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Road network vulnerability to extreme floods: accessibility-based analysis and patterns of vulnerability

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Understanding the different dimensions of vulnerability to floods is instrumental to gaining knowledge on flood impacts, to guide the development of appropriate risk analysis methods and to make critical decisions in risk management. Vulnerability assessment of complex systems, such as transportation infrastructure, demands an integrated framework to include various analytical methods to investigate the problem from the different characteristic perspectives related to their topological, functional, logic and dynamic properties. One approach to understand the impacts of transportation infrastructure disruptions on people is the accessibility-based vulnerability approach. Accessibility-based vulnerability analysis examines changes of access levels across a traffic network disrupted by floods, thereby providing insight on the impacts to a broader range of socio-economic aspects and to the society as a whole.

The presented study evaluates two different approaches. The first approach computes direct impacts and investigates different measures for extreme flood impacts to the road network. The second approach computes indirect impacts and

i) incorporates detailed information about the local road network in the accessibility-based vulnerability analysis by modifying the approach of calculating travel time between zones,

ii) includes additional contributing factors to the accessibility-based vulnerability analysis by considering residents and socio-economic opportunities in flood-affected areas,

iii) effectively identifies the most vulnerable traffic zones with respect to selected extreme flood scenarios, and

iv) investigates the influence of different spatial patterns of floods on accessibility-based vulnerability assessment.

We used three measures to assess direct flood impacts on the road network towards selecting the flood scenarios, which are representative for different flood patterns. Namely, Loss Index (LI), the total value of normalized edge betweenness centrality (Total-EBC), and the average normalized edge betweenness centrality (Mean-EBC). The Hansen integral accessibility approach was modified for two vulnerability indices considering traffic zones along with average shortest travel time as

cost and applied for selected flood scenarios. The resulted vulnerability indices were additionally analyzed to identify the most vulnerable traffic zones for each approach and the spatial influence of the flood and network pattern as well as the distribution of population and opportunities. Finally, effects of the contributing factors to the vulnerability were investigated using correlation and comparison between the flood scenarios.

The results of the direct impact assessment show that different flood scenario and varying spatial extent are selected as extreme events based on Total-EBC and Mean-EBC. The comparisons of these different measures in assessing direct impact of extreme floods to road network allows to plan different services on disaster mitigation to place mitigation policies to be efficient. Most of the highly vulnerable traffic zones are related to the flood extent in these zones and affected population and opportunities in the traffic zones. However, the most remote traffic zones were also highly vulnerable in flood scenario, if some parts of the important connecting roads for these remote traffic zones were disturbed by a flood in traffic zones faraway. The overall results implicate those different types of flood scenarios could be classified into several groups according to their patterns of vulnerability.