

**Review article: current approaches and critical issues in multi-risk recovery planning of urban areas exposed to natural hazards - Soheil Mohammadi et al., 2023**

**Reply to reviewers' comments**

**Reviewer #1 (Marleen de Ruiter)**

**General comments**

**(C1)** I think the paper could benefit from some restructuring.

**(C1.1)** There are many 1-3 sentence paragraphs, which seem to interrupt the flow of the paper and at times cause some confusion. Examples include, but are not limited to:

90 onwards: this seems to still be about the methods (critical lit review) so should this paragraph be part of the previous paragraph (L. 86-83), which is also on the critical lit review?

147-151: should this paragraph maybe be part of the previous and/or next paragraph?

**[Authors reply]** To improve the flow of the text, we checked the overall manuscript and reorganized the sentences into coherent paragraphs, avoiding having too small (e.g., 1-3 sentence) paragraphs. These changes include but are not limited to the two examples you suggested.

**(C1.2)** To me it seems that paragraphs L.46 – 54, L. 55-62, and L. 67-78 discuss definitions of / changes in thinking about resilience and recovery while in between those, L.63-66 seem to introduce the urgency to adopt a multi-risk perspective.

**[Authors reply]** To improve the logical coherence of the text and keep together all the paragraphs investigating the definitions of / changes in thinking about resilience and recovery, we moved the concepts reported in L. 67-78 just after the ones in L.46 – 54 and L. 55-62. Moreover, we made some changes in the paragraphs (L.46-78) to improve their readability and the logical flow among them. The text flow appears as it follows:

*"Urban resilience has been defined variously in the literature. Among the many different definitions of urban resilience available in the literature, one of the most*

comprehensive is the one provided by Meerow et al. (2016),: "Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." The phrase "ability to return" stands out in this definition. The fundamental concern that arises, however, is how to ensure that the urban area , as a complex system with various components and interconnected networks, has the ability to return or recover after a disaster occurs. On the other hand, the term "maintain" can be seen in Meerow et al. (2016) definition as a reference to the ability of a resilient urban system to preserve what currently exists, which is more closely tied to the concepts of disaster risk preparedness and response.

As pointed out by Rus et al. (2018), the resilience concept can be reflected in preparedness, response, recovery, and adaptation actions, depending on the temporal domain. However, research that evaluates the relationships and implications of these different actions on one another in resilience-based urban planning are still absent (Rus et al., 2018). This lack in the literature is reflected also in the confusion felt by stakeholders involved in the resilient urban planning process. Indeed, decision-makers do not know how to choose an investment direction among the various phases of the Disaster Risk Management (DRM) cycle (Kawasaki and Rhyner, 2018). Are they supposed to protect and strengthen the system, work to make it more recoverable, or even set aside funds for disaster recovery?

Although the resilience of an urban system is not solely determined by its ability to restore from a disruptive event, the recovery process represents one of the most critical and significant aspects contributing to the overall system resilience. To corroborate this perspective, Manyena et al. (2019) indicate that, since 1980 the terms "return to equilibrium," "bounce-back," "recover," "restore," "bounce-forward," "rebound," "rebuild," and "reorganize", which all have the connotation of recovery, have been frequently used in the different resilience definitions provided in the literature. According to McEntire et al. (2002), the term "resilience" emerged as a reaction to or alternative for the term "resistance". The key difference between these two concepts is that contrary to the resistance idea that prevention is the main strategy, natural hazard events inevitably occur in resilience discourse and disaster avoidance is not always achievable. As a result, the main issue in resilience is the need to focus on recovering from disasters as quickly and effectively as feasible (McEntire et al., 2002). Indeed, different researchers have used indicators such as the system's ability to function during recovery, the speed of recovery, the quality of recovery, and the area under the recovery curve to measure the system's resilience (Bruneau et al., 2003; Rus et al., 2018; Soltani-Sobh et al., 2016; Zhang and Wang, 2016). Although recovery is a fundamental aspect that is well captured by the resilience concept definition, this DRM phase is the least explored in the literature in comparison to the others (Der Sarkissian et al., 2021; Rodríguez et al., 2018)."

The concept provided on L.63-66 about the urgency to adopt a multi-risk perspective, has been moved just after this part and enriched significantly (**see answer to comment C.2.**)

**(C1.3)** The authors could consider moving the method description (second half of the intro) to a separate method section (basically, including a section header at the start of the description of the approach).

**[Authors reply]** Thank you for this valuable suggestion. We created a separate section (Sect. 2, Methodology) where we moved the text originally reported in L.86-131. This change has allowed us to provide more visibility to the methodology on one side, but also to lighten the introduction. This last aspect has allowed us to strengthen the multi-risk aspects of the introduction by adding some dedicated paragraphs(see also reply to your next comment). Moreover, as suggested by the other reviewer, we also included in the new section 'Methodology' a figure (Fig.1), where we graphically depicted the relationship between the identified Issues and the guiding Research Questions. The figure is attached to this document as an annex (**Annex 1**).

**(C.2)** I think the multi-risk aspect of the paper is an important novelty and strength of the paper. I would encourage the authors to strengthen this in their introduction. In the paragraph at L. 63-65 the multi-risk aspect seems to almost appear as an afterthought. I encourage the authors to strengthen this particular element of the paper in the introduction, including a more elaborate explanation of those "additional challenges in decision-making". In restricting the intro (see previous point), this particular element could maybe be described more prominently and extensively. I can imagine something more general on multi-risk recovery challenges and those specifically within an urban setting.

