# Use of multi-hazard fragility functions for the multi-risk assessment of road networks

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Infrastructure systems such as road networks appear to be particularlyexposed to multi-hazard eventsbecause of (i) their spatial extent,which may span various areas prone to different hazard types, and (ii) their interconnected nature, which facilitates the propagation of local losses across the whole system. Multi-risk assessment should consider interactions at both the hazard level (i.e. triggered events or independent events with a joint occurrence) and the vulnerability level (i.e. fragility models accounting for cumulated damage), thus requiring a harmonization effort on the various intensity measures, damage models or damage scales considered.

Therefore this paper presents a method for the multi-risk assessment of infrastructure systems, which concentrates on the harmonization of losses from different hazard types. The global system is first decomposed into its physical elements (e.g. bridges), which are in turn broken down into structural components (e.g. piers, decks, bearing, etc.). Each component type has a different exposure and susceptibility to different hazard types, such as earthquakes, ground failures and floods. Therefore it is necessary to identify all the hazard-specific failure modes for each combination of hazard and component. The occurrence of each of these component failure modes can then be quantified through the derivation of hazard-specific component fragility curves, provided that the adequate modelling tools are available.

In parallel, functionality losses, which are crucial metrics for the performance assessment of infrastructure systems, are estimated for each component failure mode through an expert-based survey. System failure modes can then be defined from combinations of component damage states to lead to consistent levels functionality losses (e.g. repair time, proportion of lane closure, etc.). Therefore, the consequences of various types of hazard-specific loading mechanisms can be harmonized in terms of functionality. The component fragility curves are assembled through Bayesian networks in order to update the joint probability of occurrence of the system failure modes: this results in fragility models that account for multiple hazard-specific intensity measures (i.e. vector-valued) and cumulated damage (i.e. use of component fragility curves for pre-damaged elements). Therefore such fragility functions have the potential to treat various multi-hazard configurations, such as independent or cascadingevents, while being directly associatedto functionality losses.

Based on fragility functions andthe duration of repair operations given global damage states of bridges and tunnels, an ABM infrastructure natural hazard response simulation model is developed to simulate the interactions among the different infrastructures that constitute the road network system: roads, tunnels and bridges under a certain hazard scenario.Furthermore,the overall road network recovery time canalso be estimated.Finally, the functionality losses that are potentially induced by multiple hazard events are aggregated and sampled (i.e. probabilistic scenarios), so that traffic modelling software may assess how the traffic flow changes as a consequence of road capacity reductions on the network.NEXTA, an open-source traffic equilibrium modelling software, is used to calculate additional journey time for travellers, based on a number of damage scenarios.