

Interactive comment on “Multi-hazard risk assessment for roads: Probabilistic versus deterministic approaches” by Stefan Oberndorfer et al.

Anonymous Referee #1

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General comments:

The paper describes a comprehensive study for 3 main types of risk: risk for persons, property risk and risk for operational availability for mountain hazards (encompassing hydrological hazards, geological hazards and snow avalanches). The paper addresses relevant technical questions within the scope of NHES. It contains new information about uncertainty of variables used for input to risk assessment for roads to alpine hazards as well as application of probabilistic approaches within transport risk assessment. The methods are clearly described and based on risk equations according to ASTRA (2012) guideline. However, some of the assumptions within the paper

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would need more justification (e.g. choice of uncertainty bands for input parameters in risk calculation, i.e. why are upper and lower bands of the input parameters a good approach and where do the applied values for upper and lower bands come from?). The conclusion that the deterministic approach underestimates the risk compared to the probabilistic approach in this study is quite surprising, my experience is that use of deterministic approaches tend to overestimate the risk. The conclusion should be discussed and justified. The abstract contains some unprecise information and some clarifications are suggested. Some of the content should be better structured, to highlight the main contribution of the article and potential applications of the results.

Specific comments:

Suggestion: Extend the start of the introduction; line 25-32. Identify and describe the gaps that this paper is addressing. Introduce a new main section called Background; containing the subsections "Multi-hazard risk assessment", "Deterministic risk concept", "Uncertainties within risk assessment" and "Deterministic vs. probabilistic risk". Include/Move the "Objective" subsection before the suggested "Background section".

Line 12-13: "Due to a variety of variables and data needed for risk computation, a considerable degree of epistemic uncertainty results." : Please clarify this sentence. Why do the need for a variety of variables and data lead to epistemic uncertainty?

Line 14-16: "To overcome this gap, we used a probabilistic approach to express the potential bandwidth of input data with two different distribution functions, taking a mountain road in the Eastern European Alps as case study." a) A bit unprecise formulation, I think. A Probabilistic approach is applied to analyse how the uncertainty in the input data affects the result. The uncertainty in the input data is expressed with a potential band width and two different distribution functions. b) It should also be specified, in general terms for which type of input data uncertainty is included (e.g. exposure, vulnerability and monetary values) and for which they are not included (e.g. hazard

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intensities).

Line 16-18: " The risk assessment included the damage potential of road infrastructure and traffic exposed to a multi-hazard environment (torrent processes, snow avalanches, rock fall). : Refer to terms used later in document: Risk for persons, Property risk and Risk for operational availability

Line 21-22: "The results demonstrate that with common deterministic approaches risk is underestimated in comparison to a probabilistic risk modelling setup, mainly due to epistemic uncertainties of the input data." : This conclusion is very surprising. It should be clear that this is only valid for the current study and not generally valid when comparing deterministic and probabilistic results. Usually, conservative values for the input parameters are applied in a deterministic approach to account for the uncertainties – and to provide conservative results. Alternatively, the expected value of the input parameters could be used and the results from the deterministic approach would give the expected value from the probabilistic approach. The validity and explanations for this conclusion should be discussed in the paper.

Line 22-23: "The study provides added value to further develop standardized road safety guidelines and may therefore be of particular importance for road authorities and political decision-makers. : Include in the discussion some thoughts on the application of the results, e.g. how could information about uncertainty in the results be applied within future work to improve the current road safety guidelines.

Line 32: "In contrast, there is still a gap in multi-hazard risk assessments for road infrastructure." a) In which way is this paper also addressing this gap? b) I suggest also to include some introducing text, identifying gaps regarding treatment of uncertainty, to motivate for the coming sub-sections on the topic c) Are there special challenges regarding uncertainties for multi-hazard assessment?

Line 151-159 "Objective" a) The content of the "Objective" subsection should address the scope of the study, referring to the identified gaps described in the introduction, i.e.

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both related to multi hazard assessment and treatment of uncertainties. b) Include: is the multi-hazard risk method in this paper a spatially oriented and a thematically-defined method.

Line 217-219: "Due to the catchment characteristics of the torrents two different indicator processes were assigned for assessing the hazard effect, depending on the two occurrence intervals. Therefore, the occurrence interval served as a proxy for the process type." : I didn't understand this. Could you please clarify/give an example?

Line 213- 224: : Should some of the content be moved to the description of the case study area?

Line 301-302: "These values were either defined from statistical data, expert judgement or from existing literature." : As these values are important for the results; some more documentation on how they were chosen or found should be included, i.e which statistics, literature is applied – or what is the reasoning behind the expert judgment.

Line 335 -337: " In reality, risk parameters commonly have a natural boundary. Therefore, estimating min/max values instead of standard deviation is more realistic or feasible as there is in most cases no data available to express the mean variation. : Justify the use of natural boundaries in this context and what the natural boundaries of risk parameters could be; f.ex. Vulnerability is always between 0 and 1. However; why would there be other natural upper boundaries than 1 in vulnerability; for specific intensities?

Appendix: Tables A6 – A9 : Explain symbols for non-SI units (d, y, n, etc.)

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