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1. Motivation

Disaster recovery is governed not only by the extent of physical damage, but also by a **community's ability to mobilize and allocate limited resources across space and time**. Existing recovery simulations show how resource and service constraints shape aggregate recovery trajectories, such as overall recovery time. However, these coarse-grained metrics provide limited insight into **where and why recovery stalls across localities**, especially during the critical early stages when intervention priorities must be set. In practice, pre-disaster resource availability is often treated deterministically, while **actual post-disaster resource availability is only known after the event**.

These gaps highlight the need for more informative, **locality-aware early-stage recovery metrics**. Because resource availability is only known after the disaster, **decision-making requires rapid evaluation of recovery outcomes under different scenarios**. This motivates the use of surrogate models for fast, spatially and temporally resolved assessment of resource allocation strategies under uncertainty.

2. The R2D-Pyrecodes Wrapper Encoded with UQLab

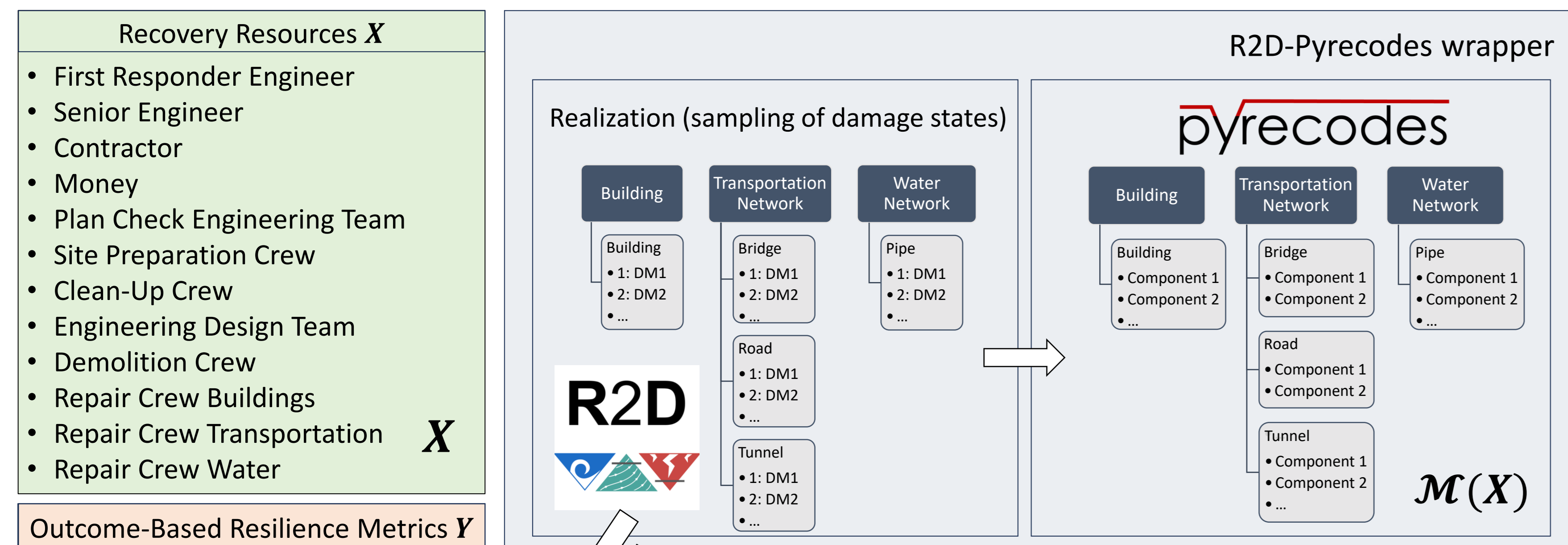


Fig.1: Computational framework of an integrated resilience assessment platform. DM denotes damage state and RM denotes resilience metrics.