**[Authors reply]** We provided more context about the multi-risk challenges in disaster recovery and the importance of adopting a multi-risk perspective in this realm, by adding some additional paragraphs in the introduction.

*"When urban systems are affected by complex disaster scenarios, involving potential impact interactions, addressing the recovery process can become more complicated. In that circumstance, the system must be resilient to many types of risks, embracing a multi-risk perspective, which will introduce additional challenges in the decision-making process regarding the recovery (Curt, 2021). Multi-(hazard)-risk, as collectively named by Ward et al. (2022), encompasses all disaster risk assessment and management approaches that consider interactions or interdependencies among different hazards, vulnerabilities, or risks. These approaches are able to better capture complex risk dynamics which are*

increasingly impacting urban areas worldwide. The interrelationship of multiple hazards and their impacts, as well as the implications of DRM decisions on different economic sectors and regions, and the diverse impact of disaster risk reduction measures on different risks, make recovery in multi-hazard environments challenging (Ward et al., 2022; Hochrainer-Stigler et al., 2023). Among the different types of multi-hazard interaction mechanisms that can lead to a disaster such as compound, triggering, or cascading, (Gill and Malamud, 2014; Marzocchi et al., 2009; Tilloy et al., 2019), the occurrence of consecutive disasters is specifically challenging for the recovery process. Consecutive disasters are two or more disasters that occur in succession and whose direct impacts overlap spatially before the recovery from the prior event is considered complete (de Ruiter et al., 2020). The results of the interaction between the impacts generated by two consecutive hazards depend on the time interval between them, the rate of recovery of the system or the asset, or a combination of them (De Angeli et al., 2022; Marzocchi et al., 2012)."

Moreover, we supported these concepts by providing a real-world example that highlighted the complex challenges posed by consecutive disasters in recovery:

"As a real example in the western part of Iran, a devastating earthquake occurred on November 12, 2017, at the Iran-Iraq border, causing the death of at least 630 people (Naserieh et al., 2022). The recovery efforts began by providing temporary shelters to the more than ten thousand affected population (Omarzadeh et al., 2021). Prior to the earthquake, the country was facing a prolonged period of drought, and no one anticipated the possibility of a flood occurring within some months (Yadollahie, 2019). However, from mid-March to April 2019, widespread flash flooding occurred, affecting large areas of Iran, including the regions that were undergoing recovery from the earthquake (Miri et al., 2023). The potential occurrence of a flood was not taken into account, leading to the establishment of temporary shelters alongside canals, which resulted in the flooding of the people residing in those shelters and imposed significant economic impacts on them."

The multi-risk concept has been also strengthened in other sessions on the manuscript, by adding some dedicated paragraphs inside the discussion of Issues 1, 2, and 3 (**see answer to comment C.11.b**).

**(C.3) 81:** "inadequacies" in terms of how we define post-disaster recovery or how we manage post-disaster recovery?

**[Authors reply]** The sentence reported in line 81 was unclear and the word "inadequacies" was not informative enough. We rephrased it as follows:

*"This study analyses the existing disaster recovery literature and guidelines in the realm of natural hazards with the dual goals of (i) identifying current issues in multi-risk recovery planning for urban areas and (ii) laying the groundwork for developing multi-hazard decision-making planning tools for recovery."*

**(C.4)** 113-114: how were these particular key words selected?

**[Authors reply]** The selected keywords (recovery requirements, post-disaster needs, resilient recovery, the difference between recovery and emergency, multi-risk recovery, recovery optimization models, recovery planning, pre-disaster recovery planning, socio-economic aspects of disaster recovery) have been selected to be linked and representative of the four identified Research Questions. We specified this aspect in the Methodology (Sect.2), by adding the following sentence:

*"To address the specific Research Questions, the following keywords were selected: difference between recovery and emergency, pre-disaster recovery planning (Question 1); resilient recovery, socio-economic aspects of the recovery (Question 2); recovery requirements, post-disaster needs, multi-risk recovery (Question 3); recovery optimization model, recovery planning (Question 4)."*

**(C.5)** Reading L. 132-133, it is unclear to me how this is different from what will be addressed in Issue 2.

**[Authors reply]** Section 5 is reporting the key findings from the critical literature review that is discussed in Sections 2 to 4, while Issue 2 (Sect. 3) is addressing a specific aspect, i.e. the recovery requirements in the current world setting.

Nevertheless, we realized that the title we provided for Sect.3 and also the description of Issue 2 in L. 126-127 is misleading and is creating confusion with the title provided for Sect. 5.

To avoid misunderstandings, we removed the word 'challenges' from the title of Sect.3 as follows:

*Recovery requirements in the current world setting*

Moreover, we also modified the text at L.126-127 in the following way:

*Issue 2: Recovery requirements in the current world setting*

**(C.6)** Table 1 is a great way to demonstrate the evolution of our understanding of "recovery" over time. Very nice!

**[Authors reply]** We are really pleased you appreciated the table. The aim was exactly, as you wisely noticed, to better illustrate how the recovery concept has changed over time, moving to a more holistic definition.

**(C.7)** 169: it may be helpful to include a definition of build back better. This may for example help to understand L. 176. In addition, I found the paragraph of which it is part (L.165 – 179) a bit difficult to follow (for example, what do the authors mean by the "subjective functions" and "objects").

