Reply for Anonymous Referee #2

Thank you very much for referee's sincere comments.
Authors corrected the pre-existing manuscript taking into account the comments. The corrected or additionally incorporated parts in the revised manuscript were underlined and red letters. For the specific comments from anonymous referee #2, authors' corrections are as follows:

Comment #1
Authors developed a simple method (but not limited to its current one) to assess debris flow hazard for expressway management. To my knowledge, this has never been tried in Korea and the method has limitations due to the wide coverage area and usage of available data throughout the whole expressway constructed in Korea.
Revision #1
Authors really appreciate reviewer's valuable and encouraging comments on our manuscript. Also, the original manuscript was corrected and improved considering the remarks and suggestions from reviewer acting as a referee. So in this response to reviewer comments, the revision of the original manuscript and point-by-point response were prepared. Author's corrections were described in the Revisions #1 to #2 presented below.

Comment #2

I agree with the first anonymous refree#1 regarding the scoring system. However, I would rather focus on the virtue of rapid decision making and wide coverage (or management system for the whole expressway system in Korea). I think the current method has permanent values that the GIS system is used for the expressway management system with the available dataset including rainfall intensity and the slope angle. The system has potential to be upgraded with more data accumulation and more case histories. I guess the scoring system itself would be updated with more case histories and dataset. I strongly recommend that the discussion on the current limitation of the system and how the program can be developed better with more precision. The current system might not be perfect but I, personally think that once the system is applied to the Korean expressway management system and the accumulation of data with upgrade of the scoring system, it can be a powerful tool.

Revision #2

Thank you for the valuable comments. The modifications on framework were considered for three testbed sites according to the clarification of attributes and grading standards. The grading standard was set using all existing data sets of each attribute, and calculating the maximum, minimum, and median values. In order to appropriately represent the differences between debris-flow occurrences and non-occurrences, modifications can be made on the assessment method. Therefore, to modify the grading standards, the average values of each attribute were calculated. When calculating the average values, sites that showed proper outcomes were not taken into consideration. Because the sites in interest were the ones that showed mixed results between occurrences and non-occurrences, only the ones that showed mixed results were considered in the average calculating process. After calculating the average values for each attribute for the occurrence and non-occurrence cases of the three target areas, the each attributes were compared. And a criterion for the grading standard was set based on logistic regression. Through various applications on different criteria, the one which indicated the highest difference between the occurrence and non-occurrence cases was chosen for each attribute. The modified *Susceptibility Value* grading standard was re-established as Table 6. The *Vulnerability Value* grading standard was also modified based on the debris-flow occurrence and non-occurrence cases of the three target areas. Considering the fact that only a very few number of the considered sites had deposit areas with volumes exceeding 2000 m^3, the grading standard was modified. The highest grading standard was altered from 5000 m^3 to 2000 m^3, and the other standards were also modified accordingly.

Based on the same condition of application for three target area, the *Hazard Value* and *Hazard Class* were determined using revised grading standard. The spatial pattern of occurrence case at the scoring chart was distributed on *Hazard Class* of S, A, and B having the

high potential of debris flow, as shown in Fig. 12. On the contrary, the points of non-occurrence case were distributed on *Hazard Class* of C, D, and E having comparatively lower potential of debris flow. In addition, the average value of the *Susceptibility Value*, *Vulnerability Value*, and *Hazard Value* of occurrence cases are distinguishable 1.58 times greater than those of non-occurrence cases (Table 7). The difference between *Hazard Value* of occurrence and non-occurrence cases based on revised grading standard are 1.37 times greater than difference (1.15) of application results using existing standard. Moreover, the framework has potential to be upgraded with more data accumulation and more case histories, considering locality of debris flow potential in Korea. Also, attributes other than those regarding the slope should be considered such as watershed size and bending of valley. According to Kim et al. (2014), With larger watershed sizes, both the debris-flow initiation risk and occurrence risk increase. An objective standard was set for the assessment of bending of valley (bending ratio). With larger bending ratios, more debris-flow materials are subjected to sedimentation, lowering the possibility of damage on road structures. Thus, the above modified parts were contained in the revised manuscript.