A balanced approach to building specified and general resilience ensures that the community is better prepared for both known risks and unexpected risks. If the community is only prepared to face known risks, its resilience in facing unexpected shocks will diminish. Similarly, if a community were only prepared to face unexpected risks, it would be less prepared and resilient in dealing with identified risks. It is important to build both specified and general resilience (Walker & Salt 2012).

Today's DRM practices are primarily focused on building specified resilience (Cavallo 2014). This is because most institutions are organized in a hierarchical manner and consequently, problem solving occurs in a hierarchical order. For example, national, state or regional and local government, constitute a hierarchy and similarly, each of them internally is organized hierarchically. Therefore, the 'institutional basis for implementation' addressed in Priority 1 of HFA is a hierarchical one, based mainly on reductionist approaches and on risk mitigation.

Interdependent risks correspond to causal networks. Implementing a 'culture of safety and resilience' (HFA - Priority 3) is a complex task, because no 'recipe knowledge' is available. Hierarchical institutions tend to solve problems in a top-down manner following a hierarchical model. This means that institutions are trying to address a complex task by using complicated approaches. In other terms, hierarchies are adequate to address hierarchical complicated risks (Table 1), whereas networks and complex approaches need to be added to the DRR strategic focus in order to strengthen the 'basis for implementation' for DRM and to contribute to achieving Priority 1 of the HFA.

In conclusion, DRM strategies should promote ambidexterity in building disaster resilience by encouraging approaches based on reductionist and Complex Systems Thinking to prepare equally for known and unknown risks; therefore, building specified and general resilience.

3. CONCLUSIONS

Disaster Risk Management strategies aim predominantly to build specified resilience, that is resilience to known risks. This way of thinking is normally reductionist and presents a number of limitations. For example, an important disadvantage is the failure to tackle unexpected interdependent risks and build general resilience, that is, resilience to unknown risks.

Priority 3 of the HFA invites the building of 'a culture of safety and resilience at all levels'. This paper argues that this is a complex task and that it needs to be addressed using network approaches, which correspond to the causal networks in which unexpected interdependent risks may emerge. If the institutional basis for DRR and the related problem-solving structure are hierarchical, they can only address certain risks, normally those that are known or knowable (also called complicated). Unexpected interdependent risks are complex risks that need to be addressed with network approaches (Cavallo & Ireland 2014), which, for example, factor in community specific needs and strengths that are pivotal in building a 'culture of safety and community resilience at all levels'.

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