Natural Hazards
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Sciences

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Discussions

Interactive comment on "Review Article: A Comparison of Flood and Earthquake Vulnerability Assessment Indicators" *by* Marleen C. de Ruiter et al.

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General comments We would like to thank the reviewers for their very valuable comments. We acknowledge the fact that we were not clear enough in defining the scope of our paper and in particular our usage of a narrow definition of vulnerability and the focus on single-hazard type risk assessment models. We recognize that this may have caused confusion and therefore we have made the following general changes: âẮc We included a more explicit explanation of the scope of our paper: to conduct a literature review comparing methods for quantitatively assessing vulnerability in flood and earthquake risk assessments within which we look at both physical and social vulnerability aspects. âẮc Therefore, we have increased the depth of our analyses by adding 22

citations to support our statements and to bring more balance in the physical and social aspects of vulnerability in risk models. We included references suggested by the reviewers, such as: o Alexander, D. (1997). The study of natural disasters, 1977–97: Some reflections on a changing field of knowledge. Disasters, 21(4), 284-304. o Tate, E. (2012). Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis. Natural Hazards, 63(2), 325-347. o de Sherbinin, A., & Bardy, G. (2015). Social vulnerability to floods in two coastal megacities: New York City and Mumbai. Vienna Yearbook of Population Research, 131-165. o Cardona, O. D. (2004). The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. Mapping vulnerability: Disasters, development and people, 17. o Cardona, O. D., & Carreño, M. L. (2011). Updating the indicators of disaster risk and risk management for the Americas. IDRIM Journal, 1(1), 27-47. âẮc We have removed contradictory comments to this goal.

Reviewer #2 The article tries to highlight insights how earthquake and flood vulnerability indicators can be improved. This is generally laudable, to improve both types of indicators by achieving more integration and learning by examples from each other. âẮc We thank the reviewer for recognizing the benefits of our research. Overall this article is a bit problematic. It is a little worrying that it reiterates certain limited visions of vulnerability indicators and formula, focusing mainly on physical and exposure aspects, especially in the beginning of the article. The literature used is quite narrow for certain fields such as local level studies or social, economic or institutional vulnerability (and resilience) and while the article claims to be a review, it is quite limited in scope and missing insights from similar review approaches. âẮc The reviewer makes a valid remark, and vulnerability is indeed a very broad topic, with a wealth of literature. We have therefore decided to revise the focus of our paper on providing insights into how vulnerability indicators (both physical and social) are used in quantitative flood- and earthquake risk assessment models. Furthermore, following the reviewer's suggestions, we have made adjustments to better explain the revised scope in the abstract, sections 1 (introduction) and 4 (conclusions). In these sections 1 and 4 we now bet-

ter explain: o the selection of models and usage of indicators only from studies that quantify vulnerability, as the goal is to improve quantitative risk assessment models. o that due to challenges in quantifying qualitative indicators, most studies use indicators that are often physical as these are more easily quantifiable than, for example, psychological vulnerability indicators. As a result, there is a focus in earthquake research on indicators stemming from physical vulnerability assessments. o that the main flood vulnerability indicators are applied to case studies with a less detailed spatial scale than earthquake vulnerability assessments where the application of vulnerability indicators are applied at more detailed spatial scale. As such, this forces us to include multiple scales (from local to national level) in trying to obtain cross-discipline lessons.

