

## ***Interactive comment on “Towards Resilient Vital Infrastructure Systems: Challenges, Opportunities, and Future Research Agenda” by Seyedabdolhossein Mehvar et al.***

### **Anonymous Referee #1**

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Review of Manuscript "Towards resilient vital infrastructure systems: Challenges, Opportunities, and future research"

Comments:

The article aims to compile all relevant literature regarding resilience assessment and quantification of vital infrastructure systems (VIS). It points out quite extensively how is this literature specific for the different types of VIS and how every resilience conceptualization originates tensions when designing such infrastructure. It certainly represents a valuable document for people interested in resilience definition and quantification of VIS. While I would like to acknowledge that this manuscript has quite some potential it

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is difficult to read, and it certainly has a promising title which to my point of view does not reflect in the content. My two main criticisms for this manuscript are:

1. It gives high importance to the collection of interviews in the methodological section and yet it never points out opinions, agreements or even discuss the view of the interviewees. If you remove the promise of using interviews from the text it would not make a change in the paper. This also makes it a bit confusing to understand as the it is not clear if the paper structure is a literature review as sometimes it seems to be written as an opinion paper.
2. It supports the author's claims based on multiple resilience concepts which require to be defined beforehand so that the reader understands and follows the story. Defining the concepts before elaborating on them is almost a rule in resilience literature as Engineering, ecological and socioecological resilience views use similar terminology with different meaning. Furthermore, resilience concept definitions almost define quantification indicators of resilience in each context. This is very important as resilience thinking is contextual and discipline biased.

For this reason and other pointed out afterwards I suggest to accept the manuscript after major revisions as I still think it will be a good contribution for the field but significant editing and clarification work is required. Another small suggestion is that there are too many subheadings in the paper which have almost now relevant formation which makes it difficult to follow and long to read. This may be synthesized making the paper a bit more clear.

Major comments:

The resilience definition is always determined by the system definition. The system is related to the field of study. I suggest this is a simple method to define resilience of a system. First define the system then elaborate of its resilience definition. Not the other way around. The paper reads more like a review paper in which is never clear how the interviews contrast the literature or support the claims. It's said that interviews where

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held but it seems that no analysis was done over them.

Analysis of resilience should be framed under an specific resilience optic, heuristic or discipline, e.g. engineering resilience, ecological resilience, socio-ecological resilience or the case specific structural resilience etc.

It also poses contradictory statements about concepts and method presented as non-engineering ones which are not true.

In my opinion (which may be very subjective), the tittle (. . . , and future research agenda) suggest that the authors will point out or give directions towards knowledge gaps and future research, but the section intended for this does not contain enough information regarding these matters. This section is more written like a recommendations section that points the things that resilience is doing wrong rather than what is envisioned by the authors as the required research agenda. In simple words, if the tittle promises something but does not deliver what it promises, it just becomes 'Scientific click bait'.

Authors tend to elaborate over concepts and definitions (e.g. Shock, pressure, hazard, Failure, system failure) which have not been previously defined and later on they explain some of them. The order follows, first you cite the concept, then you define what it means it and later elaborate. Few examples of what I'm saying are:

Line 82: Where did you explain the concept of engineering resilience

Line 232: Which are the resilience levels? Concept introduced but no explanation given before.

Detailed comments:

Figure 1: Depending on the resilience context, system and discipline Shocks and pressures can be the same or different components of the system disturbances. Furthermore, literature sometime mixes pressures and stresses. For example, shocks are instantaneous disturbances like floods and earthquakes whereas pressures can be

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long term characteristics of the system like population growth or climate change. If you are going to use both (shocks and pressures), please define what is a shock and what is a pressure or if they represent the same thing as it remains a big question along the whole paper? Also, try to include the stress definition for clarity as some of the claims are supported by stresses as well. please see : Shocks: Zseleczy, L. & Yosef, S. 2014. Are Shocks Really Increasing? A selective review of the global frequency, severity, scope and impact of five types of shocks. 2020 Conference Paper 5. May 2014. Washington, D.C.: IFPRI. Stresses (pressures) Bujones A., Jaskiewicz, K., Linakis, L. & McGirr, M. 2013. A Framework for Analyzing Resilience In Fragile and Conflict-Affected Situations. USAID Final Report. Columbia University SIPA 2013. Mock, N., Bén e, C., Conostas, M. & Frankenberger, T. 2015. Systems Cluster Paper: Systems analysis in the context of resilience. For discussion at the meeting on Resilience Measurement Technical Briefings. Resilience Measurement Technical Working Group. Rome: FSIN.

