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Progressing the research on systemic risk, cascading disasters, and compound events

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ABSTRACT

Disaster risk in the 21st century differs from the experience of past generations and is defined by its evolving systemic nature. The increased role of technological networks, societal interdependencies and climate change dynamics make crises more complex and unpredictable. Cascading and compounding dynamics are becoming the new "business as usual", challenging emergency management to maintain operations in face of complex disruptions while requiring the development of good practices and strategy for facilitate the recovery process. Our special issue aimed to support the development of a paradigm shift in the understanding of complex events, utilizing a network-based, cross-disciplinary approach to resilience. This editorial introduces and summarizes 18 papers across four thematic areas: 1) Resilience Challenges; 2) Area Studies and the Sendai Framework for Disaster Risk Reduction; 3) Community and Health; 4) Enhancing New Methodologies. The conclusions highlight open research challenges for future exploration.

1. Introduction

Over the last two decades, systemic risk, cascading disasters, and compound events have transitioned from being a "niche" subject to core topics in emerging disaster risk reduction. This increased focus is linked to events like the 2010 Eyjafjallajökull volcano eruption in Iceland and the 2011 earthquake, tsunami, and nuclear meltdown in Japan. These concepts are directly tied to vulnerability pathways across geographical and environmental scales, leading to possible escalation of secondary crises [1]. It can be argued that the interconnected nature of modern society suggests that most disasters are evolving into cascading events. The potential recombination of critical infrastructure disruptions with other dynamics, such as compounding climate change extremes, increase the possibility of concurrencies and underscores the need for a consistent holistic approach [1].

The academic literature has witnessed a rise in research and special issues on these subjects [2,3,4]. The evolution of the field highlights the need for increased cross-disciplinary collaborations, with the scientific community working closely with practitioners. Systemic risk has been integrated into flagship reports of the European Commission [5] and in two Global Assessment reports of the United Nations [6,7]. However, the complexity of the field poses a challenge for traditional approaches, requiring further research to improve management and governance principles [8,9]. The 2020 coronavirus pandemic and growing concerns about climate change tipping points have spurred literature development, linking societal aspects with capacity, organizational resilience, and tools like stress testing [10,11,12]. Similarly, new frameworks are emerging to support progress in systemic multi-hazard and multi-risk management [13].

This special issue aimed to support progress in the field by inviting contributions to enhance understanding of systemic risk, cascading disasters, and compound events. We invited authors to analyse key questions:

- ✓ How do systemic risk, cascading disasters, and compound events interact and influence each other, escalating complex crises?
- ✓ What case studies could provide a better understanding of the topic, supporting the implementation of good practices and governance?
- ✓ How can a better understanding of the role of critical infrastructure promote resilience to systemic risk, cascading disasters, and compound events?
- ✓ Are there lessons learned that are missing when considering communities, individuals, and society?
- ✓ Which new methodologies could be implemented and adopted?

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The response to our call for contributions was very positive, resulting in the inclusion of 18 papers. The special issue organizes them across four main thematic areas that contribute and complement each other:

- ✓ Challenges for the resilience of global interconnected systems, examining global risks, emphasizing preventive policies, human mobility integration, and critical infrastructure resilience.
- ✓ Area studies and the Sendai Framework for Disaster Risk Reduction, focusing on connecting cascading risk to the UN Sendai Framework for Disaster Reduction, exploring Asia Pacific, India, Metro Manila, and Central Asia.
- ✓ Community and health in systemic risk, including aspects such as disaster education, indigenous healing, health threats, and exposure during disasters.
- ✓ Enhancing new methodologies for complex events, such as diagnostic tools, challenges for evacuation and supply chain, forensic investigations.

In the next sections of this editorial, we provide a short outline of the papers that contributed to each of these themes to develop a comprehensive view of the special issue.

2. Challenges for the resilience of global interconnected systems

The paper of the special issues analysed the networked systems that are the backbone of globalised society, understanding possible root causes of cascading and complex disasters. Cernev [14] explored the impact of global catastrophic risks and Planetary Boundary crossings, emphasizing the need for preventive policies. This paper developed a scenario analysis of possible futures, deriving pathways associated with the possible implementation of international targets, and suggesting preventive polices and the integration between international frameworks. Kelman et al. [15] considered with new lenses the challenges of the 2010 Eyjafjallajökull eruption, which disrupted European airspace becoming a seminal case for understanding cascading disasters. The study explored the root causes and cascading impacts of the event, drawing insights from disaster risk reduction, complexity sciences, and health. The authors identified that managing air travel dependency and averting future calamities are two essential steps that need to be considered in policies and practices [15]. On the opposite hand, Tagliacozzo et al. [16] focused on the implications of human mobilities and their roles in shaping exposure, amplifying disaster impacts, and influencing global resilience. Embracing human mobility as a positive force, the study suggests that integrating population movements in systemic risk framework could generate positive outcomes of resilience and disaster risk reduction [16]. In conclusion, Wells et al. [17]. focused on how built environment allows interdependencies and conducted a systematic literature review to understand critical infrastructure resilience under compounding threats. The study evaluates network science literature focus on various phases of resilience across different domains, underscoring the opportunities for improving models and existing strategies on the subject [17].