âẮ In section 1, we have now added a paragraph on the focus of the paper which reads: [59] There are two distinct paradigms in assessing vulnerability: the natural sciences and the social sciences (Roberts et al., 2009). The former considers the human system to be passive while exposed elements have varying vulnerability to a hazard, which can differ in magnitude and is considered to be an active agent. In the social sciences approach to assessing vulnerability, the focus is on the coping capacity and resilience of the human system (Roberts et al., 2009). While acknowledging the studies that further subdivide vulnerability into resilience and susceptibility, or that consider resilience to be vulnerability's counterpart (e.g. Fuchs 2009), we asses vulnerability as it is defined by UNISDR (2009), but we do account for both physical and socio economic indicators for vulnerability. Content The authors distinguish social vulnerability into four groups. It is questionable to put economic indicators under social vulnerability. The examples and reasoning provided come too short and examples for instance for institutional indicators are not fully convincing. âẮ This is indeed a 'grey area', and as the reviewer acknowledges, indictor-categories aren't as clear cut as suggested by e.g. Davidsson and Shah (1997). Therefore, in quantitative assessments, economic indicators are often lumped in or have otherwise overlap with social, or socioeconomic, indicators. These discrepancies therefore also end up in our review. We agree with the reviewer that we did not carefully explain this and therefore, to support this claim,

we have included an explanation based on work by others. We addressed this more carefully in sections 2.1.2 (social vulnerability indicators) and 3.1.2 (results social vulnerability indicators) by acknowledging the overlaps as they exist in the studies we reviewed. We also added new examples supporting our choice of subdividing social indicators using economic and institutional indicators. The relevant sections now read: [124] Several studies have discussed the approach to and potential pitfalls in defining different indicator categories (e.g. Davidsson and Shah, 1997; Bruneau et al., 2003; Birkmann, 2007). Bruneau et al. (2003) suggest a framework for the quantitative assessment of seismic resilience consisting of the following four interrelated dimensions of community resilience for which there exist no single measure (note: their definition of resilience overlaps in part with the definition of vulnerability used in this paper): technical, organization, social, and economic. [. . .] Davidsson and Shah (1997) too, acknowledge that factors (or classes) of vulnerability are not distinct entities and that there are many interactions, overlaps and contradictions between indicators from the different classes. While acknowledging the difficulties in categorizing vulnerability, using categories as used in many flood and earthquake vulnerability assessments, we classify vulnerability indicators in two main classes: (a) physical indicators [. . .] and (b) social indicators, which include here: demographics, awareness, socio-economics, and institutional factors (e.g. Mileti, 1999; Cutter et al., 2003; Adger, 2006; Messner and Meyer, 2006; Roberts et al., 2009; Balica et al., 2012). [205] The definition of social vulnerability is much debated (Birkmann 2007). Hinkel (2011) states that although the debate around the conceptualization of social vulnerability continues to exist, agreement seems to have been reached on social vulnerability being context-specific and place-based as defined by Cutter et al. (2003). In this paper, we therefore use the definition of social vulnerability as provided by Cutter et al. (2003), where social vulnerability consists of social inequalities (i.e. social factors that influence peoples' susceptibility) and place inequality (i.e. factors such as urbanization and economic vitality that impact the social vulnerability of a place). [. . .] Reviewing the existing studies, there does not appear to be consensus on the aspects to include in social vulnerability. However,

many studies incorporate different combinations of social indicators (such as vulnerable age groups, population density and population growth) with political, environmental and/or economic indicators (e.g. Davidsson and Shah, 1999; Cardona 2006; Peduzzi et al., 2009). Based on this, we here distinguish four main social vulnerability indicator groups: demographic, awareness and preparedness, socio-economic, and institutional and political vulnerability. Some chapters like these or 2.2.3 are so short that the impression remains that they could rather be skipped. Three lines about the aspect of scale under a heading are not sufficient, especially, the reference and thorough discussion and link to several indices discussed before, is lacking. Moreover, the function of chapter 2.2.3 is unclear, since in chapter 3 those aspects are discussed (again) in much more detail. âĂć We agree with the reviewer and this section has been removed while keeping the relevant text in section 3.2.2 which discusses spatial and temporal scales. In terms of argumentation, the paper and logic of language is often hard to follow; certain contradictions seem to appear. For example, in lines 285 ff. There are rather unsupported claims that building codes have not been observed in flood vulnerability studies. What does this include? Building codes for earthquakes? Or specific design codes for physical stability against flooding? Do such standards exit? Which ones? And have they really not been analysed? But this is just an example of the argumentation style in this paper; claims made within one sentence and then not detailed anymore or supported merely by one source – in this case one of the authors of this paper and on earthquake not flood vulnerability. Some contradiction is also in this sentence with the following sentence "while for floods Nikolowski (2014) provides an overview" So is knowledge available or not, is a bit unclear. âĂć In cases of single referencing: additional references have been added to support claims made. âĂć In case of one-line arguments: arguments have been elaborated on and clarified. âĂć On the Nikolowski reference, we agree with the reviewer and we have adjusted the mentioned paragraph with the sentence containing the Nikolowski (2014) citation as follows: [362] Flood vulnerability assessments have seen a recent transition from focusing on traditional flood protection measures, which aim to decrease the flood probability for

