RC2 comments and responses

The overall quality of the preprint (general comments)

The overall quality of the paper is high. The topic of developing a novel fixed asset model to improve seismic loss estimation is significant for the science community. By mapping fixed assets at a 1 km × 1 km grid level, the model better serves rapid seismic loss assessments and informs emergency response plans. The research is well structured and explained. The authors made an effort to combine various data sources and techniques.

While the model represents a significant advancement, several limitations could impact its effectiveness, particularly in high-stakes applications like earthquake response. The paper's scientific contributions justify publication with minor revisions to handle specific data assumptions better and further validate the model's application. These adjustments would help ensure the model's broader applicability and robustness.

Response: We deeply appreciate the time and efforts you have denoted to improving the quality of this manuscript and thank you so much for all the constructive comments! Our initial responses are given as follows. Hopefully they can help release your concern on the current version of the manuscript.

Individual scientific questions/issues (specific comments)

Here are some topics which the authors could discuss in more detail:

Reliance on Historical Investment Data and Simplified Depreciation Rates. The model bases its estimates on historical investment data and applies a uniform 5% depreciation rate across all provinces, regardless of variations in asset type, economic condition, or regional maintenance practices. The uniform deprecation rate can introduce inaccuracies, especially for assets with different service lives or conditions. The simplified approach to depreciation may lead to skewed asset values, particularly in provinces with unique economic trajectories or asset compositions. For instance, in industrialized regions, assets may have a shorter useful life than in less industrialized provinces, affecting the accuracy of economic loss projections. Can the model be refined by including a variable depreciation rate based on more detailed asset-specific and regional data, if available?

Response: Thank you for this comment and we totally agree with your improvement suggestions. And it would be possible to refine the developed fixed asset model by including variable depreciation rates with its temporal and spatial change being considered, should the statistical data required to determine such rates be accessible for the period 1951-2020.

As a matter of fact, in a prior prefecture-level fixed asset modeling work of Wu et al. (2014) for China during 1978-2012, they did develop different depreciation rates for each province, as given in the following Table R1. To derive these depreciation rates, the residual value of the capital stock was set to be 4% of their original value, and the service life of different fixed asset types (construction and installation, equipment and instruments, and others) was set as 45 years, 20 years, and 25 years, respectively. Following Eq. (3) of the manuscript, the national-average depreciation rate can be calculated accordingly as 6.9%, 14.9%, and 12.1%, respectively. To better reflect the spatial difference in depreciation rate among provinces, Wu et al. (2014) further used the relative share of each fixed asset type in each province published in provincial statistical yearbooks dating back to 1983. Then for each province, the depreciation rate for each province can be determined separately considering the average weight of each fixed asset, as listed in Table R1. Additionally, for each province, the deprecation rate range listed in the brackets of Table R1 was determined by changing the residual value ratio from 4% to 3% and 5%.

As can be seen from Table R1, the depreciation rate for most provinces is around 9%, although the relative share of different fixed asset types has been considered for each province. And when the residual value ratio is 4%, the total range of depreciation rates for all provinces is from 7.95% to 10.05%. However, due to the big difference in development stage of China before 1980 and after 1980, we cannot directly apply the provincial level depreciation rates developed in Wu et al. (2014) by using statistics during 1983-2012 to years before 1980s. That’s why a fixed depreciate rate of 5% was finally used in this paper, which may appear to be conservative and the reason is explained in Page 9, Lines 239-243 of the manuscript that “*since the development of provincial-level fixed capital stock data in this paper is to be used for the development of empirical loss models for rapid emergency response after the occurrence of damaging earthquakes in China, the replacement values of different types of fixed capital stock in earthquake-affected areas are generally higher than their residual values even they have lasted for a much longer time than their service lives; therefore, a conservative depreciation rate of 5% is chosen for all provinces to get the final accumulated fixed asset data series from 1951 to 2020*”. The sensitivity analysis of Li (2011) indicated that the change of 1% in depreciation rate would lead to no more than 10% change in accumulated capital stock 25 years later and Li (2011) also suggested that the depreciation rate should be within the range of 5%~10%. In the performance evaluation section, when compared the modelled fixed assets with that in Wu et al. (2014) at prefecture level (as implied in Figure 11), the good correlation (R^2=0.95) between these two datasets help gain our confidence in the reasonability in our model. The above discussion will be added to the Discussion section of the revised manuscript.

Table 2
Depreciation rates across 31 provinces in Mainland China.

