REFREE COMMENTS # 1

General comment: This manuscript is about earthquake vulnerability assessment in the Indian Himalayas. The topic and techniques are good. The paper is well-written yet has errors. Consider my remarks and ideas to improve the manuscript.

Response: Thank you very much for appreciating the work. We felt gratitude to you for your thoughtful review of our work. We have now carefully revised the manuscript in light of your comments and suggestions and the point-by-point response to your comments and suggestion is provided below:

Comment 1:-The authors utilized AHP for weighting and MCA-based TOPSIS for ranking wards. The integration of these two strategies has to be clarified in the methods section.

Response: Thank you for suggestion, we have added information about the advantage of the integrative use of the two approaches in the revised manuscript from line number 401 to 410 and the same is reproduced below:

The integrative use of these two models reduces the uncertainty in the input data and improves accuracy and validity. Furthermore, decision-making based on the integrated use of the AHP and TOPSIS leads to more robust and effective outcomes for addressing complex problems (Nyimbili et al., 2018). Many studies have recommended the integrated use of TOPSIS with AHP for determining criteria and conducting analyses regarding complex decision-making problems (Behzadian et al., 2012). Additionally, the integrated use of AHP and TOPSIS helps to resolve the weighting problem by incorporating expert opinions and preferences, thereby increasing the consistency of outputs for arriving at consensus in decision-making in earthquake disaster vulnerability analyses (Nyimbili et al., 2018).

Nyimbili, P. H., Erden, T., and Karaman, H.: Integration of GIS, AHP and TOPSIS for earthquake hazard analysis, Natural hazards, 92(3), 1523-1546. https://doi.org/10.1007/s11069-018-3262-7, 2018

Behzadian, M., Otaghsara, S. K., Yazdani, M., Ignatius, J.: A state-of the-art survey of TOPSIS applications, Expert Systems with Application, 39(17):13051–13069 https://doi.org/10.1016/j.eswa.2012.05.056, 2012.

Comment 2:-Nevertheless, it would be helpful to the readers if the authors could include a quick general review of the SE vulnerability in this study. The authors did not include socio-economic vulnerability in this paper since they want to do that as part of another research.

Response: Thank you for the suggestion. As suggested, we have now added a general overview of the Socio-economic vulnerability of the Srinagar city in the revised manuscript under the section "Earthquake vulnerability analysis" from lines 575 to 587 and the same is reproduced below for your perusal:

The socio-economic conditions of an area play an important role in determining the vulnerability of an area to earthquake hazards. Srinagar has witnessed a population explosion, with the population increasing from 0.25 million in 1961 to 1.5 million in 2011. The city also has a high proportion of female and child residents (59%) and a population density of 4000 people per square kilometre. Migration from rural areas and population growth are the primary drivers of this enhanced population expansion (Nengroo et al., 2018). The city has been under pressure to expand its built-up area in order to cater to the population boom, which has also led to excessive resource depletion, widening wealth and poverty gaps, and detrimental environmental and socioeconomic concerns (Mitsovaa et al., 2010; Kamat and Mahasur, 1997). With the mounting demand for new housing, the quality and condition of houses have received negligible attention. These concerns about accelerated population progression, along with high urbanization, have increased the socio-economic vulnerability of the built environment in Srinagar to earthquakes.

Nengroo, Z. A., Bhat, M. S., and Kuchay, N. A.: Measuring urban sprawl of Srinagar city, Jammu and Kashmir, India, Journal of Urban Management, 6(2), 45-55. https://doi.org/10.1016/j.jum.2017.08.001, 2017.

Mitsova, D., Shuster, W., and Wang, X.: A cellular automata model of land cover change to integrate urban growth with open space conservation, Landscape and urban planning, 99(2), 141-153. https://doi.org/10.1016/j.landurbplan.2010.10.001 2011.

Kamat, S. R., and Mahasur, A. A.: Air pollution: slow poisoning Chennai, The Hindu Survey of Environment, 1997.

