# Review for "*Real-Time Loss Tools: Open-Source Software for Time- and State-Dependent Seismic Damage and Loss Calculations – Features and Application to the 2023 Türkiye-Syria Sequence*", by C.I. Nievas, H. Crowley, G. Weatherill and F. Cotton

## Seismica

**Review**

This manuscript presents an open-source software for seismic sequence risk analysis accounting for damage accumulation and the displacement of building occupants. The topic is of interest to a wide range of readers interested in seismic sequence risk analysis, as well as practitioners who might need a tool to run their analysis. I think the study needs some revisions and clarifications. In its current state, this manuscript looks a lot more like a report or a manual than a scientific paper. I suggest focusing more on the methodologies upon which this software is based and less on things like the format of inputs and outputs or how your software interacts with OpenQuake (I think manuals are for that sort of information). Once all this is clarified/amended, I recommend accepting this manuscript for publication in Seismica. Below is a list of revisions, several of which are just suggestions.

Salvatore Iacoletti

1. Line 24-26: I agree that changing the fragility has an impact on damage and losses, but how is the location of the occupants affecting damage and losses in your methodology? Maybe I missed something.

2. Line 86: I would avoid using the phrase "resist to a […] shock". It might be misleading for some audiences.

3. Lines 86-89: from "natural reminders […]". The sentence doesn't read well. Perhaps splitting it into two sentences might help. Also, you might want to add references for each of the mentioned events to support your statement that previously damaged buildings are more vulnerable to subsequent shocks.

4. Line 94: "the matter of damage accumulation". I think this is the first time I read "damage accumulation" so far in the manuscript. You may want to introduce this concept more clearly when you introduce the concept that previously damaged structures are more vulnerable to other shocks. I think that the concept of damage accumulation and the fact that fragility and vulnerability curves are not constant are still not clear to most researchers and practitioners, unfortunately. So, easing the readers into this concept first might benefit your manuscript.

5. Line 100: I believe you wanted to write "to the best of the authors' knowledge"?

6. Lines 101-103: This part of the sentence doesn't read well. Also, is there an extra unwanted space between lines 102 and 103?

7. Lines 103-124: This entire section seems unnecessary to me in the Introduction. Your manuscript focuses on extending the rapid loss assessment with sequences, and mentioning so

many other areas of research on how to improve RLA feels like a distraction to the reader. I would remove (or at least reduce) this section and get to the deficiency of the standard RLA you are trying to improve. If you still want to make that connection with Structural Health Monitoring, I would probably briefly add it as a discussion at the end of your manuscript.

8. Line 127: “short-term” means different things to different people. I suggest to be more specific.

9. Lines 128-129: Although I am myself guilty of always saying that there are only three certainties in life (taxes, death and aftershocks), I would probably avoid absolute language such as “undoubtedly” and “large number of aftershocks” in the context of a research paper. There are several examples of large mainshocks followed by a surprisingly low number of aftershocks.

10. Lines 144-152: Again, this seems to be distracting information that could go in the body of the manuscript instead of the Introduction. If you exclude the abstract, up to this point, readers would have read ~10% of the entire manuscript, still not knowing the objective of the paper, which is stated in the following paragraph. I suggest restructuring the Introduction and using only the info you need to motivate your proposed software.

11. Lines 153: which topics? This sentence seems detached from the previous paragraph, so it’s not clear to me what you are referring to.

12. Lines 155: you are now stating a deficiency in the literature: “there are no publicly available open-source software to […]”. Since what you mention in this sentence is the motivation of your manuscript, it seems a bit odd to also state “to the authors’ knowledge”. Although I appreciate the sentiment, if there are publicly available software to carry out similar analyses, they deserve to be mentioned and compared to your software here. If there aren’t, then I would remove “to the authors’ knowledge” as it seems a bit diminishing of your research. Also, although no software may be available, there are papers in the literature suggesting methodologies for dealing with damage calibration (e.g., Papadopoulos and Bazzurro 2020, Iacoletti et al. 2024) and population displacement (e.g., HAZUS, Paul et al. 2024, amongst others). I think past efforts deserve to be examined here and compared with the methodology you are using (which, as mentioned above, is not super clear to me).

13. Line 156-158: “seismicity forecasts” often refer to the earthquake frequency/occurrence/hazard depending on context. Damage accumulation and people displacement are risk metrics.

14. Lines 172-173: I think a sentence like this should precede the statements that RTLT was developed as part of RISE, it uses OpenQuake, it could be integrated into OpenQuake, etc, and follow the motivation of this software.

15. Line 178: I would remove this part “Among the several interesting observations that emerge from this example application,”. Too generic for the introduction.

16. Sections 2 and 3 generic comment: the structure and the language of these sections really feel like a report more than a scientific paper. Your software is very advanced and can perform a large number of tasks and analyses, but to make sense of your manuscript, I had to go and check the code. From the manuscript only, for instance, I struggled to understand what feeds into what, what is handled by OQ and what by RTLT. You mention configuration parameters

and calculation triggers (around line 250, and also have in Figures 2 and 3), but the reader basically cannot know what these are until line 310. Although writing style is very often subjective, I think that the methodologies of the software should be explained a lot more in detail for publication in a scientific paper. Details such as file types and other processes clearly handled by OQ (like rupture generation or the entire Section 3.5) may be left for the manual.
Generally, I would suggest one of the following strategies:
(1, the most common in scientific literature) -> Focus on the methodology behind the software more than the software itself (e.g., do not focus on the format of the input/output files, explain the methodologies behind the core methods RLA and OELF, reduce the "workflow" explanation to a minimum to give the readers what they need to understand the RTLT's underlying methodology, etc., all the extra info can go in appendices if you want to keep it); a great example of this strategy, in my view, is Silva et al. (2014) "Development of the OpenQuake engine, the Global Earthquake Model's open-source software for seismic risk assessment", where they focused on the background of the OpenQuake, not all the details (there is very detailed software documentation for that); or
(2, less common but still very valuable in my view) -> Provide an explanation of the inputs and outputs of the software, giving only the background mathematical framework of what the software does (like the high-level overview in section 2.1), reference the software manual for details about the methodologies, and provide multiple examples of your software's features. A great example of this strategy (in my view) is Jalilian et al. (2019) "ETAS: An R Package for Fitting the Space-Time ETAS Model to Earthquake Data"
At the moment, the manuscript seems to be a confusing mix of the two strategies above.

17. Section 2.1: in my view, I think it would be better for the reader to switch your explanations: (1) introduce Figure 1 and explain each section in detail; explain the color coding that has been used and what a yellow box is (I'm guessing outputs). Green box (I'm guessing inputs)? If you want to focus on the software (see comment 16), maybe show in Figure 1 which input is RTLT-specific and which one is an OpenQuake input.
(2) describe in sentences (not in bullet points) what RTLT can do without going into too much detail.

18. Figure 2: I think Figure 2 is better placed in Section 2.2 or 2.3. Section 2.1 is supposed to be a generic overview of RTLT.

19. Lines 476-494: I struggle to understand why this is relevant. It might be relevant from a computational standpoint, but what are the benefits from a methodological perspective?

20. Lines 510-512: Again, I think that information such as this is more appropriate for manuals and reports. While I understand that it is relevant computationally, it distracts the reader from the methodology behind the software itself. I'll stop mentioning this for the rest of the manuscript

21. Lines 675-677: You have called the Kahramanmaraş earthquake sequence "2023 Türkiye/Syria earthquakes" so far in the manuscript. I suggest picking one way of referring to this sequence and being consistent throughout the manuscript.

22. Lines 689 to 693: you are repeating almost the same info you mentioned in lines 677 to 680. I suggest avoiding repetitions.

23. Lines 700 to 704: For magnitudes <6, point sources can offer a satisfactory representation of the characteristics of earthquakes (e.g., the induced stress state, Verdacchia et al. 2018). What is the added advantage of using planar rupture surfaces instead of simple point sources for smaller-magnitude events? By using a (relatively) more complex single planar rupture representation, you had to assume that the nodal plane is aligned with that of the largest shocks. How do you justify this assumption? There are examples of subsequent shocks in the same area not aligning (e.g., Ridgecrest earthquakes in 2019).

24. Lines 722-725: since you recalibrated the coefficients of the GMM to get AvgSA, you might want to share the GMM parameter table to allow your readers to replicate your results (if not done elsewhere).

25. Lines 750-751: I would avoid a new line here.

26. Lines 787-789: I think a bit more details are needed as to how you applied "expert judgement" (an example would suffice for a reader willing to repeat the analysis)

27. Line 800: do you have any reference for this consequence model? Also, since using mean damage-to-loss is a big assumption, I would emphasize this in your conclusions and discussion of results. Maybe even a small discussion on how you expect the results to change including this important source of uncertainty.

