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Interactive comment on "From rapid visual survey to multi-hazard risk prioritisation and numerical fragility of school buildings in Banda Aceh, Indonesia" *by* Roberto Gentile and Carmine Galasso

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Legend: blue – reviewer's comment. Black – answers from the authors.

General Comments

This manuscript provides a timely discussion on how to accomplish strategic prioritisation of intervention on school buildings in a transparent way using the Analytic Hierarchy Process in a multi-hazard context (earthquakes and tsunami). The approach is validated though a detailed analysis and a simplified mechanical methodology (i.e.,

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Discussion paper

SLAMA). I report in the following what I consider minor comments that could improve the overall quality of the manuscript.

1. The explicit reference to Banda Aceh in the title could be removed as the methodology and approach is rather general and the case of Indonesia is a case-study

The reference to Banda Aceh in the title will be removed in the revised manuscript.

2. More discussion on the problem of "code enforcement" should be provided. The approach of classifying building according to the release of building codes is rationale, it makes sense, it refers to a widespread practice in regional analyses but a comparison with the real construction practice should be provided. In the specific case this is possible (e.g., comparison of reinforcement in figure 5e with code provisions.

This comment is particularly appreciated. The structural details of the archetype buildings for this study are defined based on Figure 5e (and other similar photos). Indeed, the simulated design approach according to the two considered seismic codes is adopted to confirm such visually-based assumptions. As it will be stressed out in the revised manuscript, the amount of longitudinal reinforcement observed in the field was greater than the minimum by code. On the other hand, based on the limited visual information available for the transverse reinforcement, no joint stirrups were conservatively considered for both the Pre-2012 and Post-2012 vulnerability classes, regardless of the requirement in both codes.

3. I personally do not agree with the low weight given to soil conditions in the matrix A. Is the case study area located in a relatively firm soil area? A comparison with the Vs30 model based on slope from USGS should be provided and discussed (Allen and Wald 2009)

The authors acknowledge the comment of this reviewer. However, two considerations should be given herein. Firstly, the prioritisation will be affected by the building-to-building variability in one criterion (in this case soil type), rather than the absolute

values. For this particular building portfolio, the soil type is particularly uniform (shear wave velocity in the first 30 meters of soil in the range 150-250m/s). Such comment will be added in the revised manuscript. Secondly, as it will be emphasised in the revised paper, the weights of the secondary parameters should in theory be portfolio-specific, and therefore calibrated differently for each analysis situation.

4. It is not clear how and if brittle failures are accounted for in the detailed procedure presented in the second part of the work. If not, a simple approach for element classification as ductile or brittle could be attempted comparing the amount of longitudinal and transversal reinforcement ration in typical elements as done in some previous work for the L'Aquila case in Italy (De Luca and Verderame 2013).

This comment is particularly acknowledged. Both in SLaMA and the refined numerical analyses, each beam and column in the system has been characterised considering many possible failure mechanisms (i.e., flexure, bar buckling, lap-splice failure, shear), considering that the weakest will govern its behaviour. For this particular case study, the plastic mechanisms of the archetype buildings are characterised by first shear cracking and/or shear failure in the joints and flexural plastic hinges in beams and columns (Figure 11a,b,c,d). No brittle failure is registered for beams and columns. This point will be stressed out in the revised manuscript.

Specific Comments

5. Page 1 Line 10 – change Resilience with REsilience to be consistent with the acronym; Line 17 – change demonstrated with implemented on Line 30 – add a comma after the closed bracket

These editorial changes will be implemented.

6. Page 2 Line 10 – Some of the references to prioritisation programme of schools in other countries should be already cited here Line 33 – the importance of schools should be discussed including a reference form UNHDR or UN.

Three of the references in Section 2 will be moved to the introduction (page 2, line 10) as suggested by the reviewer. Moreover, a specific reference to the UN campaigns for world disaster risk reduction will be provided.

United Nations Centre for Regional Development, UNCRD,: Reducing vulnerability of school children to earthquakes. UNCDR report, 2009.

