

## **REVIEW**

**Title: Quantifying cascading impacts through road network analysis in an insular volcanic setting: the 2021 Tajogaite eruption of La Palma Island (Spain)**

**Decision: Major revisions**

### **General review:**

This paper presents a detailed post-event impact assessment (PEIA) that highlights the compound nature of volcanic hazards and their far-reaching consequences on interconnected infrastructure systems. By adopting a forensic approach and applying graph theory-based network analysis, the study quantifies both direct physical damages and indirect systemic disruptions—particularly within transportation, emergency services, agriculture, and education sectors.

The objective of the work is clearly defined, and the case study is of utmost importance for the scientific community. The study is grounded in the specific context of the 2021 Tajogaite eruption, and this focused approach allows for a nuanced and thorough examination of local impacts and system responses. The depth of analysis provides clear value for understanding complex interactions in disaster scenarios. Nonetheless, the strong emphasis on a single case may somewhat narrow the study's relevance to broader contexts. A more explicit connection to similar challenges in other regions would further enhance the paper's applicability and reach. The case-study of La Palma is undeniably meaningful but I would suggest giving a bit more emphasis to broader implications on the aspects that would make it usable in another region and context.

I think your approach could gain relevance if discussed against similar approaches developed for other natural hazards and for tackling the deriving emergencies, as well as for multi-hazard scenarios. A wider comparative perspective or a discussion linking the results to other active volcanic areas or areas prone to other hazards (e.g. landslides) would enhance the study's impact and utility for a more diverse audience. Expanding the contextualization would help readers better understand how the presented methods and insights could be adapted to different geographic or socioeconomic settings.

With regards to the methodology, I suggest to discuss a bit more how these ex-post assessments can help future risk management. How can these be included in capacity planning, emergency management and in the definition of future exposure and impact scenarios? I really like your idea of using past lava flow locations and this might be discussed explaining how this could be complemented (e.g. with modeling) to provide future scenarios to land use planners and infrastructure managers. You already started discussing this in line 907-915 but I think a bit more emphasis could be given to this.

Finally, I think the manuscript could benefit from an overall polishing to avoid repetitions which are sometimes confusing for the reader and perhaps distract from the main message (see specific comments below).

Overall, I congratulate the authors for their rigorous and insightful work, which makes a valuable contribution to disaster impact analysis; with the suggested enhancements to broaden its contextual reach, this study has the potential to become a significant reference for the scientific and risk management communities.

## **Specific comments:**

### **Introduction:**

In this work it is somehow unclear why you use the term systemic or cascading impacts, and if you are tackling both. In particular, you mention in line 93-95 that the cascading effects are triggered due to the interaction between roads and other exposed assets, so, to my understanding, we are talking about the induced impacts due to road network disruptions. However, other systemic impacts are also described. I think the reader would benefit for a clarification in the introduction so it's clear what is meant.

Lines 100-104: It could be worth mentioning the study from Scaini et al. 2014 on the loss of functionality in terms of physical and systemic vulnerability induced by compound volcanic hazards in Tenerife on exposed assets including roads.

Fig.2: The primary road (black line) should be included in the legend, in addition to the caption

### **Methodology:**

Line 293-294: I think the reader would benefit from a broader description of the involved stakeholders and how they were involved, and for example if the same stakeholders were participating to all the encounters. Also, do the mentioned discussions only include structured interviews or is there also a different kind of interaction (e.g. group meetings)? Did they show you the location of the impacts using a map, or how did they identify the impacted areas and/or the location of the assets? Also, In line with my comment on the generalization of your approach, how do you suggest to adapt the interview questions to different contexts? How was this done passing from Dominguez et al., 2011 to this context?

Line 300: I think this sentence explains very well what is done and could be moved to the initial methodological part rather than the data acquisition section.

Table 1: why 'disrupted' is FL-I and 'reduced' is FL-II? How were these functionality levels defined? Were they all observed in the case-study?

Line 343-346: The information in the road network data should be moved to the data section

### **Results:**

Section 4.1 mostly presents the impacts in a narrative form and it's hard for the reader to distinguish if these information were collected from the presented methods, or if they are part of the context and the already available information. In the second case, these narratives could be provided at the beginning to explain to the reader what is the situation, while the results should present your original findings.

