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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "On the nexus between landslide susceptibility and transport infrastructure – agent-based vulnerability assessment of rural road networks in the Eastern European Alps" *by* Matthias Schlögl et al.

Anonymous Referee #1

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1 General comments

The authors describe a method to study the impacts of landslides on the travel behaviour of road users in a mountain area in Austria using a landslide susceptibility map and an agent-based traffic model. Clearly, a lot of thoughts and efforts were used to set up the models and do the analysis.

Although the paper provides some interesting insights on the investigation of trans-

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port infrastructures prone to landslides, there are some critical points that should be addressed before consideration for publication.

1. In the tile, the paper implies an "... agent-based vulnerability assessment of rural road networks ...". Unfortunately, this is not delivered, i.e. at the end of the paper, the reader does not have a clear answer on the question "How vulnerable is the road network (in Vorarlberg) towards landslide hazards?" Instead, 10 (very specific) Scenarios were analyzed and compared, considering the detour length and the evasion time. Hence, the concept how to assess network vulnerability has to be better expressed, beginning with a clear definition how the authors define vulnerability in their paper, and the introduction of some vulnerability measures for quantification and justification (e.g. using indices, curves, tables, maps, etc.).

2. Throughout the introduction, several times the importance of socio-economic impacts and the severe losses caused by the disrupting services are mentioned. Finally, only the prolongation of the travel is considered. Since the authors already implemented a very detailed agent-based model with many socio-demographic data (e.g. the agents are employed/unemployed), why not actually assessing the socio-economic impacts? This would also be a novel contribution of the paper, which is currently missing.

3. In the current version of the paper, the methodology can be summarized as: "Running a traffic model, thereby disabling a selected link", which is not a novel concept, or method. What's missing is a clear description of the novelty for the proposed methodology. i.e. What is new? How is it better than other approaches?

4. Concerning the landslide susceptibility map:

(a) There is a conceptual flaw, using landslide susceptibility maps for assessing network-related processes. Contrary to building assets (e.g. houses, facilities, etc.), networks are used to describe dynamic processes (e.g. traffic flow), with the consequence that local events can have a severe impact on the whole network (as the authors showed in their example). The problem is that landslide susceptibility maps describe only the relative likelihood of future landslides, however, since the network is more than its components, there is a probability that a very unlikely landslide (low susceptibility), causes more harm than a very likely landslide. For example, there is a very low susceptibility that a landslide will be triggered and affecting a major connection, causing thousands of people to stay at home while incident 6 affects only 128 agents. At the current state of the paper, such network effects are completely neglected, however, this is the core concept (and challenge) of analysing network structures.

(b) Why did the authors develop a landslide susceptibility map although "The government of the province of Vorarlberg offers an official landslide susceptibility map . . . " (Page 5/ Line 26) and "The official hazard map already provides a reasonably accurate and consistent basis for the purpose of identifying vulnerable sections." (11/30)? Additionally, the used Weight of Evidence Method (Bonham-Carter, 1994) is nothing new, and therefore worth to spent 4 pages of the paper, only to figure out that the official landslide susceptibility map is a good enough estimate.

5. Concerning the selection process of links to be blocked

(a) It is absolutely not clear, how the 12 incident sides were selected. Please, give a detailed description how this was done (quantitative?, qualitative?), especially since the authors remove later on selected sides ("... 12 had to be removed due to its close proximity to Silvretta-Hochalpenstraße ..."(13/1).)

(b) Also, it would be of interest which landslide susceptibility is associated with each incident side. See point 5: If only areas with high susceptibility are considered, the question arises, if there is not a scenario where the road network is more vulnerable to landslides in less susceptible areas.

(c) An important part missing is the interaction between landslides and road network. In the current version, it is assumed that a landslide occurs at the incident side and completely damage (block) the road section over a period of at least 24 hours (runtime for the MATSim model)? If so, these are very strict assumptions and is contradicted by the author's statement "...due to the fact that landslides, which affected traffic routes or (agri-)cultural areas, are usually fixed quickly and efficiently." (11/10). Also, how could such assumptions be made without the knowledge of the particular landslide type (initiation and run-out, volume, speed)? The likelihood of the occurrence of landslides is not a sufficient reason to assume a damaged infrastructure. Please, specify the assumptions made and give a detailed description how the (physical) damage of the infrastructure was derived from a landslide susceptibility map.