7. Page 3 Line 1 – the use of schools as shelters in crisis is highly debated can you add a reference on this topic to acknowledge this aspect? Line 14 – change representative with consistent with building codes and practice of the country.

This comment is acknowledged. According to UN, educational continuity should be prioritised in disaster conditions. Therefore, the reference to schools adopted as a shelter will be removed in the revised manuscript. Regarding the second comment, we will change representative with consistent with building codes and practice of the country.

8. Page 5 Line 33 – it should be mechanism-based and not mechanics-based

This editorial change will be implemented.

9. Page 6 Line 21 – on what basis DS3 is considered equivalent to life-safety, are you basing this on Hazus, EMS98 etc. Further specification on this is necessary

This comment is particularly acknowledged. As discussed in Section 3.1, the definition of the baseline score of the index is based on the DS3 damage state, as defined in HAZUS. This is because DS3 is deemed to be connected to the Life-Safety performance objective in modern seismic codes. To further expand on this, when considering an RC member within a frame (e.g., beam or column), DS3 corresponds to the member ultimate capacity, which can be related to flexural failure (ultimate strain in concrete or steel, buckling of the reinforcement), shear or lap-splice failure. According to modern seismic codes (e.g. NZSEE 2017, ASCE 41-13, EuroCode 8), such a damage condition (for one or a few members) would define the ultimate limit state of the frame, which

is “conventionally” related to the safety of people occupying the structure (i.e., Life-Safety). Such more-detailed comments will be implemented in the revised manuscript.

NZSEE: New Zealand Society for Earthquake Engineering, The seismic assessment of existing buildings - technical guidelines for engineering assessments. Wellington, New Zealand, 2017.

ASCE 41-13 (2014), Seismic Evaluation and Retrofit of Existing Buildings, American Society of Civil Engineer and Structural Engineering Institute, Reston, Virginia, USA.

EC8 (2005), ‘European Comittee for Standardisation. Eurocode 8: Design of structures for earth- quake resistance. Part 3: Strengthening and repair of buildings’.

10. Page 8 Table 2 – This table is too dense, try to reduce/condense the text in this table

An effort to reduce and condense the information in this table will be made.

11. Page 9 Line 13 – Pmax and Pmin in the equation are those indicated in Fig 2a or in Fig 2b? I assumed it is Fig 2a, if this is the case, I would remove the grey dots in Figure 2b.

$P_{HAZUS,max}$ and $P_{HAZUS,min}$ in the equation are defined based on the absolute maximum and minimum fragility values in the (selected portion of) HAZUS fragility database (Figure 2b). Therefore, the grey dots in Figure 2a will be removed in the revised manuscript.

12. Page 10 Line 2 – On what basis you assumed 25

The performance modifier is defined in the interval [0

13. Page 11 Table 4 – is a scoring system from 1 to 9 too granular as it is based on expert judgement?

Such a scoring system is the one defined in the original study/book introducing the AHP

(Saaty, 1980). It was successfully adopted in other engineering applications available in the literature (Caterino et al., 2008, Sangiorgio et al., 2019). This is the reason why it has been adopted for this study.

Saaty, T. L.: The analytical hierarchy process: Planning, priority setting, resource allocation. London: McGraw-Hill, 1980.

Caterino, N., Iervolino, I., Manfredi, G., Cosenza, E.: Multi-criteria decision making for seismic retrofitting of RC structures. Journal of Earthquake Engineering 12:555-583, 2008.

Sangiorgio, V., Pantoja, J. C., Varum, H., Uva, G., Fatiguso, F. (2019). Structural degradation assessment of RC buildings: Calibration and comparison of semeiotic-based methodology for decision support system. Journal of Performance of Constructed Facilities, 33(2)

14. Table 5 – again why unfavourable soil is so low

Please refer to the answer to comment 3.

15. Page 12 Line 24-27 – Asprone et al. used a similar multi-hazard index in 2013, compare differences with this approach.

In the work by Asprone et al., the authors propose to define a domain representing the capacity-to-demand ratio related to hazard j, as a function of the demand for a given value of the hazard i. This is defined for a quantitative analysis approach, therefore theoretically leading to a high number of analyses, especially if more than two hazards are considered. Contrarily, in the simplified approach proposed in this work it is assumed, rather than calculated, a shape to the multi-hazard domain. This comparison will be discussed in the revised manuscript.