Comment 3:-In the paper, I think it would be helpful to include a restriction of each of the two models.

Response: Thank you for the suggestion. We have added limitations of the two models in the revised manuscript line number 411 to 416 which is reproduced below:

The adopted methodology has a few limitations, much like any other modeling technique. In addition to the inherent flaws in Multi Criteria Decision Analysis (MCDA), there may be some limitations, such as the fact that certain layers become more dominant than others due to the weighting criteria used, which in turn depends upon the decision-makers' perceptions of which vulnerability parameters have the greatest impact on modelling outcomes in vulnerability analysis.

Comment 4:- Who, besides the writers, took part in the process of making the expert judgement, and what were their qualifications? Mention these individuals and the expertise that they bring to the table.

Response: Thank you for the comment. Though, only the four authors were involved in determining the expert judgement process, viz., Prof. Shakil Ahmad Romshoo, Ph.D., Remote Sensing and GIS; Dr. Irfan Rashid, Ph.D., Environmental Sciences; Dr. Rakesh Chandra, Ph.D., Geology; and Midhat Fayaz, M.Sc. (Geoinformatics), but a large body of literature was also consulted that informed the expert judgement process. A mention of the same has been made in the revised manuscript at line number 346 to 350.

Comment 5:- There is a lack of references to certain procedures, such as those pertaining to proximity, closeness, and separation.

Response: Thanks for the comment. We have added references for all the approaches used in paper in the revised manuscript.

Comment 6:-Both in the introduction and in the end, you made a reference to SDG-11. In the conclusion, however, you should go into more detail on how the findings of this study will contribute to the achievement of SDG-11.

Response: Thank you for the suggestion. We have added more details about the SDG-11 in the revised manuscript from line number 631 to 638 under Conclusion section.

The current study is in accordance with the 2030 Agenda for Sustainable Development Goals, which recognises and reiterates the urgent need to lower the risk of disasters. The study will help to reduce the exposure and vulnerability of people to disasters and build resilient infrastructure. The findings of this study will contribute to sensible urban planning leading to the construction of resilient infrastructure to reduce vulnerability to natural disasters, as well as sustainable development in line with SDG 11 and SDG 9, which calls for manageable densities, user-friendly public spaces, and mixed-use urban development.

Comment 7:- There are several typos in the paper which need to be corrected.

Response: Thank you very much for the suggestion. We have now rectified all the typos and grammatical errors in the revised manuscript

REFREE COMMENTS # 2

General comment: Midhat Fayaz et al. present a vulnerability assessment of the buildings in Srinagar city in the event of earthquake. The authors consider 69 municipal wards within Srinagar urban area. The analysis is based on a building inventory having details of the nature and structure of buildings. The authors perform a ground-based survey to validate the inventory which is commendable. The manuscript offers some insights into differential vulnerabilities of buildings within the urban area. Though there is not any visible flaw in the analysis and assessment some fundamental aspects of earthquake science is missing in the manuscript. Therefore, major revisions as following are required for this manuscript to be considered for publication.

Response: Many thanks to the reviewer for commending our work. Authors express their gratitude to the reviewer for the careful assessment of our work and for valuable suggestions and comments, the incorporation of which have improved the quality of the revised manuscript. We agree with the comment that some of the earthquake related parameters are not included in this study. Below is the point-by-point response to the comments/suggestions.

Comment 1:-The authors list major earthquake events in Srinagar city/Kashmir. However, they do not explain how the relate the earthquake related parameters i.e., epicenter with the vulnerability assessments.

Response: Thank you for the comment. Agreed that the location of earthquake epicentre indicates the presence of geological structures (faults) in a particular area (Sana, 2018). The available records of historical and instrumental earthquake events (Table 1) in the study area indicate a high probability of earthquake events in the Srinagar city in the future. Dar et al., 2019 have shown that the River Jhelum, running through Srinagar city itself flows along or parallel at many places to a lineament or fault known as Jhelum fault in the Kashmir Valley.

