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Natural Hazards and Earth System Sciences Discussions

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

Anonymous Referee #2

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1 General comments

The paper compares the results of a deterministic and a probabilistic risk analysis. Input data and parameters of risk analyses are subject to uncertainties mainly due to an insufficient data basis. A sufficient data basis (e.g. lethality values for road accidents due to natural hazards) would allow the derivation of robust data. As such, the paper addresses an important issue because the uncertainties of input data considerably affect the final result of risk analyses, which are often the basis for decisions on the realization of mitigation measures. Practitioners are aware of this issue but have often no explicit numbers at their disposal. Dealing with uncertainties in decisions in practice is an issue under continuing discussion; this paper therefore delivers a valuable contribution to this topic.

The applied method bases on guidelines, tools and papers published some years ago. However, all of them are still in operational use – partly with adaptations –, so the results of this paper refer to actual knowledge and are a valuable contribution to the improvement of these methods and tools.

The topic fits well into the scope of NHESS since it combines scientific research with its application in practice.

The paper is well written, but would benefit from linguistic improvements.

In my opinion, some aspects are not fully clear and could be better explained. Therefore, the paper needs revisions before publication. Some recommendations are given below.

2 Specific comments

2.1 Multi-hazard risk assessment

The section of multi-hazard risk assessment is very short and therefore only addresses some aspects of this complex topic. I would have expected that this section would show more clearly where are the main gaps and how this paper addresses these gaps. The last sentence targets the difference of results of deterministic vs probabilistic approaches and would therefore fit better in one of the following paragraphs.

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Discussion paper

2.2 Deterministic risk concept

In the paragraph lines 75–83 please explain the inconsistencies you mention (line 79–80). What means inconsistent in this context?

You are right that papers quantifying uncertainties are underrepresented and you cite a paper from 2006. However, meanwhile there are probably much more available. To name only a few, which come to my mind (may be only to show what's missing):

- Rheinberger, C.M., Bründl, M. and Rhyner, J. (2009) Dealing with the White Death: Avalanche Risk Management for Traffic Routes. Risk Analysis 29(1), 76-94.
- Schaub, Y. and Bründl, M. (2010) Zur Sensitivität der Risikoberechnung und Massnahmenbewertung von Naturgefahren. Schweizerische Zeitschrift für das Forstwesen 161(2), 27-35.
- Bründl, M. (2012) EconoMe-Develop - a software tool for assessing natural hazard risk and economic optimisation of mitigation measures. International Snow Science Workshop ISSW, Anchorage, Alaska, pp. 639-643.

If you have done an extensive search on this aspect, it's ok; otherwise I would appreciate to see some papers on uncertainty assessment cited.

2.3 Deterministic vs. probabilistic risk

I think, in this section different aspects are discussed, which are not necessarily related to a comparison of deterministic vs probabilistic approaches. I suggest to structure it more clearer. You write in line 126 "...a defined value (point value) for probability ...".

In my experience, return period intervals, e.g. for a 1 on 10 - 30 years event, are used. Are these point values?

In line 127–129 you write that risk from multiple risks are summed up, which result in an expected average loss. Despite that the term “individual risk” is usually used for the risk an individual person is exposed to (below or above a threshold), this depends how risk is depicted from different processes. Risk can be depicted for each of the processes and for each of the return period intervals (if we speak of return period, which is not the case for non-returning processes such as rockfall). Also the next topic in the bullet point list (“high probability-low consequence . . . ”) is not necessarily a topic of a deterministic vs. a probabilistic approach but of weighting, which is known as risk aversion affect (which is controversially discussed especially in the natural hazard community). In the third bullet point, the term “Value at Risk” is mentioned, which should be better explained. Overall, I have the impression that different aspect are mixed and could be structured better.

In **table 1** some things are unclear to me:

First row: you write that in a probabilistic assessment of risk one number for the probability of occurrence is required. Deriving the probability of occurrence as part of the hazard analysis is a very critical for a risk analysis if not the most important. In my opinion, the largest uncertainty is probably here (see Schaub and Bründl, 2010, citation above) and a probabilistic method should therefore also handle the uncertainty of the probability of occurrence in order to be really probabilistic. May be you could mention this somewhere in the introduction; its mentioned at the end of the conclusion section.

Second row: Mathematical addition in deterministic method: this depends how you aggregate and depict the risks. It is not necessarily the way you describe it here. Upper and lower boundaries are possible.

