Response on Interactive comment by Anonymous Referee #1

Sajid Ali

First, we would like to thank you for evaluation and highlighting the deficiencies in the manuscript. It is indeed valuable addition and help us to improve our manuscript. Please find below our response to Referee's comments.

Comment: First of all, the structure of this manuscript seems clear but some parts are missing or not well-balanced. Almost eight out of ten article pages, i.e. 80% of the written text deal with introduction, situation and methodology. The most important parts of a scientific article, results and discussion, fit in only one article page. In fact, the discussion chapter is missing at all, although some statements are "hidden" in the chapter "accuracy statement" and in the conclusions. This structure needs to be changed, and most important, a well-balanced discussion of the results has to elaborated. Please review your text passages thoroughly and sort primary information, results and discussion and clarify what the model outcomes mean scientifically.

Response: We will elaborate the results with a well-balanced discussion. We will add a case study to make it clearer.

Introduction:

Comment: I would appreciate more references on conditioning and triggering factors, and these can be used in the discussion again. Already in the first chapter, the insecurity of AHP is announced (p.2, line 29), and a combination with qualitative approaches and the use of GIS is considered a better option for regional studies.

Response: We will add more references on conditioning and triggering factors.

General situation of the study area:

Comment: How significant is the value of average annual precipitation in a Monsoon climate, also with abrupt changes to semi-arid / arid conditions?

Response: A strong association between rainfall intensity and mass movements along the Highway has been found in our previous publication (Ali et al. 2017). Rainfall is responsible for debris slides, debris flows and mud flows along the highway. The section of highway passing through semi-arid/arid zones has comparatively less number of landslides than that of passing through monsoon zone. However, Raikot Section lies in semi-arid/arid zone but contains multiple landslides because of close proximity with active Raikot Fault.

Comment: Are there more precise rainfall data available or can more datasets be taken into account in order to reduce the error source? Please clarify, how the precipitation data is used for the model.

Response: I have only one data source that is Pakistan Meteorological Department so I could not consider other data sources. I interpolated rainfall data of six weather stations to generate raster rainfall map.

Geology along the KKH:

Comment: “Highly active landslide zones were identified from the distribution of existing landslides” – what about other zones which may have not been activated yet? Actually you do not know only based on the distribution of visible deposits how active a distinct zone is at the moment or at what certain frequency and what type of trigger is the main causing factor of the landslides. There might be lots of “old” deposits summing up to a higher total number of landslides in a rather “inactive” zone compared to a recently activated zone with less, but young landslides. Please clarify how you mapped and characterized the landslides in the field. An attribute table of the landslides would be very helpful and support the discussion.

Response: For space management, we only showed the geology of four important sections. We considered detailed geology of each part of the Highway. For landslides inventory preparation, we considered data from road clearance logs of Frontier Works Organization and Geological Survey of Pakistan’s publications. We have used record of landslides events of period 1982-82, 1996-2000 and 2014-16. Therefore, this landslide data gives an overview of 35 years.

Seismology:

Comment: The earthquake events in the region seem to be well-documented. How do you include these data in your hazard assessment? Especially the recent strong ones (e.g. the referenced in Oct 2005 or Oct 2015) could be used in a detailed case study. I would strongly recommend to do a detailed case study for at least one strong landslide event including lithology, seismology, conditioning and triggering factors. This would ideally fit your GIS-based mapping results. If not, this would also need to be discussed in detail.

Response: We used seismic intensities of the events (>6) for hazard assessment.

Thank you very much for your recommendation. We will include a case study in discussion chapter.

Geomorphologic factors:

Comment: How did you divide slope steepness into classes? I wonder on what criteria you based the data processing.

Response: Division of slope steepness into classes was based on statistical analysis. I tried different classes but found this division better in our study area.

Literature review:

Comment: Do you need this subsection? p.7, line 8: six weather stations along the highway: where are they (what climate?) and how does the rainfall influence your model? Please discuss, although (or because??) you classify the susceptibility levels based on active faults, seismic zones and steep slopes.