Besides high tectonic activity and the lithology (mostly unconsolidated sediments) of the area, makes the area vulnerable to earthquakes.

Therefore, it is believed that in light of the high vulnerability and occurrences of past earthquakes with epicentre in and around Srinagar makes the earthquake vulnerability assessment of study area an important exercise irrespective of the exact location of the epicentre. We assumed that the entire city is equally vulnerable to earthquakes because of the presence of the Jhelum fault in the midst of the city.

We have modified the study area map in the revised manuscript showing the nearest faults/lineament details (see fig. 1) and made a mention of the above facts in the revised manuscript at line number 130-142.

Sana, H.: Seismic microzonation of Srinagar city, Jammu and Kashmir, Soil Dynamics and Earthquake Engineering, 115, 578-588, https://doi.org/10.1016/j.soildyn.2018.09.028, 2018.

Dar, R. A., Mir, S. A., and Romshoo, S. A.: Influence of geomorphic and anthropogenic activities on channel morphology of River Jhelum in Kashmir Valley, NW Himalayas, Quaternary International, 507, 333-341, https://doi.org/10.1016/j.quaint.2018.12.014, 2019.

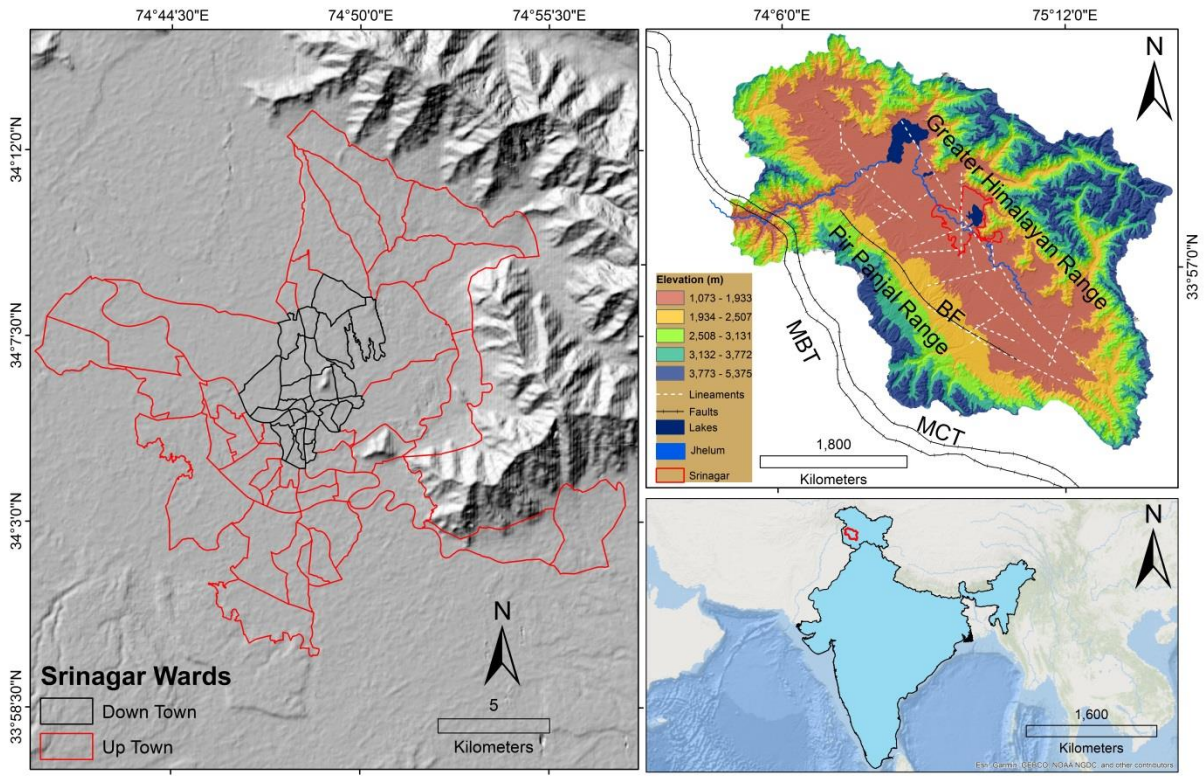

Fig.1: Location of the study area. Here MBT stands for Main Boundary Thrust, MCT stands for Main Central Thrust, BF stands for Balapur Fault.