28. Table 2: I appreciate that these numbers are highly uncertain, but there should probably be a bit more discussion on how you got these numbers (e.g., 45 days for an inspection?). The other thing that I don't think is acknowledged here is that repair time is very dependent on the surroundings (e.g., a building in DS0 or DS1 would not be re-occupied or repaired if it's surrounded by buildings in DS4). Prof Jack Baker's group published several papers on this topic (one I know of is this: https://www.jackwbaker.com/Publications/Wang_et_al_(2022)_Post-disaster_housing,_EQ_Spectra.pdf), and I would probably recommend referring to some of that work in this manuscript.

29. Line 862-867: this part is a bit confusing to me. Could you please rephrase?

30. Table 3 and 4: I think it's worth adding the timestamp and the magnitude of the earthquakes as additional columns to make your point clearer. I know this info is in the appendix, but adding extra columns might make it easier for the reader to read the tables.

31. Section 4.7 in general: since your software is capable of running the same analysis with state-independent fragility models, it would be nice to show how the results change without damage accumulation, at least in terms of losses. I think this would clearly show the benefit of including damage accumulation compared to a more traditional risk analysis where all events in the sequence are considered independently (i.e., no damage accumulation).

32. Lines 947 onwards: it seems weird to say that reproducing damage statistics from the sequence is not the scope of this section and then spending 50 lines and 3 tables explaining in detail what you did. If it's not in scope, I would stop this part to line 952. Otherwise, avoid saying it's not the intent of this section.

33. Tables 5, 6, and 7: Oddly enough, I found the figures in Appendix C more informative than the tables in the manuscript. Again, it's a matter of personal preference, but I prefer visual

aids to tables. I suggest considering swapping tables for figures between the appendix and manuscript.

34. Section 3.2 and case study: Since you do not have a case study for OELF and (judging by the abstract) the scope of the paper lies more on the RLA, I would seriously consider reducing the OELF part of the framework section. For instance, you might want to frame OELF as an added feature, which has not been discussed in this manuscript (as you say in the conclusions). It seems slightly odd to fully explain the OELF feature and then not to showcase it with a case study.

35. Conclusion section: After line 1000, I would probably discuss the case study results first and then discuss topics like future implementations, future developments/areas of improvement, other features, integration with other tools, etc.

36. Code availability: since this paper focuses on the software, I would add a sentence like "RTLT is released with GNU AGPL v3.0 license" or similar

**Real-Time Loss Tools: Open-Source Software for Time- and State-Dependent Seismic Damage and Loss Calculations – Features and Application to the 2023 Türkiye-Syria Sequence**

This comprehensive manuscript details a new software tool for conducting time-dependent seismic risk calculations. The software is integrated into the well-known publicly available OpenQuake application for earthquake loss modelling. I believe the software in question is timely, potentially very useful for the earthquake risk modelling community, and would be of interest to readers of Seismica. Furthermore, the manuscript is generally well written albeit lengthy (some suggestions for shortening it are provided below). I therefore recommend the manuscript for publication if the following comments can be addressed by the authors first.

**Main Comments:**

1. Methodology. Some clarifications on the methodology are required:
    a. One of the most important clarifications required is on the aggregation of economic losses. While the casualty calculations are discussed in depth, the accumulation of economic losses is not described in any detail. I would suggest clarifying these calculations through equations.
    b. I think it would be useful to clarify somewhere the interaction between the RLA and OELF calculations (perhaps as part of Figure 2); it seems to me from various places in the text (e.g., line 420 and line 445) that the OELF relies on the results of the preceding RLA , which makes sense, but I could not find it explicitly mentioned in the text (apart from a brief parenthetical statement at line 276 that I think could be missed by some readers). Furthermore, what if the user would like to rely on "real" damage observations for input to the OELF rather than the results of the previous RLA – is the software able to handle this different type of input?
    c. Figure 1: It would be useful to specify in the text which parts of the calculations/models are customisable, and which are predetermined.
    d. Line 262: It is not clear to me why an OELF calculation could not benefit from external sources of damage estimates that could act to determine the initial damage state of the building stock input to the calculations? (Same comment applies to line 438). (This is related to comment 2b.)
    e. Line 280: How is the time of the day accounted for in OELF calculations (is this just a random assumption?)
    f. Line 333: I think it would be useful to re-write this to more clearly convey that the factors in question potentially reduce the number of occupants considered in a building, depending on the time of day.
    g. Line 367: Could you please specify the format of the "external damage probabilities" mentioned here? I assume these probabilities need to cover the same damage states as the considered fragility functions?
    h. Line 420: To avoid confusion between both sets of calculations, I would suggest you refer to these damage states as the "initial ones input to the OELF calculations" (or similar). (This is somehow related to comment 2b).
    i. Line 480: I think it would be useful to clarify here how (state-dependent) fragility functions are assigned to individual buildings with multiple original_asset_ids.
    j. There are a couple of key assumptions that the software requires:
        1) That the user inputs a recovery period for a building in DS4 that is longer than the length of a considered seismic sequence.
        2) That the user inputs a length of hospital stay for a fatally injured building occupant that is longer than the length of a considered seismic sequence.

    The latter assumption will be incorrect in any case, given that a fatally wounded occupant does not require a hospital stay (unfortunately). I am wondering, therefore, if there is any possibility that either of these (incorrect) assumptions lead to bias in the results? Would it be better not to insert some sort of flag in the calculations that does not require a user to (possibly incorrectly) specify a (meaningless) number of days? I see that the length of hospital stay for fatal injuries was set to infinity in the case study, which makes sense, but I am not sure that all users would necessarily think to use this value.

k. Line 540: I do not follow what is going on here. It is mentioned that a DS0 gets assigned "(0.851/8.6)*C of the replacement cost, but why would no damage incur any repair cost? The repair cost should take into consideration both the level of damage incurred as well as its probability of occurrence?
l. Line 580: I thought that the software does not deal with repaired buildings, so if a building becomes unusable, it should stay unusable.. is this correct? If so, the sentence at and around this line is a bit confusing.
m. Related to comment 2j, why can't the minIML and noDamageLimit parameters just be disabled for the RTLT calculations, to avoid the user introducing an error?

2. Framing of the software as a real-time loss assessment tool. The software tool is generally described as a "real-time" or "rapid" loss assessment methodology. Yet, the case study application only demonstrates the tool in a retrospective capacity. The calculations of the case study relied on a reduction of the initial exposure model, which would not make sense to do in a real-time application. No demonstration of integrating damage observations (e.g., from SHM) was provided. I am therefore slightly concerned that the tool is being sold as something that there is so far no evidence to support. I would suggest the authors tone down the language, for instance referencing its "potential" (rather than definitive) use as a real-time loss assessment tool.
3. Length of manuscript. The manuscript is quite lengthy (although I do appreciate it is double spaced). Here are some suggestions for how it could be potentially shortened:
    a. Figure 2 is not providing much information beyond what is already described in the text and could be removed
    b. I think that Section 2.2 is probably too detailed for the overview manuscript and it might be more appropriate to leave this for a software documentation document.
    c. Lines 476 to 479 do not refer to the software tool in question, and could be removed (also to avoid possible confusion).
    d. Figure 7: I am not sure the level of detail provided here and in the accompanying text is strictly necessary, given that this is not a software documentation document and the significance of grouping damage states together is not explained sufficiently to understand its significance. I would suggest removing this figure as a result.
    e. Lines 601 to 605: I don't think it is necessary to emphasise this aspect, as it would lead to the same result regardless (if I am not mistaken).
    f. Lines 641 to 652: I would suggest removing these lines, as I am not sure it is strictly necessary for the reader to gain insight on runtime errors in the calculations.
    g. Line 805: The description of various injury levels can be removed and interested readers can simply be referred to the original documents.
    h. The obvious statement at the end of page 49 could be removed.
    i. I am not sure that Appendix C is necessary to include, given that the information is already summarized in tables provided in the main text.

