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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Indirect flood impacts and cascade risk across interdependent linear infrastructures" *by* Chiara Arrighi et al.

Chiara Arrighi et al.

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Overall a very relevant empirical paper that contributes to an area which is still lacking such studies.

Reply. Thank you for your comments. We appreciate that the reviewer recognized that the topic of cascade effects of natural hazards and associated indirect impacts is key for the flood risk community. Understanding the magnitude of potential losses of interconnected system can greatly improve preparedness and resilience of communities, thus more applied research should be carried out in this area.

On language I am not qualified to judge, but you may run a grammar check on some

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Discussion paper

sections where "a" or "the" seem to be missing such as in line 25.

Reply. A grammar check will be performed on the revised manuscript to correct typos.

Abstract first sentence: check for usage of hazard instead of threat. I suggest to modify it to "one of the..." which seems more realistic given the wide spectrum of what could be regarded a natural threat/hazard. Earthquakes are more frequent, for example, but you probably mean a certain combination with magnitude.

Reply. We are going to modify the sentence in the abstract to better recognize floods among other natural hazards.

Line 42-44. Linear structures can become complex, but must not. Within complexity theory, linear systems often are not understood as complex. Also I am not sure why point infrastructure should not become complex regarding interactions. Considering Rinaldi et al 2001 on interdependency types, I would assume that for example, logical interactions between point objects can become quite complex, i.e. non-linear. I therefore suggest to formulate it a bit more cautiously. Also, why must it be ad-hoc modeling and not before and event? "Three models are ..." you may add "in this study"

Reply. We agree that also point critical infrastructures are crucial and might interact with other points. A hospital can be seen as a point critical infrastructure and it is true that its manifold functions foresee the interaction with other points. What Authors meant here was that linear critical infrastructures (e.g. roads, piping systems, railways etc.) are complex networks of lines (arcs) and points (nodes); this networked nature makes them more susceptible to propagate impacts given both the physical and functional inter-dependency. To make this point clearer the paragraph will be rephrased and also the need for this study to use three models will be explicitly mentioned. This study shows an “ad-hoc” modelling to develop and apply a method; however, practical tools could be further develop from it, e.g. including modelling for pre-event assessment.

Line 47: I think this claim is not backed by a thorough literature analysis, so I suggest

to omit it or make it more precise; related to the specific location. Some of the authors you have mentioned above, for example, have done such assessments, too. But many others, too. Line 48 provide some examples of fields where it could be applied.

Reply. Authors carried out an extensive literature review on the topic and could not find any other paper which presented an applied work where indirect impacts and cascade effects are analyzed based on the dependence of critical infrastructure. Studies related to flood impacts on a single network or to conceptual interdependent networks were mentioned in the literature review (Section 1); this Section will be revised and updated with new works (if any).

Line 50: "Systems" are not just "CI systems"; correct the wording.

Reply. Authors adopted the definition of “systems” by Gardner (2016), which does strictly refer to an engineering and urban perspective. We are aware that other “systems” do exist (e.g. socio-economic, biological, etc.), but these are out of the scope. This aspect will be clarified in the manuscript.

Line 52: Some sources have rightly criticized that CI are more than just physical or organizational; they include staff, humans as user, environment, non-structural aspects such as regulations etc., too.

Reply. Authors absolutely agree, the perspective here described is more an engineering perspective related to ‘hard infrastructures’, but it is worth mentioning what you suggested. We will broaden the description in the text.

Line 70. A "more thorough understanding" should also go beyond traditional magnitude/probability formula, some argue and should include impacts in terms of different types of impact spheres (human, environment etc.) but also include questions of which quality, quantity and volume of values are affected and what types of risk management or protection goals exist to help prioritize such criticalities.

Reply. Authors recognize that a more thorough understanding may require a paradigm

shift going beyond the traditional approach. However, a disruptive change in evaluating impacts implies a wide agreement in the research community. Authors believe in the need of including robustly the societal sphere in these analyses but as engineers we need to involve other expertise in a multi-disciplinary work, often hard to achieve. We fully understand that considering the human sphere is key in understanding indirect (often intangible) impacts and this paper represents an attempt towards that direction. In fact, we presented different impact metrics where the people are central by evaluating the population not served and delayed commuters.

135: check the term "shorts-out"

Reply. The term will be substituted by “impair”.

166 Add a source to AAL. What about the maintenance and repair cars and teams that are mentioned above as a main motivation?

Reply. AAL is the frequency-weighted amount of loss that can occur on average in any year, we will add a reference to a widely used manual by USACE who introduced its application to a broad audience. (USACE, 1989 - USACE: Expected annual flood damage computation [available online at https://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/CPD-30.pdf] last access 2-5-21, 1989. A source will be added also for the critical need of granting access to WSS main plants for repairs and replacement during flooding.

202: instead of the tiny URL, provide a proper source description. What type of railway is this etc.

Reply. A proper citation to “Technical overview: Payments relating to disruption” of Network Rail (UK national railways) will be specified.

302: sources for the quantitative measures? or is this computed by you? until 320: it seems you have computed those values; what data did you use to achieve it (i.e. road network data sources, types etc.?)

Reply. Authors made the simulations and obtained the results described in the section. For the Water Supply System, the data about the piping network (e.g. pipe diameter, nodes, demand at nodes, position and capacity of storage tanks, position and power of the pumps and lifting station) were provided by Publiacqua s.p.a. the society in charge of managing the integrated water cycle in the area. The road network information (road shapefile and associated attributes related to type, speed, etc.) are openly available in the geographic data portal of the Region. For both models, the exposure analysis was carried out by intersecting the network with flood hazard maps as described in the "case study" paragraph. We will better describe the WSS data and road network data necessary for running the model in section 2.

Table2 very nice and relevant results. Could you provide estimates of possible error margins? A sentence or two would suffice, maybe in the discussion. Just since this looks too exact.

Reply. The results are integer numbers because they are calculated as the sum of the population equivalent (PE) assigned to each affected node, i.e. a node not capable of supplying the nominal demand. PE is based on the density of resident population (census data) and type of the demand (e.g. residential, industrial etc.). Errors in the estimation of PE are comparable to the variations of resident population in census data (updated every 10 years) and of the order of a few, negligible percent in this analysis. We will add this information in the discussion.

356 check grammar

Reply. Grammar will be checked.

359 do those SUVs permit higher wading depths, such as trucks (0,5m)?

Reply. The instability threshold for any vehicle in floodwaters is function of both: (i) water depth and velocity and (ii) geometry and weight of the car (see a whole paper by the first author devoted to this hydrodynamic analysis: Arrighi et al. 2015, "Drag and

lift contribution to the incipient motion of partly submerged flooded vehicles", Journal of fluids and structures). In principle, SUVs and other emergency vehicles are less vulnerable than passenger vehicles (higher planform height and heavier); however, since the flow velocity is not known in this application and the lifting station is very close to the river banks, 0.3 m are assumed as a conservative threshold.

399 This must not be so, road nodes and section, crossing could also be of interest. Maybe just add "within this study"

Reply. The text will be amended.

403 add a source for Value of Time, or VOLL

Reply. A source for the Value of Time will be added (e.g. Pregnolato et al., 2016)

428-433 Interesting areas for future work. Might be illustrative for readers to add a few sources as examples who covers bridges, power supply, operation times etc.

Reply. We will add some new references for the suggested purpose.

Literature Some sources cited in the text are missing in the reference list.

Reply. The reference list will be checked.

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