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Interactive comment on “Estimating flood damage to railway infrastructure – the case study of the March River flood in 2006 at the Austrian Northern Railway” by P. Kellermann et al.

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General comments:

The paper by Kellermann, Schöbel, Kundela and Thieken analyses empirically the structural damage to railways caused by floods, and illustrates an original damage assessment model RAIL. This research is a valuable contribution to advancing the field of economic assessment of natural hazard risks. The model has some limitations which may be overcome by further research propelled by complementary empirical investigation. Yet the paper has merits which makes it worthy of being accepted for publication

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in NHESS journal. The RAIL model is built for (three) discrete damage categories (see also below) based on Moran et al. (2010) but otherwise the model is inspired by and comparable with stage-damage-curve (SDC) models with staircase damage function. Each damage category is assigned a single value of the (most likely) economic damage determined through expert judgements but compatible with the standard cost estimates of the railway company (i.e. Austrian Federal Railways, ÖBB). The damage is documented through visual interpretation of empirical photographic material collected in the aftermath of a flood. A statistical analysis links the damage categories with the simulated flood characteristics such as water depth and flow velocity, or their derivatives. In the paper, the RAIL model is tested and applied to (re)assess a past flood event, and used to estimate the expected annual damage for the entire railway track. The RAIL results are compared with the results of other conventional models (RAM and DSM, see the paper for more detail), demonstrating a better performance.

Specific comments:

[1] The RAIL model is applicable to track's cross-sections and leaves out other rail infrastructure elements. More importantly it distinguishes only three damage categories that are suitable, as the authors acknowledge, for 'fast and practical in-field damage assessments' (page 2634, para 2). Given the recent technological advances of the remotely piloted aircrafts (drone), one can reasonably expect that extensive photographic material can be collected and processed at rather modest costs. To exploit the full potential of these technological advancements, a more detailed categorisation of damage would be needed, similar to one in Koseki et al. (2012) for railways damage caused by earthquake.

[2] A critical point in the RAIL model development is the linking of determined damage with the (simulated) flood characteristics. The authors opted for matching flood grid to polygons obtained as buffers to linear, 100m-long rail segments that were previously assigned to a damage category. The ensuing non-parametric (Spearman's rank) correlations between aggregated flood characteristics and predetermined damage cat-

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egories are highest for flood depth (h) and Energy head (E) and 5m-wide polygon buffers. The authors however chose to use 10m-wide buffer polygons and discarded the better performing 5m-wide polygons as a result of 'technical consideration', not further explained. Arithmetic mean as an aggregation function of flood grid cells within the buffered rail segments outperformed the max values in terms of estimated correlations. I wonder whether grids with different resolutions would confirm the authors' choice. In principle, the highest structural damage to rail subsection determines the attribution of the rail segment to a damage category. Intuitively, this would mean that the max value of the aggregated flood grid cells for the relevant rail segment should be preferred to the arithmetic means. I would recommend analysing the correlations more in depth also using the flood grids with different resolutions, so as to determine whether or not the Spearman's rho is subjected to a bias resulting from the modifiable areal unit problem (MAUP).

[3] Another important point in the RAIL model is the estimation of thresholds in simulated flood characteristics used for determining the damage category. The authors opted for using the intersection points of Gaussian kernel density estimations (KDE) for different damage classes for this purpose. The KDE for the lowest damage class is determined by using only 3 observations. The relatively low correlations between chosen flood characteristics and the analysed damage classes result in overlapping kernel density estimates which casts a doubt about whether or not the definition of damage categories is the most suitable one. The need to re-calibrate the damage values for each of the three categories when applied for the 2006 March flood (see also the technical comments) may pinpoint to the fact that the threshold values are not representative enough.

[4] More in general terms, I was wondering whether the assumption of constant value for the total damage along the railway track really holds true (page 2640, para 2). Intuitively I would expect that beside the standard material, machinery and labour costs what matters is also the remoteness and accessibility of the damaged railway segment.

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Technical comments:

[5] The text on pages 2637 (para 2), 2642 (para 1) and 2643 (para 1) suggests that the initial damage values for each damage category (reported in Table 1) have been adjusted in Table 4 so as to better fit the reported damage in the aftermath of the March 2006 flood. In fact, however, the values reported in Table 1 and 4 are the same. In addition, the description of the table 1 does not fit the content of the table (only costs per segments and not per running meter are reported).

[6] The authors have chosen to consider values of Spearman's rho exceeding 0.5 as 'significant' (sic) ones. This is confusing as the statistically significant values are highlighted by the reported p values. Rather, the authors may use verbal description of the strength of the correlation (moderate or strong).

[7] Figure 3 should be improved as it is hardly readable in the current form.

[8] Although not important for the core of the paper, it was not very clear to me how the simulated 2006 flood could have been calibrated on the basis of the previous (1997 and 1999) floods (page 2635, para 1).

[9] It would be valuable to revise the text so as to make it easier to follow, and describe briefly the final structure of the RAIL model at the onset of the article. There are some typos in the text which I can pass to the authors directly.

References

Koseki, J., Koda, M., Matsuo, S., Takasaki, H. and Fujiwara, T.: Damage to railway earth structures and foundations caused by the 2011 off the Pacific Coast of Tohoku Earthquake, *Soils Found.*, 52(5), 872–889, doi:<http://dx.doi.org/10.1016/j.sandf.2012.11.009>, 2012. Moran, A., Thieken, A., Schöbel, A. and Rachoy, C.: Documentation of Flood Damage on Railway Infrastructure, in *Data and Mobility SE - 6*, vol. 81, edited by J. Düh, H. Hufnagl, E. Juritsch, R. Pfliegl, H.-K. Schimany, and H. Schönegger, pp. 61–70, Springer Berlin Heidelberg., 2010.

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