Response to Referee #2

We wish to thank the Referee for his/her time and effort reviewing the manuscript. We greatly appreciate the constructive comments and suggestions, which we have carefully addressed in this response. Where applicable, changes are proposed to the manuscript accordingly (and marked up for clarity). Following the guidelines of the NHESS Editorial Board, the revised manuscript was not prepared at this point.

General comments

- In general, I got lost reading the results from where the concept in graph theory relates to vulnerability. I realize that is in another paper, but that other paper at least needs to have terms summarized in a table to help the read apply the concept to Mexico City. It seems useful to think about how a disaster causing cascading effects to different "hubs" of services and how vulnerability propagates.

We agree, and propose adding the following summary table to address this issue:

Table 1: Analogy of risk variables with graph properties.

Risk variables	Analogy with graph properties
Exposure	The authority represents how the system privileges the nodes, conferring them more or less importance compared with others, according to the connections established in the system.
Vulnerability	The propensity of parts of the network to be isolated because of hazard events. The closeness of a node is a measure of the single node vulnerability within the system, while degree distribution, hub, and betweenness are measures of vulnerability of the system as a whole.
Resilience	The percolation threshold, together with the network fragmentation analysis, explain the resilience of the network after a perturbation.

This table will be referenced at L41 as follows:

> "The comparison of the proposed approach with the traditional one exhibits analogies between certain graph properties, relative both to single parts and whole systems, and traditional risk features. The analogies proposed are summarized in Table 1."

- I am unclear however if this is a conceptual case for Mexico City or an empirical one, because I don't know where any of this data really comes from. There are way more schools and hospital than are placed on this map. And two of the most vulnerable boroughs- especially Xochimilco to floods- is for some reason erased.

We decided which elements to consider in the analysis according to the available data (L89). We agree that this was not sufficiently clear in the original manuscript. In order to address this, we propose the following modifications in the text:

> L89: "Given the very large scale of the city, certain simplifications and hypotheses had to be assumed for conceptualizing the network. Furthermore, the choice of element typologies, the connections between them and the definition of rules are also done considering the availability of data, which were provided by the Engineer Institute UNAM México D.F. While this data is only partially representative of the entire exposed assets present in MCFD, we consider it suitable for the specific purpose of this work, which is to illustrate the proposed approach and show the benefits of using it. The selection of typologies, connections and the studied geographical area define the boundaries of the system. These simplifications and hypotheses of the real open-ended systems, while necessary to enable the computational analysis, should be recognized and taken into account when evaluating the results of the analysis (Clark-Ginsberg et al., 2018)."

> L110: "This approach does not aim to be representative of ~~model~~ the complete behaviour of the road network system, particularly the paths between nodes or possible alternative paths, but it does allow considering transportation network in the analysis in a simplified manner."

> L295: "The purpose to introduce the hazard scenarios is to show the potentiality of this approach to assess the direct impacts and the indirect consequences over the whole system, rather than to develop a standalone model to be

representative of the flood hazard in Mexico City. This will allow to show the impacts of flood scenario even outside the flooded area, based on the graph built for this specific study."

L335: "In this application, the complexity of Mexico City is depicted by modelling certain selected typologies of elements of the urban system and by assuming simplified rules of connection between them. Furthermore, the system complexity acknowledged in this study is restricted only to the elements inside the MCFD and neglects any potential contributions from outside elements. The definition of a geographical boundary condition, which is a straightforward assumption in the traditional reductionist approaches, can be controversial in the holistic approaches that aims to model the emergent characteristics of open-ended systems."

We consider this case study an empirical one, as it is based on real data from MCFD, even if these data only partially represent the complexity of the city. In the article we recognize that certain simplifying assumptions were adopted, which are considered adequate given the intended aim of the article, which is to illustrate implementation of the proposed approach.

- And how are you dealing with informal settlements? Is that population (which is somewhere between 200,000-1 million people in the city) represented? Data exists for them, and I would expect it would be interesting to include them because they will have demand for services but won't provide anything.

We agree with the reviewer and recognize that the informal settlements, which are currently not considered, would represent important service-receiving elements in the graph. However, given the main aim of the article, which is to illustrate the approach rather than to model exhaustively the exposed assets in MCFD, we believe that the introduction of such elements (which are not included in the data provided by UNAM that we use in this study) is not strictly necessary. This modelling simplification will be properly acknowledged in the revised article.

- The graphs need work to help the reader (maybe a table will solve this) because as written its tough to related skewness/sd of each variable to: : :what it ideally should be (consider adding the "ideal" line to the graph).

