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Understanding and mitigating cascading crises in the global interconnected system

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ABSTRACT

Cascading crises and disasters in the global interconnected system are emerging topics in today's disaster risk reduction research. The primary objective is improving the capability of our societies to cope with such events and mitigate their detrimental consequences through an evolved understanding of their nature. Rather than being merely considered as an outcome of low-probability/high-impact processes, cascading events can be associated with the cross-scale accumulation of vulnerability paths constituted by events waiting to happen. In this context, instead of focusing solely on triggering events, it seems important to point out the interactions orienting the escalation of secondary emergencies through vulnerability paths.

This special issue integrates those emerging aspects with an operational approach that considers cascades as the complex, non-linear escalation of secondary emergencies. Key topics addressed by the contributions include: cross-domain modelling of interdependent systems; decision support systems; economic impact assessment of critical events; and cascades in the built environment, in social domains, and in applied emergency management. Our conclusions support the work of academia, and of public and private stakeholders, by providing a comprehensive analysis of the topic for the improvement of theory, the assessment of resilience, the formulation of policies for managing crises, and operational planning for emergencies.

1. Introduction

Cascading crises and disasters in the global interconnected system are emerging fields of research in disaster risk reduction. Adopted since the early 2000s in different contexts e.g. [11,19,3], these concepts have become more common in the global community since recent events such as the 2010 eruption of the Eyjafjallajökull Volcano and the 2011 triple disaster in Japan. Cascades have often been intended vaguely to describe some disruptive event chains or consecutive failures by associating them with the analogy of toppling dominoes or regarding them as synonymous for "knock-on" effects. However, the literature has developed significantly in the last few years, leading to evolution of the interpretation of such phenomena and to the development of specific frameworks for analysis. This research area has also been supported by national governments, international institutions, such as the European Commission, and private enterprises.

Significant new evidence has been provided on "traditional" topics related to cascading events, such as the resilience of critical infrastructure [17], and interaction with environmental hazards [9]. Moreover, the complex causal chains that join environmental dynamics to human stressors have been explored in the study of cross-border ecological crises stemming from climate change [5]. In addition, global interconnected risks have been interpreted in the light of cascading effects in major international networks [10]. Overall, the literature suggests that it is necessary to go beyond risk management in order to address the high levels of uncertainty of future challenges [18].

This special issue (SI) integrates these points of view with an operational approach that interprets cascading events in terms of the complex, non-linear escalations of secondary emergencies, as defined by Pescaroli and Alexander [24]. The main goal is to present a range of perspectives that could show the interactions and interconnections that guide the escalation of secondary events through vulnerability paths, instead of focusing only on triggering events [28]. In other words, we explore the different aspects of cascading events as cross-scale accumulations of vulnerability paths waiting to happen, rather than being merely an artefact of low probability, high-impact processes. Although this process has already started [22,30], it can benefit from the integration of more cross-disciplinary perspectives in sectors such as emergency and contingency planning [1], and scenario building [25,26]. This may include cross-domain modelling of interdependent systems [8] and economic impact assessment of critical events [13,7].

Cascading risk can be distinguished from other concepts used in the literature, such as compound, interacting and interconnected risk. This calls for a different approach to the analysis of the vulnerability drivers and its translation into operational tools for disaster management and policy making [29]. Beyond enhanced theoretical interest in cascading events, this perspective has very practical implications and opens the possibility for a number of applications that are relevant to disaster management stakeholders. In this sense, the United Nations' (UNISDR) *Guidelines on National Risk Assessment* [32] have recognised the need to include a cross-sectoral and multi-risk approach to cascades in the implementation of the Sendai Framework for Disaster Risk Reduction[1]. Moreover, [15] have acknowledged the challenges associated with the dynamics of cascading events

[1] https://www.unisdr.org/we/inform/publications/43291.

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when linked to drivers such as climate change. Finally, the concept of escalation has been applied in joint documents produced by academic scholars and local authorities for improving the training of emergency planners to cope with events such as blackouts [27].

This special issue explores the topic of cascading crises with the aim of expanding the field by means of 14 papers. First and foremost, this was made possible thanks to the interest and collaboration of many colleagues who contributed their research and committed time to the review process. Moreover, the support of the European Commission's Joint Research Centre and the University College London's Institute for Risk and Disaster Reduction was fundamental. We are confident that the work in its present form can provide a solid basis both for future literature and for the development of practical applications. To support these expectations, methodological results have been put side by side with a number of case studies that cover a broad range of disaster scenarios, which result from both natural and anthropogenic triggers. In this way, interconnections and interactions have been contextualized in the built environment and the social domains. Thus, they provide a comprehensive portrait of the topic and support the improvement of contingency planning, scenario building, vulnerability assessment and the cultivation of resilience.