**Minor Comments:**

1. Around line 55: It would be good to quantify the time scales associated with a rapid loss assessment.
2. Line 75: I would suggest providing a reference for DYFI for some readers that may not be familiar with this term
3. Line 88: It would be good to clarify what you mean by the term "reminder"
4. Line 100: I would suggest acknowledging here some work that has been done on the transfer of patients to hospitals after an earthquake, e.g.: https://doi.org/10.1038/s41467-020-18072-w
5. Line 220: The current status of exposure is mentioned here, but the text should also acknowledge that the software additionally accounts for the current status of vulnerability. This comment also applies to the end of page 12 where there is a reference to the "update of the exposure model files" and the Figure 4 box that discusses the current exposure but includes the term "damage states" in parentheses.
6. Abstract and introduction: There is a general emphasis on damage and displacement outcomes from earthquake disasters. While I appreciate that these types of consequences are the main focus of the software tools (and perhaps the real-time/immediate post-even period of interest), I think it would be

useful to generally acknowledge that these are not the only considerations of interest when it comes to seismic loss assessment.

7. Line 640: Please clarify the difference between the two maximum distance parameters mentioned here.
8. Table 5: It would be useful to put the percentage breakdowns for DS3 and DS4 in the A3 and A4 columns.

**Comments on Figures:**

1. Figure 6:
    a. It would be worth describing either in the text or in the caption how non-whole numbers of buildings per id are possible.
    b. It would be better to avoid using similar light yellow colours in the first panel that refer to different things; as it stands, some (in the main plot) refer to the number of buildings associated with a given building id and some (in the pie chart) refer to various proportions of original asset ids per building id
    c. In the middle square of (c), it looks as if four different building ids are being showed; three that correspond to individual buildings and one that refers to a collection of buildings. Please clarify in the caption if this correct.

# Real-Time Loss Tools: Open-Source Software for Time- and State-Dependent Seismic Damage and Loss Calculations – Features and Application to the 2023 Türkiye-Syria Sequence

C.I. Nievas, H. Crowley, G. Weatherill and F. Cotton

# Reply to Reviewers

We would like to sincerely thank both reviewers for their very detailed comments and suggestions, which have prompted us to carry out a deep re-structuring and re-writing of the manuscript aimed at improving clarity and readability. We have added some new sections, figures, clarifications and comparisons to address some of the reviewers' comments, which we believe have improved the manuscript. However, owning to this we have not been able to reduce the length of the manuscript.

Some of the key changes in this revised version are:

- We have eliminated Section 2.2 and former Section 3.5.
- We have substantially re-structured and re-written Sections 2 and 3. We have eliminated a figure and added a new one to aid in the explanation of the interaction between the RLA and OELF algorithms.
- We have added a new section (new Section 3.5) specifying details on the calculation of economic losses and human casualties.
- In the case-study, we have added a comparison against economic losses results obtained using state-independent fragility models.
- In close relation with the previous point, we have added an appendix (new Appendix A).
- In the conclusions, we have added a paragraph to discuss the most interesting observations from our case-study. We have also added a few associated sentences to the abstract.
- All throughout the manuscript we have added clarifications addressing points raised by the reviewers.

The rest of this document provides a detailed reply to the reviewers' comments and explanations on how we addressed each of them.

## Reply to Dr. Salvatore Iacoletti (Reviewer A)

1. Line 24-26: I agree that changing the fragility has an impact on damage and losses, but how is the location of the occupants affecting damage and losses in your methodology? Maybe I missed something.

   State-dependent fragilities have an impact on the final damage and economic losses, while the location of occupants has an impact on injuries and deaths, which we summarise as human losses. For the purpose of succinctness (200-word limit for the abstract), we compress this to be "losses" in general.

2. Line 86: I would avoid using the phrase "resist to a […] shock". It might be misleading for some audiences.

   The phrasing has been changed to "*are more vulnerable when subject to a subsequent shock*".

3. Lines 86-89: from "natural reminders […]". The sentence doesn't read well. Perhaps splitting it into two sentences might help. Also, you might want to add references for each of the mentioned events to support your statement that previously damaged buildings are more vulnerable to subsequent shocks.

   We have eliminated the "natural reminders" phrase and have followed the suggestion of the reviewer to add appropriate references.

4. Line 94: "the matter of damage accumulation". I think this is the first time I read "damage accumulation" so far in the manuscript. You may want to introduce this concept more clearly when you introduce the concept that previously damaged structures are more vulnerable to other shocks. I think that the concept of damage accumulation and the fact

that fragility and vulnerability curves are not constant are still not clear to most researchers and practitioners, unfortunately. So, easing the readers into this concept first might benefit your manuscript.

Thanks for pointing out this late mention of the concept. As per the reviewer's suggestion, we have re-phrased the sentence where we introduced the concept of increased vulnerability to read "*It is known that previously-damaged buildings are more vulnerable when subject to a subsequent shock due to damage accumulation (Bazzurro et al., 2004; Yeo and Cornell, 2005; Polese et al., 2013; Mouyiannou et al., 2014), as has been demonstrated in…*". Moreover, as we have now eliminated what used to be the second paragraph of the introduction, this first mention of "damage accumulation" comes up a lot earlier.

5. Line 100: I believe you wanted to write "to the best of the authors' knowledge"?

   We thank the reviewer for noting this, but we have now changed this whole sentence while addressing other comments/suggestions.

6. Lines 101-103: This part of the sentence doesn't read well. Also, is there an extra unwanted space between lines 102 and 103?

   We have fully changed these sentences while addressing other comments.

7. Lines 103-124: This entire section seems unnecessary to me in the Introduction. Your manuscript focuses on extending the rapid loss assessment with sequences, and mentioning so many other areas of research on how to improve RLA feels like a distraction to the reader. I would remove (or at least reduce) this section and get to the deficiency of the standard RLA you are trying to improve. If you still want to make that connection with Structural Health Monitoring, I would probably briefly add it as a discussion at the end of your manuscript.

   As suggested by the reviewer, we have removed the discussion about structural health monitoring from the introduction and placed some of its contents when discussing the RLA algorithm as well as in the concluding remarks.

8. Line 127: "short-term" means different things to different people. I suggest to be more specific.

   We have rephrased it as "*in the short-term (hours, weeks, months)*".

9. Lines 128-129: Although I am myself guilty of always saying that there are only three certainties in life (taxes, death and aftershocks), I would probably avoid absolute language such as "undoubtedly" and "large number of aftershocks" in the context of a research paper. There are several examples of large mainshocks followed by a surprisingly low number of aftershocks.

   Whilst we cannot promise that we won't steal this catchphrase, we can confirm that we have rephrased the text as follows: "*particularly after the occurrence of an event of large magnitude that will most likely be followed by aftershocks*".

10. Lines 144-152: Again, this seems to be distracting information that could go in the body of the manuscript instead of the Introduction. If you exclude the abstract, up to this point, readers would have read ~10% of the entire manuscript, still not knowing the objective of the paper, which is stated in the following paragraph. I suggest restructuring the Introduction and using only the info you need to motivate your proposed software.

    We have removed this paragraph from the introduction. Some of its contents can now be found in section 2 and the conclusions.

11. Lines 153: which topics? This sentence seems detached from the previous paragraph, so it's not clear to me what you are referring to.

    We have rephrased it as "*several components of the estimation of damage and losses during seismic sequences*".

12. Lines 155: you are now stating a deficiency in the literature: "there are no publicly available open-source software to […]". Since what you mention in this sentence is the motivation of your manuscript, it seems a bit odd to also state "to the authors' knowledge". Although I appreciate the sentiment, if there are publicly available software to carry out similar analyses, they deserve to be mentioned and compared to your software here. If there aren't, then I would remove "to the authors' knowledge" as it seems a bit diminishing of your research. Also, although no software may be available, there are papers in the literature suggesting methodologies for dealing

with damage calibration (e.g., Papadopoulos and Bazzurro 2020, Iacoletti et al. 2024) and population displacement (e.g., HAZUS, Paul et al. 2024, amongst others). I think past efforts deserve to be examined here and compared with the methodology you are using (which, as mentioned above, is not super clear to me).

Thanks to this observation, we have now realised that there were some relevant references missing in our introduction. Addressing this comment as well as Reviewer B's minor comment #4, we have added references around lines 100 and 155 of the previous version of the manuscript (i.e., reference to Iacoletti et al., 2024, HAZUS, Chang et al., 2008, Ceferino et al., 2020, Costa et al., 2022). We were already citing Papadopoulous and Bazzurro (2020) as well as Paul et al. (2024). We are not including a systematic review and comparison of existing software and methods because our software integrates a large number of components, each of which are worth their whole discussion of existing literature. Instead, in our added sentences/references we have focused on fundamental differences with respect to our work in the context of the topic we are discussing in each paragraph. Around line 100 (of the previous manuscript) we focus on discussing the movement of people, and the fact that previous efforts are oriented towards individual earthquakes while our software aims at incorporating the effects of damage accumulation and the displacement of people on the calculation of subsequent damage/losses due to later earthquakes, while in line 155 we focus on damage/loss accumulation. We have eliminated the phrase "to the authors' knowledge".