an area to building-specific resilience measures (Ashley et al., 2007; Naumann et al., 2011). One example where this has been done is a study by Nikolowski (2014) which provides an overview of different ranges of building age and their flood vulnerability; structural (load carrying) and non-structural (mechanical) components; roof types; and building maintenance factors. For flood, vulnerability of building- or land-use types are often related to flood hazard indicators such as flood depth or flood velocity to estimate potential losses (e.g. Roos 2003; Barroca et al., 2006). Text from 285 to 315: well, the authors cited here (from the same institutions as the authors) use earthquake models also in flood studies. But this is not justifying the argument the authors make; that there would exist no flood vulnerability indicators that also analyse built environment or road infrastructure or else. In fact, there are even papers out by the same institution that specifically analyse road vulnerability, but are not mentioned here (Keller and Atzl 2014 International journal of disaster risk science) This again underscores the main impression that this article leaves; limited in scope and line of justification as based on own work of the authors and certain colleagues who have a strong focus only on certain aspects of risk or vulnerability. Their focus is fine, but this paper tries to be a review paper and should be much more balanced and informed by the diversity of approaches that exist. âĂć We agree with the reviewer and rewrote the paragraph fine-tuning the claims made and included more references from other institutes than those related to the authors, among which the suggested citation as follows:

[387] Infrastructure and lifeline indicators are used both in earthquake and flood vulnerability assessments, for example in HAZUS-MH. Atzl and Keller (2013) provide a framework which links social vulnerability to critical infrastructure and create indicators at the individual level for infrastructure-specific social vulnerability of commuters in Stuttgart (e.g. travel distance, availability of alternative transport, and number of available public transport lines). As shown in Table 1 and as argued in other work (Miletti, 1999), there appear to be fewer flood vulnerability assessment studies including infrastructure related indicators compared to earthquake vulnerability assessments. Keller and Atzl (2014) add to the existing body of experimental research by assessing the

causal relation between extreme precipitation events and the impacts on German infrastructure using an explanatory approach. In other studies, earthquake vulnerability assessment models are occasionally adopted in flood vulnerability models to address infrastructure risk (Merz et al., 2010). However, the knowledge gap continues to exist and there is a need for further research (Keller and Atzl, 2014).

âẮ To assess the differences or similarities between earthquake and flood vulnerability models and the indicators used, we only include risk assessment models that include a vulnerability component consisting of physical and/or social indicators and that pertain to either of the two hazard types (or, such as HAZUS-MH, models that incorporate separate assessment models for different hazard types). We agree that we have not stated this clearly and have therefore addressed the scope in the abstract and in section 1 as follows:

[17] In assessing the differences and similarities between indicators used in earthquake and flood vulnerability models, we only include models that separately assess either of the two hazard types.

