

Dear authors,

The paper you wrote touches upon an important subject. The paper starts with a title which attracts the attention and promises a research agenda. The authors claim to provide an overview from literature on vital infrastructure resilience, to make a conceptual framework on resilience and identify gaps and based on those come up with a research agenda. The paper partly is interesting, but it is difficult to read and not convincing. It is not clear what the authors mean by resilience and how that links to their framework. The link between the literature review, gaps and opportunities is weak. The paper could therefore also be presented as a opinion paper instead of a literature overview.

**Main comments:**

- Provide a section on resilience definitions and then clearly explain how you define resilience of vital infrastructure systems in your paper and stick with that definition. This could be done right after the introduction. It may mean part of the conceptual challenges need to be solved, and therefore in a different structure of the paper. This means it is a significant change. However, it will increase the readability enormously.
- The authors conclude literature focuses on designing and conceptualising resilience, but provides little guidance for designing resilient infrastructures. Their paper, however, does the same.
- The review message is not convincing. The list of literature considered is long, but the outcome is not clearly linked to needs or issues in resilience enhancement plans. It is not clear if the recommendations are based on an analysis of what goes wrong in designing or adapting vital infrastructure, nor is it clear when a system would be sufficiently resilient. It is not even clear what must be resilient: the technical system including its management or the functionality towards society (e.g. if there is no power but society has backup generators which can replace power networks for 2 days and the power is back on in time, the system is very resilient, isn't it? Or not?)
- The definition of resilience adopted in the paper and the one on risk are unclear which sometimes makes the paper confusing. In the end the aim is to enhance resilience of society to disturbances and perhaps trends. The resilience of infrastructure contributes to resilience of society. This is not always clear in the paper. It seems sometimes resilience is used as a system property which contributes to the system's ability to cope with disturbances and at other locations as an aim in itself.
- The questions in chapter 2 are promising. However, the answers to the questions are not clearly provided or discussed in the paper. There is no discussion of current practice in designing vital infrastructure systems and gaps in there in relation to your resilience framework. This state of the art is crucial when promising gaps and a research agenda to fill gaps.

**Consider literature such as:**

- Pitt review: [Pitt Review Lessons learned from the 2007 floods - Designing Buildings Wiki](#)
- Resilience principles: [Resilience in practice: Five principles to enable societies to cope with extreme weather events - ScienceDirect](#)
- Literature on requirements which must be met when designing vital infrastructure or performance targets etc.
- Béné, C., Cannon, T., Gupte, J., Mehta, L., Tanner, T., 2014. Exploring the Potential and Limits of the Resilience Agenda in Rapidly Urbanising Contexts. Institute of Development Studies.

- Carpenter, S., Walker, B., Anderies, M.J., Abel, N., 2001. From metaphor to measurement: resilience of what to what? *Ecosystems* 4, 765–781. doi:[http:// dx.doi.org/10.1007/s10021-001-0045-9](http://dx.doi.org/10.1007/s10021-001-0045-9).

## Detailed comments

### 1. Introduction

- page 2, line 73 → resilience is related to the ability to cop with performance variability? I would say the performance variability shows the system is an outcome which shows its degree of resilience? And why is this definition of Hollnagel et al. (2006) in line with the definition of Davodi et al. (2012) according to you?
- Page 3, line 95: confusing sentence. It says shocks and pressures affect resilience. How do you then define resilience? In my view, shocks and pressures affect the system, not its resilience. The system needs resilience or uses its resilience to cope with those shocks and pressures.

### 2. Method and materials

- Page 3 --? Line 110 --? Again: what types of shocks and pressures affect infrastructure resilience? What do you mean by resilience in that question? Isn't it a systems property which enables systems or societies to cope with shocks and pressures?
- Page 3 → line 112, question 2 → this is a question for literature review. Based on the outcome you define resilience in the paper, right? It is strange to ask how you define it in the paper. You should know...rephrase.

### Chapter 3: current approaches in designing VIS

- the title suggests that current approaches are discussed. I would expect some description on the design standards, or performance targets where the design is made for, requirements taken into account, life span of the design or other aspects related to resilience. However, this chapter is not on design but on definitions again.
- Chapter 3.2: why do you take the capacity-oriented approach and not the performance-based approach? Is it really the dominant approach in critical infrastructure resilience literature? What is resilience then in this approach.
- The definitions mentioned in 3.3 are not all linked to vital infrastructure systems, some are linked to e.g. socio-ecological systems such as the one at line 193. What do you mean with absorb changes and keep the same functioning in the context of vital infrastructure systems? How would a critical infrastructure absorb change? Clarify.
- In line 211 and further the example on flood protection is mentioned. Resilience of a flood protection system is unclear if it is based on resilience of the embankments only. It is about resilience of society to floods. Embankments help to protect the more vulnerable parts of the system, which enable the whole valley or basin to cope with high discharges more easily: only the less vulnerable parts with lower protection standards are flooded and may suffer from adverse impacts. The area as a whole (including society along the rivers) recovers faster then. Here, in this paper it seems that resilience is linked to adaptive capacity which provides a different angle. It is then about resilience to climate change, or resilience if societal preferences change? I think the paper would be much clearer if in examples like that a few words are added explaining where you are talking about: resilience of what precisely (the embankments, or society in the riverine area) to what (high discharge waves coming down the river, or climate change or ?)
- Line 231 → “resilience to disturbances”. Change to “resilience to disturbances and trends” in order to make it consistent with figure 1, where this line refers to.

