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Vulnerability analysis methods for road networks

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Road networks rank among the most important lifelines of modern society. They can be damaged by either random or intentional events. Roads are also often affected by natural hazards, the impacts of which are both direct and indirect. Whereas direct impacts (e.g. roads damaged by a landslide or due to flooding) are localized in close proximity to the natural hazard occurrence, the indirect impacts can entail widespread service disabilities and considerable travel delays. The change in flows in the network may affect the population living far from the places originally impacted by the natural disaster. These effects are primarily possible due to the intrinsic nature of this system. The consequences and extent of the indirect costs also depend on the set of road links which were damaged, because the road links differ in terms of their importance.

The more robust (interconnected) the road network is, the less time is usually needed to secure the serviceability of an area hit by a disaster. These kinds of networks also demonstrate a higher degree of resilience. Evaluating road network structures is therefore essential in any type of vulnerability and resilience analysis.

There are a range of approaches used for evaluation of the vulnerability of a network and for identification of the weakest road links. Only few of them are, however, capable of simulating the impacts of the simultaneous closure of numerous links, which often occurs during a disaster. The primary problem is that in the case of a disaster, which usually has a large regional extent, the road network may remain disconnected. The majority of the commonly used indices use direct computation of the shortest paths or time between OD (origin – destination) pairs and therefore cannot be applied when the network breaks up into two or more components. Since extensive break-ups often occur in cases of major disasters, it is important to study the network vulnerability in these cases as well, so that appropriate steps can be taken in order to make it more resilient.

Performing such an analysis of network break-ups requires consideration of the network as a whole, ideally identifying all the cases generated by simultaneous closure of multiple links and evaluating them using various criteria. The spatial distribution of settlements, important companies and the overall population in the nodes of the network are several factors, apart from the topology of the network which could be taken into account when computing vulnerability indices and identifying the weakest links and/or weakest link combinations.

However, even for small networks (i.e. hundreds of nodes and links), the problem of break-up identification becomes extremely difficult to resolve. The naive approaches of the brute force examination consequently fail and more elaborated algorithms have to be applied.

We address the problem of evaluating the vulnerability of road networks in our work by simulating the impacts of the simultaneous closure of multiple roads/links. We present an ongoing work on a sophisticated algorithm focused on the identification of network break-ups and evaluating them by various criteria.