13. Line 156-158: "seismicity forecasts" often refer to the earthquake frequency/occurrence/hazard depending on context. Damage accumulation and people displacement are risk metrics.

    We agree with the reviewer, the sentence was badly written. In the original sentence, "*as well as seismicity forecasts*" was intended as an alternative to "*earthquake sequences*", i.e. "sequences of real earthquakes or stochastic catalogues", and "*accounting for damage accumulation and the displacement of the building occupants along the process, as well as external sources of damage estimation*" applied to both cases (real earthquake sequences and seismicity forecasts). We were not speaking of "seismicity forecasts accounting for damage accumulation". We have now fixed it to read "*of earthquake sequences/seismicity forecasts accounting for damage accumulation…*"

14. Lines 172-173: I think a sentence like this should precede the statements that RTLT was developed as part of RISE, it uses OpenQuake, it could be integrated into OpenQuake, etc, and follow the motivation of this software.

    Perhaps we are missing something from the reviewer's comment. From our perspective, we are stating the motivations of this software in a logical order: (1) no publicly available open-source software available and (2) need to demonstrate integration of RISE developments led to the realisation that there was (3) a need "*for a transparent and publicly-available software that the research community could use as a starting point to explore the different aspects of this integration and develop strategies and research questions for future scalability and operationalization*". We decided to (4) build the tools around OpenQuake because it is a well-established open-source software, and this led to the additional motivation (5) that the RTLTs could be "*a first-exploration implementation of what could eventually directly become an OpenQuake feature*" (though we have eliminated this last statement to focus on what the RTLTs are at the moment). The following paragraph then simply describes the organisation of the paper and a small teaser of the application case-study. We would like to keep this flow of thoughts.

15. Line 178: I would remove this part "Among the several interesting observations that emerge from this example application,". Too generic for the introduction.

    We have removed the phrase.

16. Sections 2 and 3 generic comment: the structure and the language of these sections really feel like a report more than a scientific paper. Your software is very advanced and can perform a large number of tasks and analyses, but to make sense of your manuscript, I had to go and check the code. From the manuscript only, for instance, I struggled to understand what feeds into what, what is handled by OQ and what by RTLT. You mention configuration parameters and calculation triggers (around line 250, and also have in Figures 2 and 3), but the reader basically cannot know what these are until line 310. Although writing style is very often subjective, I think that the methodologies of the software should be explained a lot more in detail for publication in a scientific paper. Details such as file types and other processes clearly handled by OQ (like rupture generation or the entire Section 3.5) may be left for the manual.

    Generally, I would suggest one of the following strategies:
    (1, the most common in scientific literature) -> Focus on the methodology behind the software more than the software

itself (e.g., do not focus on the format of the input/output files, explain the methodologies behind the core methods RLA and OELF, reduce the "workflow" explanation to a minimum to give the readers what they need to understand the RTLT's underlying methodology, etc., all the extra info can go in appendices if you want to keep it); a great example of this strategy, in my view, is Silva et al. (2014) "Development of the OpenQuake engine, the Global Earthquake Model's open-source software for seismic risk assessment", where they focused on the background of the OpenQuake, not all the details (there is very detailed software documentation for that); or (2, less common but still very valuable in my view) -> Provide an explanation of the inputs and outputs of the software, giving only the background mathematical framework of what the software does (like the high-level overview in section 2.1), reference the software manual for details about the methodologies, and provide multiple examples of your software's features. A great example of this strategy (in my view) is Jalilian et al. (2019) "ETAS: An R Package for Fitting the Space-Time ETAS Model to Earthquake Data"
At the moment, the manuscript seems to be a confusing mix of the two strategies above.

The manuscript has been submitted as a "software report" type of contribution, not a "research article", and we believe this is inevitably reflected in the style we have adopted for its writing. However, we have taken this observation seriously and have made substantial changes to both sections (2 and 3), trying to improve the clarity, removing excessively technical or IT details, and adding methodology explanations. While it would be difficult to list all the changes herein (though they can be reviewed through the Track Changed version that has been submitted), as an example, we have removed what used to be Figure 3 and its detailed listing of file types and directory structures, we have added "RTLT" and "OQ" to inputs in Figure 1, to help convey what is handled by OQ and what by the RTLT (as per the reviewer's comment, see above), and we have created a new figure (new Figure 3) to represent the interaction between the OELF and RLA calculations.

17. Section 2.1: in my view, I think it would be better for the reader to switch your explanations: (1) introduce Figure 1 and explain each section in detail; explain the color coding that has been used and what a yellow box is (I'm guessing outputs). Green box (I'm guessing inputs)? If you want to focus on the software (see comment 16), maybe show in Figure 1 which input is RTLT-specific and which one is an OpenQuake input. (2) describe in sentences (not in bullet points) what RTLT can do without going into too much detail.

    We have moved Figure 1 to the beginning of the section and modified it to include now the "OQ" label to indicate which inputs are taken directly by OpenQuake. We are now explaining the colour-coding. We have replaced the bullet points with prose, and moved the bullet points to the concluding remarks section, as we believe this makes it easier for the reader to quickly get a concrete statement of what the RTLTs do, as we often find that standard prose can lead to confusion regarding what is a feature of the software (or something that has been done) and what is a conceptual discussion. If the reader wants to come back in the future to quickly remember what the RTLTs do, this is the list that will quickly tell them what they want.

18. Figure 2: I think Figure 2 is better placed in Section 2.2 or 2.3. Section 2.1 is supposed to be a generic overview of RTLT.

    We have now merged sections 2.1 and 2.2. We have kept this figure as we believe it provides the general overview of the fact that the software works with a user-defined number of triggers that then go into each of the specific algorithms. Sections 3.1 and 3.2 then explain what these algorithms do in detail.

19. Lines 476-494: I struggle to understand why this is relevant. It might be relevant from a computational standpoint, but what are the benefits from a methodological perspective?

    We have added two sentences to make the relevance of these concepts more explicit: "*These three concepts have a fundamental role in the calculations, as some operations are carried out at the level of the asset (with an asset_id), while others are carried out at the level of the original_asset_id*" and later "*The asset_id then addresses different damage states of the original_asset_id*". The computation and method go hand-in-hand, as the method was defined for a direct practical implementation. As explained later on in that same section, the section on the updating of occupants and the new section on the economic losses, some operations are carried out at the level of the *asset_id*, while others are carried out at the level of the *original_asset_id*. Apart from the added sentences, we explain in the manuscript why this is relevant, for example, in the paragraph "*Carrying out these calculations at the level of the original_asset_id … due to the next earthquake taking longer to run*".

20. Lines 510-512: Again, I think that information such as this is more appropriate for manuals and reports. While I understand that it is relevant computationally, it distracts the reader from the methodology behind the software itself. I'll stop mentioning this for the rest of the manuscript.

    As explained in our reply to the previous comment, the methodology and the computational strategy go hand-in-hand, as the methodology was defined for the purpose of being implemented as a software.

21. Lines 675-677: You have called the Kahramanmaraş earthquake sequence "2023 Türkiye/Syria earthquakes" so far in the manuscript. I suggest picking one way of referring to this sequence and being consistent throughout the manuscript.

    We thank the reviewer for pointing this out and we have now adopted Türkiye/Syria throughout the manuscript.

22. Lines 689 to 693: you are repeating almost the same info you mentioned in lines 677 to 680. I suggest avoiding repetitions.

    We have now erased the first mention of these details.

23. Lines 700 to 704: For magnitudes <6, point sources can offer a satisfactory representation of the characteristics of earthquakes (e.g., the induced stress state, Verdacchia et al. 2018). What is the added advantage of using planar rupture surfaces instead of simple point sources for smaller-magnitude events? By using a (relatively) more complex single planar rupture representation, you had to assume that the nodal plane is aligned with that of the largest shocks. How do you justify this assumption? There are examples of subsequent shocks in the same area not aligning (e.g., Ridgecrest earthquakes in 2019).

    While rupture finiteness is not necessary a major issue for small earthquakes, in the $M_w$ 5 - 6 range the fault lengths can still be on the order of a few kilometres, and thus differences in ground motion may still be relevant in the near source (< 10 km) region. As there are urban areas very close to these ruptures, we believe there is still a strong case for trying to capture rupture finiteness, especially when the fault planes can be relatively easily identified from the focal mechanisms and predominant rupture planes. We have not seen any evidence of complexity of mechanisms in the aftershock sequence in our case study that would be comparable to the Ridgecrest case.