Line 362: What is a favorable system regime?

The main comment after finishing the paper is that it is missing clear definitions of what the authors want to attribute to VIS resilience or want to deliver as their own definition VIS resilience (see first paragraph of section 3.3 for example). So, I strongly suggest to either explain what the authors understand themselves as VIS resilience since the early start of the paper of the paper to make the scope of the paper clearer. Also, I suggest moving section 3.3 towards the beginning of the paper.

I also feel that the confusion of which type of paper in which type of paper is this manuscript is what makes the paper so long to read and makes it lose its powerful message.

In the introduction is clear that Ecological and Engineering resilience distinction is made but I think you are missing to include analysis of systems resilience. A systems resilience analysis is related but not the same thing as a structural engineering

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resilience analysis. Sometimes they are not even methodologically connected. See your own citation of Hosseini (2016). He clarifies the definition of engineering resilience

Line 53: "Estimates show that disruptive impacts on people cost at least \$90 billion per year (Koks et al., 2019; Nicolas et al., 2019)." Please geo-reference this statement like "90 billion per year in European countries or in Delta regions" as it is highly unlikely that this value is the same all over the world.

Line 55: What does it mean direct damage of Natural Hazards? Is it structural damage? Or is it operational damage? Or incurred losses due to disruption?

Lines 61-to63: Please check sentence as grammar is sloppy.

Line 66 to 68: What does the classic distinction claim from Holling (1996) in short? Why is it important to cite this author if his claim cannot be confronted with the subsequent claims citation from Hickford (2018) and Hollnagel (2006) which you DID explain in short?

Line 80-81: I Do agree that only few studies present actual assessments of infrastructure resilience but if they are only few why you don't cite them?

Line 82: Where did you explain the concept of engineering resilience (this ia also linked to the general comments)? Otherwise is difficult to understand why it is difficult to apply.

Line 106: I this a literature review type of paper or a state-of-the-art kind of paper? These are two different types of manuscript and therefore they should be written in different ways. To my view, is a mix of both and I personally don't see the added value. I suggest to adapt the paper into a state of the art type of paper as the main claim of it is that until now, applying the resilience concept to VIS is difficult and this paper tries to organize this and from there it identifies new challenges and opportunities in resilience research of VIS.

Lines 118 to 119: Which are the four selected infrastructure systems? Please list them. I'm aware that you listed them in line 41 a 109 is not clear if they are standard or you

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chose them for the study. Is it correct to say that VIS are more than the four listed ?

Paragraph 117 to 126: Is it correct to attribute all 30,000 documents for example to resilience related documents? Or does this mean that your search query words were found in 30,000 documents?

Line 143: I'm not sure if the word "infrastructures" is correctly used in this sentence as infrastructure is already a plural. Please double check.

Lines 143-to 144: Are shocks and causes the same thing? Please unify terms to make it clearer.

Line 143-144: What is the difference between accidents, system failures, attacks and hazards? Is an attack a type of hazard? Isn't a system failure the result of a shock? It seems that these definitions are mixing concepts like causes with effects. Please define terms before using them. This applies to the whole manuscript.

Line 148: Climate change is not included in Natural hazards (just previous sentence item (4))?

Line 153: Other examples of what? Cyber physical systems? Natural hazards? Or types of Infrastructure? What do you mean by discourse? A trend? and imposed (authoritarian) idea?

Paragraph 161 to 173: Please explain what capacity is and what is performance are first and later elaborate on both.

Lines 176: What do you mean by dominant discourse? Is it a discourse or is an approach?

Section 3.3: Before elaborating on the resilience engineering concept please explain it.