**[Authors reply]** We agree that a definition of Build Back Better (BBB) should be provided to better understand L.176. For this reason, just after the first time the BBB has been mentioned in the manuscript, we added the following:

*According to the UNDRR (2020), BBB is defined as “the use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment”.*

Moreover, we tried to simplify L.165 – 179, avoiding the use of the terms “subjective functions” and “objects”. Please, find the rephrased paragraph hereafter:

*The fundamental distinction between the two definitions of ‘recovery’ and ‘reconstruction’ provided by UNDRR lies under the fact that the ‘reconstruction’ definition refers to more tangible elements. On the other hand, in the ‘recovery’ definition, a broader array of functions, (sub)systems, and activities of a community or society, which also encompass intangible elements, are mentioned. This emphasises the fact that recovery encompasses more than the rebuilding of the physical components of the systems. In addition, while both definitions of reconstruction and recovery from UNDRR contain advice about aligning with BBB principles, the reconstruction definition refers to the goal of reaching a full community functioning, while the recovery definition emphasises more on the opportunity for ‘improvement’.*

**(C.8) 261:** I think it is very nice that the authors mention an example that shows the fuzziness of the boundaries between stages. Maybe they can describe this in a bit more detail to demonstrate the fuzziness more clearly to people who are less familiar with the aftermath of this particular disaster?

**[Authors reply]** We provided more details about what happened in the aftermath of this devastating earthquake and we provided additional information to better highlight the fuzziness between early recovery and the development phase of the recovery:

*The recovery in L’Aquila following the earthquake in 2009 is a good illustration of how the boundaries between the various stages of recovery are not always clear and can be fuzzy. In April 2009, L’Aquila, Italy was hit by a 6.3 MW earthquake with a hypocentral depth of 10 km. Reconstruction efforts led to the construction of 5722 housing units in 19 new settlements distributed around the city within one year of the earthquake (Contreras et al., 2013). The newly built housing included features like seismic isolation and solar cells, typically associated with the development phase of recovery. However, by 2014, damaged houses could still be found in the city center, indicating the presence of the early recovery phase. The simultaneous presence of early recovery and development recovery actions highlights the fuzziness boundaries between different phases of post-disaster recovery (Contreras, 2016; Contreras et al., 2014)."*

**(C.9)** At the start of section 2.2, it may be nice to remind the reader of the phases of the DRM cycle.

**[Authors reply]** We added a couple of sentences at the beginning of section 2.2 to introduce the main phases of the DRM cycle:

*"The DRM cycle is widely recognized in the global DRM community as a framework for managing various types of disasters, both natural and anthropogenic (Coetzee and Van, 2012). It is characterized by separate and sequential phases with varying durations and actions. While phases' number and their naming vary in the literature, the following main ones (before, during, and after the event) can be identified: preparedness and mitigation, response, and recovery."*

Moreover, according to the suggestions of the other reviewer, we highlighted the difficulty of the current DRM cycle to capture the dynamics and interaction of multiple hazards, particularly those involving both sudden-onset and slow-onset hazards, and we mentioned alternative DRM models, such as the ones recently proposed by Bosher et al. (2021), Staupe-Delgado (2019) and Terzi et al. (2022).

**(C.10)** Since some sections are lengthy and contain a lot of information, the authors could consider adding a couple of sentences at the end of each issue bringing it together.

**[Authors reply]** To facilitate the reader in keeping some "take-home messages", we added a dedicated section at the end of each issue, where we summarized a few key points each.

### Issue 1 key points

- The concept and definition of recovery have evolved over time passing from merely focusing on physical reconstruction towards inclusion of socio-economic aspects of recovery in the definition.
- The distinction between emergency and recovery phases is still a controversial issue and has been the motivation for defining the transition phase between them.
- Recovery planners typically view recovery as a sequential and predefined process, divided into subphases. However, real experiences challenge this perspective, as the recovery process is often more complex and unpredictable.
- Determining the ultimate goal of recovery, such as achieving resilience through a BBB approach to prevent future disasters, adds complexity to recovery planning, especially in multi-risk environments.

### Issue 2 key points

- The post-disaster needs and priorities of the population, which should be at the core of recovery planning, vary across different social and geographic contexts.
- The needs of the population change over time in the aftermath of a disaster.
- Community involvement might occur both in the needs and capacity assessment phase to tackle the problem at the community level and efficiently employ local resources.
- Current approaches to multi-risk recovery planning only partially address the complexity of such topic, since: (i) they focus on hazard prioritization ignoring vulnerability dynamics exacerbated by consecutive disasters; (ii) they do not take into account potential synergies between DRR measures, as well all damage accumulations; (iii) they do not evaluate systematically the interdependencies amongst different components of the urban system.

### Issue 3 key points

- Lifeline infrastructure networks are the main physical elements that have been addressed in decision-making models and methods for optimization of investment to improve recovery in urban areas
- The decision-making models for optimizing investments to improve recovery are mainly concerned with the post-disaster reconstruction time frame

**(C.11.a)** Since section 5 aims to focus on challenges specific to multi-risk planning (in urban areas?), I wonder if it would be possible to focus that section and the identified challenges specific to multi-risk (in urban areas?). As I understand it now, some of these challenges are not unique to multi-risk recovery but rather recovery in general.