Lines 385 -389 and Supplementary material on impacts to other critical infrastructure systems: I am unsure why these impacts are summarized here, if it's to demonstrate the impacts due to the volcanic hazards or to the road closure. This links back to the question on the definition of cascading and systemic impacts, which I think could be made clearer in the text.

Table 5: I think this table is very relevant to understand what are the results of this work.

Row 2, column 5: 'Highly disruptive' is a bit generic

Row 7, column 4: is the surface missing?

Section 4.2.2: The initial part is a repetition of the method which should be already explained in the methodology section.

Section 4.2.3: Similarly to section 4.1 there is a broad description of what happened but it is somehow unclear what fraction of this information was gathered using your methods (e.g. interviews) and which information was already available in advance. Even in this second case, if you reinterpreted this based on the impact chains that you identified and on your methods, this can be part of the results, but it should be made clear to the reader.

### **Discussion:**

Line 730-740: I would include in the introduction some background on the ex-post analyses and the forensic approach in the field of disaster risk reduction, with literature references (e.g. AM Ferreira et al., 2023; F. Atun, 2024), in order to highlight the relevance of your work beyond the case-study. Also, this could be discussed to show what are the improvements of the approach that you propose.

Line 745-746: 'identify the most impactful cascading effects': Is this shown in the figures? Or was this part of the replies that they gave you to the interviews?

Line 760-764: It would be relevant to explain what kind of data would support a deeper and more extended deductive/inductive reasoning. This could help other researchers interested in applying this tool in other areas where such data might be available.

Line 765-768: This sentence is not super clear to me, could you rephrase? Does it mean that, since the majority of the tephra deposition happened in the first phase and that the impacted road length are almost constant during the following phases?

Given that you comment on different CI (e.g. water networks) and given the presence of the water reservoirs that are, both here and in other Canary Islands, so relevant for local activities, I would suggest adding some references in the introduction about the exposure and vulnerability of these (e.g. Stewart et al., 2006, 2009).

Fig. 6C: Is it systemic or cascading?

Line 814-815: how much of this analysis can be done a priori? e.g. analyzing the existing network and its potential pitfalls using a combination of scenario modeling and network analysis?

Apart from the road type (and associated speed), did you account for the road path (e.g. if it is mostly straight or curved) and the pavement type? Also, how different could this scenario in case of different weather conditions (e.g. under heavy rainfalls), especially in areas served by unpaved secondary or tertiary roads?

Do you foresee to tackle the lack of traffic data in some other way (e.g. using phone data, such as in the work of Yabe et al., 2022; Wilson et al., 2016; Giardini et al., 2023)? Or, if not, shall this be addressed in the future?

### **Conclusions:**

Following my comment on the results, I think the conclusions are a bit generic and could be made stronger by giving more emphasis to the specific results achieved with the analysis (e.g. from table

5, fig. 10-11). In particular, from Fig. 10 it seems that the travel time increases a lot for R1, and this might set a priority for emergency managers.

#### **Minor comments:**

If possible, I would suggest to translate the tables in S2 into english

I'm not a big fan of acronyms and sometimes I feel their use could be reduced in favor of readability.

#### **Supplement:**

In the section regarding air traffic disruptions, I think the Sara et al. Reference Barsotti et al.: Sara, B., Simona, S., Giovanni, M., Alicia, F., Aline, P., Georgios, V., de Zeeuw van Daltsen, E., Lars, O., Adriano, P., Jean-Christophe, K., Susan, L., Rita, C., Mauro, C., Jordane, C., Charlotte, V. B., Mauro, D. V., de Chabalier, J. B., Teresa, F., Fontaine Fabrice, R., Arnaud, L., Rui, M., Joana, M., Roberto, M., Anne, P. M., Jean-Marie, S., Ivan, V., Kristín, V., Samantha, E., and Giuseppe, S.: The European Volcano Observatories and their use of the aviation colour code system, Springer Berlin Heidelberg, <https://doi.org/10.1007/s00445-024-01712-0>, 2024

Also, on the tephra-induced impacts there are more references that could be provided.

With regards to the selection and classification of exposure assets (S3), I think it should be discussed and compared with other existing classification and taxonomies (e.g. the GED4ALL) and their adoption for exposure assessment in other study areas. Exposure is inherently multi-hazard, so the approach would benefit from the adoption of a more general taxonomy. Also, I suggest discussing how local-scale methods such as the one proposed here can be integrated in the overall multi-hazard risk assessment.