Province	Depreciation rate (%)
Beijing	9.76 (9.12, 10.58)
Tianjin	9.56 (8.93, 10.36)
Hebei	9.83 (9.18, 10.65)
Shanxi	9.53 (8.91, 10.33)
Inner Mongolia	9.22 (8.62, 10.00)
Liaoning	9.49 (8.86, 10.28)
Jilin	9.43 (8.81, 10.23)
Heilongjiang	9.28 (8.67, 10.06)
Shanghai	10.05 (9.39, 10.89)
Jiangsu	9.62 (8.98, 10.42)
Zhejiang	9.53 (8.90, 10.33)
Anhui	9.75 (9.11, 10.57)
Fujian	9.44 (8.82, 10.24)
Jiangxi	9.68 (9.04, 10.49)
Shandong	9.49 (8.87, 10.29)
Henan	9.45 (8.83, 10.24)
Hubei	9.58 (8.95, 10.38)
Hunan	9.20 (8.60, 9.98)
Guangdong	9.35 (8.74, 10.14)
Guangxi	9.44 (8.82, 10.24)
Hainan	9.35 (8.74, 10.14)
Chongqing	9.21 (8.61, 9.99)
Sichuan	9.27 (8.66, 10.05)
Guizhou	9.35 (8.73, 10.13)
Yunnan	9.03 (8.44, 9.79)
Xizang	7.95 (7.42, 8.63)
Shaanxi	9.87 (9.22, 10.70)
Gansu	9.30 (8.69, 10.08)
Qinghai	8.74 (8.17, 9.48)
Ningxia	9.32 (8.71, 10.11)
Xinjiang	9.08 (8.48, 9.84)

Note: Data source: Depreciation rates are calculated by the authors, the depreciation rate inside of the parentheses is calculated by the average relative efficiency rate of 3% and 5%, respectively, as described in the text.

Table R1: The provincial level depreciation rates estimated in Wu et al. (2014).

Inconsistencies in the Data Sources for Ancillary Datasets. The model relies on ancillary datasets (e.g., nighttime lights, population, built-up areas) which are not consistently available across all years. This results in the use of alternative data types to approximate missing data. For instance, population data alone is used in the early years when nighttime light data is unavailable. These proxies may not accurately represent economic activity, especially in rural areas or less-developed regions, leading to potential over- or under-estimations in asset distribution. Could the model be strengthened by incorporating more recent, high-resolution satellite data or by exploring alternative disaggregation methods that do not depend solely on proxies like nighttime lights?

Response: Thank you for this comment. A big effort made in this paper is to find reasonable combination of ancillary data to disaggregate provincial level fixed assets into grid level. For periods (1991-2020) when nighttime light data are available, the combination of nighttime light and population are used to create the lit-pop index, which is exactly to better avoid the over- or under-estimation problems in asset distribution by using nighttime light or population data alone. For years before 1991 (1971-1990), when nighttime data are unavailable, the built-up surface area data and population data are used to create area-pop index. However, for earlier periods (1951-1970) when only grid level population density data are available, we choose to apply the pop-pop index (derived from the squared value of population in each 1km×1km grid) to further disaggregate the asset value of years before 1970. And the correlation analysis in Figure 10 between each pair of three disaggregation indexes (lit-pop, area-pop, pop-pop) further validates the consistency and reasonability of these indexes.

But we do want to emphasize that for earlier period (1951-1970) when only population density data are available, we consider it is still not appropriate to incorporate the high-resolution satellite data in recent years with population data to disaggregate the asset value during 1951-1970. The reason is still that China has experienced quite different economic development stages before the 1970s and after the 1970s divided by the issuing of opening and reform policy in 1978, while before 1970 the economy development in China was very slow due to natural disaster, political movement and the planned economic system.

Lack of Structural Detail in Asset Composition. The model's focus on fixed capital should differentiate between asset types (e.g., residential vs. industrial buildings) in disaggregation. This lack of structural specificity reduces the model's utility for applications that require asset type differentiation, such as insurance underwriting or infrastructure resilience planning. Different asset types respond differently to seismic events; for instance, infrastructure like bridges and roads may sustain different levels of damage compared to residential buildings. This generalization could lead to misaligned resource allocations during emergency responses. Introducing asset type categorization, possibly by incorporating land use or building inventory data, would enhance the model's accuracy for specific asset loss estimations.

Response: We totally agree with this comment. However, when the perpetual inventory method (PIM) is used to systematically estimate the accumulated fixed asset data series for periods dating back to 1951, it means that we have no better or more detailed statistics to constrain the building types (residential/industrial/commercial) and even the quota of different fixed assets (buildings, infrastructures, instruments) exposed to past years.