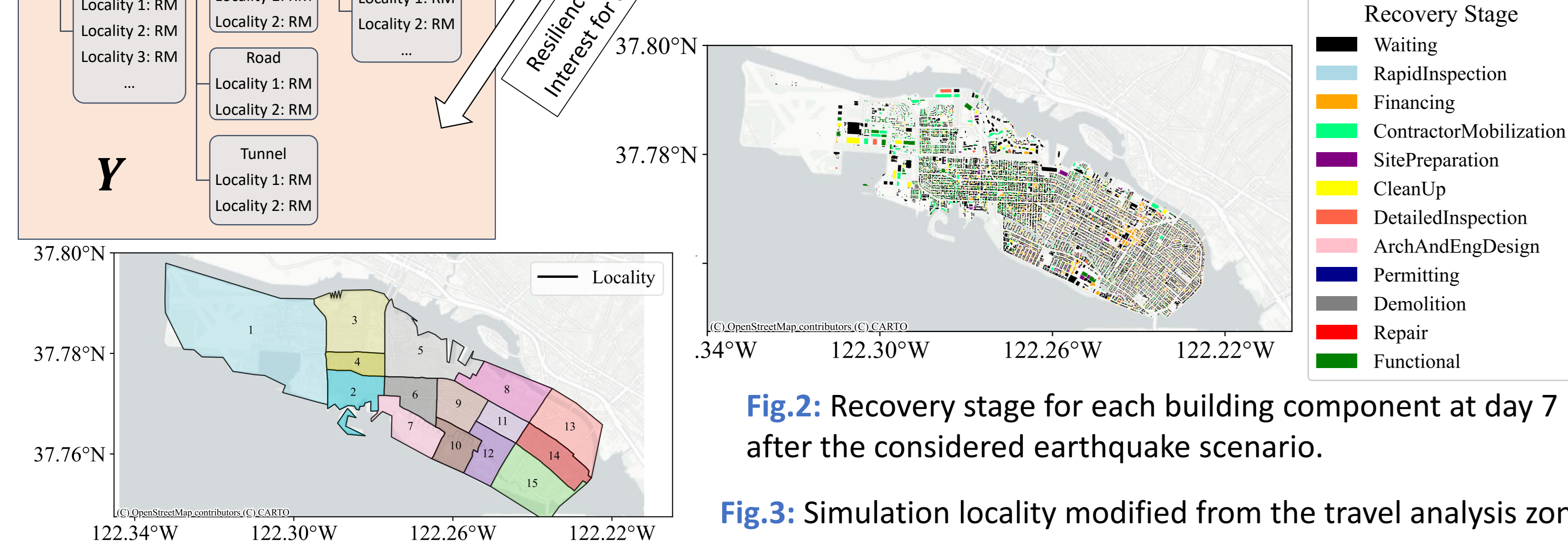


Fig.2: Recovery stage for each building component at day 7 after the considered earthquake scenario.

Fig.3: Simulation locality modified from the travel analysis zones.

3. Probabilistic Model For Recovery Resources: X

- Feasible ranges of recovery resource quantities are established using a preliminary screening approach to aggregate recovery indicators
- A log-uniform distribution is assumed within the identified feasible ranges
- A total of **160 training samples** and **40 validation samples** are generated using Latin Hypercube Sampling (LHS) via ETH Euler HPC cluster