3. Area studies and the Sendai Framework for Disaster Risk Reduction

The authors of our special issue connected the broader considerations on cascading and systemic risk with the development of new case studies that were linked to the United Nations Sendai Framework for Disaster Risk Reduction. Ahamed et al. [18] delve into the evolving understanding of systemic, cascading, and compound risks in disaster management and explored the experience of the Asia Pacific region. Through a literature review and the analysis of 40 case study analysis, the study provides insights into these complex risks and offers recommendations for their effective management [18]. Mitra and Shaw [8,9] analyse India's disaster management history and recommend systemic risk management principles to address contemporary challenges. The study emphasizes the need for comprehensive, proactive risk management methods and highlights the alignment of these principles with international objectives and global strategies [8,9]. Ner et al. [19] explored the integration of resilience attributes into local disaster management in the case of in Metro Manila, identifying gaps in areas such as ecosystem protection and disaster victim participation. The research recommends solutions, including inter-city learning platforms, nature-based strategies, and inclusive recovery planning [19]. In conclusion, Smith and Shashkina [20] recorded the stakeholder perceptions of critical infrastructures facing compounding threats in Central Asia. The results highlight some limited awareness of cascading risk, that need to be further considerate in local strategies.

4. Community and health in systemic risk

Our special issue considered the healing process and how this could be used for increasing resilience. Pormon and Lejano [21] advocated for a new relational approach that could reimagining the "subject-other" relationship. The papers discuss some possible pedagogical changes, proposing a case study where students become climate change risk communicators. The results suggest positive outcomes in awareness, sustainability, and resilience that highlight the potential of integrating this approach into formal disaster education. Quinn et al. [22] focus on the relevance of indigenous perspectives, including healing practices, in disaster resilience. The study proposes an Indigenous-informed healing framework to address collective trauma arising from complex crises. The author suggests merging indigenous healing and disaster recovery, recommending some new culturally responsive practices to enhance resilience that could be applied to the broader society [22]. The other author of this session focused on the important topic of how cascading effects that could create and escalate cascading crisis within society. Cuthbertson et al. [23] apply disaster risk reduction concepts to examine health threats arising from societal disruptions like drug addiction, domestic violence, and suicide in Australia. The study identifies these events as disasters according to established classifications, advocating for the integration of health emergency and disaster risk management practices to mitigate their impact [23]. Finally, Dodd Butera et al. [24] provided a timely overview how extended power loss and subsequent use of makeshift heating and cooking elements in poorly ventilated spaces could cause disaster-related carbon monoxide (CO) and has implication for the. This study synthesizes evidence related to disaster-associated global CO exposures, reports of CO exposures in pregnancy, and associated individual outcomes in the maternal-fetal dyad, which represents a particularly vulnerable category of population that require target actions [25].

5. Enhancing new methodologies for complex events

Finally, the papers of our special issue focused on the existing methodological gaps that need to be addressed for increase system resilience. A first relevance has been attributed to modelling and quantitative approaches. Bodin et al. [26] highlighted how the literature on compound disasters has been lacking insights on how compounded emergencies can challenge response systems. The authors introduce a diagnostic tool for promote effective responses to compound crises, defining possible scenarios, creating network-based system model of actors and functions, and formulate diagnostic questions to identify the existing vulnerabilities [26]. Bian et al. [27] focused on the challenges associated with evacuation strategies and how they could impact household evacuation decisions in complex emergencies. The study promoted a survey that reveals how traffic management can motivate a percentage of households to evacuate, but there is the need for clear information to address decisional uncertainties. The paper proposes new multinomial logit models can be used to estimate these impacts, supporting a pathway toward better evacuation [27]. Two studies drove on

the lessons learned of the coronavirus pandemic. Haraguchi et al. [28] proposed new conversion strategies for managing disruptions in interconnected supply chain risk management during complex crises. The authors compared supply disruptions from natural hazards and the coronavirus pandemic, deriving considerations to support policy and decision makers on six critical areas that could adaptation measures including location, line, storage, usage, distribution, and workforce skills to support policy and decision makers [28]. Finally, Terzi et al. [29] maintained a focus on complex multi-hazard conditions, proposing a 'parallel phases' model that analyses the characteristics of slow-onset hazards for enhancing preparedness, the allocation internal resources, and implementing multi-hazard seasonal forecasts for anticipatory planning [29]. In conclusion, some consideration on methodological approach included the social sciences, complementary to the existing modelling approaches. McDermott et al. [30] analysed the potential of adopting forensic investigations for addressing the challenges of systemic risk. The paper considered the use of qualitative methods and in particular visual representations to determine system boundaries, root cause analysis and generating collective mental models. The authors suggest that process such as developing using interviews for developing casual maps could enhance the use of cross-disciplinary expertise an [30].

6. Conclusions

The papers in this special issue have advanced the state of the art on systemic risk, cascading disasters, and compound events. However, there are still many gaps that have been highlighted by our contributors. Future research should give priority to steps in the following areas:

- ✓ Integrating the social and cognitive domains into existing models and resilience strategies. This should give some particular attention to the integration of risk perceptions for tailored information and effectively using data to support vulnerable categories;
- ✓ Addressing gaps in risk assessments by incorporating critical infrastructure network preparedness adaptation and developing complementary methods, such as causal mapping, to understand interacting complexities;
- ✓ Promote a better understanding of which vulnerabilities can escalate cascading crises, focusing on underlying risk drivers like human mobility, health disparities, and operational capacity;

In conclusion, disaster risk reduction remains an applied field with an eagerness to translate theory into impact. However, the challenge lies in how science can effectively support multi-stakeholder engagement, fostering collaborations among governments, scientists, non-profits, and the private sector. Moving beyond in improving the science-policy interface can promote the development of proactive and reactive strategies for collaboration in complex crises.

CRediT authorship contribution statement

Gianluca Pescaroli: Conceptualization, Writing – original draft. **Anawat Suppasri:** Writing – review & editing. **Luca Galbusera:** Writing – review & editing.

Declaration of competing interest

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Data availability

No data was used for the research described in the article.

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