Third row: To my knowledge, the result of a risk analysis is risk, expressed either in monetary terms per time unit, e.g. Euro per year or number of fatalities or injured persons per year. If you differentiate different scenarios, e.g. occurrence probability 0.1, 0.033, etc., you'll get several numbers, which however can be added following conventions (e.g. cumulative-complementary probability).

In **figure 1** the differences between probabilistic and deterministic approach does not become clear to me. The way, risk is calculated is the same, but for the probabilistic approach with a distribution of a parameter, whereas in a deterministic approach, a single parameter is used. This is not clearly shown in the graph. Instead of "Process specific risk classes" you could name the column processes and process areas. What does not come out, how risk from individual process areas are handled (added). In the upper left graph (PDF) the unit "kEuro" for impact represents "risk", right? Then the unit should be "kEuro/year". See also comments below.

2.4 Hazard analysis (section 3.1)

In line 189 you probably mean by "potential hazards" potential release areas which serve as input for the numerical simulation. In line 201, I suggest to replace "expression" by "extent".

In the lines 217–219 it's not clear to me what you want to say. I suggest to rephrase these sentences. In line 223, you might want to replace "west district" by "western part".

2.5 Standard guideline for risk assessment (section 3.2)

I suggest to explain somewhere how you separate the object of risk affected by one or several processes in the different scenarios. What are the objects? Road sections affected by one single hazard?

In the lines 254–255 you describe the monetization of fatalities. Please briefly mention the approach (I assume by "value of statistical life (VSL)") and the value. Although it can be found in the annex, it would be helpful here.

In the lines 257–259 you give the link to the equations how risk is calculated. Please carefully check the equations for the correct denominations, especially calculation of collective vs. individual risk (see comment below).

2.6 Results and Discussion

I have some problems interpreting the results. Experiences in practice indicate that risk is overestimated compared to real-case events with accidents. In your study you show that deterministic risk analysis underestimates the risk compared to the probabilistic analysis. For me, it becomes not clear why this is the case. The reason could be that the standard value of an input parameter is much too low and the "real" distribution of this input parameter is left skewed (median values are higher than the mean values). But how you know the right distribution?

What would be helpful for the reader is to better explain the meaning of "Value At Risk" (see comment above). Choosing a higher Value-At-Risk-Level (in this case 95% non-exceedance probability) would mean a higher safety level. May be you could write some words more about this concept.

In Figure 3, Table 3, Figure 4 and 5, I see some inconsistencies regarding the units (see also comment above). All numbers which depict risk should must have the unit k per year, so deterministic risk (clearer than "result") and also the "Value At Risk". In Figure 4 and Table 3 I suggest to use the same description of processes. In Table 3 percentages should sum up to 100% (or least close to, which is a problem of rounding of numbers).

As mentioned above, the right-skew in Figure 4 is not clear in relation to the distribution of the input parameters.

For figure 5, I suggest the same scale for both x-axes so that results can be better compared.

At the end of this section, you discuss some consequences of your work for practice. It might be helpful to discuss the consequences of dealing with these uncertainties for practice. Discussions with risk experts reveal that they are aware of uncertainties in input parameters, but it is often not clear how to deal with these results, when uncertainties are explicitly assessed? Communication in practice is very critical in this respect especially to end users such as stakeholders in authorities and communities. What would this mean in regard to the allocation of public money for mitigation measures? Following your argumentation, we could argue that societies in most countries spend too less money for mitigation measures. I think it would be worth to say that your result are the consequences of the chosen distribution of the input values (e.g. upper bounds determined by experts). May be you can add some sentences addressing these aspects.

3 Technical corrections

- Line 43: reference to table 2 does not fit here; Please check the order of the table and their numbering.
- Line 186: "The hazard analysis was conducted in technical studies" → "The hazard analysis was part of technical studies"
- Appendix: Please carefully check the equations for the correct denominations, especially calculation of collective vs. individual risk, e.g. Table A1: If you calculate the risk of a person i in scenario j, this would the individual risk; therefore

N_P in equation 1A would be 1.

- Table A4: would is the meaning of l in equation 4A?
- Equation 5A: you probably mean p_j instead of p_i?
- Table A7: I suggest to use the correction term for C_P: it is the value of statistical life (VSL) (?).
- Table A9: variable $C_{Rb,W}$ = expenses?

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