**[Authors reply]** We agree that the challenges reported in Sect.5, as a result of the summary of the main outcomes discussed in Sects. 2-4, were not focusing enough on the multi-risk aspect. Therefore, we added additional sentences referring more specifically to multi-hazard aspects in 6 over 9 of the remaining challenges (one of them was already multi-risk oriented). Please, find in **Annex 2** the new version of the challenges, with the additional text reported in red.

Regarding your observation about the fact that some of these challenges are not unique to multi-risk recovery but rather recovery in general, this is correct indeed. Many of the identified challenges are relevant also in a single-risk perspective. Nevertheless, multi-risk can exacerbate them. We highlighted this concept at the beginning of Sect. 5, adding the following paragraph:

*"Many of the identified challenges are also relevant from a single-hazard perspective, nevertheless, multi-risk conditions can exacerbate or add further complexity to their*

*management. This multi-risk perspective is discussed in detail for seven of the ten identified key challenges. "*

**(C.11.b)** This is maybe something the authors could also reflect on in the earlier sections; whether these sections can be tailored more to multi-risk?

**[Authors reply]** According to your main suggestion, we strengthen the focus of the overall manuscript on the multi-risk aspect. We added some dedicated paragraphs in the introduction (*see answer to comment C.2.*)

Moreover, we added some dedicated paragraphs inside the discussion of Issues 1, 2, and 3 discussing more in detail:

- the difficulty of keeping DRM phases separate when dealing with multi-risk and emerging DRM models alternative to the traditional cyclic approach (Sect. 2.2)
- the exploitation of the build-back-better concept from a multi-risk perspective (Sect. 2.3)
- how multi-hazard conditions can exacerbate the communities' dilemma in balancing the need to enhance resilience against future disasters and the desire to quickly rebuild their houses and livelihoods (Sect. 3.1)
- multi-risk multi-sectoral challenges related to interdependencies among urban system components (Sect. 4)

As a consequence of this spread of multi-risk related criticalities along the manuscript, we also reorganized more effectively the section originally devoted to multi-risk (Sect. 3.2). More specifically we focused it more on the recovery requirements seen from a multi-risk perspective and we consequently renamed it as "Multi-hazard risk recovery requirements". Furthermore, we moved some of the paragraphs into the Introduction, and added some paragraphs covering the following aspects:

- multi-risk prioritization in recovery planning
- synergies of DRR measures implemented during reconstruction and recovery
- impact of multi-risk scenarios on the allocation of resources for recovery activities

### **Minor comments**

**(C.12)** Some writing issues. E.g. the first sentence of the abstract: there is a strong push within the field to move away from using "natural disasters". Here I think it could be easily avoided by writing "Post-disaster recovery...".

**[Authors reply]** We replaced "natural disasters" with "post-disaster" in the abstract.

**(C.13)** In the third sentence of the abstract: do the authors mean planning (that takes place before a disaster) of recovery-related actions (e.g., getting a contract for debris cleaning) or do they mean preparedness actions (e.g. to mitigate the potential impacts of a disaster).

**[Authors reply]** The intended meaning of the sentence encompasses more than just recovery planning or soft action; it also emphasizes the need for proactive measures to enhance the recoverability and resilience of urban areas. Therefore, in addition to preparedness actions, the sentence highlights the significance of implementing changes in pre-disaster periods, particularly through modifications in physical structures and infrastructures, to augment the recoverability of urban areas. The underlying concept of the sentence revolves around the notion that recovery efforts should not be restricted to immediate response and recovery but should encompass long-term measures aimed at strengthening the capacity of urban areas to recover and bounce back or bounce forward from adverse events. For more clarification, we changed the sentence to:

*“Furthermore, recovery has been only marginally explored from a pre-disaster perspective in terms of planning and actions to increase urban resilience and improve urban systems recoverability.”*

**(C.14)** 26: I assume the time stamp here is a typo?

**[Authors reply]** The time stamp was a typo and has been removed.

**(C.15)** 28 “dates” back to?

**[Authors reply]** It is modified to:

*“back to 1973”*

**(C.16)** 31: it is a bit unclear what is meant here with “complex system”. In general, the authors use many different disaster related terms (e.g., natural hazard event, extreme event, disturbance, etc); this can create some confusion. The authors could consider adding a box or table defining some of the key terminology used in their paper.

**[Authors reply]** We included a definition of “complex system” and “disturbance” along the text as reported hereafter:

*“Holling's writing was the basis for developing the resilience concept and applying it to understand the performances of complex systems, i.e. systems “in which there are multiple interactions between many different components” (Rind, 1999), when encountering disturbances (Walker et al., 2004; Gunderson and Holling, 2002). According to an ecological science perspective, disturbances can be seen as massively destructive and rare events (Rykiel, 1985) that impact the system from the outside. ”*

Regarding the term 'extreme event', this was mentioned only once (L.24). To avoid misunderstandings we removed it from the sentence, which is now written as: "*To cope with natural hazard event impacts, planning and procedures that anticipate their occurrence, mitigate possible damages, and allow for the speedy restoration of key services and recovery are required (Berke et al., 2009).*"

**(C.17)** 37-38: I am not sure I understand the second half of the sentence; it is not clear to me how the previous statement (or definition) supports the claim in this sentence that resilience is linked to DRM.