24. Lines 722-725: since you recalibrated the coefficients of the GMM to get AvgSA, you might want to share the GMM parameter table to allow your readers to replicate your results (if not done elsewhere).

    We have added a sentence in the manuscript that directs the readers to the OpenQuake implementation of the AvgSA ground motion model used: "*The coefficients of the model can be found in the OpenQuake implementation*[8]". A dedicated publication for this GMM might exist in the future, but with this link we now guarantee immediate access to the model.

    [8] https://github.com/gem/oq-engine/blob/master/openquake/hazardlib/gsim/weatherill_2024.py

25. Lines 750-751: I would avoid a new line here.

    We have merged the two paragraphs into one and cut out part of the explanation, prompted as well by comment #2 by Reviewer B.

26. Lines 787-789: I think a bit more details are needed as to how you applied "expert judgement" (an example would suffice for a reader willing to repeat the analysis)

    We have added an example in parentheses ("e.g., CR/LFINF(CBH)+CDL+LFC:11.0/HBET:1-3 from the exposure model maps to…").

27. Line 800: do you have any reference for this consequence model? Also, since using mean damage-to-loss is a big assumption, I would emphasize this in your conclusions and discussion of results. Maybe even a small discussion on how you expect the results to change including this important source of uncertainty..

    The reference for this consequence model is the ESRM20 report, Crowley et al. (2021), which we have now added. In the section on the calculation of losses that we have added to address comment #1a from Reviewer B, we have included the following sentence: "*The current version of the RTLTs does not account for the uncertainty associated with these loss ratios, but central expected values (which are those output by the RTLTs) would not change*

*significantly otherwise*". We have also included a sentence in the conclusions regarding our plans to incorporate uncertainties in future versions of the software: "*Planned future developments of the RTLTs include the incorporation and output of different kinds of modelling uncertainties, such as the variability in the economic loss ratios associated with different damage states (input consequence model) and the range of damage and losses resulting from each calculation (output)*".

28. Table 2: I appreciate that these numbers are highly uncertain, but there should probably be a bit more discussion on how you got these numbers (e.g., 45 days for an inspection?). The other thing that I don't think is acknowledged here is that repair time is very dependent on the surroundings (e.g., a building in DS0 or DS1 would not be re-occupied or repaired if it's surrounded by buildings in DS4). Prof Jack Baker's group published several papers on this topic (one I know of is this: https://www.jackwbaker.com/Publications/Wang_et_al_(2022)_Post-disaster_housing,_EQ_Spectra.pdf), and I would probably recommend referring to some of that work in this manuscript.

    We believe that a lengthy comment on how these numbers were selected would only be distracting, as they are indeed highly uncertain, subjective, and dependent on very complex factors of the post-disaster process. We have nevertheless added a comment to explain what they are based on: "*which were defined (by expert judgement) based on the post-earthquake timelines reported by Dolce and Di Bucci (2018) and Reuland et al., (2022), as well as several considerations described in what follows*". What is more important to us is that the user understands the implications of the selected numbers when compared against the duration of the sequence, as explained in the last paragraph of section 4.6, to which we have added some sentences addressing both this comment and comment #11 of Reviewer B.

    We have added a comment in section 3.4 on the influence of damaged buildings on the repair time of surrounding structures: "*due to their own damage state, ignoring the influence that severely damaged buildings will have on the repair times of their less-damaged neighbours*".

29. Line 862-867: this part is a bit confusing to me. Could you please rephrase?

    To clarify these sentences, we have added an example referring to Figure 11 of the results ("*e.g., see Figure 11 in the Results section, where it is evident there would likely be no evacuation of undamaged buildings in the areas coloured in yellow after the first earthquake*"), where it becomes clear that cities and towns on the eastern end of the exposure model would likely not feel the need to evacuate undamaged buildings due to an earthquake with more damage concentration on the south-western end of the exposure. As the recovery timelines are applied to the whole exposure model, the user needs to be cautious to not kick out building occupants across a very large geographic area that covers cities and towns untouched by the early earthquakes of the sequence.

30. Table 3 and 4: I think it's worth adding the timestamp and the magnitude of the earthquakes as additional columns to make your point clearer. I know this info is in the appendix, but adding extra columns might make it easier for the reader to read the tables.

    We have added a column to both tables indicating the time difference between the start of each earthquake and the start of the first earthquake, as we believe this will help the reader have a feel for the progression of time more than the timestamps themselves (the actual dates and times are still shown in the appendix).

31. Section 4.7 in general: since your software is capable of running the same analysis with state-independent fragility models, it would be nice to show how the results change without damage accumulation, at least in terms of losses. I think this would clearly show the benefit of including damage accumulation compared to a more traditional risk analysis where all events in the sequence are considered independently (i.e., no damage accumulation).

    To address this suggestion, we have now added a paragraph after the already existing paragraph "*Figure 12 shows how the contribution of different earthquakes to the absolute cumulative economic losses is different across the five provinces…*" reporting the difference in cumulative economic losses by the fourth earthquake when using state-independent fragility models, both when looking at results aggregated by province and at individual 30-arcsec exposure cells. We have carried out two alternative computations. One in which we compute losses for each earthquake independently and we add them all up, and another in which we use state-independent fragility models to calculate the probability of exceeding each damage state for each earthquake, but account for the probabilities of exceeding the same damage state calculated for all previous earthquakes. The latter is an alternative method that the

RTLTs have but we hadn't described in the original paper, and we have now included in a new appendix (Appendix A). The new paragraph starts with "*These geographic differences arise…*".

32. Lines 947 onwards: it seems weird to say that reproducing damage statistics from the sequence is not the scope of this section and then spending 50 lines and 3 tables explaining in detail what you did. If it's not in scope, I would stop this part to line 952. Otherwise, avoid saying it's not the intent of this section.

    We included the clarification that the intent was not to reproduce the damage and loss results of the earthquake sequence because we feared that not doing so could result in the readers/reviewers having the expectation to find an in-depth discussion of how each component of the model can have an influence on the final results, which is not what we intended to do. With so many dials that can be tuned in such models, the comparison between model results and observations is a whole paper of its own. We did not want the value of the paper to be diminished by disappointing readers who might think our objective was indeed to fine-tune to match target values or to enter in discussions on why values do not match.

33. Tables 5, 6, and 7: Oddly enough, I found the figures in Appendix C more informative than the tables in the manuscript. Again, it's a matter of personal preference, but I prefer visual aids to tables. I suggest considering swapping tables for figures between the appendix and manuscript.

    Following this suggestion, we have transformed Table 7 into a bar plot and eliminated the table itself. We have not done the same with Table 6 because we feel that the large difference in the order of magnitude of the numbers of buildings leads to difficulties in selecting a scale for the vertical axis that helps convey the info. We have kept these global results in the main text and the province-by-province results in the appendix, as we feel the minimum comparison that the reader should see is the global one.

34. Section 3.2 and case study: Since you do not have a case study for OELF and (judging by the abstract) the scope of the paper lies more on the RLA, I would seriously consider reducing the OELF part of the framework section. For instance, you might want to frame OELF as an added feature, which has not been discussed in this manuscript (as you say in the conclusions). It seems slightly odd to fully explain the OELF feature and then not to showcase it with a case study.

    The software was designed from the very beginning to feature both the RLA and OELF algorithms, and to be able to use any of the two in any user-defined order. The methods and strategies to account for the accumulation of damage and relocation of building occupants is the same for both algorithms. Moreover, the generation of stochastic ruptures within the OELF routine is a feature of interest that maybe useful for some readers even on its own (we have had interest in this already from members of the seismicity forecasting community). For these reasons, we would like to keep the OELF section as it is, even if we are not presenting a case-study. For the case-study we thought it was interesting to focus on a recent relevant sequence like the 2023 Türkiye/Syria earthquakes. The paper is already long as it is, and we would thus like to keep focusing just on this series of RLA calculations. At the end of the introduction we refer the reader to the RISE project deliverable for "*further details on the software as well as different case-study applications for both RLA and OELF*". We have added the following sentence to the conclusions: "*While the present paper has focused on a case-study application of a series of RLAs, detailed case-study applications including both RLA and OELF calculations can be found in Nievas et al. (2023a, 2023b)*".

35. Conclusion section: After line 1000, I would probably discuss the case study results first and then discuss topics like future implementations, future developments/areas of improvement, other features, integration with other tools, etc.

    We have added a whole paragraph discussing the results of the case-study application, as suggested. I.e., "*The application of the RTLTs to the 2023 Türkiye/Syria earthquake sequence presented herein illustrates… […] The validation of such observations in the field is undoubtedly harder, as post-earthquake field assessments have only been carried out in Türkiye after the occurrence of all the strong shocks in the sequence*".