[98] The main goal of this study is to conduct a literature review comparing methods for quantitatively assessing vulnerability in flood and earthquake risk assessment models and therefore does not aim to provide a comprehensive overview of all vulnerability indicators in the domain of floods or earthquakes. Instead we analyze only those indicators that have been addressed in both modeling domain and systematically assess the differences in using those indicators in both flood vulnerability and earthquake risk models. Because the field of vulnerability assessment is wider (Adger 2006; Birkmann 2007), we here focus on the two main types of quantitative vulnerability assessment methods that are commonly used in risk assessment models: vulnerability indices and vulnerability curves We recognize that the study of cascading events is an important, emerging field as discussed extensively in Pescaroli and Alexander (2016), however our focus is on single events only. More specifically, we analyze which vulnerability indicators have been addressed in such quantitative methods by comparing the fields

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of flood and earthquake risk assessment. Through this comparison, we hope that both fields can learn from each other's respective approaches, further developing vulnerability as an important component in risk modeling. State-of-the art: what about other review papers on vulnerability indicators such as Tate, de Sherbinin, or on similar resilience indicators etc. what did they find? What do UNISDR processes at the moment on indicators search for, demand, have achieved? The SREX report of IPCC and similar documents by Cardona and others have substantially contributed a joint understanding of vulnerability indicators on all types of hazards, and earthquake and floods are amongst the most prominent. âẮ The suggested references as listed in the general comment to the reviewer have been added where appropriate as well to the indicator overview tables. For example:

[46] A recent review of the Sendai framework by Mysiak et al. (2016) shows that one of the key components is to identify and increase understanding of the main vulnerability indicators that drive risk.

[456] Tate (2012) argues that the social vulnerability index is the social equivalent of the quantitative physical vulnerability assessment. In these indices, demographic data are often used to describe social, economic, political and institutional vulnerability. However, since there is a lack of systematic evaluation of how social vulnerability indices are constructed, little is known about how well these social vulnerability indices perform (Tate 2012). Tate (2012) concludes that most studies only provide limited justification for the inclusion of specific indicators. He argues that researchers should give more thought as to which social indicators to include as well as their statistical properties.

[465] To assess exposure differences to flooding and whether those who are most exposed also have the highest social vulnerability, de Sherbinin and Bardy (2015) apply their social vulnerability index using different sets of indicators to New York and Mumbai. Their method builds on earlier work by Cutter et al. (2003) and the IPCC Special Report on Extreme Events Framework (IPCC 2012). Inclusion of indicators differed for the two cities and was often dependent on data availability and applicability to the case

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study (de Sherbinin and Bardy, 2015).

[590] An important aspect of vulnerability assessments is their spatial scale (Cutter et al., 1996). Vulnerability assessment models can be applied on different spatial scales (high versus low resolution) and using different data types (object versus aggregate, or raster, based). This is often dependent on data availability: particularly for social vulnerability indicators it is challenging to find high quality social vulnerability data for measuring those indicators at a local level (e.g. de Sherbinin and Brady, 2015). Method: it is not clear, how the table cells are justified – it is decisions by the authors to fill these cells and quite many of those appear to be based rather on assumptions and feelings by the authors, what should be emphasised or placed into a box. Is this 'method' the right approach? Some of the authors are really strong in quantitative data analysis or case study approaches – wouldn't 'it be much more compelling to provide those arguments for better indicators based on real data or on cases? A theoretical underpinning is lacking as well; the cited work by Bruenau et al 2003 might serve as a starting point or an analysis of conceptual frameworks who tried to structure vulnerability dimensions already and provide insights that physical and social and cultural and economic etc aspects must be combined in indictors. Davidsson and Shah 1997 are a classic; but many who tried to apply it have struggled with the application since physical and social and exposure and hazard are often overlapping; where are the existing lessons learned studies here? A section also about the pitfalls and advances made? âĂć In agreement with the reviewer, we elaborated on our scope setting, focusing on risk assessment models that have a vulnerability component where supported by the literature we distinguish two classifications: (1) physical versus social and (2) the sub-components vulnerability curves and indices. We also included theoretical underpinnings such as in the references provided by the reviewer to better explain and justify our revised scope. We also included a discussion on the difficulties of creating indicator categories without overlap. In restructuring our scope, we also added Bruneau et al. (2003) as suggested by the reviewer.

