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Civil & Environmental Engineering

Quantifying the Post-Earthquake Downtime Induced by Cordons Around Damaged Tall Buildings

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Introduction

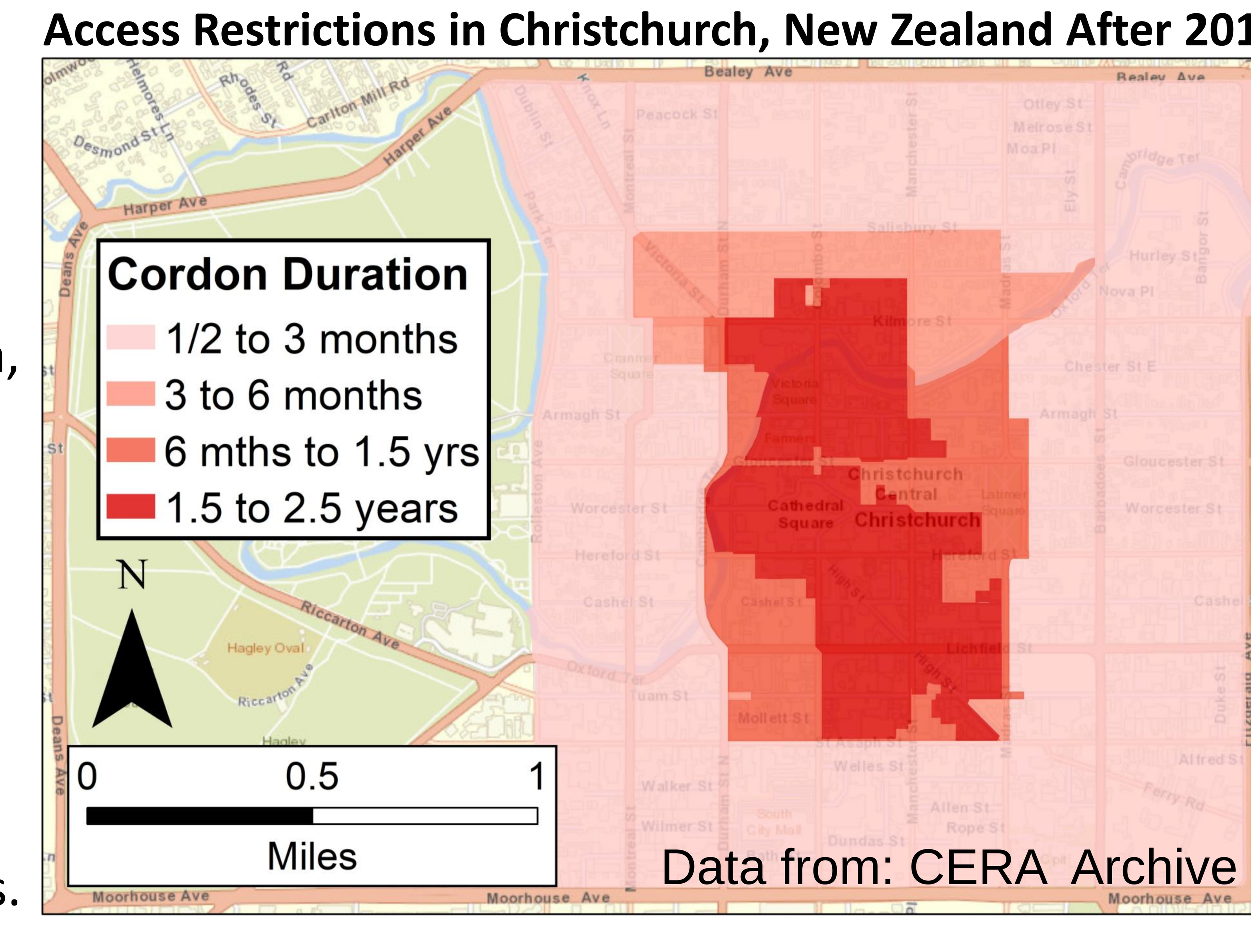
TARGET STATES OF RECOVERY FOR SAN FRANCISCO

