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Co-location and Self-Similar Topologies of Urban Infrastructure Networks

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The co-location of urban infrastructure is too obvious to be easily ignored. For reasons of practicality, reliability, and eminent domain, the spatial locations of many urban infrastructure networks, including drainage, sanitary sewers, and road networks, are well correlated. However, important questions dealing with correlations in the network topologies of differing infrastructure types remain unanswered. Here, we have extracted randomly distributed, nested subnets from the urban drainage, sanitary sewer, and road networks in two distinctly different cities: Amman, Jordan; and Indianapolis, USA. Network analyses were performed for each randomly chosen subnet (location and size), using a dual-mapping approach (Hierarchical Intersection Continuity Negotiation). Topological metrics for each infrastructure type were calculated and compared for all subnets in a given city. Despite large differences in the climate, governance, and populace of the two cities, and functional properties of the different infrastructure types, these infrastructure networks are shown to be highly spatially homogenous. Furthermore, strong correlations are found between topological metrics of differing types of surface and subsurface infrastructure networks. Also, the network topologies of each infrastructure type for both cities are shown to exhibit self-similar characteristics (i.e. power law node-degree distributions, [p(k) = ak-γ]. These findings can be used to assist city planners and engineers either expanding or retrofitting existing infrastructure, or in the case of developing countries, building new cities from the ground up. In addition, the self-similar nature of these infrastructure networks holds significant implications for the vulnerability of these critical infrastructure networks to external hazards and ways in which network resilience can be improved.