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Dynamic physical vulnerability: a Multi-risk Scenario approach from building- single- hazard fragility- models

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In scenario-based and probabilistic single-hazard risk and loss estimation over urban building portfolios, it is customary to use specific exposure/vulnerability schemas that entail a set of mutually exclusive, collectively exhaustive (MECE) building classes, each associated with a fragility/vulnerability model focusing on the specific reference hazard., In a multi-risk application, where the same built structure can be subjected to the action of different natural hazards, possibly in close succession, a number of different schemas should be then jointly applied. Another option would be using a single set of building classes with as many fragility / vulnerability models as the considered natural hazards, as in the case for instance of the HAZUS multi-hazard framework. Unfortunately the latter approach requires a multi-hazard calibration that is rarely attainable with consistent results, while the former approach is complicated by the need for harmonizing different types of building classes. Furthermore, although fragility surfaces for independent hazards have been recently reported, they do not consider the nonlinear contribution of the different failure mechanisms (e.g. earthquake and tsunami) to the overall damage of a single asset. A timely update of the exposure model accounting for the progressive damage accumulation, thus describing a dynamic vulnerability framework, is then required.

We propose an alternative, innovative approach based on three main components: 1) a comprehensive multi-hazard building taxonomy able to address most of the building attributes driving the vulnerability with respect to different hazards, 2) a generalized description of the damage state of a building based on a set of low-level observable damage types and 3) a methodology to implement probabilistic mapping across different hazard-dependent building schemas and damage states.

A matrix describing the degree of compatibility between building types from two different schemas is estimated, partially making use of the fuzzy scores methodology suggested by Pittore et al., 2018. Since two building schemas may have different number of damage states (e.g. four in seismic, and six in tsunami), and are associated to different physical damage descriptions, the probability of the damage states conversion between the different schemas is also required.

This transparent and flexible formulation allows the implementation of multi-risk scenario

assessment exploiting single-risk fragility/vulnerability models available in literature for a wide range of natural hazards. A preliminary state-dependency of these fragility models is based on expert knowledge. This work has been carried out within the scope of the RIESGOS project and exemplified in a study area in South America and further highlights the importance of defining accurate exposure models and compatible damage states descriptions in a multi- hazard-risk context.