**Natural Hazards
and Earth System
Sciences**

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Discussions

Interactive comment on "Dynamic risk simulation to assess risk along roads" *by* J. Voumard et al.

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Thank you for your comments, an answer to all comments is given below. Questions or remarks are in bold, whereas answers are normal police.

I feel the paper would benefit from making stronger links and greater reference to the existing body of research within the transportation literature. Indeed, dynamic modelling of traffic flow is not a new idea in itself. Moreover, dynamic traffic simulators have been used for other natural hazards such as hurricanes and earthquakes. By discussing and explaining what has already been done, this creates a stronger case for what you are doing (as there is relatively little literature looking at the interactions of mass movements and transport networks).

Ok, I try to balance more the transport literature relative to the natural hazard literature.

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Interactive Discussion

Discussion Paper

About 10 new references about transport literature were added. The added transport literature shows a large part of what has already been done in the natural hazards and transport field.

(i) It would be difficult to replicate the experiment with the information supplied in the paper. It would be useful to have a table of the speed, visibility and kinematics parameter values (visible in box 2 of Figure 2), along with sources of information. (ii) This also makes it difficult to judge how easy it would be to apply the model to different locations without detailed traffic surveys. What I would really like to know is if generally applicable parameters could be derived based on road geometry features (for example, road x is this sinuous, so decision sight distance will be y etc., thus dynamic risk on this section will be z). (iii) I would have thought some of these parameters could be generalized from the transportation literature. I think this would make this research very useful for practitioners to incorporate into existing models.

(i) Chapter 3.3 was completed with explanations about the parameters used in the simulations. Two new tables were created to show the values of the parameters used in the simulations. There is now enough information to replicate the experiments. (ii) Text paragraph was added at the end of chapter 3.3 Numerical setups about how difficult it is to obtain traffic and kinematic parameters and road geometry and what are the ways to obtain it (in situ measurements, measurements from a satellite image, information from the literature and experience from people knowing the studied road section). When it is difficult or impossible to obtain enough precise traffic data, we try to estimate the unknown values with examples of well-known similar roads sections, in a similar region. But data from the Alps could not be exported directly to Himalayan roads for instance. Usually some kind of information exists for most of important transport corridor in mountain region. (iii) Like point (ii), some explanations about the parameters obtaining are given now in chapter 3.3 Numerical setups. We did not find in the transport literature generalized data that could be used directly everywhere. Roads quality,

traffic and vehicles can be quite different in the Alps, Andes or Himalaya. Nevertheless, we can expect that parameters for the Alps will quite similar to those for other European mountain ranges.

The title is somewhat ambiguous as it does not mention what kind of risk along roads. The fact that this is risk of rockfalls and/or landslides needs to be mentioned here. I would suggest something like "Dynamic traffic simulation to assess rockfall risk along mountain roads"

Yes, it was not clear in the paper if the method is only for rockfalls or for natural hazards in general. As the methods can be used for many types of natural hazards (rockfalls, landslides, roads collaps, debris flows, . . .) we redefined more clearly the scope of the method to natural hazards (and not only to rockfalls). Then the title was changed to "Dynamic risk simulation to assess natural hazards risk along roads "

The introduction has some technical terms which could do with further explanation to ensure good understanding for readers from both the hazards and transportation research fields. Particularly paragraph 1 of the introduction.

Few technical terms are now better defined to ensure an enough understanding for readers of the two domains e.g. microscopic and macroscopic traffic simulator in chapter 2.1 Dynamic traffic simulator.

i) Throughout the introduction, the focus of application seems to be on rockfall modelling, but throughout the methodology and results, the authors more generally refer to "hazards" rather than specifically mass movements. I would recommend either talking more generally about mountain hazards in the introduction or giving more detail on rockfall modelling throughout the methodology, and ensuring there is consistency and linkages between sections. ii) The introduction quickly jumps to talking about various scales of rockfall hazard modelling – I am not totally clear on the relevance of this. iii) The first two sentences of section 2.2 (lines 20 to 23, page 1290) are strong, and I would encourage the authors to

use this in the introduction to make it really clear from the outset why this work is important. iv) It would also be good to devote a couple of sentences to the basics of how rockfall models work. v) Make clear how rockfall and landslide are being defined (there are various definitions).