**[Authors reply]** Your observation is truly correct. We modified the sentence eliminating the link to the DRM:

*"As one of the most complex systems exposed to natural hazards, urban areas have also been included in the resilience concept's extent."*

**(C.18)** 47: I believe that with a quote, the citation also need to include a page number – but I may be wrong there.

**[Authors reply]** Thank you for noticing that. We carefully checked it and we found that it is not required according to the "English guidelines and house standards" section in the NHESS Submission instructions.

**(C.19)** 63: "a variety of sorts and categories" -> not sure what the authors mean here. Could they be more explicit?

**[Authors reply]** The sentence was removed entirely by answering other comments (specifically the one related to strengthening the multi-risk perspective in the manuscript) and reordering the paper.

**(C.20)** 85: maybe include a "(e.g., XXXX)" to explain what you mean by physical elements (buildings, infrastructure,...?)

**[Authors reply]** The sentence was modified to:

*"In this research, we focus on decision-making concerning investment prioritization to improve the resilience of physical elements (e.g., structures, buildings, infrastructures, open spaces, etc.) at the urban scale."*

**(C.21)** 130-131: maybe for legibility, the authors could consider adding this info to the issue 1 -3 description in L.125-129 instead of having a separate sentence on this.

**[Authors reply]** Your observation is truly correct. For increasing legibility, we changed the format of the numbers of the questions and the correspondences amongst questions and issues:

*Issue 1: Recovery and its role in the risk management cycle (Sect. 3) that corresponds to Research Questions 1 and 2.*

*Issue 2: Single and multi-risk recovery and requirements in the current world setting (Sect. 4) that corresponds to Research Question 3.*

*Issue 3: Decision making models and methods for investment in physical elements to improve recovery in urban areas (Sect. 5) that corresponds to Research Question 4.*

**(C.22)** 140-142: “recognizable activities” and “evolutionary notions” not sure what the authors mean.

**[Authors reply]** The expression “*recognizable activities*” has been changed to “*pre-defined activities*”, to highlight how recovery was seen as a static and standardized process.

The term “*evolutionary notions*” has been replaced with “*progressive concepts*”, since it was referring to the inclusion of some new ideas (i.e. risk reduction, decreased vulnerability) in the original definition of recovery provided by Haas et al. in 1977.

**(C.23)** 208-211: I wonder if there is any literature to support these statements.

**[Authors reply]** Five references were added. Now the text it appears as follows:

*“As shown in panel (b) of Fig. 1, by increasing the intensity of socio-economic recovery activities, the common zone (functional recovery) could be preserved or even increased during the recovery period. Furthermore, the intensity of socio-economic recovery activities could be increased without external support in a disaster-struck community (Alifa and Nugroho, 2019). These cooperatively evolving activities enable people to take part in the restoration of their communities independently (Nigg, 1995; Talbot et al., 2020; Perce, 2007). For instance, as more enterprises of all sizes become involved in the economy, people will be more capable of actively participating in the economic recovery of their community (Freeman, 2004). Setting this balance between physical reconstruction and socioeconomic recovery would be possible if the disaster area needs assessment (see Sect. 3) is considered.”*

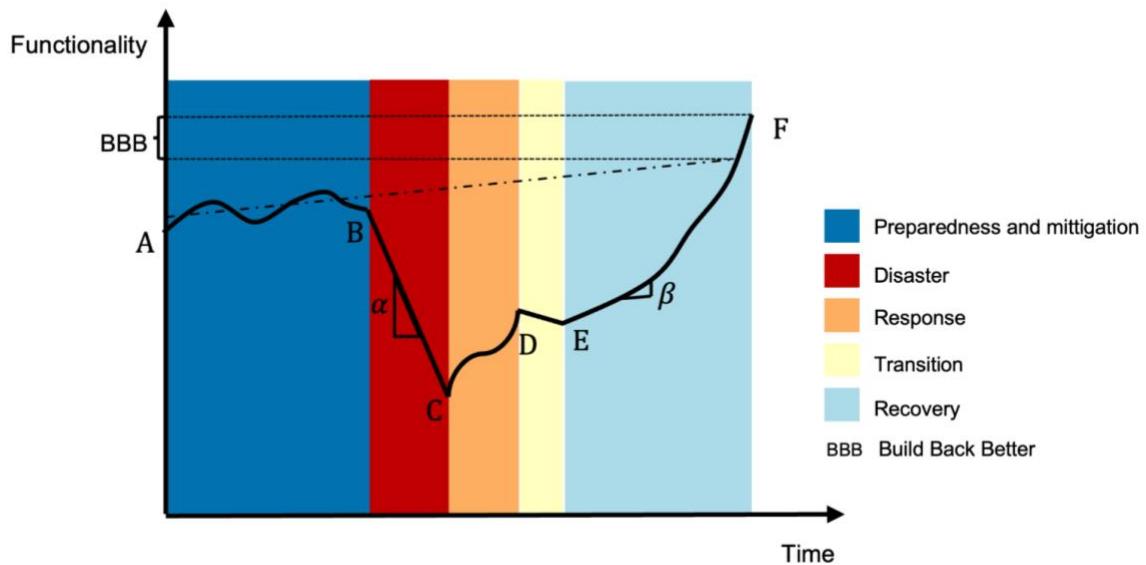
**(C.24)** 219: what is meant by “diverse groups”?

**[Authors reply]** It has been modified to:

*“social classes, races, ages, genders, and family statuses” according to Cutter et al. (2006) and Fussell (2015).*

**(C.25)** Figure 2: looks great, very useful. Maybe the authors can add BBB to the legend or description and explain its meaning (in relation to Point F). Maybe the font size of the x and y-axis labels could be decreased a little.