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[124] Several studies have discussed the approach to and potential pitfalls in defining different indicator categories (e.g. Davidsson and Shah, 1997; Bruneau et al., 2003; Birkmann, 2007). Bruneau et al. (2003) suggest a framework for the quantitative assessment of seismic resilience consisting of the following four interrelated dimensions of community resilience for which there exist no single measure (note: their definition of resilience overlaps in part with the definition of vulnerability used in this paper): technical, organization, social, and economic. Davidsson and Shah (1997) acknowledge the necessity of the development of "an index of vulnerability". Their Earthquake Disaster Risk Index (EDRI), a composite index, allows for the inclusion of different factors of vulnerability (i.e. physical infrastructure, population, economy and social-political system) (Davidsson and Shah, 1997). Davidsson and Shah (1997) too, acknowledge that factors (or classes) of vulnerability are not distinct entities and that there are many interactions, overlaps and contradictions between indicators from the different classes. While acknowledging the difficulties in categorizing vulnerability, using categories as used in many flood and earthquake vulnerability assessments, we classify vulnerability indicators in two main classes: (a) physical indicators that pertain directly to characteristics of the exposed assets, namely infrastructure and lifelines (including transportation infrastructure, utility lifelines, and essential lifelines) and buildings (including structural elements, occupancy, and environment related factors); and (b) social indicators, which include here: demographics, awareness, socio-economics, and institutional factors (e.g. Mileti, 1999; Cutter et al., 2003; Adger, 2006; Messner and Meyer, 2006; Roberts et al., 2009; Balica et al., 2012).

âĂć On the further justification of these two main categories, we have changed the categories in the table to better match the description in section 2.1.1 and elaborated on the method used for distinguishing the different classes in the table in that same section and in section 1. This has been explained more thoroughly by justifying choices pertaining both to the physical and social aspects of vulnerability in risk assessment. The following pieces of revised text underpin this revised description of categories:

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[86] The quantification of vulnerability is most detailed for earthquake risk assessment models although challenges remain (Douglas 2007; Roberts et al., 2009). Historically, the assessment of physical vulnerability (often referred to as 'fragility') is well-developed and recently it has been attempted to improve the quantification of social vulnerability as well (Sauter and Shah, 1987; Tiedemann, 1991; Yücemen et al., 2004; Carreño et al., 2005; Douglas, 2007; Roberts et al., 2009).

[161] Adger (1999) discusses how some indicators of vulnerability can also be both direct and indirect; such as social inequality which can be a direct measure of the coping capacity of a household or community to respond to a disaster but it can also be interpreted as an indirect measure of increased poverty and insecurity. Therefore, we have decided to omit the classification of indicators between direct and indirect as well as tangible versus intangible from this paper.

[167] The physical factor of vulnerability is the most thoroughly researched segment of vulnerability science, in part because physical vulnerability is more easily quantifiable than social vulnerability (Notaro et al., 2014), and relates to the physical vulnerability of the assets exposed to natural hazards – in our case floods and earthquakes. In accordance with several of the studies reviewed, we make a distinction in three main exposed assets: (a) infrastructure and lifelines; (b) buildings and their structural and occupancy components; and (c) environment (e.g. Davidson and Shah, 1997; Mileti 1999; Carreño et al., 2007; Douglas 2007).

[180] As mentioned, there are challenges in grouping indicators in distinct categories. Some studies perceive lifeline vulnerability as part of social vulnerability (e.g. Cutter et al., 2003; Holand 2014). For example, Holand (2014) defines lifeline vulnerability as the aspects of social vulnerability that are influenced by lifeline failure and he reviews common indicators used. He argues that there has been little discussion on how to measure lifeline vulnerability and distinguishes three lifeline indicator categories: (1) indicators addressing lifeline density and financial impacts caused by a natural disaster; (2) indicators measuring network redundancy and the potential for losing connectivity;

(3) indicators measuring travel time to facilities that provide critical services. Many of the studies reviewed by Holand (2014) group lifeline indicators with built environment or other physical indexes.

