Thank you very much for your extensive review of our paper including comments and suggestions. A major revision of the paper has been carried out to take account of all the comments. We believe, during the process, the paper has been significantly improved.

We have sequentially addressed all of the points raised by the referee in each section of the paper along with the general and technical comments. The major changes include reformulation of abstract, inclusion of discussion, and correction of the presentation of maps. The revised maps are added in the last section of this document.

Major changes:

1. Discussion

The findings of this study can be briefly summarized into three parts: evaluation of the social vulnerability index, physical risk assessment, and integration of the social vulnerability & physical risk. The objective of the social vulnerability assessment is to quantify the vulnerability in Nepal considering socio-economic parameters at the local level. Based on z-scores, the total SoVI scores were classified into five quintiles from very low (< -1.5 standard deviation) to very high (> 1.5 standard deviations) vulnerability. The total SoVI scores were calculated by summing all principal components. The results of social vulnerability show that the most socially vulnerable places are located in the Far-Western, eastern Terai region, and western Terai region of Nepal. Our findings exhibit differences in social vulnerability in areas located in the same ecological region. The main reason behind this could be the pre-existing conditions like infrastructures, education, economy, etc. The population in the Far-Western region and the eastern Terai region are mostly minorities, Dalits, and marginalized groups who are behind in education and development (Gautam, 2017). As for Mountainous and Hilly areas in the Far-West region, the geographical terrain has affected the development path of these areas. Aksha et. al (2019) and Gautam (2017) also found a similar vulnerability in their respective studies. However, Aksha et. al (2019) classified Kathmandu valley as a high vulnerability class, while Gautam (2017) it as a very low class. Our social vulnerability result agreed with the latter case. This variability in the result is due to differences in variables and hazards considered during the analysis. Moreover, more recent data for SoVI will depict the more exact status of society and its vulnerability to disaster. This study uses Census data from 2011. And, the census is done every 10 years in Nepal, and the most recent census was held in 2021. However, data from 2011 were considered due to the unavailability of recent comprehensive data. More recent data can be used in future studies, once the Nepal census 2021 is published and made available.

Likewise, the objective of physical risk assessment is to evaluate the physical risk index using a probabilistic approach. As in Burton and Silva (2016), the Classical PSHA risk-based calculator was used to assess loss exceedance curves, risk maps, and average annual loss. There are several studies that show a varying range of seismic hazard analyses of Nepal. According to Stevens et al. (2018), in the large part of Nepal, the accelerations in the range of 0.4g-0.6g and 1.0g-3.0g may be expected for 10% and 2% probability of exceedance over 50 years period respectively. Chaulagain (2015) evaluated the estimated peak ground accelerations (PGA in g) at 10% and 2% probability of exceedance in 50 years in the range of

0.22-0.5 and 0.42-0.85g, respectively. Thapa and Guoxin (2013) estimated the PGA (in g) at 10% and 2% probability of exceedance in 50 years in the range of 0.21–0.62 g and 0.38–1.1 g, respectively. In this study, a probabilistic approach and region-specific steps were used to evaluate the seismic hazard curves as in Chaulagian, et al. (2015).

The probabilistic method of estimating seismic hazards used in the study utilizes the Poisson distribution model. Although earthquakes are assumed to occur randomly in space and time, the Poisson model assumes that earthquakes make a stochastically independent sequence of events in space and time (Anagnos and Kiremidjian, 1988) Despite such counterintuitive characteristic, the Poisson model is widely used due to its simplicity in the formulation and smaller range of parameters to be estimated. Moreover, the recent research (Weatherill et al., 2015; Schiappapietra and Douglas, 2020) in seismic risk assessment have incorporated spatially-correlated distribution not only to estimate simultaneous intensity measure levels at locations during a specific earthquake but also to quantify the correlation between locations. The present studies have suggested modelling of spatial correlation of earthquake ground motion since attenuation of ground motion is not only period-dependent but also regionally dependent. However, in our study, we have used the conventional method of probabilistic seismic risk assessment due to its simplicity. Nonetheless, a certain standard approach is necessary to evaluate comparable estimates of seismic hazards.