2. Theory, methodologies, and organisational steps for understanding and mitigating cascading crises

This special issue has begun to address some key questions: –

- How do cascading disasters propagate and escalate?
- How do primary triggers and vulnerability paths interact?
- Which nodes concentrate most of the vulnerability and what are their carrying capacities?
- What are the relationships and interdependencies among critical infrastructure that may frequently be underestimated?
- What can be done to contain escalations, and at what spatial and temporal scales?
- How can assets and infrastructures be tested against stresses and critical events in order to promote their resilience in the face of cascading or escalating events?

In this section, we aim to provide an organized overview of the contributions proposed as part of this special issue. In particular, this SI involves three main thematic areas, which interact and converge with one another.

(a) A number of the papers assess and promote the evolution of the theory of cascading disasters, often with an emphasis on novel interdisciplinary aspects to be taken into account in future research.
(b) A group of authors tackle the development of assessment criteria for a better understanding of interdependencies. They propose additional approaches that could be of interest for stakeholders in the public and private sectors.
(c) As a whole, the issue contains a rich portfolio of new strategies that aim to improve organisational resilience by targeting emergency planning and policy making, with the support of empirical case studies.

In the rest of this section we provide a short outline of the contents of the papers that contribute to each of these themes.

2.1. Evolving the theory of cascading crises

In recent times, a number of research projects have substantially nurtured the development of the theory of cascading disasters. Notable examples include EU-funded FP7 projects such as FORTRESS[2], SNOWBALL[3], CASCEFF[4] and CiprNEt[5]. The literature cited in the introduction also suggests the need to explore additional theoretical and practical aspects of cascades.

In first instance, Miller and Pescaroli [20] apply a social-ecological approach to how psychosocial capacity building (PCB) could address the escalation of cascading disasters. Indeed, the loss of services and secondary emergencies can influence collective behaviours for which the dominant paradigm disseminated among mental health professionals would not be effective alone. The paper argues that integrating PCB will support local processes of healing, psychosocial restoration, and sustainable recovery in cascading disasters, thus mobilizing new resources for responders and citizens [20].

A different analysis is proposed by Kelman [16], who explores the possible conceptual interactions between cascading disasters and disaster diplomacy in order to understand possible theoretical synergies between these two emerging fields. Differently from cascading disasters, disaster diplomacy examines how and why disaster-related activities influence the prospects for peace or conflict. The paper suggests the idea that cascading disasters could help to map the causal pathways of disaster diplomacy while highlighting the need to make use of social perspectives from the literature [16].

The paper by Alexander [2] focuses more on merging the theoretical components of the literature with the needs of modelling and emergency planning. This is achieved by developing a magnitude scale for cascading events. This study builds upon previous findings e.g. [24,28] and develops theory from the earlier works for specific empirical uses. The magnitude scale aims to facilitate the comparison between events in order to maximize the exchange of information and the ability to learn lessons, which is the basis for improving mitigation and training, in particular in the domain of the cross-sector influences of critical infrastructure disruption [2].

The same approach has been utilised by Galbusera and Giannopoulos [6]. These authors review the role of input-output (I/O) models in the analysis and assessment of disaster impacts, in particular those associated with the quantification of multi-regional loss and responses to shocks in global supply chains. The paper highlights the emerging challenges and opportunities for I/O analysis and its application to complex disaster scenarios. The discussion approaches the contribution of new models to I/O techniques, including triggering perturbations, static and dynamic representations, and the analysis of economic resilience [6].

Finally, the contribution of our SI to the theory of cascading disasters is completed with the work of Zuccaro et al. [35]. From a theoretical point of view, their research discusses the modelling needs and the main challenges that have to be considered for the development of simulation tools for cascading effects, integrating the outcomes of the EU-FP7 SNOWBALL project (2014–2017) mentioned above. The primary goal of this paper is to derive a framework model for developing scenarios on cascading effects at varying spatial and temporal scales, using levels of detail that could be derived from what data is available at the local level [35].

2.2. Methodologies for assessing interdependencies

The analysis of interdependencies and complexities that underlie the development of cascading events is a primary aspect of interest. Accordingly, the authors of this special issue have brought a vast range of cross-disciplinary perspectives to the area of interdependency assessment.

Clark-Ginsberg et al. [4] define a conceptual structure from among the different methods used to evaluate the complexity of systems, hazards and consequences, and also their practical applications. In this research, linear and networked risk assessment methodologies are

[2] https://cordis.europa.eu/project/rcn/185488_en.html.
[3] https://cordis.europa.eu/project/rcn/185475_en.html.
[4] https://cordis.europa.eu/project/rcn/185490_en.html.
[5] https://cordis.europa.eu/project/rcn/107425_en.html.