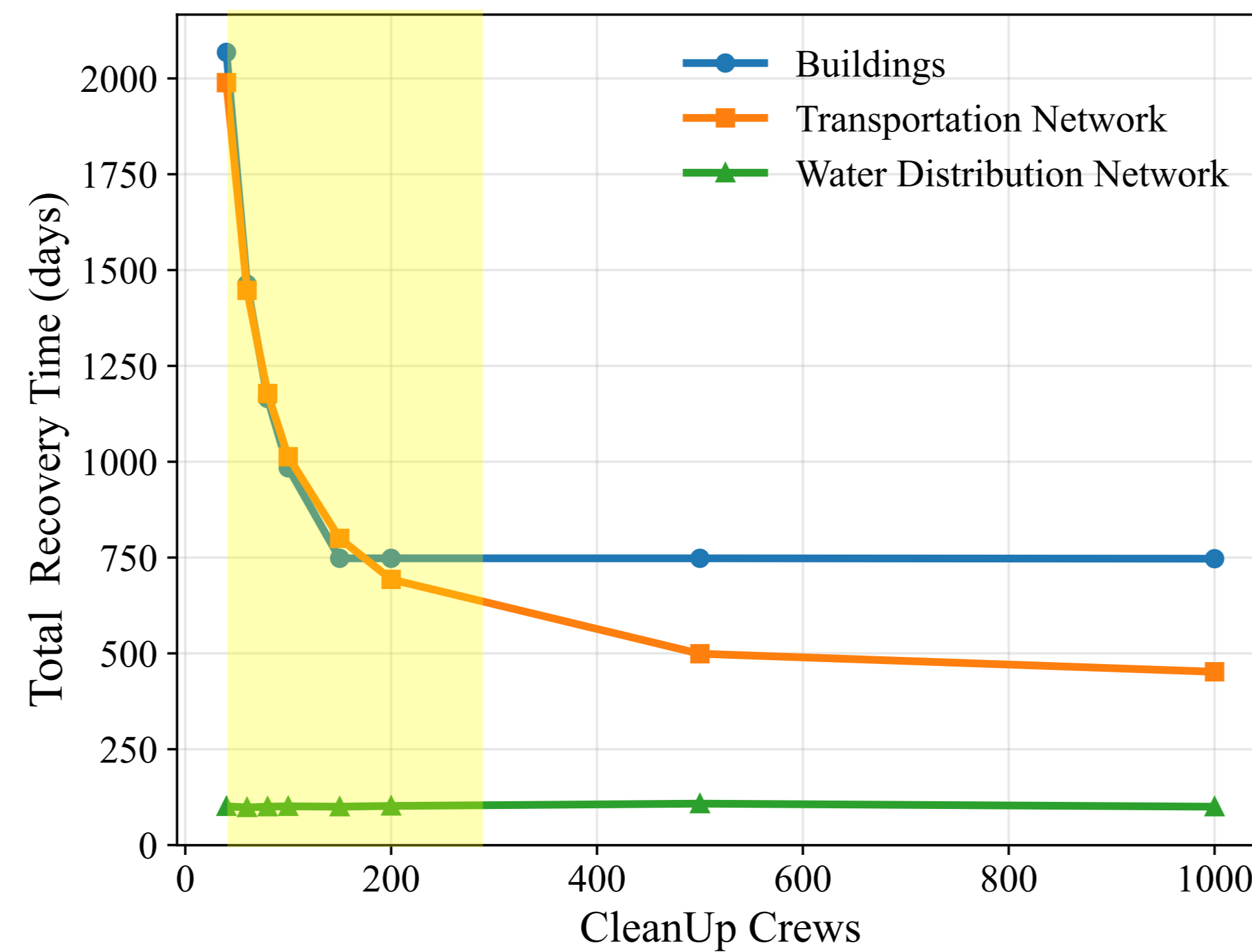