Moreover, the authors are aware of the fact that numerous estimations such as casualties, non-structural damage, business interruption loss, and loss to critical infrastructure may improve the indicator of physical risk. However, only economic losses to buildings were utilized in this study as an initiation for this type of research for Nepal. The results of physical risk and average annual loss estimates were rescaled using the MIN-MAX method as mentioned in previous sections. The rescaling is necessary to integrate social vulnerability with physical risk although the rescaling of the estimates may have resulted the loss of spatial information of physical damage results. The mapping of the spatial distribution of average annual losses and social vulnerability is very useful, but it doesn't reflect the true effect of components inducing seismic risk at a particular location. This can be due to the compounding nature of the spatial risk as the areas of medium to high levels of social vulnerability compound moderate levels of physical risk to generate high levels of integrated risk. The medium level of social vulnerability in the eastern Terai region is compounded with the high level of physical risk to create a higher level of integrated risk which can be seen in Figure 14. On the other hand, there is a higher degree of seismic risk and integrated risk in Kathmandu valley although the social vulnerability results depict lower degree of vulnerability. In light of the limitations of this study, it is clear that robust procedures and methods should be used in future analyses of integrated risk assessment. Although this study is accompanied by certain shortcomings, it is within the context that the inclusion of a higher number of factors that contribute to the mitigation of earthquake risk provides better approaches in the development of policy and plans to reduce overall seismic risk.

2. Title changes:

2.2 Earthquake risk assessment to Parameters of earthquake risk assessment

3.1.1 Data and SoVI Modification is changed to Indicators of social vulnerability assessment

3.1.2 Principal component analysis changed to Calculation of Social Vulnerability Index (SoVI) by Principal Component Analysis (PCA)

3.2 Seismic Risk Assessment changed to Assessment of physical risk

4.1 Social vulnerability index (SoVI) changed to Results of social vulnerability analysis

4.2 Seismic Risk Assessment changed to Results of seismic risk assessment

4.3 Integrated Risk Assessment to Results of Integrated risk assessment

A. Reply to the general comments:

→ We agree that there are grammatical errors within the text, we have tried to correct them to the fullest. The words "methods" and "method" that were mentioned in the paper have been substituted. We have added a big section called "Discussion" prior to conclusion. The detailed comparison of the study with past studies has been carried out. In addition, we have also included limitations and steps to overcome these setbacks.

B. Reply to the specific comments:

1. Abstract

 \rightarrow The abstract has been reformulated. All of the points are addressed in the reformulated version of abstract.

2. Introduction

→The introduction has been organized as per suggestions mentioned above. <u>Comment 2.1</u>: The national and global aspects of earthquakes have been separated. <u>Comment 2.2</u>: The text "lack of seismic mapping" has been replaced with "lack of social data for analysis and mapping." <u>Comment 2.3</u> The sentence has been paraphrased. <u>Comment 2.4</u> The OpenQuake reference has been cited. <u>Comment 2.5</u> The administrative division of Nepal has been introduced. <u>Comment 2.6</u> As mentioned, we have rewritten the section according to the comments.

3. Theory and Background

→<u>Comment 3.1</u>: Reformulated sentence as per suggestion: "There are many social vulnerability parameters that determine the impact of natural hazards such as socioeconomic status, geographical features, ethnicity (minority), renter, gender, and age (Burton and Silva, 2016)." <u>Comment 3.2</u>: We have removed the subjective statement "There have always been stories of…" <u>Comment 3.3 and 3.4</u>: Reformulated as per suggestion. <u>Comment 3.5</u>: Included in discussion part.

4. Materials and methods

→<u>Comment 4.1</u>: Reformulated the first sentence to: "This study assesses seismic risk by combining it with the human dimensions within the hazard zone similar to that in Burton and Silva (2016). This approach is an integrated seismic risk assessment." <u>Comment 4.2.2 & 4.2.3</u>: Table 2 provides the list of all the variables used for social vulnerability assessment. Out of 45 variables, district-wise indicators were represented by 22 variables and each sub-section (municipality and VDCs) was assumed to have uniform value. Among these 45 variables, seven of them were weighted combination of multiple variables as shown in Table 2. These weighted variables were obtained from 54 variables mentioned in Table 3. Therefore, altogether 92 variables (45-7+54) were considered for SoVI index. <u>Comment 4.2.5</u>: Figure 1 has been moved to the introduction as a part of background information and study area description and the background information in this section has been moved to the theory part.