**[Authors reply]** We have modified the figure accordingly. Here is the updated version:

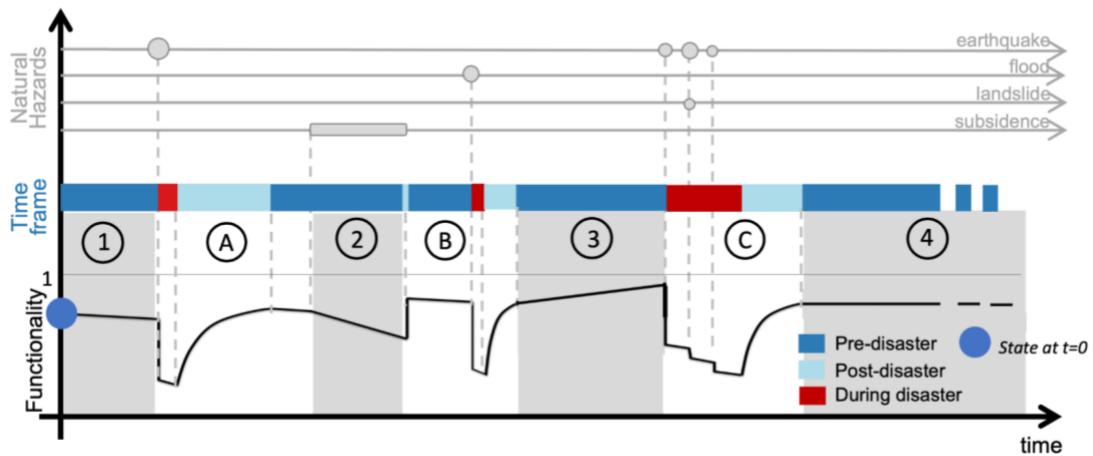


**(C.26)** 485-489: the use of both multi-risk and multi-hazard may cause some confusion.

**[Authors reply]** In order to prevent potential confusion and to provide a more comprehensive representation, we have made the decision to revise all the terms to "multi-hazard risk" throughout this paragraph.

**(C.27)** Figure 4 is again; I was just a bit confused by the use of different DRM phases compared to those presented in figure 2. It may be helpful to the reader to add the meaning of ABC to the figure caption.

**[Authors reply]** We appreciate your feedback and valuable input. In Figure 4, our intention was to depict the functionality of an urban system across different temporal domains in relation to the occurrence of a disaster. In order to avoid any potential confusion, we have made the necessary amendment of changing the term "phases" to "time frames" in both the figure and its description. We also changed the colors of the time frames to create a link between them and the DRM phases reported in figure 2. Here is the updated version of the figure:



We intentionally used the “time frames” in Figure 4 instead of the DRM phases (as we did in Figure 2) to present a broader perspective. We intentionally chose not to strictly adhere to the traditional DRM phases in order to encompass a wider range of actions taken during the pre-disaster time frame. By doing so, we sought to include not only preparedness and mitigation actions, but also other forms of actions that have an impact on the recovery process during the pre-disaster phase.

For demonstrating the meaning to A, B, and C panels we added the below paragraph to the caption of the figure:

*“Distinct variations in recovery rates are discernible across the white panels. Panel A illustrates the recovery process following a single rapid onset hazard. In Panel B, recovery ensues after a slow onset hazard, disregarding other potential hazards, resulting in a system vulnerable to other hazards such as floods. Nevertheless, the subsequent recovery rate surpasses the rate of the recovery after the initial rapid onset hazard, namely the earthquake. Panel C highlights a segmented decline in system functionality, attributed to inadequate recoverability in the face of consecutive events happening within short intervals.”*

**(C.28)** In general, and as pointed out by the other reviewer, the paper could benefit from an English language check (sentence structure, word use, missing words, etc). I highlight some things but these are just some examples:

- 28 “dates” back to?
- 57: “DRM cycle phases one on another” -> “on one another”
- 75: “recovering from them” -> from disasters?

- Incorrect use of "the" (e.g., L. 93: 'the recovery" -> recovery; L. 111 "the google scholar" -> google scholar)
- 194: "However, this would not be possible." -> this is never possible or this is challenging?
- 197: "because socioeconomic recovery is dependent on physical structure" -> is dependent on the recovery of physical structures (?)
- 208: "in a disaster community" -> in a disaster-struck community (?)
- 214: "evaluating quantitatively recovery plans" -> "quantitatively evaluating recovery plans"
- 242: "quick interventions like financial support or food for reconstruction" -> "quick interventions such as financial support for reconstruction or food"
- 275: "Fig." -> Figure
- 346: "while" -> during