36. Code availability: since this paper focuses on the software, I would add a sentence like "RTLT is released with GNU AGPL v3.0 license" or similar.

    We have added mention of the license under "Data code and availability" and in the introduction.

## Reply to Reviewer B

***Main Comments***

1. Methodology. Some clarifications on the methodology are required:

   a. One of the most important clarifications required is on the aggregation of economic losses. While the casualty calculations are discussed in depth, the accumulation of economic losses is not described in any detail. I would suggest clarifying these calculations through equations.

      We have now added a small section (new Section 3.5) to explain this.

   b. I think it would be useful to clarify somewhere the interaction between the RLA and OELF calculations (perhaps as part of Figure 2); it seems to me from various places in the text (e.g., line 420 and line 445) that the OELF relies on the results of the preceding RLA , which makes sense, but I could not find it explicitly mentioned in the text (apart from a brief parenthetical statement at line 276 that I think could be missed by some readers). Furthermore, what if the user would like to rely on "real" damage observations for input to the OELF rather than the results of the previous RLA – is the software able to handle this different type of input?

      We have added a new figure (Figure 3 of the new manuscript) to clarify the interaction between the RLA and OELF calculations, as we believe Figure 2 would otherwise become too complicated. We have added relevant comments about this figure around the paragraph where we were already discussing this (around line 276 of the original manuscript, as spotted by the reviewer).

      The reviewer is correct, the OELF algorithm does take as input the RLA-updated damaged exposure model and previous RLA recovery timelines. It also calculates its own updates to the exposure model and its own recovery timelines, but this are used only within each stochastic event set. The user can input real damage observations for the RLAs. This is what the box "external damage assessment" of Figure 1 represents. When external damage is input to the software, the RTLTs take these damage results and override the damage calculated by OpenQuake, which results in the external damage being reflected in the updated damaged exposure model after a RLA. As the next calculation (RLA or OELF) takes this last updated exposure model as the starting point, the external damage assessment is taken into account in all subsequent calculations. We have added a phrase to the manuscript to highlight this (please see reply to comment #1d below).

   c. Figure 1: It would be useful to specify in the text which parts of the calculations/models are customisable, and which are predetermined

      All the input components shown in Figure 1 are customisable, i.e., user-defined. We have added a comment to clarify this ("*Some of the inputs remain the same during the calculation, while others, such as the OpenQuake configuration file and the exposure model, are updated by the RTLTs. All inputs are user-defined*").

   d. Line 262: It is not clear to me why an OELF calculation could not benefit from external sources of damage estimates that could act to determine the initial damage state of the building stock input to the calculations? (Same comment applies to line 438). (This is related to comment 2b.)

      We have added a clarification to this sentence, as we realised thanks to the reviewer's question that it was not clear. External sources of damage estimates are only used for RLA, because OELF earthquakes have not happened yet, and thus there cannot be observations of damage from field assessments or SHM, for example. However, in a calculation flow that contains both real earthquakes (RLA) and seismicity forecasts (OELF), if external damage results are provided for RLA, they are used to update the damage state of the buildings in the exposure model, and they are subsequently considered when carrying out the OELF calculation. The OELF calculation always starts from the "current" exposure model, which is already damaged if it comes out of the RLA calculations. We have added the following phrase to the manuscript "*though they do influence the damage and losses from OELF if provided for RLA in a calculation that contains both RLA and OELF triggers*".

   e. Line 280: How is the time of the day accounted for in OELF calculations (is this just a random assumption?)

      The input format of the OELF earthquake catalogues requires that a date and time be specified for each earthquake. We have added a sentence specifying this: "*This requires that all earthquake catalogues both for RLA and OELF*

*contain date and time of occurrence*". The way in which date and time is assigned to earthquakes in a seismicity forecast depends on the software used to create the forecast and is fully independent from the RTLT. This means that the user has full control over the assumptions they want to make in this regard.

f. Line 333: I think it would be useful to re-write this to more clearly convey that the factors in question potentially reduce the number of occupants considered in a building, depending on the time of day.

The factors can be anything the user wishes. We have also removed the "≤ 1" comment, which was inaccurate (i.e., it was an assumption we made when using the RTLTs, but it is not hardcoded). Depending on how the census occupants have been calculated (by the author of the exposure model) the user might want to use factors larger than 1 to convey, for example, the presence of customers in shops, or guests in hotels. We have added a sentence to the end of this paragraph to convey this: "*The RTLTs makes no assumptions regarding the magnitude of the time-of-day factors specified and the user has complete freedom to decide whether to use factors smaller than 1, which will lead to the number of occupants considered being smaller than the census occupants, or larger than 1 for the opposite effect*".

g. Line 367: Could you please specify the format of the "external damage probabilities" mentioned here? I assume these probabilities need to cover the same damage states as the considered fragility functions?

We have added a comment in the paragraph to read "*External damage probabilities need to be specified by the user using the same damage scale as the input fragility models*". Details about the exact format of this and all inputs can be found in section 4.6 of the RISE project deliverable (Nievas et al., 2023a) as well as the documentation of the software on GitLab: https://git.gfz-potsdam.de/real-time-loss-tools/real-time-loss-tools/-/blob/main/docs/03_Input.md?ref_type=heads#damage-states-from-structural-health-monitoring.

h. Line 420: To avoid confusion between both sets of calculations, I would suggest you refer to these damage states as the "initial ones input to the OELF calculations" (or similar). (This is somehow related to comment 2b).

We have substantially changed the wording of this explanation and linked it to the new figure added to address comment #1b above to increase clarity. It now reads: "*At the beginning of each SES, the RTLTs return to the current damaged exposure model, that is, the exposure model being updated with each RLA calculation (see Figure 3). This is represented in Figure 5 by the box saying "initialise OELF exposure". This damaged exposure model is not to be confused with the projected damaged exposure model that results from running each earthquake of an OELF calculation. Each SES starts over from the RLA-damaged exposure model and updates it internally, resulting in a projected damaged exposure model that takes into account damage accumulation within the SES and only reflects the results associated with a specific forecasted realisation of seismicity that may or may not occur"*.

i. Line 480: I think it would be useful to clarify here how (state-dependent) fragility functions are assigned to individual buildings with multiple original_asset_ids.

An individual building_id with multiple original_asset_ids will make use of several rows of the exposure CSV file (in OpenQuake format), not only for its different original_asset_ids but also for its different damage states (asset_ids). Each of these rows will specify different building classes, such as "CLASS_A/DS0", "CLASS_A/DS1", "CLASS_B/DS0", and so on (as shown in Fig. 7 of the original manuscript). The exposure-to-vulnerability conversion file (also in the OpenQuake format) then specifies the link to the fragility model, which is input as an XML file in the OpenQuake format. In a trivial case, this can just direct to the same name, saying, for example, "for CLASS_A/DS0 in the exposure model, search for CLASS_A/DS0 in the fragility model". In a non-trivial case, it can say, for example, "for CLASS_A/DS0 in the exposure model, search for CLASS_X/DS0 in the fragility model". Then the damage calculations are carried out by OpenQuake for each asset_id using each individual fragility curve. When results are presented in terms of original_asset_ids and/or building_ids, they are aggregated as per the number of assets specified in the exposure model. Following the example in Fig. 7 of the original manuscript, damage results after the second earthquake aggregated per original_asset_id would say there are 0.374 buildings of CLASS_A in damage state DS0, 0.885 buildings of CLASS_A in damage state DS1, …, 0.057 buildings of CLASS_B in damage state DS0, 0.167 buildings of CLASS_B in damage state DS1, and so on. Damage results after the second earthquake aggregated per building_id would say there are 0.431

(=0.374+0.057) buildings of TILE_1 in damage state DS0, 1.052 (=0.885+0.167) buildings of TILE_1 in damage state DS1, and so on. To clarify this, we have added the following sentence to the manuscript: "*In any of the two cases, damage calculations are carried out by OpenQuake for each individual asset_id as per the fragility curves indicated in their corresponding row of the exposure model and the exposure-to-vulnerability conversion file, and total numbers of buildings per damage state per original_asset_id or building_id are only summed up afterwards*".

j. There are a couple of key assumptions that the software requires: 1) That the user inputs a recovery period for a building in DS4 that is longer than the length of a considered seismic sequence. 2) That the user inputs a length of hospital stay for a fatally injured building occupant that is longer than the length of a considered seismic sequence.

