

Integrating System-Level Infrastructure Resilience and Sustainability Based on Fractal: Perspectives and Review

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Abstract : Urban infrastructures refer to the fundamental facilities and systems that serve cities. Due to the global climate change and human activities in recent years, many urban areas around the world are facing enormous challenges from natural and man-made disasters, like flood, earthquake and terrorist attack. For this reason, urban resilience to disasters has attracted increasing attention from researchers and practitioners. Given the complexity of infrastructure systems and the uncertainty of disasters, this paper suggests that studies of resilience could focus on urban functional sustainability (in social, economic and environmental dimensions) supported by infrastructure systems under disturbance. It is supposed that urban infrastructure systems with high resilience should be able to reconfigure themselves without significant declines in critical functions (services), such as primary productivity, hydrological cycles, social relations and economic prosperity. Despite that some methods have been developed to integrate the resilience and sustainability of individual infrastructure components, more work is needed to enable system-level integration. This research presents a conceptual analysis framework for integrating resilience and sustainability based on fractal theory. It is believed that the ability of an ecological system to maintain structure and function in face of disturbance and to reorganize following disturbance-driven change is largely dependent on its self-similar and hierarchical fractal structure, in which cross-scale resilience is produced by the replication of ecosystem processes dominating at different levels. Urban infrastructure systems are analogous to ecological systems because they are interconnected, complex and adaptive, are comprised of interconnected components, and exhibit characteristic scaling properties. Therefore, analyzing resilience of ecological system provides a better understanding about the dynamics and interactions of infrastructure systems. This paper discusses fractal characteristics of ecosystem resilience, reviews literature related to system-level infrastructure resilience, identifies resilience criteria associated with sustainability dimensions, and develops a conceptual analysis framework. Exploration of the relevance of identified criteria to fractal characteristics reveals that there is a great potential to analyze infrastructure systems based on fractal. In the conceptual analysis framework, it is proposed that in order to be resilient, urban infrastructure system needs to be capable of “maintaining” and “reorganizing” multi-scale critical functions under disasters. Finally, the paper identifies areas where further research efforts are needed.

Keywords : fractal, urban infrastructure, sustainability, system-level resilience

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