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Evaluating Interventions to Improve the Resilience of Transport Networks against Climate-Induced Hazards: A Simulation Approach

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Infrastructure systems are susceptible to hazard events, which disrupt their functionality leading to direct and indirect consequences for the users and the owners. To ensure these consequences are not excessive, infrastructure managers have to plan and execute interventions to improve the resilience of their networks. Interventions can contribute to enhancing resilience through a multitude of techniques such as reducing hazard intensity, reducing exposure to hazards, decreasing the vulnerability of exposed assets, implementing adaptive capacity, enhancing restoration programs, and the combination thereof. Moreover, interventions can be executed on a spatially and temporally variant domain, including those that can be executed prior to the occurrence of hazard events, e.g., construction of flood levees; while the hazard is taking place and evolving, e.g., deployment of temporary sandbags during a flood; and after the hazard event, e.g., repair activities. This spatiotemporal variability, along with the possibility of having a portfolio of interventions each targeting certain aspects of resilience, however, has not yet been adequately addressed in the literature. Most studies focused on standalone pre-hazard interventions, and have not addressed the collective benefit of interventions of different types. This study addresses this limitation by proposing a simulation approach to quantitatively evaluate the effects of portfolios of interventions of various types for improving the resilience of transport networks against climate-related hazards. It is achieved through a resilience assessment methodology that, under both existing and intervened conditions, exhaustively models the: 1) occurrence and evolution of hazards, 2) performance of transport network over the course of hazard evolution, and 3) restoration efforts to recover performance. Subsequently, through generating a host of simulated scenarios, interventions are evaluated based on their contribution to reducing the ensuing economic consequences, e.g., repair costs, as well as socio-economic ones, e.g., increased travel time and loss of connectivity. This approach will be showcased through an application to a transport network located in Switzerland subject to heavy rainfall, flooding, and landslides. The proposed simulation approach serves as a virtual representation of the real system that can enable decision-makers to objectively investigate and compare the effects of various interventions.