The latter assumption will be incorrect in any case, given that a fatally wounded occupant does not require a hospital stay (unfortunately). I am wondering, therefore, if there is any possibility that either of these (incorrect) assumptions lead to bias in the results? Would it be better not to insert some sort of flag in the calculations that does not require a user to (possibly incorrectly) specify a (meaningless) number of days? I see that the length of hospital stay for fatal injuries was set to infinity in the case study, which makes sense, but I am not sure that all users would necessarily think to use this value.

The RTLTs do not make any assumptions regarding the damage or the injury scale used, and thus cannot make any assumptions regarding the number of days needed for hospitalisation or repair (i.e., introducing a flag system is not straightforward). In the case-study example we use a recovery period for DS4 longer than the length of the sequence because, for this sequence, no repair took place in between earthquakes and DS4 stands for complete damage. However, there is nothing that obliges the damage scale to go all the way to complete damage, neither in the RTLTs, nor in OpenQuake. The only implicit assumption in this regard is that all buildings which do not fall into any of the defined damage states are not damaged any further. If a damage scale consisting only of DS1 and DS2 is introduced (in the definition of the fragility model), OpenQuake assumes that the whole population of buildings can be composed only of DS0, DS1 or DS2, whatever these damage states are. The same translates to the RTLTs, with the additional considerations of state-dependency, i.e. that instead of assuming that the rest of the buildings are not damaged (DS0), the RTLTs assumes the rest of the buildings are not damaged *any further*; they remain in their current damage state, whatever that is. The same applies for the injury scale. The injury scale could be anything and not cover deaths, for example. Or it could be only deaths and ignore non-mortal injuries. We have coded it this way to provide maximum flexibility to the user. If the user does use an injury scale that includes deaths, then the way to convey this mathematically to the software is to use a number of days in hospital larger than the sequence, to make sure the deaths are removed from the exposure permanently. The same happens if the user uses a damage scale that includes complete damage: the way to represent this mathematically is a number of recovery days larger than the seismic sequence (or larger than anything that makes sense, e.g. 9 million days, if the user wants to be absolute sure they are not making a mistake). The one assumption that the current version of the RTLTs makes here is that no repair takes place during the sequence (to update the exposure model) because even if the user inputs a recovery time smaller than the sequence for the completely damaged buildings, all that will happen is that those buildings will remain completely damaged (i.e., they won't be re-set to DS0) and people will be allowed back into them, which would lead to them becoming injured/killed more easily in the next earthquake calculation. This is why we specify that adaptations of the software might be needed to be able to use it in longer-term contexts. In the conclusions we say "*For use in a long-term seismicity context, adaptations would be needed to consider the replacement and repair of damaged buildings that can take place in such extended timeframes*". Around the explanation for Fig. 7 of the original manuscript we say "*Figure 7 also shows how, by definition, assets can only remain in the same damage state or move to a worse damage state after each earthquake. This is true in the short-term, while buildings have not been repaired or replaced yet. A full scale real-time RLA/OELF system designed to run continuously should include the possibility of taking this and other longer-term changes in exposure and vulnerability into account*".

We agree with the reviewer that the current wording is treating deaths as infinitely long hospital stays and this is a very loose use of language, but we selected it over the alternative of hard-coding the assumption that the injury scale included deaths, as the user may not want this. This logic is explained in the documentation of the software, which the user will need to consult to be able to input these values (https://git.gfz-potsdam.de/real-time-loss-tools/real-time-loss-tools/-/blob/main/docs/03_Input.md?ref_type=heads#timelines-for-damage-inspection-and-

hospitalisations). We agree with the reviewer that the risk exists that the user inputs values that lead to inconsistencies in the calculations, and we thus thank the reviewer for the suggestion of transforming this into a flagging system, which we will consider in the future.

k. Line 540: I do not follow what is going on here. It is mentioned that a DS0 gets assigned "(0.851/8.6)*C of the replacement cost, but why would no damage incur any repair cost? The repair cost should take into consideration both the level of damage incurred as well as its probability of occurrence?

The term "replacement cost" is used herein (as in the general literature) to represent the value of the building, even when undamaged. It is how much it *would* cost to replace the building, it is not a loss value, as it is not multiplied yet by the loss ratio. In the example mentioned by the reviewer, "CLASS_A/DS0" gets assigned (0.851 / 8.6) * C after the first earthquake", but then if the loss ratio associated with DS0 (in the user-defined consequence model) is 0%, then the loss is 0. This definition of "replacement cost" is implicit in the definition of vulnerability curves in general, which are calculated through the summation across all damage states of the product of their probabilities by their loss ratios. We have edited the text to say "replacement value" instead of "replacement cost", and added a sentence in the manuscript for clarification ("*These replacement values get multiplied by the loss ratios of the consequence model later on, to calculate the economic losses*").

l. Line 580: I thought that the software does not deal with repaired buildings, so if a building becomes unusable, it should stay unusable.. is this correct? If so, the sentence at and around this line is a bit confusing.

The reviewer's comment is correct and we thank them for pointing out our lack of clarity on this aspect. The inspection and repair times (and, consequently, the timelines of building usability) are used only for the purpose of updating the number of occupants in the buildings, but not for the purpose of calculating the final damage and economic losses. In other words, the damage state of the buildings is not updated based on the inspection and repair times. We recognise this is a limitation of the current version of the software that we plan to further develop upon in the future. We have added one paragraph to each of the sections on the updating of the exposure model and the updating of building occupants to clarify this. We have also added some comments under the "Recovery models" section of the case-study application. (Additions not reproduced herein for brevity).

m. Related to comment 2j, why can't the minIML and noDamageLimit parameters just be disabled for the RTLT calculations, to avoid the user introducing an error?

At the time of writing, OpenQuake uses a default value of *minIML* of 1E-10 and automatically sets *noDamageLimit* to match the value of *minIML* if not provided or equal to zero. This is why we specify the need to be careful with these parameters for the RTLTs. We had originally included this statement in an earlier version of the manuscript but decided to eliminate it as OpenQuake could change its assumptions at any time and, when/if this happens, the statement becomes obsolete and confusing. We have now eliminated the whole "Special considerations" section.

2. Framing of the software as a real-time loss assessment tool. The software tool is generally described as a "real-time" or "rapid" loss assessment methodology. Yet, the case study application only demonstrates the tool in a retrospective capacity. The calculations of the case study relied on a reduction of the initial exposure model, which would not make sense to do in a real-time application. No demonstration of integrating damage observations (e.g., from SHM) was provided. I am therefore slightly concerned that the tool is being sold as something that there is so far no evidence to support. I would suggest the authors tone down the language, for instance referencing its "potential" (rather than definitive) use as a real-time loss assessment tool.

We understand the concern of the reviewer that this tool should not be oversold, however we do already explain at several points along the manuscript that this is a research software that carries out damage and loss calculations due to earthquake sequences accounting for damage accumulation and the relocation of building occupants, and not a full-scale real-time implementation. For example:

- The title states "*Open-Source Software for Time- and State-Dependent Seismic Damage and Loss Calculations*".

- Lines 163-166 of the original manuscript: "*As work progressed, however, the need emerged for a transparent and publicly-available software that the research community could use as a starting point to explore the different aspects of this integration and develop strategies and research questions for future scalability and operationalization*". We have now transformed the last part to read "*and research questions for **potential** future scalability and operationalization*".

- Lines 170-171 of the original manuscript: "*In this sense, the Real-Time Loss Tools could also be seen as a first-exploration implementation of what could eventually directly become an OpenQuake feature*". We have now erased this sentence.

- Lines 246-252 of the original manuscript: "*From the descriptions above it becomes apparent that the concepts of RLA and OELF are used to name and explain the algorithms in the RTLTs due to the simplicity with which they convey the kind of calculation that is being carried out. However, as the user is free to run the calculations for any (set of) earthquake(s) at any time, it is clear that the RTLTs are not running RLA and OELF calculations strictly speaking (i.e., triggered by the occurrence of an earthquake in real life) but the fundamental calculations that would allow RLAs and/or OELFs to be carried out in real time if desired*".

- Lines 601-605 of the original manuscript: "*The storage and retrieval of these future timelines of building usability and hospitalisations/deaths was preferred over the alternative of updating building occupants based on the time gap in between earthquakes input as RLA or OELF triggers, so as to resemble the needs of an operational real-time system in which the time of occurrence of the next earthquake would not be known a priori*". This last part was now modified to read "*so as to resemble the needs of **a potential** operational real-time system*".