[228] Reviewing the existing studies, there doesn't appear to be consensus on the aspects to include in social vulnerability. However, many studies incorporate different combinations of social indicators (such as vulnerable age groups, population density and population growth) with political, environmental and/or economic indicators (e.g. Davidsson and Shah, 1999; Cardona 2006; Peduzzi et al., 2009). Based on this, we here distinguish four main social vulnerability indicator groups: demographic, awareness and preparedness, socio-economic, and institutional and political vulnerability. However, as mentioned before, we recognize that indicator categories are not clear cut and overlaps continue to exist (Davidsson and Shah, 1997).

[274] It should be noted however, that in some studies an index is generated and subsequently incorporated in a vulnerability curve (e.g. Giovinazzi and Lagomarsino, 2004). In those cases, we classified the indicator used to construct the index in the index based models category. Scientific language and style of argumentation needs major improvement. Sentences such as in line 326 are an example: "However, building age does not appear to be an important vulnerability indicator used in flood vulnerability assessments." They do not "appear to be": how do they come to this conclusion? How exactly is this to be derived from the previous sentence? âĂć We agree with the reviewer and have removed the sentence and included a more nuanced paragraph which reads as follows:

[438] Within flood vulnerability assessments, some research have been conducted regarding non-structural damages and disaster risk reduction measures (e.g. building regulations pushing for flood-proofing) to reduce building content damages (Dawson et al., 2011). However, rather than using a separate indicator, several models include content damage by adjusting the shape of the damage curve or changing maximum damage values. HAZUS-MH uses a 0.5 factor for estimating residential content dam-

ages in relation to structural damages (Scawthorne et al., 2006) and this factor has been used by other studies as well (e.g. Penning-Rowsell et al., 2010; de Moel et al., 2014). The Damagescanner, a curve based flood vulnerability assessment model, accounts for three types of flood-proofing measures (i.e. wet-proofing, dry proofing and a combination of the two) in assessing future potential for damages by adding damage reduction factors (0-1) (Poussin et al., 2012).

âĂć We also thoroughly checked the paper for one-line arguments and adjusted them accordingly. Abstract: "In a cross-discipline study" please name the disciplines later on in detail and explain a bit how there might exist differences in focus. âĂć We have adjusted the abstract incorporating the reviewer's suggestions as follows:

[10] In a cross-discipline study, we carried out an extensive literature review to increase understanding of vulnerability indicators used in the disciplines pf earthquake- and flood vulnerability assessments. We provide insights into potential improvements in both fields by identifying and comparing quantitative vulnerability indicators grouped into physical- and social categories. [. . .] In assessing the differences and similarities between indicators used in earthquake and flood vulnerability models, we only include models that separately assess either of the two hazard types. Conclusion: I suggest a much more balanced differentiation and more caution. Sentences such as "Flood vulnerability assessments have generally used a higher scale of geographical aggregation compared to earthquake vulnerability assessments." are wrong, if they are generalised. A great number of household level flood vulnerability indicator studies exist as do aggregated indices at multi-national level. Overall, the paper runs the risk to be limited in scope to characterise vulnerability assessments per se as physical vulnerability assessments. Maybe it would help if the authors provide a better delineation of their scope – regarding content, ambition, and countries and disciplines covered. âĂć We have made large efforts to improve and better describe the scope of the revised paper; please see earlier comments for details. âĂć In agreement with the reviewer, we have adjusted the sentences mentioned in this comment have been addressed and

we carried out a thorough read-through of the article. âĂć We aimed to include an equal number of physical as well as social studies and tried to have a balance between the number of earthquake and flood vulnerability models included despite some research suggesting that there are more earthquake risk assessment models than flood risk assessment models.

Minor comments: Line 54: Source is Davidson and Shah 1997 Line 380: Author is Rufat? âĂć We thank the reviewer for pointing this out and have adjusted the citations accordingly.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-45/nhess-2017-45-AC2-supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2017-45, 2017.