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Topology and Failure of Interdependent Infrastructure Networks

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Cities play a major role in modern societies, with >50% of the global population living in urban agglomerations. Infrastructure networks are critical components of urban communities and enable the provision of essential services (potable water deliver, waste and storm water removal, energy delivery, transportation, communications). Over time, intense competition for space within cities has dictated that much of the physical structure of the various infrastructure networks supporting these urban services be geospatially co-located. Furthermore, these infrastructure networks do not operate independently, but are instead interdependent, requiring the effective operation of one or more other infrastructure networks or services in order to function (i.e. electricity to run pumps, effective storm water removal to drain streets, etc.).

Together, these characteristics of urban infrastructure networks suggest inherent vulnerabilities to the resilience of these networks, either under chronic (i.e. localized, frequent disruptions due to unexpected failures or maintenance) or acute (i.e. wide-spread, less frequent disruptions such as extreme weather events) disruptions. Given the geospatial co-location and interdependence of infrastructure networks, such events may lead to cascading structural and functional failures within and between networks, leading to fragmentation or isolation of the networks, and resulting loss of critical services to large sections of the urban communities. Recovery from such losses may take few days (functional failures) to few months (structural failures).

Here, we used complex network-based approaches to investigate similarities and differences between the road, water distribution, and urban drainage networks for $\sim$100 global infrastructure networks, serving populations ranging from 5,000 to more than 5,000,000 We find these networks to follow heavy-tailed node-degree distributions with similar, predictable characteristics. We address possible implications of our analyses through selected case studies and highlight local topological variations that may enhance or reduce the resilience of subsections within the cities to either chronic or acute disruptions.