## Chapter 4

- You state that conceptual tensions are a challenge for designing critical infrastructure. Are they really? What if in applications it is just stated what is meant by resilience, robustness etc. without claiming that the definition applied is the best for everyone? There are also many papers out there which conquered those challenges: bouncing back is often replaced by “continuing to develop similarly as before the disturbance” and in a way bouncing forward maybe seen as an advantage/opportunity instead of a challenge for design. I think you have to focus on the other type of challenges and solve part of the conceptual challenges in your framework and definitions to make the paper readable.
- Line 289-301 → are those relevant? The figure 3 on technical and social and ecological aspects is not convincing. Most challenges are in the centre (thus link to all three aspects). All challenges are linked to the social system. It is not clear why the distinction between the 3 aspects is made or how it is used in the remainder of the paper (it is used? Why do you mention it?)
- Line 325 → the “resilience goal of promoting justice”. Since when is this “the resilience goal”. It was not mentioned in your definitions before. How does that link to your definition of resilience? Is resilience a goal or a means? I thought the goal was to enable systems/societies to cope with shocks and trends. Social justice might help there, but that is another topic outside the scope of your paper. Resilience was never an aim in itself. In line 330 you suggest it is and also that it is narrowly defined.
- Resilience versus robustness → that is a matter of wording. Sometimes as by Mens who you refer to, resilience and resistance together are seen as robustness. Resistance is then referred to as the ability to prevent damage from disturbances and systems need that to cope with more frequent disturbances (otherwise they would be in a state of recovery all the time). Resilience is for the more frequent event that do cause damage or disruption and is the systems ability to limit impacts/damages and recover fast. Together resilience and resistance then relate to the system’s ability to cope with disturbances. Sometimes resistance is considered as part of resilience and then the word resistance can also be replaced by robustness (especially in infrastructure related literature and relates to the threshold at which damages occurs). Resistance/robustness is then the ability to prevent damage. This is not really a challenge for defining resilient infrastructures, but a matter of wording, isn’t it? As long as it is considered that some disturbances must be resisted, others must be coped with by allowing little damage and fast recovery, a system will function. It does not matter which words you use for those system’s ability.
- Line 358 → new definition of resilience. Why? Move it to the beginning of the paper and define what you mean by resilience of critical infrastructure systems. Why would you now define resilience as the adaptive capacity of a system? The discussion on definitions is described in section 3.2? How would you relate that definition to critical infrastructure systems anyway?
- Risk versus resilience: (line 392): how do you define risk? Risk is usually defined as a combination of probabilities and consequences, or as a combination of hazard, (exposure), and vulnerability and expressed in units like euros/per year or number of fatalities per year or expected annual damage. In your text I think you define it as probability? You state it depends on the hazard type and its magnitude and that is an exponent of resilience but it is not completely clear. In line 407 I lost track when you discuss hazard impacts and hazard risks. What do you mean by hazard impacts or hazard risks? Is that equal to risk? Why introduce a new concept then.
- In line 411 you say embankments may result in a risk increase and then you discuss the well-known spiral of embankment raising and economic growth. I think you should describe that more

carefully. It is not the embankment which increases the risk, in fact, it reduces risk. It is the economic development. That development is in many cases a positive thing which is enabled by the reduced flood frequency.

- In line 415 you state that the concept of risk changes more rapidly than climate. That sounds like a weird comparison. Rephrase.
- Challenge g to j are clear. Challenge k must be better formulated. Since it is not easy to quantify resilience, it is more difficult to take decisions or to evaluate alternatives aiming to increase resilience. This makes decision makers more reluctant to take resilience into their decision-making processes.
- Line 512 → raising dikes decreases the system's resilience. Why? What do you mean?? Line 512-523 are not clear at all. Why does raising decrease resilience and why would multi-functionality increase resilience. Resilience to what then?
- Line 525-538 → long time-scales play a role when planning measures. Perhaps you should point out it is therefore important to be pro-active instead of reactive?
- Line 562 → costs are mentioned as a limitation. Perhaps move that sentence to the challenge of balancing resilience and efficiency?

## 5. Toward resilient VIS

- Figure 4 does not explain the link at all. It just summarizes the opportunities you identified and the resilience framework and puts a line between the two. The link between them is not clear at all. Explain how the opportunities identified are linked with the 5 aspects in the framework. (the framework itself is also not explained well: I still do not understand what you mean by absorb changes, respond etc. in the context of infrastructure systems....

- the motivation of why nature based solutions are leading to more resilient systems is not clear. Do they absorb changes better, or monitor, or respond differently? Explain that in the text.

**-6. Conclusions:** they are interesting, but they do not deliver what the title promised.