Response: We showed these weather stations with rainfall intensities in Fig. 1. We will make it visible in map and caption.

Field reconnaissance:

Comment: These data sets should be presented in more detail. A landslide inventory map with classification and indication of magnitude and/or frequency and a case study could improve this paper a lot. So far only the location (Fig. 1) and the number (72) of the mapped landslides are given. For instance, you could set up tables like the colleagues T. Stanley and D. Kirschbaum (2017) in their study on global landslide susceptibility mapping (Table 4 and Table 5).

Response: We will include landslide inventory map with types of failures. We think inventory map is better than table.

Remote sensing:

Comment: DEM-quality of 30x30 m2 and its influence on the results needs to be discussed, as several recent studies have shown that the DEM quality is crucial for modelling outcome. The accuracy of the land cover map of 87% needs to be discussed – is it a good or bad value compared to other studies?

Response: We will compare with previous land cover maps. We will discuss the limitations of data.

Weighted overlay method:

Comment: crucial part of this study. You should disclose the criteria.

In Table 2 the reader cannot follow your working procedure and how you chose the weighting factors.

Response: Firstly, we will explain Weighted overlay method more. Secondly, the procedure to weight the factors is based on pairwise comparisons to avoid biasness (Saaty 1987). It involves expert opinion and statistical analysis.

Results:

Comment: You need to explain the classification into four classes. What does a certain susceptibility level stand for? For this, table 3 could be developed in more detail (presence of active faults, seismic zones, steep slopes etc.).

Accuracy assessment: Please clarify, how the 72 landslide locations were used for validation. Only the location? What does the value of 72% tells us? Please discuss this outcome.

Response: We will explain classification and accuracy assessment.

Comment: Chapter discussion is missing!

Response: We will include a case study to make discussion chapter more understandable.

Conclusions:

Comment: Primary information, for instance the classification of landslides into rock-fall, debris slide etc., must be provided earlier in the results (landslide map, attribute table as suggested above). Furthermore, some interpretation is mixed in here (stable/quite stable parts of the highway). This interpretation and discussion is very important for the paper. You should lay out a new chapter, as indicated above, including limitations of analysis and sources of error.

Response: We will add an inventory map containing types of slope failures.

Table 4:

Comment: Please indicate the absolute values of area and number of landslides because this improves the transparency of your data processing. Why/ based on what criteria did you reduce the number of 9 susceptibility levels to 4 in your final map? Please clarify.

Response: We will indicate absolute values of area and observed landslides.

We converted 9 susceptibility levels into four equally with interval of two except *High Susceptibility* which contains susceptibility levels of 5, 6 and 7. We did so to distinguish the locations that are more hazardous.

Figure 1:

Comment: Please indicate subfigures a), b) and c) and legend. Too many (bold) lines in mid-zoom map.

Response: We will indicate and make lines light.

Figure 3:

Comment: Scale in W-E direction is missing.

Response: We will insert scale.

Figure 4b:

Comment: Why don't you also focus on the earthquake zone in the south of highlighted section a)? Not only lithology but also seismic situation should be considered here!

Response: We have considered seismic intensity of these events along with active faults (MMT) and lithology.

Figure 5:

Comment: Where is the highway? Please improve visibility.

Response: We will improve visibility.

Figure 6:

Comment: a) How would your model change, if you split the group of 31-45◦ again? Why do you show the group >65◦ and in subfigure d) the group 4000-4700m? Is the y-axis "landslide %" based on all 72 landslides? Please clarify. Please use these values in the suggested landslide map/attribute table (case study) and compare with other studies.

Response: We tried the interval of 10^{o} but results were random. We showed it because the elevation of the Highway is 4604 meters. No, this landslide% is not based on 72 landslides but on all landslides events of period 1982-82, 1996-2000 and 2014-16. We only used random 72 landslides from this data set for validation purpose.

Figure 10/11:

Comment: Captions of subfigures a), b) and c) are missing. One of these recent events might be suitable for a detailed case study.

Response: We will insert above-mentioned captions.