Comment 2:- Nowhere it is mentioned how does the geology, lithology and faults are considered to zonate the likelihood of earthquake events within the city. It would have been helpful if the authors have at least considered an earthquake hazard zonation map in their analysis. Without these it is surprising that how the authors assess the earthquake vulnerability of buildings. The present manuscript gives an impression of vulnerability of buildings alone but not for earthquake events.

Response: Thanks for the comment. The present study was carried out to look into the vulnerability of built-up environment at a high spatial resolution at building footprint scale ward-wise in the Srinagar city. Geology, lithology, and lineaments faults were taken into account during data analysis. However, keeping in view the high occurrences of the past earthquakes with epicentre in and around Srinagar irrespective of the exact location of the epicentre and distribution of other geological/geomorphic and soil parameters, the entire city wards are equally vulnerable to earthquakes in the eventuality of an earthquake. The River Jhelum, running through the Srinagar city, itself flows along or parallel at many places to a fault known as Jhelum fault in the Kashmir Valley. Besides because of the high tectonic activity and the lithology (mostly unconsolidated sediments) of the area, it was found that there is very little difference in earthquake vulnerability between various wards because of the similar tectonic, lithologic and geomorphic set up of the city wards; therefore all of these parameters were kept constant. All of Srinagar's wards are situated on consolidated alluvium, or Karewas, which share similar characteristics in terms of how they react to earthquakes. Panjal volcanics are located in a few inconspicuous places, however these are hills that have no habitation, making lithology the least influential parameter in this study. Additionally, there is a very high earthquake risk in each of Srinagar's wards (Sana, 2018; Yousuf and Bukhari, 2020) (see Fig.2). Since the assessment of ward level earthquake vulnerability is the primary focus of the current study, all of the wards were treated as having an equal risk from seismic activity. Please see figure 2 and Figure 3 below for details about the distribution of earthquake related parameter and earthquake hazard map. Accordingly, we have made a mention of same in the revised manuscript from line number 130-142 under Introduction Section.

Sana, H.: Seismic microzonation of Srinagar city, Jammu and Kashmir, Soil Dynamics and Earthquake Engineering, 115, 578-588, https://doi.org/10.1016/j.soildyn.2018.09.028, 2018.

Yousuf, M., Bukhari, S. K., Bhat, G. R., and Ali, A.: Understanding and managing earthquake hazard visa viz disaster mitigation strategies in Kashmir valley, NW Himalaya, Progress in Disaster Science, 5, 100064, https://doi.org/10.1016/j.pdisas.2020.100064, 2020.

