A Stochastic Model for Evaluating Interconnected Critical Infrastructure Decontamination and Recovery

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Large-scale chemical, biological, radiological, and nuclear (CBRN) incidents have the potential to impact a wide area that would include core infrastructure assets. In such an event, the impact may extend beyond directly affected infrastructure sectors due to the interconnected nature of critical infrastructure systems. For example, an event damaging an electric power plant may reduce the ability of dependent infrastructure (e.g., transportation systems, communications facilities, hospitals, etc.) to operate at full capacity. In order to more effectively respond to CBRN events and efficiently bring services back online, an in-depth understanding of the dependencies and interconnections of infrastructure systems is necessary. Existing modeling tools in this field provide estimates of the immediate losses in connected infrastructures after a disruption, but the restoration process of infrastructure sectors has not been modeled in both a dynamic and interconnected manner. We have developed a framework for modeling the time-dependent process of critical infrastructure restoration within an interconnected system of infrastructure sectors. The model uses the Gillespie algorithm to stochastically simulate the use and production of infrastructure assets based on a network of infrastructure nodes and one-way connections. The process of infrastructure restoration is modeled as reactions, where resources from one or more infrastructure sectors are used to restore service in another sector. The model also accounts for a decrease in productivity due to injuries and/or temporary relocation of the population as a result of the CBRN event and an increase in productivity due to input from external forces (e.g., government involvement) to repair damaged critical infrastructure. This provides an opportunity to analyze the allocation of government resources and assess response strategies in the restoration effort. The stochastic nature of this algorithm enables the model to account for discrete events and capture the inherent uncertainty in the infrastructure restoration process. In this study, the model is applied to notional biological contamination scenarios, where the direct impact on critical infrastructure assets is assessed using data from FEMA's HAZUS database overlaid on a GIS map of a metropolitan area.