## P4.35

## DEBRIS FLOWS IN URBAN ENVIRONMENTS: COMBINING HAZARD AND EXPOSURE TOWARD A TAILORED EMERGENCY EVACUATION RESPONSE

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**Purpose:** Debris flows are one of the most dangerous types of landslides in mountain regions. Therefore, the urban development in these areas increase the exposure of population, structures and infrastructures, often leading to loss of lives and severe socio-economic impacts. In this work, we use a dynamic debris flow run-out model to simulate a worst-case scenario in a mountain region, several times affected by this type of landslide in the last two hundred years. Based on this scenario, different elements at risk are identified, as well as the exposed population per building and by age group, allowing to simulate different pedestrian travel times to safe areas.

**Methods:** The implemented methodology has the following sequence: 1) debris flow run-out modelling and estimation of flow velocities and thickness of the debris deposits; 2) identification of the buildings at risk; 3) estimation of the exposed population by using a dasymetric distribution; 4) calculation of the time between the debris flows initiation and the impact of the run-out in each one of the buildings at risk, which reflects the time required for evacuation; 5) calculation of the time needed for evacuees to arrive at safe meeting points while taking into account different travel speeds.

**Results:** We identified 96 buildings located in areas affected by debris flows deposits with thickness equal to or greater than 0.5 m, while around 4 % of these buildings are intercepted by a flow velocity above 3 m/s. Regarding the residents exposed to debris flows, 56 % are 65 years old or older. Moreover, we estimated that in 23 % of the buildings at risk, the evacuation time is longer than the arrival of debris flows, considering a slow walking speed (1.10 m/s).

**Conclusions:** The outputs of the dynamic model allowed the calculation of flow velocity, thickness of the deposits, volume and extend of travelled material, which constitutes critical parameters for hazard and risk assessment. The identified buildings at risk must be checked one by one and the resident's capacity to cope with an emergency evacuation (e.g. mobility difficulties, cognitive disorders...) needs to be assessed in order to define specific strategies. We advise to designate new safe meeting points or consider a vertical evacuation in circumstances where the evacuation time surpasses the arrival of the debris flows. If the latter is taken as an alternative, then the buildings' structural capacities must be evaluated.

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