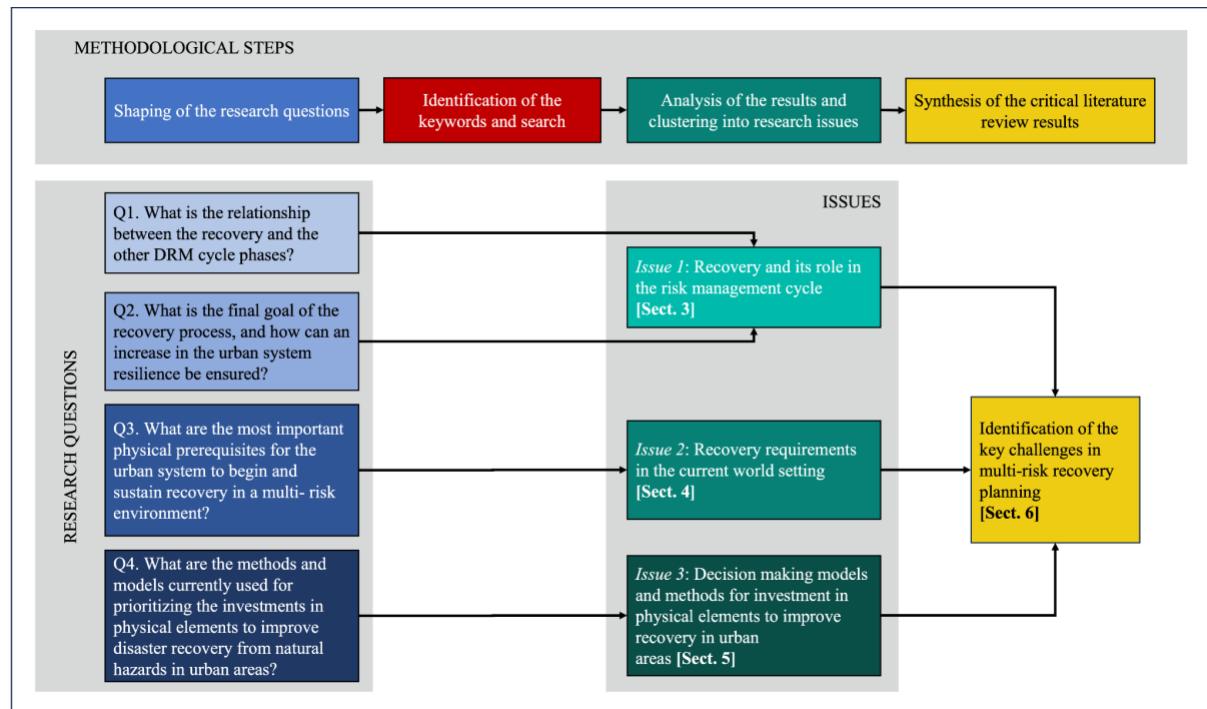
**[Authors reply]** We did a language check, including all the issues you highlighted. Regarding specifically your comment:

197: "because socioeconomic recovery is dependent on physical structure" -> is dependent on the recovery of physical structures (?)

The intended meaning here was that physical structures are required for the following socio-economic recovery. We rephrased in such way:

*"However, it is important to note that the socioeconomic recovery process also requires physical infrastructure."*

## Annex



**Figure 1.** Graphical representation of the methodological steps implemented to perform the critical literature review on multi-risk recovery planning, highlighting the relationship between the guiding Research Questions and the multi-risk recovery planning Issues.

## Annex 2.

1. *Current disaster recovery approaches do not evaluate how pre-disaster (i.e., prevention, preparedness, and mitigation) activities can influence the capability of urban systems to recover efficiently and timely from disasters.* Recovery from disasters does not only encompass post-event actions, but also pre-event planning, as it is well underlined in some of the definitions of recovery reported in Sect. 3.1. According to the literature, pre-disaster actions play a significant role in determining the speed of the recovery process (Sect. 3.2). Nevertheless, there are only a few approaches in the literature (Sect. 5) that consider both pre- and post-disaster activities as well as how they relate to and affect recovery. These studies are all focused on specific infrastructures. Since the concept of resilience encompasses a range of time domains from pre-disaster to post-disaster and recovery, an evaluation of the relationship between the different phases of the disaster risk management cycle, considering the activities that are carried on in each phase, is important for taking measures to increase the resilience of the urban system. This issue is not sufficiently addressed so far, specifically by considering socio-economic aspects of the urban system. Moreover, during the pre-disaster phase, recovery planners often focus on allocating resources and efforts to prioritize single hazards without considering the potential occurrence of consecutive disasters during the recovery process. The lack of consideration of consecutive disasters can result in increasing the vulnerability and reducing the coping capacity of the population from other types of hazards, by lacking knowledge and equipment to mitigate additional risks that may arise during the recovery period. Furthermore, as it has been depicted in the series of disasters that happened in Japan in 2018 (Sect 4.2), this issue extends to insurance companies as well, as

they may not anticipate the possibility of multi-hazard risks and, in the event of their occurrence, may face unexpected resource constraints in supporting the affected population for recovery and reconstruction.

2. *The recovery process involves a heterogeneous group of stakeholders, characterized by different capabilities, shortages, and expectations.* Decision-making in the recovery process is challenging due to the heterogeneity of the engaged groups specifically in urban areas. Indeed, stakeholders rarely agree on recovery goals (Sect. 3.3). If the different options in defining the objectives for the recovery procedures are not considered and the participation of all stakeholders is not promoted, the outcomes could be detrimental to one or more groups, leading to greater inequality in the community. Stakeholders' heterogeneity can be seen as a resource in the different stages of the recovery planning (e.g., needs and capacity assessment, or the implementation of the recovery actions) since it would bring different skills, mindsets and capabilities which would enrich and improve the overall process (Sect. 4.1).

