

Response to the NHESS Editors,

Executive Editor, Prof. Dr. Bruce Malamud

Handling editor, Dr. Elisabeth Elisabeth Schoepfer

I would like to thank you for the positive response of accepting our manuscript pending minor corrections.

The technical corrections of the two anonymous reviewers have been satisfactorily solved in the revised version of the manuscript. Moreover, I would like to express my apologies for having submitted the PDF version with some figures with a wrong black background. That was a mistake that I did not notice while uploading the file, but luckily the original Word version was undamaged. Thanks for your understanding.

I sincerely thank the helpful feedback of Prof. Dr. Bruce Malamud. Please find the answers to each of your comments. They have been listed using numbers (18 comments) in the case punctually addressing each suggestion is required in the future. With this, I consider that the manuscript has been significantly improved.

1. Abstract.

>>The Editor suggested to be more explicit with numbers and economic losses. However, he also said **"It is fine if you want to leave as is"**. Therefore, we have decided to mostly leave it as it was written on the previous version of the manuscript. This is because we consider that the assumptions involved in the proposed method as well in the data used on the application part of the paper require a significant overview that cannot be given in the abstract, which to our opinion should tell the generalities of the paper while motivating to read other parts of the paper. However, the words "direct economic" (referring to the forecasted losses) has been added to this new version of the abstract to emphasize that only this type of metric was considered in our study.

2. GENERAL. This will be picked up in copy-editing, but throughout, remove ',' before (YYYY). So for example "Goda and De Risi (2018)" not ", (2018)". Park et al. (2019) not Park et al., (2019).

>>Before doing this change, I remembered that the 'al,' is the advised style of citation by the NHESS journal. Please note that this is also included in the Zotero default style for NHESS. I also cross-checked a few of published papers in the same journal (including some authored by myself and by Prof. Dr. Bruce Malamud), and I could notice that the 'al,' style was used in the final print version. I hope this explanation helps to understand why no change was done in this matter. In any case, if there is a recent formatting that I do not know well, I am sure that, the copy-editing service of the Journal will satisfactorily fixed, as already written on this comment.

3. INTRODUCTION. The introduction meanders a bit in its text. It takes a while (paragraph 2) until the reader knows what exactly will be studied. Paragraph 2 does explain it, but you could be more explicit.

"This study narrows down the scope of ******* cascading events, you decide on words ******** by assuming that a second hazardous event is always triggered after the occurrence of the first one," You want a self-contained sentence not dependent on the first paragraph.

>>This sentence has been updated as follows: *"Therefore, this study narrows down the scope of scenario-based multi-hazard risk by assuming that a second hazardous event is always triggered after the occurrence of the first one, thus eliminating the need to quantify the probability of this occurring"*. Thank you for your helpful suggestion.

4. INTRODUCTION. For the second paragraph. At the end of it, tell us what will be in the rest of the introduction. "The rest of this introduction will discuss *******, *******, and ********" This will help the reader understand what is to come.

>>Following the Editor's helpful comment, we have introduced some new lines of text presented below. This will allow the reader having a smoother experience while reading the rest manuscript.

'As a premise, this study contributes to the field by proposing a modular method to probabilistically integrate sets of single-hazard vulnerability models that are being constantly developed and calibrated by experts from various research fields to be used within a multi-risk context. The rest of this introduction will discuss the state of the art in exposure modelling for large-scale building portfolios for multi-hazard risk assessment, focusing on the underlying assumptions to propose generalised building typologies with associated fragility functions used to assess their physical vulnerabilities to earthquake and tsunami. Having done that, the last part of the introduction summarises the general scope and capabilities of the original method that will be described in detail afterward.'

5. INTRODUCTION. At the very end (new paragraph) tell us how the rest of the paper will be organized.

>>The last two paragraphs of the Introduction have been almost entirely rephrased. The first one refers to the proposed method whilst the second one does to the application part. Now, we are clearly announcing since this earlier stage that the method is made up of four distinctive modules, while mentioning the section of the paper where their respective explanations and details are provided. We consider this has improved the overall quality of the paper (this is also related to the last comment of the Editor about making the manuscript "a bit more user friendly in its structure". The new version of these two paragraphs are presented as follows:

This study proposes a modular method to probabilistically integrate existing sets of single-hazard vulnerability models (or "reference schemes"). For this aim, this method comprises four main modules. The first two ones refer to sets of compatibilities between the vulnerability models selected for each single-hazard vulnerability (e.g., between existing seismic and tsunami building classification schemes). The first probabilistic compatibility set are obtained between (1) building classes (as presented in Sect. 2.1), whilst the second is obtained between (2) damage states (Sect. 2.2). These two conversions are done through the use of taxonomic attributes that are independent to the definition of the reference schemes. This is done with the purpose of representing the damage distribution resulting after the first hazard (i.e., earthquake) through a damage-updated exposure model whose damage scale is dependent on the classification scheme required for assessing the vulnerability to a triggered event (i.e., tsunami). The third module results from the need to perform risk assessment for

the triggered hazard using the damage-updated exposure model that is now represented in terms of the second vulnerability scheme (e.g., building classes and damage states for tsunami fragility). Hence, this module comprises the proposal of (3) sets of state-dependent fragility functions for the second hazard (e.g., tsunami), as presented in Sect. 2.3. These three modules are valuable inputs for ultimately assessing the expected cumulative damage. They are later complemented by a last fourth module: (4) a consequence model to assess the incremental direct economic losses (Sect 2.4) that are expected from consecutive hazard scenarios.

