Review of "Roads at risk – traffic detours from debris flows in southern Norway", NHESS, December 2014

Summary:

This paper is an excellent addition to the literature. It is well written and includes quality figures. It sets out a clear, repeatable and sound methodology, which I hope will be repeated and developed by others and applied to other locations to improve our understanding of landslide impact on road networks and I can clearly see how this methodology could be used to inform policy.

I believe that the majority of assumptions/simplifications are justified to perform analysis at the regional/national scale (although there are a couple of places which would benefit from slightly more detailed explanation of these simplifications). The majority of my comments are minor adjustments that I would like the authors to implement to improve the communication of this paper (bearing in mind that the paper spans two topics of landslides and graph theory and generally most readers will not have expertise in both!). I look forward to reading the revised article.

Medium level comments:

The introduction is generally strong and provides a good justification for the research. However, the authors state that "we are not aware of any analysis of the overall functional value of the road network in Norway" – although this is most likely the case, I think it is important to review papers on this topic from other countries. Although there are not many, a couple of examples that come to mind include:

Hearn, G. J., et al. "Landslide impacts on the road network of Lao PDR and the feasibility of implementing a slope management programme." *International conference on management of landslide hazard in the Asia-Pacific region, Sendai*. 2008.
Winter, M. G., Forbes Macgregor, and Lawrence Shackman. "Scottish road network landslides study summary report." (2005).

The Data section is a little too compact in places and could do with some further explanation: the authors discuss aggregating data to the first order catchment scale without really justifying why this is done/why it is appropriate. It would also be useful to know what kind of scale (e.g., in m^2 or km^2) these catchments are.

I found Figure 4 difficult to understand. For instance, not all lines have directional arrows, the multiplication boxes could be placed in between the factors that area actually being multiplied. It is also a little confusing that when looking from top to bottom, the excess distance is being calculated for the road network before we consider the likelihood of debris flows on a link. I think it would be useful to have some simple illustrations in this figure (e.g., a couple of catchments with different likelihoods of debris flow impacts, simple roads going through those catchments).

From both the perspective of a reader unfamiliar with graph theory and a reader who would like to use the methodology from an operational perspective, it is a little confusing to discuss and calculate excess distances before we have considered the likelihood of failure. For the non-expert reader, it would seem more intuitive to calculate a distance matrix, then "disrupt" the network with the debris flows and then calculate the next alternative shortest path. From an operational perspective, this seems like a lot of additional data to store (i.e., twenty alternative shortest paths between nodes) if certain links have 0 probability of failure.

I think the conversion from vehicle km to primary fuel cost is considerably more useful for decision makers (it recently came up at a conference that measuring landslide impact in term of economic value is rarely done, but is actually extremely important for justifying future research funding!). I would actually consider using this as the primary impact metric throughout the paper, rather than vehicle km, or at least emphasizing this point throughout (I acknowledge that you discuss difficulties in this due to fluctuations in fuel costs etc.).

It feels like quite a large assumption that if a debris flow occurs in a catchment that it will actually run out a long enough distance to reach the road? Does this assume that all roads are along the valley floors? Did you do any analysis to confirm this was the case (e.g., measuring at what distance up the slope road segments tend to occur)? I think this could do with some further explanation.

It would be interesting to have some discussion about the interaction between road building and debris flow susceptibility (e.g., drainage and accumulation of water, steepening of slopes for cut and fill road building). As the susceptibility map resolution is probably a slightly coarser spatial resolution than the road infrastructure, I assume this is not factored in, but possibly a key factor in debris flow triggering along the road network.

In the first paragraph of the discussion, the authors state that there is a higher observed failure rate than the computed value. The only reason they give for this is the short time period of the observed data. I think a few more sentences discussion are needed here. E.g., is it that some roads failure more often than the computed rate, but others fail less often? Could there be physical reasons behind this? What does this mean for someone trying to implement a tool like this operationally?

Minor level comments:

Figure 1. It would be useful to translate the road hierarchies into more general English terms (e.g., “Major roads”, “Minor roads” etc.). In the caption, it is not quite clear what the “traffic data” is (is this the shapefile of the road network or do the different colours correspond to different traffic volumes? – if so this is not clear).

Figure 2D needs to be a separate figure as it is not really a data input, but a result.

The authors do an excellent job of introducing the basics of graph theory and adjacency matrices. I think an example adjacency and distance matrix would really help to visualize this. This could possibly be included as a sub-figure within Figure 3.

I think Table 1 is excellent and really emphases the relevance of this research from an operational perspective. I think this could be slightly improved to aid visualization by using conditional formatting to make a clear distinction between low and high probabilities of failure (e.g., high = red cells, low = green cells). This would also make the distinction clearer between the lower left and upper right parts of the matrix which show different information.

Figure 7 needs a more standalone figure caption. It would also be useful to make clearer the towns of Lom and Skjolden as the origin and destination pair of nodes.

In Figure 8, it is difficult to see the overlaying lines (original route and alternative route). This would be easier to see if the background colour map was made more transparent (whilst retaining the origin and destination names as opaque).