

Long-Term Resilience Performance Assessment of Dual and Singular Water Distribution Infrastructures Using a Complex Systems Approach

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Abstract : Dual water distribution systems have been proposed as solutions to enhance the sustainability and resilience of urban water systems by improving performance and decreasing energy consumption. The objective of this study was to evaluate the long-term resilience and robustness of dual water distribution systems versus singular water distribution systems under various stressors such as demand fluctuation, aging infrastructure, and funding constraints. To this end, the long-term dynamics of these infrastructure systems was captured using a simulation model that integrates institutional agency decision-making processes with physical infrastructure degradation to evaluate the long-term transformation of water infrastructure. A set of model parameters that varies for dual and singular distribution infrastructure based on the system attributes, such as pipes length and material, energy intensity, water demand, water price, average pressure and flow rate, as well as operational expenditures, were considered and input in the simulation model. Accordingly, the model was used to simulate various scenarios of demand changes, funding levels, water price growth, and renewal strategies. The long-term resilience and robustness of each distribution infrastructure were evaluated based on various performance measures including network average condition, break frequency, network leakage, and energy use. An ecologically-based resilience approach was used to examine regime shifts and tipping points in the long-term performance of the systems under different stressors. Also, Classification and Regression Tree analysis was adopted to assess the robustness of each system under various scenarios. Using data from the City of Fort Collins, the long-term resilience and robustness of the dual and singular water distribution systems were evaluated over a 100-year analysis horizon for various scenarios. The results of the analysis enabled: (i) comparison between dual and singular water distribution systems in terms of long-term performance, resilience, and robustness; (ii) identification of renewal strategies and decision factors that enhance the long-term resiliency and robustness of dual and singular water distribution systems under different stressors.

Keywords : complex systems, dual water distribution systems, long-term resilience performance, multi-agent modeling, sustainable and resilient water systems

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