(i) Yes, your're right. We decided to talk more generally about mountain hazards. The introduction focus was slightly changed towards natural hazards in general and not only about rockfalls. (ii) Yes, your're right. A paragraph talking about various scales of rockfall hazard modelling was deleted, it made no sense to keep it. (iii) OK. The important sentences of section 2.2 are now used in the introduction too. (iv) As the paper focus now on natural hazards and not only about rockfall, I do not believe that it is relevant to devote a couple a sentences to the basics of how rockfall model works. The thematic of the paper is the simulation of traffic within natural hazards and not about rockfall modelling. Thereby, we propose not to add extra information about rockfall modelling. (v) Definitions of landslide and rockfall are now given in the introduction.

On page 1292, lines 22 to 24, it is implied that the most dangerous portions of the road co-occur in the most sinuous sections of road. Potentially, there could be a straight (ergo, fast) section of road that is also high risk, but drivers spend less time in due to higher speeds. For this reason, it would be interesting to see how the dynamic risk compares to static risk when looking over a wider road section (e.g., with different sections of sinuous road, straight road etc.). I wonder if over a larger region, the values average out to the static risk. Please put something acknowledging this variability in the paper.

The best scale of this microscopic traffic simulator is up to few kilometres to analyse in details the risk on a hazardous road section. It's right that taking a regional scale will average the results and that the dynamic risk results will be averaged. The effects of an increase of risk will be less observed at a regional scale than at a local one. Presently the simulator is designed to work on relatively short section and we think that its main interest is to analyse a short road section and to see if e.g. to place traffic lights on that

site will increase the risk to a high level. A comment on this point has been added in chapter 5.3 Recommendations.

Please put more quantitative information in the abstract, for data/model used and for the results.

The abstract contains now more information about the data used in the simulator for the three scenarios (vehicle speed, number of vehicles, road sections geometry).

Might it be appropriate to add in supplementary material (e.g., more extensive model results)?

We add some graphs to better illustrate the simulations results (e.g. road sections geometry, traffic lights phases and images of vehicle tailback stopped in front of a natural hazard or a traffic light).

The authors may want to consider using the term "vehicle tailbacks" or "traffic tailbacks" rather than "vehicle columns". This is more commonly used in the literature and intuitive for non-experts.

The terms "column" have been replaced by "tailback" in the paper.

There are a number of cases where the authors use the plural "vehicles" when "vehicle" would be more appropriate (and vice versa). For instance, p.1286 line 7, p.1288 line 12.

The 167 times where vehicle is written were analysed. Numerous cases were changed.

It would be useful to introduce Table 1 (listing parameters) before the equations are introduced, for example at p.1287 line 23. Please ensure that 'all' variables in the paper are in the table of variables used (such as H, Expi, V, W, X and Dk).

Now referred in p. 1287, line 23. H, Expi, V, W and X variables added in the Table 1. Dk variable not found in text.

I am not exactly clear on why the conversion factor f is used to convert [km m-1] to [m day-1]. I cannot see any other variables with the units [m day-1].

An explanation was added in chapter 2.2 Static risk calculation; before the static risk calculation was explain in 1. Introduction. The conversion factor is to simplify Nv equation (Eq. 3) to obtain a number of vehicles as unit.

On page 1288, line 16, should Expi[full stop] be Expi [multiplication symbol]? If not, perhaps Expi should go in brackets so this is clear (i.e., "Nv represents the sum of exposures (Expi).").

Yes, you are right! Exposure in bracket. Corrected.

Please try to avoid one sentence paragraphs (e.g., p. 1290).

Short paragraph in page 1290 regrouped with another one.

In equation 7, I am unclear on what σ represents

There is no sigma in the original equation 7. It's a conversion problem from Word document to NHESS document. Figure 1 (in this document "Answer to reviewer 1") is the jpeg image of the equation in the Word original document and figure 2 (in this document "Answer to reviewer 1") is the jpeg image of the equation in the NHESS document.

Please ensure consistency in equations. Equation 7 has multiplication symbols [.] between all variables apart from $\sigma\beta$.

Same as before: transcription problem between Word document and NHESS document. Figure 3 (in this document "Answer to reviewer 1") is the jpeg image of the equation in the Word original document and figure 4 (in this document "Answer to reviewer 1") is the jpeg image of the equation in the NHESS document.