As explained in Page 2, Lines 34-46 in the manuscript, the fixed asset model developed in this paper is based on the Level 1 data. Based on this level information, the estimated seismic loss is relatively a rough estimation since the input data mainly include demographic data and building-related statistics extracted from the national census. And when seismic loss is rapidly estimated after the occurrence of a damaging earthquake (for which we develop this fixed asset dataset), the vulnerability function to be used is also a quite empirical one, similar to those developed in Jaiswal and Wald (2011) in the PAGER project. Such empirical vulnerability curve only describes the relation between general loss ratio and the macro intensity, which is regressed from damaging statistics (intensity map, total loss, exposed asset value) of historical earthquakes for specific countries and regions. And such loss estimation is quite different from the one based on the structure type and apply the corresponding vulnerability curves for specific buildings. More details are given in Page 2, Lines 48-59 of the manuscript.

In the fixed asset dataset for periods 1951-1982, we even have no more clue to confidently differentiate the quota of different fixed asset types (construction and installation, equipment and instruments, and others), which makes it even harder to differentiate different building types, as verified by the work of (Wu et al., 2014). But for studies mainly focusing on developing the replacement value for existing buildings and structures, it is possible to make such differentiation. We also made such an attempt in our previous work (Xin et al., 2021) and we also compared the modelled fixed asset value in this paper with that for residential buildings in Xin et al. (2021), as shown in Figure 12 of the manuscript. However, models with detailed building attributes for specific year is not enough for us to develop the empirical vulnerability curve, which entails the fixed asset for past years as well, as explained in Page 3, Lines 67-77 in the manuscript. Considering the availability of input data, the perpetual inventory method (PIM) is the best practice to follow to develop such asset data series.

Technical corrections

The article's language quality is overall sound, with a few areas where readability and formality can be improved. Here are specific suggestions regarding grammar, spelling, and phrasing.

- Maintain past tense in descriptions of the completed study. For example, in the sentence, "The fixed asset model to be developed in this paper is also based on the Level 1 data."

  Response: Thank you for pointing this out. We will thoroughly check the use of verb tenses when revising the manuscript. However, we have to confess that sometimes it is kind of confusing to decide which tense should be used. For example, the expression "*The fixed asset model to be developed in this paper is also based on the Level 1 data*" can also be regarded as a description of the fact. In this case, it seems the present tense should be used…
- Remove redundant phrases. For example, "To summarize, the nighttime light data and GHS-POP data are used to generate the lit-pop disaggregation indexes from 1991 to 2020, while the GHS-BUILT-S data and GHS-POP data are used to construct area-pop disaggregation indexes from 1971 to 1990..."

Response: Thank you for this suggestion. If our understanding is correct, do you recommend the cited expression "*To summarize, the nighttime light data and GHS-POP data are used to generate the lit-pop disaggregation indexes from 1991 to 2020, while the GHS-BUILT-S data and GHS-POP data are used to construct area-pop disaggregation indexes from 1971 to 1990...*" should be removed as a whole? The initial consideration to give such summarization in the Results section is mainly to help readers who only roughly scan this work to quickly understand the difference in ancillary data used for different periods. And the feedback given from other readers indicates it is still necessary to keep it as a reminder.

- Avoid Informal Language. For example, replacing "Luckily" with "Fortunately" is more formal.

  Response: Thank you for this suggestion, accepted! We have reread the manuscript carefully and replaced the expression like "Luckily" to "Fortunately" accordingly. However, we're afraid we could not thoroughly rectify or recognize all the remaining informal expressions due to the long-time usage habit… But if the manuscript can be fortunately accepted, the NHESS journal will also offer excellent language editing service before publishing the final version of the manuscript, which will help ensure that all the expressions will be formal.

- Revise for Consistency in Abbreviations and Acronyms. Introduce abbreviations consistently upon first mention, ensuring they are used uniformly throughout.

Response: Thank you for this suggestion. We will keep checking such inconsistencies when revising the manuscript later.

References mentioned in the responses:

Jaiswal, K. and Wald, D. J.: Rapid estimation of the economic consequences of global earthquakes, US Department of the Interior, US Geological Survey Reston, VA, 2011.

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Xin, D., Daniell, J. E., Tsang, H.-H., and Wenzel, F.: Residential building stock modelling for mainland China targeted for seismic risk assessment, Nat. Hazards Earth Syst. Sci., 21, 3031–3056, https://doi.org/10.5194/nhess-21-3031-2021, 2021.