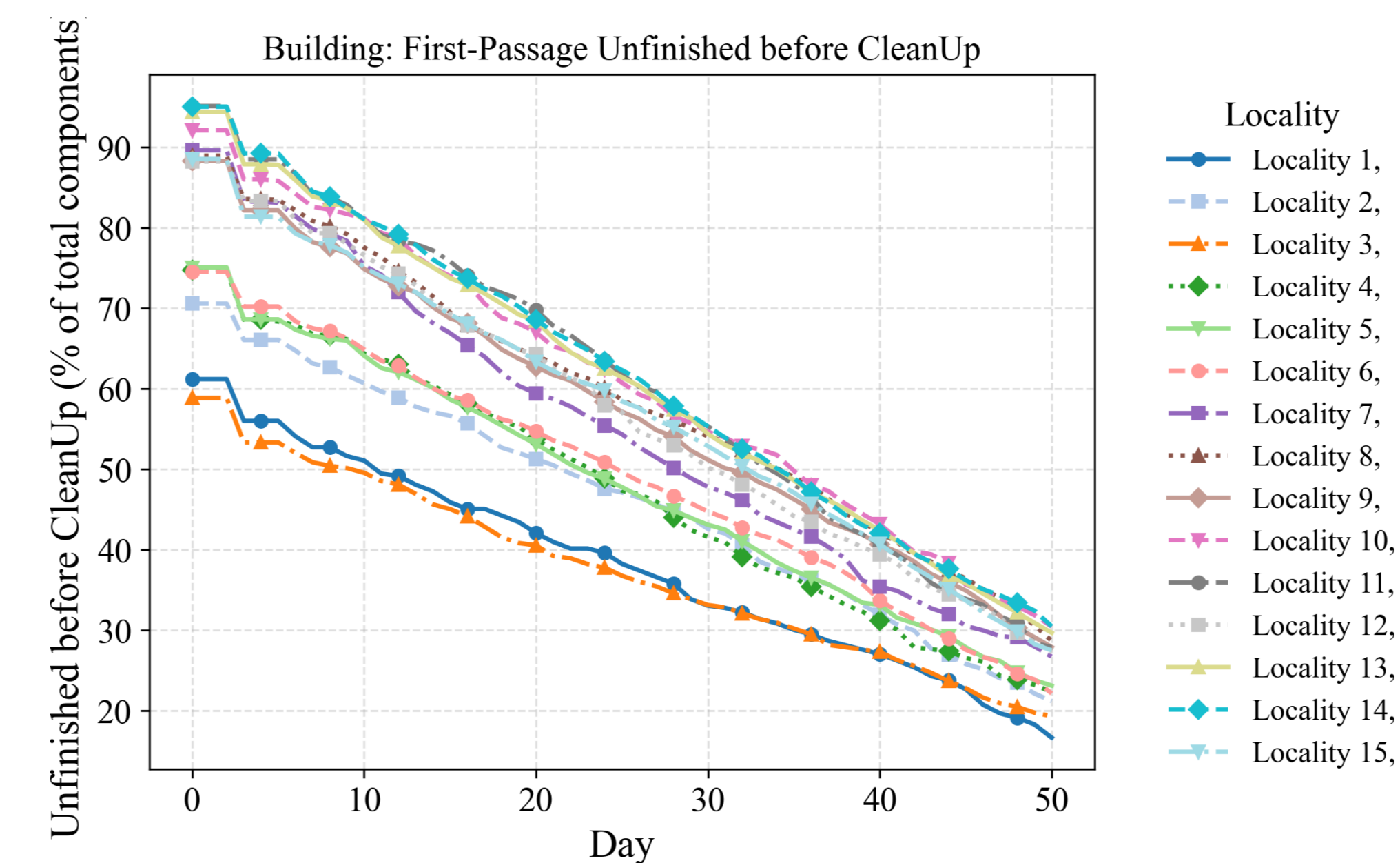


