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Facility-Level Downtime Estimation Using Only Publicly Available Data

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This paper develops a model for estimating the likelihood of building-level loss of infrastructure services due to natural hazards based on only publicly-available information. The three steps to the method are: (1) generate synthetic infrastructure systems, (2) generate engineering performance models for these systems, and (3) simulate hazard impacts on these synthetic systems. The approach provides a strong basis for buildng-level downtime estimation for infrastructure systems.

Keywords: natural hazards, risk analysis, infrastructure, downtime.

1. Introduction

One of the key challenges in natural hazard risk and resilience estimation is estimating the downtime of key infrastructure services at the level of individual facilities such as a residential home, a hospital, or a commercial facility. Here downtime consists both of estimating the probability of a given service (e.g., electric power, drinking water, or cellular communications) being lost as a result of a hazard event together with the conditional distribution of how long that service is out at that location given that it was initially lost.

Downtime estimation is critical for a number of different uses. The first is determining which sub-populations in a community face the greatest risk of not having access to essential services after a disruptive event. This is essential to support assessment of inequities in hazard resilience within a community (Logan and Guikema, 2020). A second key use of downtime estimation is to help community members, businesses, government agencies, and other organizations better plan risk mitigation measures. This requires the ability to assess the impacts of specific interventions (e.g., installation of a backup generator at a particular water pumping station). Third, downtime estimation is essential for better pricing of downtime insurance by insurers and better ability to consider downtime insurance as a risk transfer option by commercial entities and others in the community. All of these uses require detailed, facility-level estimation of the likelihood of losing each of the critical infrastructure services and the duration of the outage if an outage occurs.

2. Challenge and Approach

A key challenge in infrastructure downtime estimation is that detailed data about infrastructure system layout and performance models is generally not available outside of the utility operating the system, yet the downtime estimation is needed by many other entities without access to this data. This paper presents an approach for infrastructure downtime estimation that is based on only publicly available data yet yields validated estimates at the facility level. The general steps in this approach are: (1) create a synthetic representation of the infrastructure system layout, (2) create a system-appropriate engineering performance model or

approximation of the performance model, (3) simulate hazard loading on the system from hazard events, (4) simulate loss of service at the facility level, and (5) simulate the restoration process at the facility level if outage duration is needed. This approach is demonstrated for power distribution systems, drinking water systems, and cellular communication systems. The advantage of this approach is that it allows detailed, accurate estimation of downtime at a facility level without requiring security-sensitive infrastructure data that is generally not available.

3. Example Results

Figure 1, from Zhai et al. (2021), gives and overview of the synthetic system generation approach applied to generate a power distribution system. This approach first clusters the service points (buildings) and assigns them to substations. It then creates network topologies, including both lines and poles. It then uses a validated machine learning model to determine if each line segment is an overhead line or a buried line.

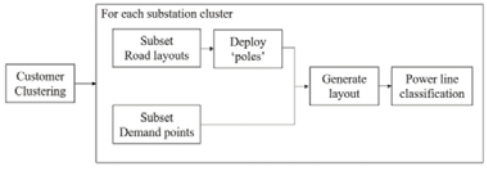

Figure 1. Example of the synthetic system generation approach (Zhai et al., 2021).

This synthetic system is then coupled with an appropriate hazards model and asset-level fragility functions to form the basis of a Monte Carlo simulation of the impacts of a hazard on the system. The end result is an estimate of the number of the probability of each building losing power. An example of this output is given in Figure 2. This figure is an estimate of the probability of experiencing a power outage at the building level for Hurricane Harvey impacting Corpus Cristi, Texas, United States.

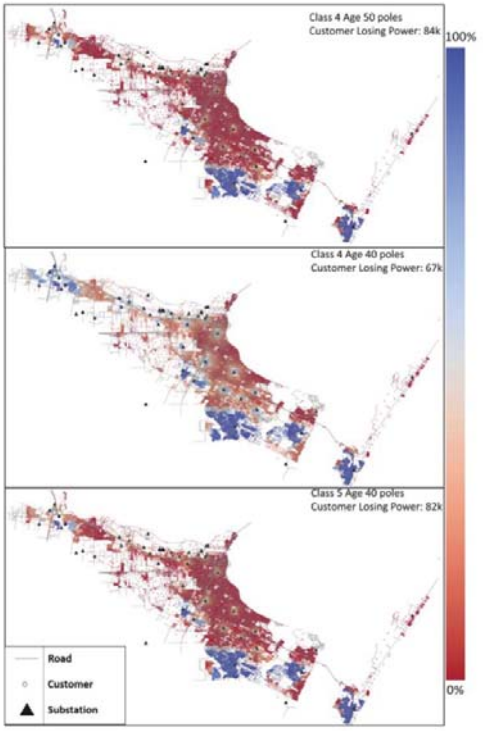

Figure 2. Example of output from the coupled synthetic system – hazard impact simulation model. Zhai et al. (2021).

4. Conclusions

This approach provides a basis for estimating building-level risk of loss of infrastructure service based on only publicly-available information. The approach has been extended for both potable water systems and cellular communication systems.

References

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