<u>**Comment 4.2.8**</u>: Yes, we have rechecked and we obtained the test value of 0.000, as shown below. Similarly, we found some other studies with same cases. For example, the study by Yogamalar and Samuel $(2018)^1$.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.888
Bartlett's Test of Sphericity	Approx. Chi-Square	258644.625
	df	1035
	Sig.	.000

KMO and Bartlett's Test

Comment 4.2.11: Reformulated statement: "As presented in the paper Tate (2012), SoVI scores were used in the form of standard deviations (z-scores) or quintiles to emphasize their relative value." All other comments of section 4.2 and 4.3 have been addressed in accordance to the suggestions. Some important changes are: **Comment 4.3.12:** Reformulated statement: "In this study, the building description and data from Census 2011 were used to develop the exposure model without considering the industrial or commercial buildings. In other words, only residential buildings were considered for the exposure model. The exposure models used in the study are part of seismic risk assessment with uncertainties, although present studies like Kalakonas et al. (2020) and Gomez Zapata et al. (2022) have pointed how the epistemic uncertainties embedded in exposure models are propagated throughout the computation of seismic risk. We have considered five types of residential buildings —....." It is also mentioned in "Discussion" section that "The authors are aware of the fact that numerous estimations such as casualties, non-structural damage, business interruption loss, and loss to critical infrastructure may improve the indicator of physical risk. However, only economic losses to buildings were

¹ Yogamalar, I., & Samuel, A. A. (2018). Classification of shared values for educational research. *International Journal of Human Resource Studies*, *8*(2), 47. DOI: <u>10.5296/ijhrs.v8i2.12818</u>





Figure 5: Fragility curves for a) adobe b) cement bonded c) mud mortar d) wooden buildings



Figure 6: Fragility curves for RCC buildings



Figure 7: Vulnerability curves a) adobe, mud mortar, cement bonded, and wooden buildings b) RCC buildings

Comment 4.4: The section Integrated Risk Assessment has been reformulated as: "A total risk index was constructed by combining the social vulnerability index and estimates of average annual loss in rescaled metrics. The framework or workflow of the integrated risk assessment is shown in Figure 5. The first step in Figure 5, seismic hazard, was evaluated using the Probabilistic approach. The geographic features represent exposure modelling for residential buildings and their physical vulnerability. Combining these parameters, seismic risks were evaluated in terms of Average Annual Loss (AAL) which was further recomputed by using the Min-Max rescaling method. The physical vulnerability and exposure model interacts with the social and economic parameters or overall capacity of the population to sustain hazards (Burton and Silva, 2016). The social features define socio-economic parameters related to the demographic population to prepare for, react to, and recuperate from damaging events (Burton and Silva, 2016). The integrated risk is the combination of physical risk and a set of contextual and social vulnerability conditions (Carreño et al., 2012). In this regard, the paper evaluates the integrated risk grounded on direct factors or physical risk and socio-economic factors."

5. Results and Discussion

We have reorganized results sections with different titles as mentioned above. A new section "Discussion" has also been added. The figures and results without further elaboration have been included in "Results" section whereas, the explanation, limitations, and suggestions have been included in "Discussion" section.

6. Conclusion

Similarly, we have also modified "Conclusions" section as per the comments.

C. Reply to the technical comments:

We have addressed all of the technical comments. We have added the DOI of each reference and also changed the titles of the different sections.

Figures:

Addressing Comment 4.2.5 (Figure 1), 4.3.8 (Figure 3), 4.3.17 (Figure 4), C_7 (Figure 6), following changes are made.

- ➤ "_" are removed on legends.
- Borders of India and China are added.
- > The font size of coordinates is reduced.
- Historical Earthquake data are added in figure 4.
- > Numbers are made consecutive in figure 4.
- Captions are changed as per suggestions.



Figure 1: Administrative Map of Nepal showing 3983 VDCs and municipalities, 75 districts, seven provinces with their headquarters, and three geographical regions



Figure 2: Seismic Source Zones along with spatial distribution of earthquakes in Nepal (Thapa and Guoxin, 2013).



Figure 3: a) Spatial distribution of total buildings in Nepal b) Box and Whisker plot describing the distribution of each building types



Figure 4: Spatial distribution of Social Vulnerability Index in districts and VDCs of Nepal.



Figure 5: Average Annual Loss per capita, as calculated from OpenQuake, for Nepal.



Figure 6: Spatial distribution of Seismic Risk Index in Nepal.



Figure 7: Spatial distribution of Integrated Risk Index in districts and VDCs of Nepal.

D. References

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