6. Concerning the agent-based traffic model

(a) The implementation of an agent-based model is very ambiguous, please clearly state why such an approach was used, especially since most of the results (affected persons, detour lengths, evasion times) could also be observed by a flow-based traffic assignment.

(b) In the current version of the paper, several assumptions made and several limitations of the traffic model are not clearly stated. e.g. the MATSim simulation considers only/maximum one day, an agent has perfect knowledge of the interrupted section, origin and destination do not change during and after extreme events, etc.

(c) A major shortcoming is that only trips of inhabitants of Vorarlberg are considered, which does not reflect reality and certainly leads to an underestimation of the socio-economic impacts in the region. The question is how can the vulnerability assess given this constraint? Additionally, how could the traffic model be calibrated and validated, neglecting a majority of the travellers on the network?

(d) Why was so much focus put on introducing and analyzing 10% scenarios, without any additional benefit for doing so? It could have been stated, that for computational reasons a pre-sampling with 10% of the agents has been done, but the evaluation has been done with a 30% scenario.

(e) It is not clear how many simulations (not iterations) have been done for each incident. In other words, how often was the traffic model run for one incident? Since the agent-based model tries to optimize the behaviour of multiple agents, the simulation results might change over time.

(f) Using advanced modelling tools often suggests precise outcomes, however, since many unknown input parameters are necessary, the results might come with high uncertainties. These uncertainties have to be quantified in order to make meaningful statements. At least a more detailed (quantitative) description how accurate the traffic model compared to the actually measured traffic volumes should be given.

7. As mentioned in the beginning, it is hard to interpret the results and conclude how vulnerable the road infrastructure is. For example for side incident 10, 4709 agents are affected by an average evasion time of 3:10 minutes over a whole day. Does this mean there is almost no vulnerability against landslides? How can road authorities derive conclusions from this results? Should they invest in some protection measures or not?

8. Given the shortcomings of the current version, I kindly would like to suggest a rejection and encourage the authors to re-submit once the major issues mentioned

above are fixed and the storyline is clear and focused on what has been promised in the title.

2 Specific comments/questions

1. (1/10): "The focus of this case study is on resilience issues and support for decision making in the context of a large-scale sectoral approach." this is clearly not the case in this paper. Either this will be added to the paper of this statement should be deleted.

2. (1/15) Here only single events are considered, however, in reality, we often have to deal with the occurrence multiple hazard events (e.g. heavy rainfall caused several landslides). How can the proposed methodology cope with such situations?

3. (7/23) "Road capacity was derived from the functional road class." For personal interest, how was this done and in which range where those values per road class?

4. (10/1) Figure 1. The different road classes should be indicated (e.g. highway, primary road, ...) in order to give the reader an overview how the network is structured and where the major links are located. Additionally, since the base scenario is already computed, a map with the traffic volume should be added, to indicate the traffic flow. Next, to such a figure, it would be interesting to see a figure for the traffic volumes of an interrupted network.

5. (14/3) "In some situations, the blockage of a non-redundant link can occur, meaning that no alternative routes are available, as is the case for incident 11. Here, it is of no benefit to run a traffic simulation on the modified road graph affected

by the landslide event." Actually, what would happen is that the overall travel time will decrease for the network since fewer people are on the roads. The issue of missed trips (people who are cut off from the network) is neglected in the current version of the paper, however, it is important problem and should also be treated. Especially since this could cause more socio-economic impacts than a trip prolongation of several minutes.

6. (15/9) How many agents were simulated? 30% of 260000 is 78000 and not 5518. Probably this sentence has to be clarified.

7. (16/1) Figure 2. Why showing the 10% and the 30% example, is there any additional value in showing and discussing the 10% example?

8. (19/4) "In this paper, we have shown that agent-based traffic modelling allows gaining interesting insights into the impacts of road network interruptions on the mobility behaviour of affected communities by modelling their responses to network disturbances." This might be true but is only slightly related to the topic of road network vulnerability which was promised in the title of the paper.

