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Using structural approach to understand transportation networks vulnerability

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Transportation networks are crucial items when assessing territories vulnerability to various hazards, because they are threatened not only in a material way (damages to their infrastructure) but also in a functional way (damages to the activities related to them).

The infrastructures damages are direct damages, $i.e.$ damages which are directly caused by the physical impact of hazards: they induce a 'material vulnerability' to networks, whose features are quite well-studied in specific relevant fields (physics, networks planning, etc.). The activities damages are indirect damages, $i.e$ damages which are caused by direct damages: they induce a 'functional vulnerability' to networks, which is difficult to assess because of the indirect and untangible damages character. Indeed, these damages result from a chain process and do not correspond to tangible deteriorations, but to profits loss caused by increasing travel times.

In order to improve the functional vulnerability assessment, we propose to highlight the chain process which links functional damages to activities and material damages to infrastructures. In that respect, we consider transportation networks through their ability to carry out the relations between the different places in the territory: this structural level is intermediate because on the one hand, the relational opportunities supplied by the networks depend on the infrastructures conditions (material level), and on the other hand, these opportunities determine the good-working of the activities, according to the users demand (functional level).

Within a risk context, the deterioration of relational opportunities can be assessed thanks to accessibility and centrality indicators supplied by quantitative geography and graph theory. Then, the structural vulnerability of a transportation network is theoretically described by accessibility loss and centrality variations observed on each of its damaged configurations. However, the exhaustive study of each damaged configuration is unrealistic. That is why we propose to organise these configurations inside an appropriate graph. From this graph, we aim at extracting sets of configurations which are likely to reveal the structural network weaknesses.

In particular, the study of elementary configurations – the configurations where only one component is damaged – provides a first idea of the network structural vulnerability which can be easily displayed on a map. Furthermore, we propose to consider damaged configurations involving several components. In that respect, it seems relevant to test the components whose removal are likely to cause a maximal impact on the network. Such components are selected by attacking strategies, whose purpose is to identify the most important components in the network relational organisation, especially thanks to structural indicators such as the betweenness centrality. This way to extract relevant configurations can be developed by considering step by step successions of damages according to the same criteria, in order to reveal the main dynamical aspects of the network vulnerability.

By crosschecking, the information collected on all these configurations finally give an overview of the network structural vulnerability, which helps to locate its main weaknessess and to understand the flexibility of its relational opportunities.