- Lines 1007-1013 of the original manuscript: "*The RTLTs can be seen from different perspectives by different kinds of users. For those particularly interested in the RLA and OELF applications, the RTLTs may be a starting point to explore the different aspects of this integration and develop strategies and research questions for future scalability and real-time operationalization in an open, transparent and customisable fashion. The exploration of the whole integration chain may facilitate the delineation of expectations for individual components and shed light on their value and the way they relate to all other components of a broader model*". We have now modified it to read "*and research questions for **potential** future scalability and operationalization*".

- Lines 1064-1067 of the original manuscript: "*It is the hope of the authors that the RTLTs may facilitate the application and understanding of future developments and advances on each of the components of the cumulative damage and loss calculations and that they may serve as a framework through which future innovations could eventually find their way into deployment*".

Regarding the reduction of the exposure model for the case-study application, we agree that a real-time application would not rely on running the whole 30-arcsec model once to then select fewer cells and run it again for the whole sequence. However, a small variation of this approach could make sense for a real-time application instead. For example, a first very quick run of the calculations could be done with the model aggregated at the province level (or aggregated into 60 arc-sec cells by joining the 30-arcsec ones), which runs extremely fast, so as to identify areas where damage is expected, and then a second run could use the more refined 30-arcsec model but focusing only on those areas. Within a full-scale RLA implementation, this could be coded to take place in an automatic fashion. We thank the reviewer nevertheless as their comment made us realise that the details on how the reduction of the exposure model was done were probably unclear and not adding anything relevant to understand the software or the case study. We have shortened this explanation in the paper.

The deliverable for the RISE project, which is cited in the manuscript (Nievas et al., 2023a), contains not only all the details about the software input and output, but also vast discussions on what would be required for a full-scale real-time implementation, as well as demonstration case-studies that include the integration of damage probabilities derived from SHM as well as OELF calculations. We have added a sentence about this to the conclusions: "*Details on these demonstration activities as well as vast discussions on the requirements of a potential full-scale RLA/OELF real-time implementation can be found in Nievas et al. (2023a)*".

3. Length of manuscript. The manuscript is quite lengthy (although I do appreciate it is double spaced). Here are some suggestions for how it could be potentially shortened:

We appreciate the reviewer's suggestions, as it is always challenging to identify sections/parts that could be removed from a manuscript. Apart from looking into each of the reviewer's suggestions (below), we have erased text whenever we have found it possible.

a. Figure 2 is not providing much information beyond what is already described in the text and could be removed.

We would like to keep Figure 2 as we think that visualising the general triggering logic might help the reader understand that the kind and order of the triggers is user-defined.

b. I think that Section 2.2 is probably too detailed for the overview manuscript and it might be more appropriate to leave this for a software documentation document.

We have removed Section 2.2 and its corresponding figure. We have recovered some of the information contained in it and placed it in Section 2.1 (though now Section 2 is no longer split).

c. Lines 476 to 479 do not refer to the software tool in question, and could be removed (also to avoid possible confusion).

We believe this statement is needed to be able to put the concept of *original_asset_id* and *building_id* in context, and explain how the accumulation of damage is carried out by the software.

d. Figure 7: I am not sure the level of detail provided here and in the accompanying text is strictly necessary, given that this is not a software documentation document and the significance of grouping damage states together is not explained sufficiently to understand its significance. I would suggest removing this figure as a result.

We believe this figure and the accompanying text are important, as they are a fundamental part of the method used in the software to calculate damage and losses. When the initial exposure model refers to an undamaged starting condition, each exposed asset (in the OpenQuake sense) then becomes as many assets as damage states there are. However, certain calculations and outputs refer to the original asset (the *original_asset_id*), as explained later on in the text (the new section added to explain the calculation of the economic losses, the section on the updating of building occupants) and it would be very hard to explain this without introducing these concepts by means of this figure and text. See, for example, the paragraph "*Carrying out these calculations at the level of the original_asset_id … due to the next earthquake taking longer to run*".

e. Lines 601 to 605: I don't think it is necessary to emphasise this aspect, as it would lead to the same result regardless (if I am not mistaken).

These lines explain how the software has approached a potential future full-scale real-time implementation in which the timeline of the earthquake sequence is not known at the start of the sequence. We believe such explanations help address comment #2 above.

f. Lines 641 to 652: I would suggest removing these lines, as I am not sure it is strictly necessary for the reader to gain insight on runtime errors in the calculations

We have eliminated the whole "Special considerations" section, which contained this paragraph. This information can still be found in the software documentation.

g. Line 805: The description of various injury levels can be removed and interested readers can simply be referred to the original documents

We have removed the detailed description and replaced it with a more succinct overview.

h. The obvious statement at the end of page 49 could be removed

This sentence introduces the results and observations we are discussing in the subsequent paragraphs, and it has become more relevant in this new version of the manuscript, as we have now added comparisons against results obtained using state-independent fragility models (following the suggestions from Reviewer A), which highlight the relevance of taking into account the spatial component of such calculations. We would thus like to keep it for the sake of clarity.

i. I am not sure that Appendix C is necessary to include, given that the information is already summarized in tables provided in the main text

The information contained in the plots of Appendix C is not summarised in the tables provided in the main text, as the former refer to province-by-province values while the latter refer to the aggregated portfolio results. At the same time, Reviewer A highlighted how interesting these figures were. For these reasons, we would like to keep Appendix C.

***Minor Comments***

1. Around line 55: It would be good to quantify the time scales associated with a rapid loss assessment

   We have added "(e.g., within the first half hour after the earthquake)" to the text.

2. Line 75: I would suggest providing a reference for DYFI for some readers that may not be familiar with this term.

   With the intent to cut down the length of the paper, we have removed the paragraph that mentioned DYFI.

3. Line 88: It would be good to clarify what you mean by the term "reminder"

   We have eliminated this phrase.

4. Line 100: I would suggest acknowledging here some work that has been done on the transfer of patients to hospitals after an earthquake, e.g.: https://doi.org/10.1038/s41467-020-18072-w

   We have now included a reference to this paper and other relevant work.

5. Line 220: The current status of exposure is mentioned here, but the text should also acknowledge that the software additionally accounts for the current status of vulnerability. This comment also applies to the end of page 12 where there is a reference to the "update of the exposure model files" and the Figure 4 box that discusses the current exposure but includes the term "damage states" in parentheses.

   We believe that the point raised by the reviewer is correct, but whether the current damage state of a building is part of the exposure or vulnerability component (as a dataset) is a philosophical question. The current damage state of a building certainly changes its vulnerability, and this is reflected in the methods and algorithms with the use of state-dependent fragility models. However, we believe that the actual damage state the building is in is a property of the building and thus belongs to the exposure component. We have clarified this in the text by adding a parenthesis to the mentioned sentence, which now reads: "*The intermediate outputs generated by the RTLTs can be of interest themselves, as they provide snapshots of the status of the exposed buildings (including their state of damage, which further informs their level of vulnerability) and people after each individual earthquake in the form of…*".

6. Abstract and introduction: There is a general emphasis on damage and displacement outcomes from earthquake disasters. While I appreciate that these types of consequences are the main focus of the software tools (and perhaps the real-time/immediate post-even period of interest), I think it would be useful to generally acknowledge that these are not the only considerations of interest when it comes to seismic loss assessment.

   We have added the following sentence to the introduction: "*Within the large scope of post-earthquake consequences that can be of interest for a seismic loss assessment, which include, among others, damage to lifelines, damage/interruption of roads/transportation, need for hospital beds, and costs of business down-time, the RTLTs currently focus on damage to buildings and estimation of human casualties as main outputs*".

7. Line 640: Please clarify the difference between the two maximum distance parameters mentioned here

   We have eliminated the whole "Special considerations" section, which contained these sentences. This information can still be found in the software documentation

8. Table 5: It would be useful to put the percentage breakdowns for DS3 and DS4 in the A3 and A4 columns

   We have changed the format of the table to now state more clearly the percentages.

***Comments on Figures***

1. Figure 6:

a. It would be worth describing either in the text or in the caption how non-whole numbers of buildings per id are possible.

   We have added the phrase "*including non-integers (the same as in OpenQuake, as assets may represent expected values of an aggregated exposure model in a statistical sense and not necessarily physical buildings)*" further up in the text.

b. It would be better to avoid using similar light yellow colours in the first panel that refer to different things; as it stands, some (in the main plot) refer to the number of buildings associated with a given building id and some (in the pie chart) refer to various proportions of original asset ids per building id

   We have changed the colours of the pie charts.

c. In the middle square of (c), it looks as if four different building ids are being showed; three that correspond to individual buildings and one that refers to a collection of buildings. Please clarify in the caption if this correct

   We have added this clarification to the caption.