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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Integrated risk assessment due to slope instabilities at the roadway network of Gipuzkoa, Basque Country" *by* O. Mavrouli et al.

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Q1. The paper presents a model of evaluation of multirisk in selected points of the route network of the roadway network of Gipuzkoa, Basque Country. The model tries to quantify risks in four scenarios pertaining to about 100 already detected point of risk. The tran formation of the inhomogeneous and scarce data in a quantitative score is made up with criteria driven by the judgement and on the basis of the historical available data about instability on the roadway network. So the model is a heuristic one, currently not yet validate. The paper is well articulated and developed, but generates some perplexity.

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Discussion paper

A1 The authors would like to thank Reviewer 3 for the comments that helped us to improve the quality of the manuscript. Please check also our comments to Reviewers 1 and 2. As also we responded to the comments of Reviewer 1 and 2, we would like to emphasise that our approach, except for the risk related to see walls is not heuristic, instead it is based on analogs and proportionalities for calculating the probability of occurrence of the events of a given magnitude/intensity which is assessed based on quantitative data, as most of the procedures for risk assessment are based on analogs.

Q2. First of all, the referee #3 agree with all the specific comments on the submitted paper from referees #1 and 2. One main concern is about the use of the velocity concept in several part of the text and particularly in the section about the slow landslides. Although velocity is widely adopted in many landslide classification systems, it is well known (from Physics) that in a force system the velocity of a rigid body mass is not representative of its equilibrium or disequilibrium state, which is demanded to the first derivative or gradient of the velocity vs time. About the classification and risk management of the "slow landslides", the main references to this kind of landslide are the monthly slope deformation (periodically measured in inclinometers) andthe one year cumulate displacements. So the Authors indirectly and correctly use the terms that contribute to the velocity vs time gradient (the acceleration).

A2. We use two criteria, the maximum monthly horizontal displacement rate and the annual cumulative horizontal displacement. The reason for using the monthly velocity (displacement rate) here is not to indicate the slope equilibrium or disequilibrium state, but to provide a measurement of the stresses and strains induced to the road due to the landslide movement, and to associate this movement with a certain extent of damage. Higher displacement rates (irrespectively of the landslide being in a dynamic equilibrium or not) induce larger actions on the road and cause higher damage. The probability of a given landslide intensity, based on displacement rate and the cumulative displacement is based on observations of the inclinometers and not on a geotechnical analysis providing results on the equilibrium/disequilibrium state.

Q3. Some points are not clear or instill some doubts: We start with the consideration that number and position of the available instruments in each site are well positioned and representative of the deformative field of the whole landslide body; are the deformation readings in the inclinometers constantly and regularly (which is the frequency) performed? Do the deformations of the inclinometer allow durability of the measures? Bigger movements are usually at the head, but do we analyze the correct one phenomenology, i.e. a shallow instead of a most dangerous and deeper incoming failure? Finally: measurements normally refer to a pre-peak failure stage: the post peak behaviour with the typical range of strength reduction (and then the hazard magnitude) is strongly controlled by the dominant lithology, which has been missed throughout the decisional points of the whole proposed model. Lithology and soil plasticity are common factors in many heuristic hazard models. Similar consideration should be extended to short term vs long term groundwater variations.

A3. We would like to thank the reviewer for these comments. The selected inclinometers to measure the data used here are in most cases placed in the vicinity of the road, with a few exceptions. Local accelerations, if any, in areas not monitored by the inclinometers are indeed not captured. However it is not always the case that those local movements affect the roads, and thus of interest. After 2010, deformation readings are constantly taken, every 3 months. As some inclinometers are functioning about 15 years now, there have been some gaps in measurements, but before 2011 (mostly in 2008-2009). Indeed, some inclinometers become inoperative after suffering large deformations. The proposed procedure takes this into account through the criterion of annual cumulative horizontal displacement. The slow-moving landslides in the area are well identified and geological and geotechnical studies have been performed, for the identification of the fracture/sliding surface and the back analysis of the stability, at least in most cases. As mentioned in the text, in the area there are clay materials with a viscous behaviour. Inclinometers in principle are deeper that the identified sliding surfaces. There are exceptional suspicions for deeper sliding surfaces not monitored. . As mentioned in section 3.3, the relation between the inclinometer indications and the road damage was established for 24 points, out of which 20 yield consistent predictions (coherent results between movement rate and damage), only one presented damage overestimation and 3 presented damage underestimation (out of which one inclinometer was identified to have low reliability). The afore-mentioned indicate a high rate of consistency of inclinometers with the damage. In exceptional cases, further geotechnical studies would have to be performed to provide us with new data for the risk calculation. In any case, the authors agree that the inclinometer measurement related uncertainties that the Reviewer mentions might be present, and they point this out in the discussion session. However, despite uncertainties, the focus here has been on the identification of patterns of movements, especially during and after the critical 2011 and 2013 events, trying to see the potential of each landslide for a given intensity (displacement rate), instead of measuring movements with precisión, and this has been possible.

Q4. The model has been applied to a system spatially extended for about 10.000 sq kilo- metres and developing several hundreds of kilometres (see fig.1), whose health and wellness rely on a limited number of instrumentations and on periodical inspections; it is characterized by several geological frames and by a well-developed surface hydrography. The local control apparatus is aged about 16 years and does not allow real time measurements in spite of its expensiveness. In other words, the monitoring system installed and which is the main source of data on which the proposed model works can be considered somewhat obsolete. Today the large areas can be controlled by means of active or passive PS INSAR techniques (measurement return time about 6 days); inclinometers can be flanked by optical or capacitive TDR and other kind of devices able of continuous and real-time response. While the meticulous and complete care in the model deserves great appreciation, some perplexities already expressed, together with the considerations about the repeatability of the scenarios, significantly limit the usefulness of the model in future scenarios.

A4. The methodology was developed according to the available data in the area and an update of the monitoring systems was not part of this work. The Authors are well aware of the technologies and studies involving InSAR and DinSAR measurements for the calculation of the ground terrain movements on roads and certainly consider that these methods could be proved useful for future studies in the area.

Q5. Technical corrections In fig.6, Patterns of movement for landslides responsive and not responsive to rainfall, nowhere is reported a numerical scale (also indicative) of time

A5. The Figure was replaced and the scale was added.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-234/nhess-2018-234-AC3-supplement.pdf

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