We will modify the plots to make them clearer by taking out the values of skewness/sd from the legend and formatting them in a separate table. However, please note that there are not "ideal" or reference values neither there's an ideal distribution to which they should converge to. The purpose of the plot is mainly to compare the different distributions to highlight the different network properties discussed in the manuscript.

- Finally, how do the results line up with actual vulnerability in the city? Can you compare to existing risk maps or media data?

It is not straightforward to define what "*actual*" vulnerability is, because many definitions of vulnerability exist depending on the scope of the risk assessment (e.g. physical vulnerability, social vulnerability, systemic vulnerability, to name a few). Here, the vulnerability is evaluated from a new systemic perspective, which is not readily comparable with other vulnerabilities of the study area. Regardless, we believe that such comparison, even if possible, would be outside the scope of this work. Note that we did not produce risk maps against which others could be compared, but only impact maps for this particular hazard scenario.

It's hard again to know if we are supposed to take this as an empirical case or a conceptual one.

As we mentioned above, we consider this case study an empirical one, as it is based on real data from MCFD, even if these data only partially represent the complexity of the city. In the article we recognize that certain simplifying assumptions were adopted, which are considered adequate given the intended aim of the article, which is to illustrate implementation of the proposed approach.

Specific comments:

- Line 160. I presume most cities are going to have this distribution. Non-homogenous. Is there any reason to suspect Mexico city departs form what is likely the norm of how humans tend to self-organize and adapt?

We agree with the suggested comment, but since this is the first time that this methodology is applied in general, and also to Mexico City, we believe that it is interesting to show the results of the analysis and check our supposition. These results can also depend on the scale of the analysis (large city vs small town), and the specific results obtained can be used as baseline for future different analysis and comparison with different case studies.

- 190-200. I am not totally getting why closeness in is making something more vulnerable. I think I need a conceptual diagram or table of definitions of what is normatively desired vs. non desired for risk management.

The full theoretical explanation of the analogy between vulnerability and closeness is given in part I (L323-326). In part II at L193-197, we propose the application of the analogy in accordance to the model conceptualization of MCFD. To better illustrate the analogy also in the part II, as suggested above, we propose also adding Table 1.

- Line 305. This is a very short description of a flood model. Where did you get the DTM. I don't think 10m of flooding is realistic. Was this validated in any way?

We decided to omit certain technical details of the hazard model to avoid making the manuscript too heavy for readers and distracting the attention from the actual application of the proposed approach, which is independent from the type of hazard and the hazard models. However, we do agree that more information on the flood hazard model are necessary, and will therefore add some additional details in the revised manuscript, such as the information regarding the uniform Depth Duration Frequency curves and the specific parameters adopted for the ietographs for MCFD. We also propose to insert the following modifications to clearly explain that the hazard model is not the main topic of this study:

> L295: "The purpose to introduce hazard scenarios is to show the ~~its~~ potentiality of this approach to highlight the impacts on the indirect consequences over the whole system, rather than develop a standalone model to be representative of the flood hazard in Mexico City. This will allow to show the impacts of flood scenario even outside the flooded area, based on the graph built for this specific study."

> L343: "We have adopted a simple flood scenario to illustrate how some of the measures of a graph can be used in the context of natural hazard risk assessment. However, within our framework, beyond the development or adoption of a standalone flood hazard model (e.g. 2D flood propagation) for Mexico City, additional potentially relevant information can be obtained."

- 345. percolation threshold? Why introduce a totally new term this late!

The percolation threshold is mentioned in the introduction (L49) and has now also been added in Table 1 (L41). This aspect tis horoughly discussed in part I, but has not been considered for the practical application in part II. We have decided to mention it in Section 5 ("Final considerations") because we believe it can be an interesting future development.

Figures

- Figure 2. Tlahuac is spelled wrong.

This will be corrected in the revised manuscript.

- Why is xochimilco and milpa alta excluded? Where is this data from? Is this conceptual or empirical?

As we believe is now clear from our above responses, this pilot study does not aim to be exhaustive in terms of the exposed assets in MCFD, but instead aim to illustrate the feasibility of the approach and show the benefit of using it. The source of data is mentioned at L89, and based on the available data we decided which elements to consider in the analysis.

References

Clark-Ginsberg, Aaron, Leili Abolhassani, and Elahe Azam Rahmati. 2018. "Comparing Networked and Linear Risk Assessments: From Theory to Evidence." *International Journal of Disaster Risk Reduction* 30(April):216–24. Retrieved (https://doi.org/10.1016/j.ijdrr.2018.04.031).