In the application chapter of this paper (Sect. 3), we demonstrate the application of this method by investigating the likely cumulative damage on the residential buildings of Lima (Peru) by considering this city's exposure to six mega-thrust earthquake scenarios (main shock) and subsequent tsunamis. This is done using existing vulnerability models per hazard, and addressing the probabilistic compatibilities between building classes and damage states. Complementarily, a set of tsunami state-dependent fragility functions that are obtained through the use of simple ad-hoc scaling factors are proposed. Nonetheless, as it will be discussed, these functions can and should be replaced by other sets of state-dependent tsunami fragility functions derived from more sophisticated methods when they become available. Every damage distribution is translated into direct economic losses to gain a comparative risk metric and disaggregate the contribution of each hazard scenario.

6. GENERAL. All variables must be clearly defined where they are first introduced. For example, IM^A , it is not clear if this is "IM" or I and M. Although it might be obvious that A is a constant, this needs to be stated. Please go through and ensure that all variabilities have been defined where they are first introduced. Please ensure that equations have references where appropriate.

>>I have ensured that all of the variables are clearly defined where they were first introduced, as well as that equations are appropriately referenced. Regarding the punctual example of IM^A , the next modification has been included to provide a clear understanding. Please note that 'IM' had been previously defined several lines before.

For example, one building that is expected to be affected by a first hazard intensity measure IM^A (here A refers to an IM used to model ground-shaking (e.g. PGA in g)) and a second one IM^B (B refers to an IM used to model inland tsunami inundation (e.g. inundation depth in m))

7. Table of variables and acronyms. Because of the number of variables, your paper will be easier to read if you have a table of variables (and I suggest a separate part of it with acronyms), introduced early on. This can include units.

>>This suggestion is the only one that has not been incorporated in the updated version of the manuscript. We consider that with the modifications on the text where all the variables used in equations, text, and figures are now clearly defined, the table of variables is no longer needed and would be repetitive. It is clear to us that, the former modifications, as well as new improvements (i.e., changes to table 1, and by including explicit explanations to the captions of every figure), can satisfactorily replace the aim of a table of variable and acronyms. Thanks for your understanding on this matter.

8. Figure 1. Currently black. I think it has been inverted? Ensure that colour is not the only distinguishing feature (e.g., you could take the 'red' and also make it a dashed line) as there are colour blind people.

>>The black background of this figure has been fixed in the updated version of the manuscript. Figure 1-b has been modified. First, a schematic overview of how each component will look like after its respective development in the application section is displayed. This is aligned with one of the former comments by one of the anonymous reviewers who suggested to include a link of schematic workflow at an earlier stage. Moreover, following the Executive Editor's suggestion, the modules (i.e., the four parts of the equation on Figure 1-b) are now being shown by enclosing boxes with distinctive line styles (i.e., dotted/dashed/ continuous/ double line). We agree that this modification will be helpful for colour blind people.

9. GENERAL. Figure caption and table headers. Make sure these are self-standing, so that one does not need to go to the text to figure these out.

>>This suggestion has been included although the updated manuscript. Thank you.

10. REFERENCES. Please go again through the text and ensure that ALL facts/information/ideas which build on other people/equations have appropriate in-text citations. In most places this is fine, but I was spotting a couple examples (e.g., line 268, you state the population of Peru, but no reference). Again, this is in general well done, but please do a double check.

I have double-checked the references and I do believe that it is now complete. About the mentioned reference about the Peruvian population, the following reference has been added:

In 2022, Peru had a population of around 33 million people, with nearly 58% of this living in coastal communities (INEI, 2022).

This citation corresponds to: *INEI: Perú: 50 años de cambios, desafíos y oportunidades poblacionales, Instituto Nacional de Estadística e Informática (INEI; Institute of Statistic and Informatics), 2022. Available on: https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1852/libro.pdf*

11. Figure 4. Please put the (a), (b) (c) as part of the figure, and below the sections, not above. Will read better. If you use an acronym in the figure (TIH) then you need to define this in the figure caption "Expected tsunami inundation heights (TIH) in m for three out of six...".

Figure 1. Expected tsunami inundation heights (TIH) in meters (m) for three out of the six considered scenarios per moment magnitude (Mw), namely: (a) Mw 8.6; (b) Mw 8.8; and (c) Mw 9.0.