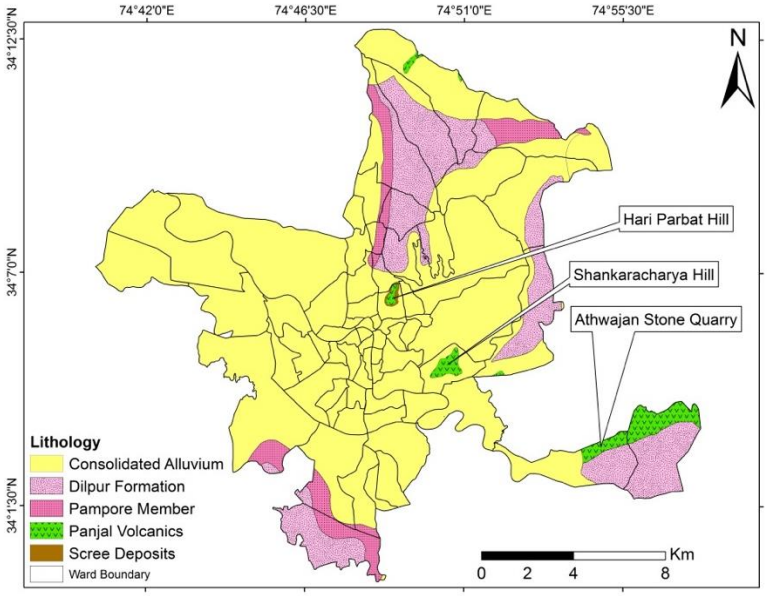

Fig.2: lithology map modified after Thakur and Rawat, 1992.

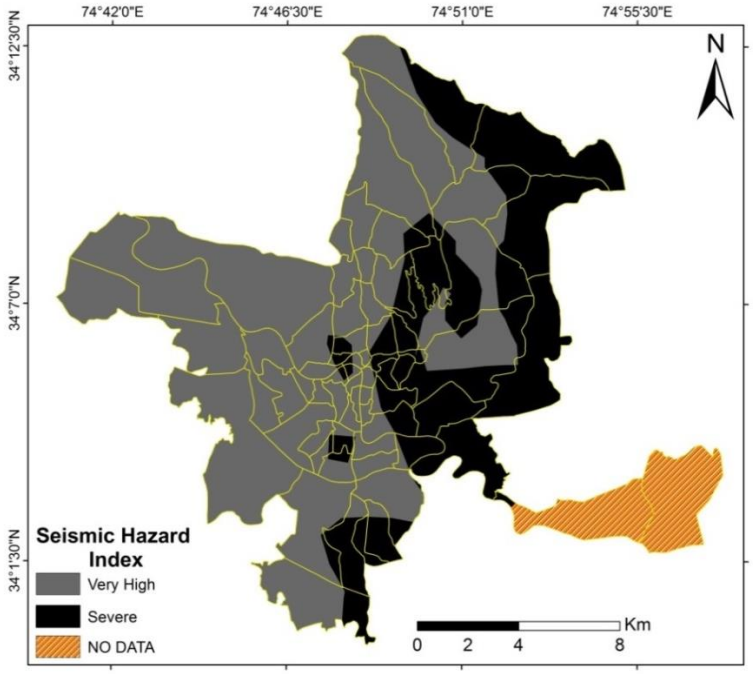

Fig.3: Seismic Hazard Index map modified after Sana, 2018.

Comment 3:- In addition, buildings are susceptible to failures due to ground failure during earthquakes i.e., liquefaction and other soil-structure related damages. Nowhere in this study these aspects have been mentioned or considered.

Response: Thanks for the comment. In a similar fashion like that of the lithology, soils and lineaments, the Liquefaction Potential Index (LPI) of the Srinagar shows very small variability from one ward to another. Please see Figure 4 below for the Liquefaction Potential Index of the Srinagar city (Sana et al., 2016). All the wards of the city fall within the LPI zone of high to very high zone. Thus, like other geological factors, this factor was also kept constant for all the wards of the Srinagar city under study. It is pertinent to mention here that there are several studies conducted globally that have not included the geological and earthquake parameters in the analysis of earthquake vulnerability assessment of built up environment of cities because of the reasons outlined above e.g. Srikanth et al., 2010; Ishita and Khandaker 2010; Islam et al., 2013; Alizadeh et al., 2018; Adhikari et al., 2019; Menegon et al., 2019; Fan et al., 2021.

In light of the reviewer's comments and above explanations, we have made a mention of the above response in the revised manuscript at line number 130-142.