Fig.4: Sensitivity of total recovery time to clean-up crew supply capacity across infrastructure systems. The shaded region indicates the range used to define feasible allocation bounds.

For each of infrastructure systems (e.g., buildings), the total recovery time T_{system} is taken as the maximum recovery time among all its components. Let T_i denote the recovery time of component i . The system-level recovery time is then given by

4. Outcome-Based Metrics for Early Phase Recovery Bottlenecks: Y

Fig.5: Example of locality-level recovery metrics for the building clean-up stage with 300 crews, using the **first-passage unfinished metric**. Results highlight spatial heterogeneity in recovery progress across localities.



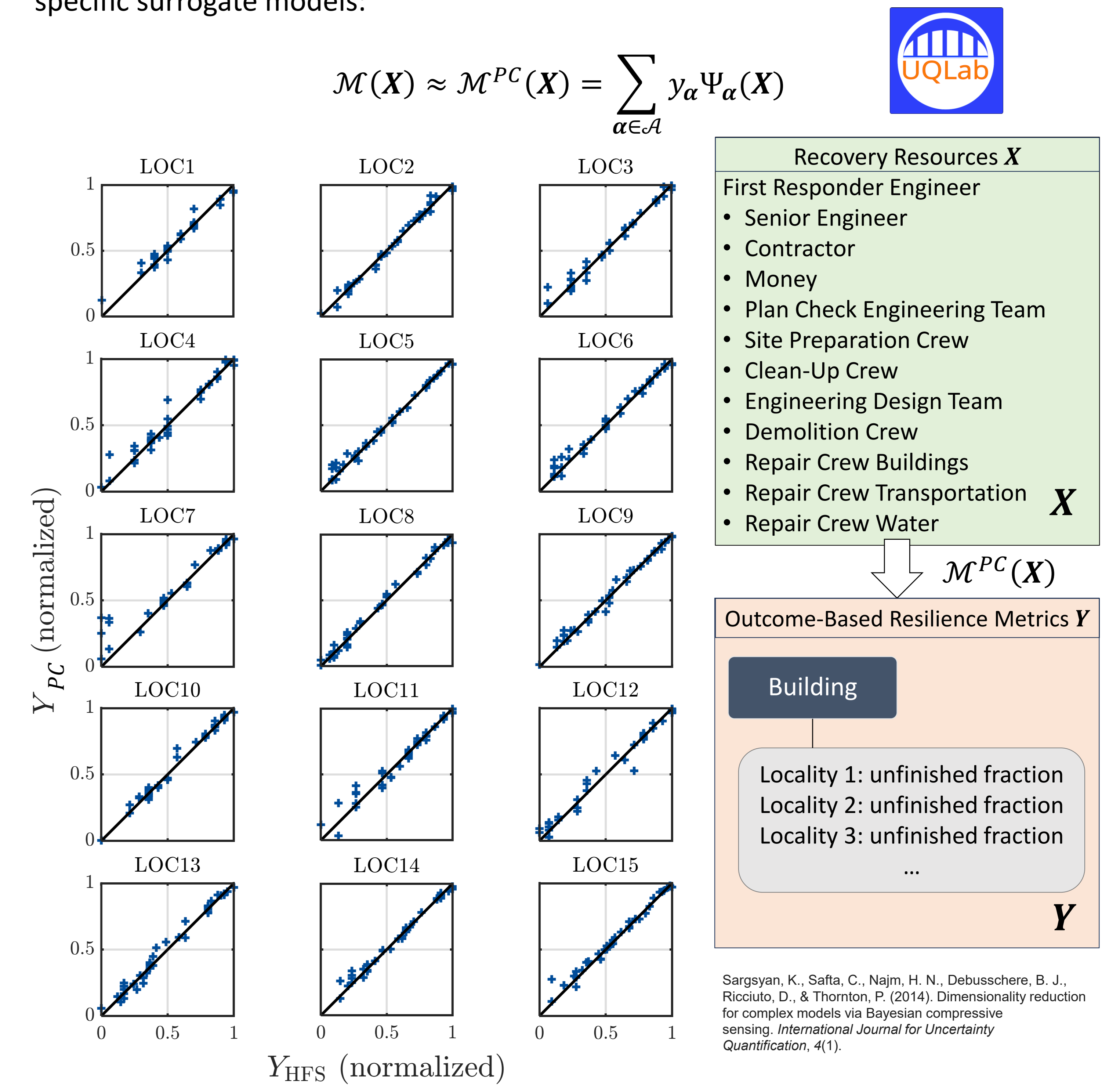
For a target recovery state s , the **unfinished fraction** with locality loc at time t is defined as

$$\frac{N_{unfinished,loc}(t)}{N_{total,loc}}$$

The **unfinished fraction metric (the number of components that have not yet entered recovery state s up to time t)** reveals where recovery stalls by tracking components awaiting recovery and helps identify localities that require additional recovery resources.

5. Surrogate Models for Rapid Post-Disaster Decision Making

Fig.6: Validation of surrogate models against high-fidelity simulations (HFS) across localities. Truncated sparse polynomial chaos expansion with Bayesian compressive sensing (BCS) (Sargsyan et al., 2014) is used to construct locality-specific surrogate models:



Sargsyan, K., Safta, C., Najm, H. N., Debusschere, B. J., Ricciuto, D., & Thornton, P. (2014). Dimensionality reduction for complex models via Bayesian compressive sensing. *International Journal for Uncertainty Quantification*, 4(1).

6. Conclusions

- Locality-level, outcome-based metrics reveal where and why recovery stalls in early stages
- Surrogate models enable rapid evaluation of resource allocation under different disaster scenarios
- The framework supports timely post-disaster decision making and optimal allocation of the available recovery resources