Please ensure consistency in units. For example, year is referred to as year and yr (page 1287, line 26). Also "per" is sometimes /year, other times yr-1.

Same as before: transcription problem between Word document and NHESS document. Figure 5 (in this document "Answer to reviewer 1") is the jpeg image of the unit in the Word original document and figure 6 (in this document "Answer to reviewer 1") is the jpeg image of the unit in the NHESS document

We also replace every year with "yr" and X/year with " X yr-1 ".

In section 3.3, line 24, further clarification of what the Vaud Canton (referenced as Canton Vaud) and FEDRO actually are is required.

Now: better definition of Vaud Canton and Fedro.

In section 5.1, there are two sentences that could do with clarification. These are page 1295, line 24 to 26 and page 1296 line 19 to 20.

The 2 sentences in paragraph 5.1 have been reformulated.

In Table 1, the word "appellation" is used in the table header. This does not really translate. Perhaps "Description" would be better.

Complete appellation replaced by "Description" in table 1.

In Figures 5 and 6, the small rectangle (which I assume is a rockfall) needs to be added to the legends.

Add of rockfall and traffic lights legend on figure 5 and of rockfall, traffic lights, hazardous area and vehicles on figure 6.

In Figure 7, the y axis should be labelled as "Percentage" (not pourcentage).

Y axis labelled now with "Percentage . . ." instead of pourcentage.

The full URL for websites should be given. For example, references 2 and 3 in the reference list are reports accessible at http://www.planat.ch/ which is the landing page – for the reader, it would be useful to know which section of the website these reports are located at.

Full URL are now given in the bibliography.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 1285, 2013.

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$$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \boxed{\lambda} \cdot \beta = F_e \cdot P_s \cdot \frac{t_{cum}}{t_{sim}} \cdot \boxed{\lambda} \cdot \beta \qquad (7)$$

Fig. 1.

$$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \boxed{\sigma} \beta = F_e \cdot P_s \cdot \frac{t_{cum}}{t_{sim}} \cdot \boxed{\sigma} \cdot \beta \qquad (7)$$

Fig. 2.

$$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \boxed{\lambda \cdot \beta} = F_e \cdot P_s \cdot \frac{t_{cum}}{t_{sim}} \cdot \lambda \cdot \beta \qquad (7)$$

Fig. 3.

$$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \boxed{\sigma\beta} = F_e \cdot P_s \cdot \frac{t_{cum}}{t_{sim}} \cdot \sigma \cdot \beta \qquad (7)$$

Fig. 4.

61   Where R is the risk $\left[\frac{dead}{year}\right]$ or $\left[\frac{\$}{year}\right]$ with n objects, H is the hazard $\left[\frac{1}{year}\right]$, Exp_i is the

62   object exposure, i.e. the probability that vehicle is hit in the hazardous area $[-]$, V is the

63   object vulnerability $[-]$ and W is the potential total loss of persons or costs: $[dead]$ or $[\$]$.

64   Based on Eq. (1), the object risk equation on a road modified from Fell (2005) and Bründl

65   (2009) is calculated with:

66    $$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \lambda \cdot \beta \quad\quad\quad\quad\quad (2)$$

67   Where R_{ob} is the object risk $\left[\frac{dead}{year}\right]$, F_e is the occurrence frequency of an event $\left[\frac{1}{year}\right]$, P_s is

Fig. 5.

where R is the risk [dead/year] or [\$ yr^{-1}] with n objects, H is the hazard [1 yr^{-1}], Exp$_i$ is the object exposure, i.e. the probability that vehicle is hit in the hazardous area [–],

1287

V is the object vulnerability [–] and W is the potential total loss of persons or costs: [dead] or [\$].

Based on Eq. (1), the object risk equation on a road modified from Fell (2005) and Bründl (2009) is calculated with:

$$R_{ob} = F_e \cdot P_s \cdot N_v \cdot \lambda \cdot \beta \qquad (2)$$

where R_{ob} is the object risk [dead/year], F_e is the occurrence frequency of an event [1 yr^{-1}], P_s is the proportion of the hazardous section which is destroyed when a hazard

Fig. 6.