16. Page 13 Line 12-16 – The 50-50 split should be assumed and changes on the basis of how suitable are Hazus typologies with respect to the building stock to the country considered. In a more general context this could be 70-30 or 30-70 if the typologies

are more or less representative of the building stock. I understand this is arbitrary, but more discussion should be provided on this.

The suggestion from this reviewer is rationale and valuable. However, the authors believe that such an approach would be against the definition of the INSPIRE index. Indeed, given the assumption of relying on the HAZUS database, an effort has been made to decouple, as much as possible, the aspects of the building(s) that are covered in HAZUS, represented by the baseline score, and the ones that are not covered, represented by the performance modifier. The selection of the appropriate fragility curves to apply for each building in the considered portfolio is an expert decision provided by the user. As it will be stressed out in the revised manuscript, any other type of fragility curves, if deemed appropriate, can be used to define the index.

17. Page 16 Line 10 – was there any double-check of code-enforcement? Situations like Figure 5e allow this sort of discussion and this should be provided. See general comment 2).

The visually-based information on the structural details have been compared to the results of the simulated design process. The final definition of the archetype building is based on both approaches. Please also refer to the answer to comment 2.

18. Page 17 Line 6 – why you assumed modal values (and not median for example?)

In our opinion, an archetype building, being representative of a given building class, should reflect the more frequent geometric/material characteristics observed over the entire portfolio. Such a condition is achieved when distribution modal values are adopted.

19. Page 18 Line 9 – Are you referred to length of the elements or section dimensions? If this is the overall length of the elements why they increased with time?

The authors refer to the depth of the cross-section. This editorial change will be provided in the revised manuscript.

20. Page 19 Line 1 – again, did they correspond to what was prescribed by code? Table 6 – I am surprised that 2012 code was not prescribing stirrups in joints, is there again a difference between practice and code?

Based on the limited visual information available for the transverse reinforcement, no joint stirrups were conservatively considered for both the Pre-2012 and Post-2012 vulnerability classes, regardless of the requirement in both codes. Please also refer to the answer to comment 2.

21. Page 23 Line 14 – can SLAMA account for brittle failures? If not a preliminary classification of the elements as ductile or brittle could be useful, see general comment 4).

For beams and columns, SLaMA is capable to consider flexural failures, as well as lap-splice failures, rebar buckling and shear failure. Therefore, brittle failures are considered in this study. Please refer to the answer to comment 4.

22. Page 25 Line 26 – can you provide a reference for the drift thresholds?

This comment is particularly appreciated. The adopted inter-storey drift thresholds are defined according to the definitions in Kircher et al., 2006 by post processing the results of the pushover analyses. Such values are consistent with the highlighted displacements in Figure 11 and are building-specific. For this reason, no further reference is needed, since such values are directly calculated in the context of this study.

Kircher C.A., Whitman R.V. and Holmes W.T.: HAZUS Earthquake Loss Estimation Methods". Natural Hazard Review, 7:45-59, 2006.

23. Page 27 Line 26-28 – How did you compared the Inspire index results with results of the fragilities? A more detailed discussion should be provided right after Table 8. At the moment the comparison/validation is not very clear.

Comparing the HAZUS-based fragility curves with the refined ones derived in section 4.3 is deemed to be inappropriate. In fact, those two types of curves have a

particularly-different purpose. The HAZUS-based fragilities, at least in this context, are used to define relative estimates of the seismic risk (i.e., the prioritisation scheme). Conversely, the structure-specific fragilities obtained with the analyses in Section 4.3 can be used to provide such quantitative estimates of the seismic risk. As it will be conveyed in the revised manuscript, the purpose of Section 4.3 is not to compare/validate the adopted HAZUS fragilities. Conversely, this section shows that using the INSPIRE form allows to define refined numerical models of some selected buildings (in this case, the archetype buildings). These concepts will be added in the revised manuscript.

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