Line 190: what are the aspects? First list the aspects and then use the expression aspect.

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Line 210 to 212: While self-organizing is in fact an important part of resilience of flood defense systems, defense level also highly determines the resilience of the system. Just compare the Netherlands to other deltaic systems. They have very robust self-organization and still their defense levels are very high due to risk inclusion. Please take a look at “Assessment of critical infrastructure resilience to flooding using a response curve approach – Murdock et al. 2018” for better insight.

Line 223 to 224: This sentence is redundant. I suggest to change it “From a socio-ecological perspective, social and ecological systems are also interlinked systems”. If they were not interlinked, why they will fit in the socio-ecological category?

Paragraph 229 to 237: This could be a good definition of what the vital infrastructure SYSTEM is for the authors. Word conglomeration is a bit confusing. What do you mean by conglomeration?

Level 232: Which are the resilience levels? Were they explained before?

Level 232: Again, you are elaborating an idea supported by the engineering concept which was not clearly defined or chosen. What is the definition of resilience engineering over which the paper should be evaluated on?

234: instead of than “to”

234: replace infrastructure systems by “VIS” otherwise it seems they are two different concepts.

Figure 1. Where can I find a definition of shock and pressures to understand how they differ?

Line 245: Why inter-relation instead of relation? Are they reciprocal or not? Example: Power outage affect transport system implies that transport system affects power system? Damage in roads represents damage in flood protection system ?

Line 245: Why inter-dependency instead of dependency? Are they reciprocal or not?

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Line 270: I really like that you define them as “Conceptual Tensions”!

Line 272: Again, elaboration over the concept of resilience engineering which was never formally defined as the one the reader needs to use to understand the claims.

Table 1 is full of concepts which are not previously defined. For example, what is transformative capacity? What is bouncing back or bouncing forward? Please move table after definitions of section 4.1. Otherwise is difficult to understand the reasoning behind their location in triangle.

Paragraph Line 323 to 333: “calling communities or individual “resilient” may be an excuse of not changing”. Please connect these ideas to VIS.

Paragraph Line 336 to 341: Note that resistance can be included in a systems resilience. If so, resistance of a system partly defines its resilience as it can decrease or increase the magnitude of the damage which will result in a lower resilience level to be required for the system.

Paragraph 343 to 354: Use adapt instead of responding as resisting can also be a way of response to a shock.

Line 354: Replace the last sentence part “that changes” to “that change” as is referring to the disturbances which is a plural noun.

Line 358: replace by “Flexibility of the system allowing changes while controlling disruptions”.

Line 362: What is a favorable system regime?

Paragraph Lines 370 to 380: I personally think that the temporal and spatial scale is part of defining the system and its boundaries which will later shape its definition of resilience. What do you think? IS it valuable to elaborate on this? Are there any authors claiming this as well?

Paragraph 380 to 390: First define what do you mean by unit and the proceed to

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elaborate the idea. A suggestion for this could be by moving the first two sentences:

“Infrastructure systems as coupled socio-ecological-technical systems are designed and managed by different organizational levels. This different unit of analysis can and perhaps should be considered when analyzing the resilience of an infrastructure system.”

To the end of the paragraph.

Paragraph 392: What shall the reader understand as risk? Probability of a Hazard or Probability times the consequence? Magnitude of the damage? Casualties? Please define risk to be able to understand why it is different of similar to resilience concept.

Line 411: Moving close to the flood defenses will change the risk indeed but because the people are increasing the exposure. This will be according to the definition of Risk = Exposure X Vulnerability X Vulnerability. Please make sure that every assumption must be framed under a common understanding of the definition.

Line 416: How is it possible to determine that the risk concept from people has a faster rate of change than climate and other ongoing pressures? BTW you are supporting this claim without explaining what you mean by pressures in the flood risk context.