12. Table 1. I found it difficult to read 'quickly' going from left column to middle, as acronyms are not always defined (e.g., RC, which I think means reinforced) and acronyms are only used once. Consider having another part of the table or another table which has a list A to Z of the acronyms, specific for this table? So I figured it out 'after' reading it through a couple times, but it was not user friendly (So

I needed to 'interpret' that H1 is 1 story, H3 is three stores, that MUR for line one is unreinforced masonry, etc.

>> Thanks a lot for your helpful feedback. After including your suggestions, I have payed attention that all of the building attribute values contained in the GEM v.2.0 taxonomy are appropriately and successively mentioned in the updated version of the manuscript. This means that each attribute is only reused to describe a building typology only if it was previously defined. I have asked a few external colleagues to please read again the table and check if now they can understand the building classes once each acronym was already defined, and their response was positive. I feel it is now much more organised. Thanks again for this meaningful suggestion that has improved the quality of presenting this relevant information.

13. Table 1 and GENERAL. Any time that monetary amounts are stated (e.g., USD/bdg) then you need to state for what year it has been normalized to.

>> After including your suggestions, the header of this table has been updated as follows:

Table 1. SARA building classes proposed for the residential building stock of Metropolitan Lima and Callao, with their respective replacement costs per building unit (Repl. Cost (USD/bdg.) as reported in Yepes-Estrada et al., (2017) in the frame of the SARA model released by GEM (Global Earthquake Model) in 2015, which was based on official census data reported by INEI, (2007). The intensity measures (IM) of the associated seismic fragility functions to each building class, as reported in Villar-Vega et al., (2017), are also provided.

14. Figure 5. Black should not be black? Cannot read any other text above legend or surrounding map, because of the black. Do you mean to have your beginning and ending points exactly the same for your ranges? For example, 23.2 is repeated as upper end of one range and lower end for another range. For this figure, please label the separate parts (a), (b), (c) and then refer to these in the figure caption (which gets around 'just' using colour, which does look nice, but not everyone will be able to see).

>> The black background of this figure has been fixed. I fully understand the Editor's concern about the fact that the ranges on this figure are repeated. The reason behind this is that our preferred manner to show these percentages is by only using one decimal value. We do not consider that the overall concept or aim of this figure will change if a second decimal value is added. The interpretation of this figure by the reader will remain the same. Thanks for your understanding on this matter. Complementary, after including your suggestions, the caption of this figure has been updated by including these lines that separate the parts (a), (b), (c) as suggested:

“(a) masonry and earthen (red); (b) reinforced concrete, RC and Unknown, UNK (blue); (c) wooden types (green)”.

This new version mentions the main material of the building typologies in the first place and the colour is a secondary descriptor mentioned at the end of each class, and hence. Thanks for your suggestion.

15. Figure 6 caption. This is an example of making it complete. The reader will have no idea what all the acronyms mean, so either define them here (I recognize this might take too much space) or refer the reader to a table where they are defined "Acronyms for building class component types are given in Table *".

>>Thank you for your kind comment. After including your suggestions, the caption of this figure has been updated by including the following lines:

Acronyms for SARA building classes are given in Table 1, whilst the six Medina (2019) classes are: M-PN (wooden), M-MP (masonry), M-PCP1-T1 (framed RC, one storey with similar length-width ratio), M-PCP1-T2 (framed RC, one storey, with a higher length to width ratio), M-PCP2 (framed RC, 2 storeys), and M-PCP3 (framed RC, 3 or more storeys).

16. Figure 7. Is this meant to be black? In all figure captions, ensure that acronyms are defined. If someone were to remove this figure without the text, they would not know what AeDES means. Because there are only four of them, define VS, FL, RF, IP.

>> The black background of this figure has been fixed. After including your suggestions, the updated caption of this figure is:

Figure 7. Examples of the AeDES-based heuristics (see original AeDES form (Baggio et al., (2007) on Figure 2)) that describe the expected observable damage onto the four selected building components listed in Eq. 3 (vertical structure (VS); floor (FL); roof (RF); infills and partitions (IP)) using the scale from I-A (i.e., I=0 (null) to A=9 (>2/3 extension within the "very heavy" damage level). This is done per damage state per building class within two hazard-dependent vulnerability schemes.

17. Section 6. Something happened here to your font. It is now all bold.

>> Sorry about this. The last paragraph of the discussion was merged with the format of Section 6. It has been fixed in the updated version of the manuscript.

18. The manuscript has some very detailed and interesting research, but would benefit overall to be made a bit more user friendly in its structure, making it easier for the reader to go from one section to another 'quickly' without having to read in detail (a couple of times) a given section. I've given some notes above of some items that might be changed, but you might want to consider how you can really make the paper useable to the average reader.

>> Indeed, after having included the Executive Editor's suggestions, the quality of the paper has been largely improved. Several new changes in the format have made it possible. We would like to express our deepest gratitude for the time invested on this matter.