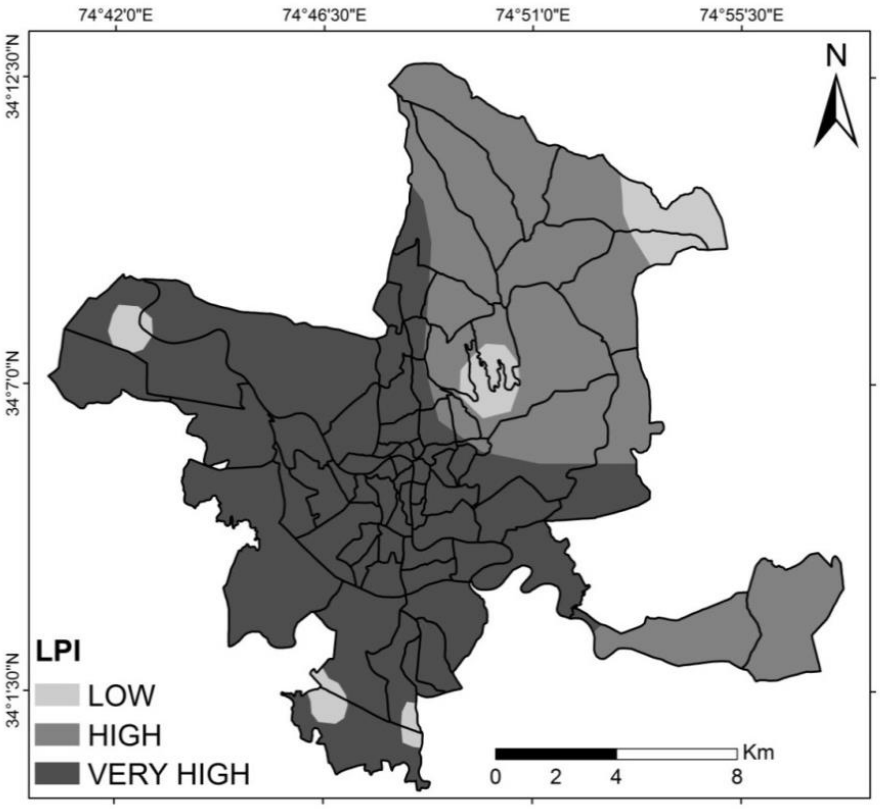

Fig.4: Liquefaction Potential Index map modified after Sana, 2016.

Sana, H., and Nath, S. K. (2016). Liquefaction potential analysis of the Kashmir valley alluvium, NW Himalaya. *Soil Dynamics and Earthquake Engineering*, *85*, 11-18.https://doi.org/10.1016/j.soildyn.2016.03.009

Srikanth, T., Kumar, R. P., Singh, A. P., Rastogi, B. K., and Kumar, S. (2010). Earthquake vulnerability assessment of existing buildings in Gandhidham and Adipur cities Kachchh, Gujarat (India). European Journal of Scientific Research, 41(3), 336-353.

Ishita, R. P., and Khandaker, S. (2010). Application of analytical hierarchical process and GIS in earthquake vulnerability assessment: case study of Ward 37 and 69 in Dhaka City. J Bangladesh Inst Plan ISSN, 2075, 9363.

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Alizadeh, M., Hashim, M., Alizadeh, E., Shahabi, H., Karami, M. R., Beiranvand Pour, A., ... and Zabihi, H. (2018). Multi-criteria decision making (MCDM) model for seismic

vulnerability assessment (SVA) of urban residential buildings. ISPRS International Journal of Geo-Information, 7(11), 444.

Adhikari, A., Rao, K. R. M., Gautam, D., and Chaulagain, H. (2019). Seismic vulnerability and retrofitting scheme for low-to-medium rise reinforced concrete buildings in Nepal. Journal of Building Engineering, 21, 186-199.

Menegon, S. J., Tsang, H. H., Lumantarna, E., Lam, N. T. K., Wilson, J. L., and Gad, E. F. (2019). Framework for seismic vulnerability assessment of reinforced concrete buildings in Australia. Australian Journal of Structural Engineering, 20(2), 143-158.

Fan, X., Nie, G., Xia, C., and Zhou, J. (2021). Estimation of pixel-level seismic vulnerability of the building environment based on mid-resolution optical remote sensing images. International Journal of Applied Earth Observation and Geoinformation, 101, 102339.