3 NHESS aspects

1. Does the paper address relevant scientific and/or technical questions within the scope of NHESS?

Yes, the paper tries to addresses the question of vulnerability related to networks exposed to landslides.

1. Does the paper present new data and/or novel concepts, ideas, tools, methods or results?

Not in the current state. Right now the method is "Running a traffic model, thereby disabling a selected link" which was done already years before. The novelty of using part of using landslide susceptibility maps needs a lot of improvement.

1. Are these up to international standards?

   See above.

2. Are the scientific methods and assumptions valid and outlined clearly?

   Partially. The used model for the creation of the landslide susceptibility map and the agent-based traffic model is explained well, but the interaction of both of them is not.

3. Are the results sufficient to support the interpretations and the conclusions?

   No. What was done was a simple traffic simulation, which does not indicate the vulnerability of the road network to landslides. This link is missing in the current version.

4. Does the author reach substantial conclusions?

   No. at the beginning of the paper an "... agent-based vulnerability assessment of rural road networks ..." was promised, but it ended up in a simple traffic simulation. No conclusions about the actual vulnerability were made.

5. Is the description of the data used, the methods used, the experiments and calculations made, and the results obtained sufficiently complete and accurate to allow their reproduction by fellow scientists (traceability of results)?

   Yes. The authors put emphasis on open source data and open source software. However, I would like to encourage the authors also to publish their code, so that fellow scientists actually can reproduce their results.

6. Does the title clearly and unambiguously reflect the contents of the paper?

   No. The title indicates a vulnerability assessment, which was not done.

7. Does the abstract provide a concise, complete and unambiguous summary of the work done and the results obtained?

   No. The abstract indicates topics which are not treated at all in the paper e.g. "The focus of this case study is on resilience issues and support for decision making in the context of a large-scale sectoral approach."

8. Are the title and the abstract pertinent, and easy to understand to a wide and diversified audience?

   See above, both have to be adapted!

9. Are mathematical formulae, symbols, abbreviations and units correctly defined and used? If the formulae, symbols or abbreviations are numerous, are there tables or appendixes listing them?

   No mathematical formulae, symbols, abbreviations were used in this paper.

10. Is the size, quality and readability of each figure adequate to the type and quantity of data presented?

    Partially. The content of the figures can be enhanced so that the reader gets more information about the investigated area (see point 4).

11. Does the author give proper credit to previous and/or related work, and does he/she indicate clearly his/her own contribution?

    Yes.

12. Are the number and quality of the references appropriate?

    Yes. The authors have done an extended literature review.

13. Are the references accessible by fellow scientists?

    Yes.

14. Is the overall presentation well structured, clear and easy to understand by a wide and general audience?

    The structure of the paper is okay, but the content has to be improved.

15. Is the length of the paper adequate, too long or too short?

For reading the length of the paper is okay, however, it could be shortened (see below).

1. Is there any part of the paper (title, abstract, main text, formulae, symbols, figures and their captions, tables, list of references, appendixes) that needs to be clarified, reduced, added, combined, or eliminated?

   As indicated in comment 5, the authors stated that "The official hazard map already provides a reasonably accurate and consistent basis for the purpose of identifying vulnerable sections." This raises the question why a new set of susceptibility maps had been created? Using the existing ones would reduce 4 pages, which can be used to describe in more detail how a researcher can come from a susceptibility map to a damaged road intersection.

   As mentioned in comment 7, the use of a 10% traffic scenario is not necessary at all and can be removed from the paper, since the results are given for the more accurate 30% traffic scenario anyway.

2. Is the technical language precise and understandable by fellow scientists?

   To avoid misunderstanding the authors should state their (used) definition of vulnerability at the beginning of the paper. Also, they should use a consistent (and approved) terminology for risk, resilience, vulnerability, consequences, ...

3. Is the English language of good quality, fluent, simple and easy to read and understand by a wide and diversified audience?

   n/a

4. Is the amount and quality of supplementary material (if any) appropriate?

   n/a

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