Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2018-277-RC1, 2018

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Natural hazard risk of complex systems – the whole is more than the sum of its parts: I. A holistic modelling approach based on Graph Theory" *by* Marcello Arosio et al.

Anonymous Referee #1

Received and published: 23 October 2018

Natural hazard risk of complex systems part I introduces graph theory into risk analysis to promote a paradigm shift from reductive to holistic approaches to risk assessment and assess the risk of complex systems. Through a review of graph theory as it relates to risk, including issues of exposure, vulnerability, and resilience, and the development of an illustrative case, the authors show how network analysis can be employed to assess complex interdependent systems. The authors' main argument is that current risk assessment approaches fail to capture complex interactions between systems as a whole, and that network analysis techniques can be used to capture that complexity.

The authors are correct that current risk assessments are often reductionist and fail to

account for interconnections and the properties of the system as a whole. Readers will also benefit from this topic given the prevalence of risk analysis that take a reductionist perspective. However, there is a significant body of work using graph theory for risk analysis. A large literature builds on Rinaldi et al. (2001) to use graph theory to assess critical infrastructure risks, interdependencies, and cascades (Lewis 2014; Setola et al. 2016), and another focuses on the systemic risks in financial systems (Summer 2013) Instead of focusing primarily on the connections between physical structures of infrastructure, another body of work focuses on the interconnections between hazards or hazards and vulnerabilities showing how risks can propagate and cascade (Clark-Ginsberg 2017; Gill and Malamud 2014).

This literature (and the broader qualitative literature on networks of risk) identifies several challenges with using network analysis for risk. Chief among them is how to account for the multi-level, open-ended nature of systems in graph based approaches. For instance, Schulman and Roe (2016) and other high reliability theorists point out that infrastructure systems are vastly more complex than modelers make them out to be, with substantial coupling across components that is difficult to discern. Clark-Ginsberg et al. (2018) applies these insights to argue that network bases approaches of open-ended systems can never be complete and require careful decisions on how to delimit boundaries and describe networks. The authors allude to the idea of system incompleteness when discussing the nestled nature of power infrastructure, but then purport to offer a complete network (p6), which is not possible given the open-ended nature of risk.

This literature shows how graph theory can be used for representing complex issues of risk in a holistic way and also provides a grounding in some of the challenges associated with the topic. The authors need to clearly state how their work contributes to this literature. Because they do not engage with this literature I do not believe there is enough for a standalone theoretical paper on their topic. Rather than publishing this as a separate piece, I recommend using this article as a basis the literature review/methodology of the empirical paper, which provides a useful contribution to the literature.

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