3. *Rather than viewing recovery as a process, it is mainly addressed by focusing on the outcome.* Most definitions of recovery, even the less recent ones, referred to disaster recovery as a process (Sect. 3.1). However, it emerged from experience that while planning for recovery, the main emphasis was on the outcomes. This issue has led stakeholders to think about recovery mainly out of a static mindset, even in identifying the needs and scopes (Sect. 4.1). Moreover, stakeholders usually compare the states of the system before the disaster and at the end of the recovery process, while it has been outlined that it would be better to compare the trends that the system exhibits in each time domain to determine whether the system was improved or not (Sect. 3.3). Therefore, even though the need to view recovery as a process rather than a product has been highlighted in theory, this approach mostly has not been executed in practice. **Moreover, avoiding to consider recovery as a process developing in time, might lead to disregarding the changing vulnerabilities of the community after a disaster and throughout the recovery process.** Consequently, this neglect may lead to insufficient preparation and planning for potential hazards that may happen during the recovery (Sect. 4.2).

4. *Physical reconstruction has been the focus of recovery plans.* The planning for other recovery activities that support the restoration of urban socio-economic institutions has been only partially explored in the literature. Reconstruction and recovery are different even in definition (Sect. 3.1). Insufficient research has been conducted on the interaction between physical reconstruction and socioeconomic recovery efforts, as well as the coordination of these two types of activities so that they would be carried out with the same objectives and in line with each other (Sect. 3.1).

5. *The current literature does not establish a clear relationship between the response and recovery phases.* Communities show different needs and goals, passing from the short-term response phase to the long-term recovery process. Additionally, from response to recovery, capacities and external contributions may change significantly. Therefore, the transition between the two phases needs to be managed effectively so that stakeholders and decision-makers would not become confused by abrupt changes (Sect. 3.2). **Moreover, it could happen for a community to be in the recovery phase from a disaster while in the response phase for another.** From a multi-risk perspective environment, the DRM cycle framework has shown limitations in addressing simultaneously response and recovery activities, particularly in multi-risk conditions. In response to these shortcomings, researchers have proposed new frameworks that aim to capture the complexities involved. However, it is worth noting that limited effort has been put to transfer these frameworks into executive guidelines

and plans. (Sect 3.2) to ensure that planning and actions in response and recovery phases should be coordinated to not conflict with one another (Sect. 4.2).

6. *Recovery is a dynamic and non-linear process, characterized by different paces and parallel activities.* Different communities and even different groups within the same community may experience varying rates of recovery, depending on their equipment capabilities, willingness to participate in the recovery process, and recovery objectives (Sect. 3.3 and 4.1). In addition, past experiences indicate that recovery efforts would not be carried out in every community in the same pattern and order, since the built environment components could be damaged at different levels depending on their significance to the functioning of the urban system. Therefore, it is not a realistic approach to prescribe and demonstrate an ordered linear recovery roadmap for all communities (Sect. 3.2 and 4.1).

7. *Disasters are not seen as an opportunity to improve the urban system's resilience.* Planning and investments for recovery are concentrated mainly on getting the system back to its pre-disaster state (Sect. 3.3 and 5). There are not enough plans and strategies that view recovery from disasters as a springboard for achieving sustainable development goals or making urban areas more resilient. The BBB concept has been in existence for years, but it is still ambiguous. All the components of this concept ('build', 'back', and 'better') are still controversial and there is disagreement amongst stakeholders on a practical definition of the terms (Sect. 3.3). **Moreover the existing literature on the concept of BBB lacks sufficient integration of the multi-hazard risk perspective.** In practical terms, during the recovery process, the emphasis is predominantly placed on addressing the hazards that have recently affected the urban area and improving its resilience in relation to those specific hazards. However, other potential hazards that have not recently impacted the recovering area, even though they may pose significant risks, are not taken into account when implementing DRR measures during the recovery process (Sect 3.3).

8. *Community needs are not always incorporated into the recovery planning and reconstruction process.* Therefore, the physical reconstruction of a built environment after a disaster is not always compatible with stakeholders' expectations and needs and eventually results in the malfunctioning of the system. Needs are changing constantly and answering one need leads to the emergence of another (Sect. 4.1). **Furthermore, effectively managing the balance between addressing community needs and enhancing resilience against hazards beyond those that have caused damage from a multi-risk perspective, requires the incorporation of co-production knowledge processes involving stakeholders and the scientific community.** By involving these key stakeholders, all aspects of multi-risk resilience can be addressed, including those that may not be readily apparent to the local community and decision-makers (Sect 4.1).

9. *Multi-risk recovery planning approaches are still lacking.* Neglecting synergies, cumulative damages, recovery dynamics, and any other interactions at different levels (hazard, vulnerability, exposure, or DRR measure) might result in recovery plans that would strengthen the system's resilience regarding a particular hazard but leave it vulnerable, or even increasing its vulnerability to other hazards (Sect. 4.2).

10. *Recovery planning requires a multi-objective optimization including maximization of the socio-economic benefit of the community.* The socio-economic importance of the urban assets and their contribution to the overall system functionality has been neglected in the planning and orientation of the investment for the recovery process. Only cost and time minimization and in some cases maximizing serviceability of specific infrastructures were the main objectives in current optimization models. Moreover, socio-economic interdependencies amongst urban assets (e.g., buildings, critical infrastructures, lifelines, etc.) are ignored so far in urban system modeling for

recovery (Sect. 5). In an interdependent system hazard negative effects can propagate beyond their initial point of impact. This can lead to multi-risk systemic impacts that could occur even though two or more hazards do not overlap in space and time. These types of interdependencies have not been addressed in available optimization models.