Line 426: The claim that infrastructure is constructed to their minimum/limit capacity is wrong. In case of limit state design, the structure is designed so that the ultimate load can be withstand before failure (limit state). Structural design is mostly ruled by three main design philosophies: 1-Working stress: Structures are designed before the threshold were material present permanent deformations. 2-Ultimate Load: Structures are designed for estimated maximum loads affected by safety factors. This will not only allow to cope with material uncertainty, but it will also allow to include increase in the working loads plus deterioration in time, e.g. increase in estimated traffic over a bridge. 3-Limit state: In the limit state, safety of the structure is determined by the ultimate load that a structure can bear either before loss of serviceability or before

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failure, e.g for service load design go until maximum tolerable deformations, erosion depth, initiation of cracks or amplitude of vibration (e.g. roads) whereas for limit state the design goes until, fatigue, permanent deformation and even collapse (e.g. dikes).

Line 442: Please check in the whole document the proper use of the word infrastructure versus infrastructures.

Line 443: How can a limit the limits be defined if they represent two different things which are even measured in different conceptual and physical units ?

Paragraph Line 438 to 453: Seems to me after reading it that according to the content, the section and challenge should be referenced as data scarcity rather than predicting long term pressures.

Paragraph Line 507 to 523: How can the multi-functionality decrease adaptability? Multi-functionality actually aims to increase adaptability. For example, MFFD's aim to make flood defenses livable and profitable. From a risk cost benefit perspective, MFFD's are attractive as they have an added value which increase their benefit term allowing them to have higher safety standards and consequently adapt better to unknown flood events. Increasing the dikes height not necessarily reduces the resilience of a system as once they are breached, they will reduce the magnitude of the shock for locations downstream of the breach. This means that this assumption is again dependent on the system's definition and boundaries.

Paragraph Line 553 to 563: I suggest including macroeconomic unforeseen situations like Brexit or 9/11 which does not affect the infrastructure directly but still reduces their resilience due to their overuse or lack of maintenance and reduction of maintainer budget. E.g. Road bridges in Italy and railroads in the US.

Line 604: What do you mean by “A later correlation”? Correlation between observed recovery and what else ?

Line 619: Grey infrastructure is not necessarily more costly than green projects. Just

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look at the cost of the Sand Engine, Room for the river or Noordwaard wave attenuation willow. Depending on their function and importance, both gray and green solutions are often dimensioned based on risk-based cost benefit analysis which means that in principle their cost is optimal with respect to their benefits.

Line 644: If I'm correct, the room for the river didn't aim to widen the embankments but to widen the conveyance channels and flood plains and maybe strengthening the dikes but that does not mean making them wider either.

Line 648 to 654: With Tough dikes are you referring to a "unbreachable dikes" ?. If so, this means that they are designed to withstand events with very large return period. Residual strength is related to the amount of un-accounted strength of conventional dikes for which the failure mechanisms DOES occur but still it does not translate instantaneously as a BREACH. Hence, there is a period in which the dike can withstand the water while being in failure state. Please rephrase it terms of failure mechanism, breach, and flooding. Also note that one thing is damage recovery of the flood defence system and another is recovery of the protected system from a resilience point of view (e.g. GDP, employment, etc).

Paragraph 691: the first paragraph of the Other measures section is not really written for alternative measures but for ways of modeling and quantification of resilience. Check if it fits there or not.

Line 714: Systems thinking is by definition an Engineered approach and therefore tittle a) and heading 5.1.2 are contradictory. Ball and cup system heuristics (Holling, Walker, Foster, Carpenter , etc . . . ) is a clear example of how the engineering resilience concept (inspired by engineering approach to design) is based on systems theory which is the basis for systems thinking. I suggest changing the 5.1.2 tittle to non-structural measures, but the question is if this fits the scope of your paper.

Line 758: risk assessment is a purely engineering way of designing and assessing. Fault trees and reliability theory are used in all engineering designs and safety assess-

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ments around the world.

Line 806: Recent literature is reviewed or literatures are reviewed. Choose one.

Line 835: remove 'a' so that ' . . . , little appears' and add by in 'by using other measures'.

Lune 846: So, the experts provided relevant literature but not opinions? What is the goal of the interviews if the collected responses are not cited, contrasted or discussed in the paper ?

Line 851: What is the impact of having inter-sectoral dependency? Note that the resilience concept agreement is contextual, system dependent and discipline oriented?

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2020-12>, 2020.

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