INFRASTRUCTURE CLUSTER FACILITIES	Event Occurs	Phase 3 Months		
		4	36	36+
COMMUNITY RECOVERY				
All residences repaired, replaced or relocated		■		X
95% neighborhood retail businesses open		■	X	
50% offices and workplaces open		■		X
Non-emergency city service facilities			■ X	
All businesses open			■	X
100% utilities			■	X
100% roads and highways			■	X
100% travel			■	X

adapted from: SPUR 2009[1]

Resilience has been an increasing priority for policy-makers. San Francisco is an exemplar in seismic resilience, publishing a document that defined target timelines for post-earthquake recovery of key functions, versus the current expectations.[1] However, the current conditions are difficult to quantify, as highlighted by the multi-year access restrictions in Christchurch, New Zealand's Central Business District after the 2011 earthquake. Current downtime models consider communities as the sum of isolated buildings, which ignores the effect that safety cordons around damaged buildings may have on the accessibility of nearby, undamaged buildings. The framework presented here allows building-level PBEE assessments to be incorporated into a spatially distributed community model that includes access restrictions due to damaged tall buildings. This type of analysis can support policy-makers in identifying, and developing strategies to reduce, the gap to the recovery targets.

Access Restrictions in Christchurch, New Zealand After 2011

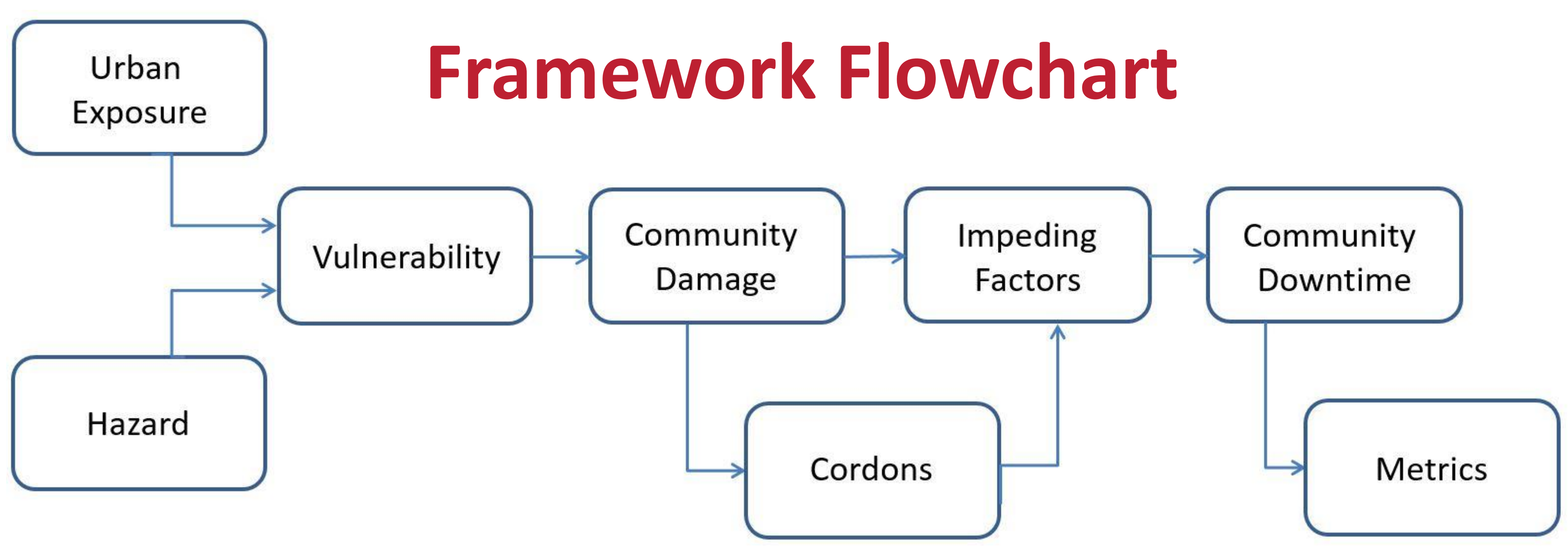


Input

Urban exposure is modeled using similar building/occupancy archetypes as HAZUS[2] but is spatially distributed throughout the community.

Hazard is based on the full range of earthquake scenarios and their individual probabilities. Spatial and spectral correlations to obtain realistic response spectra across the community.

Framework Flowchart

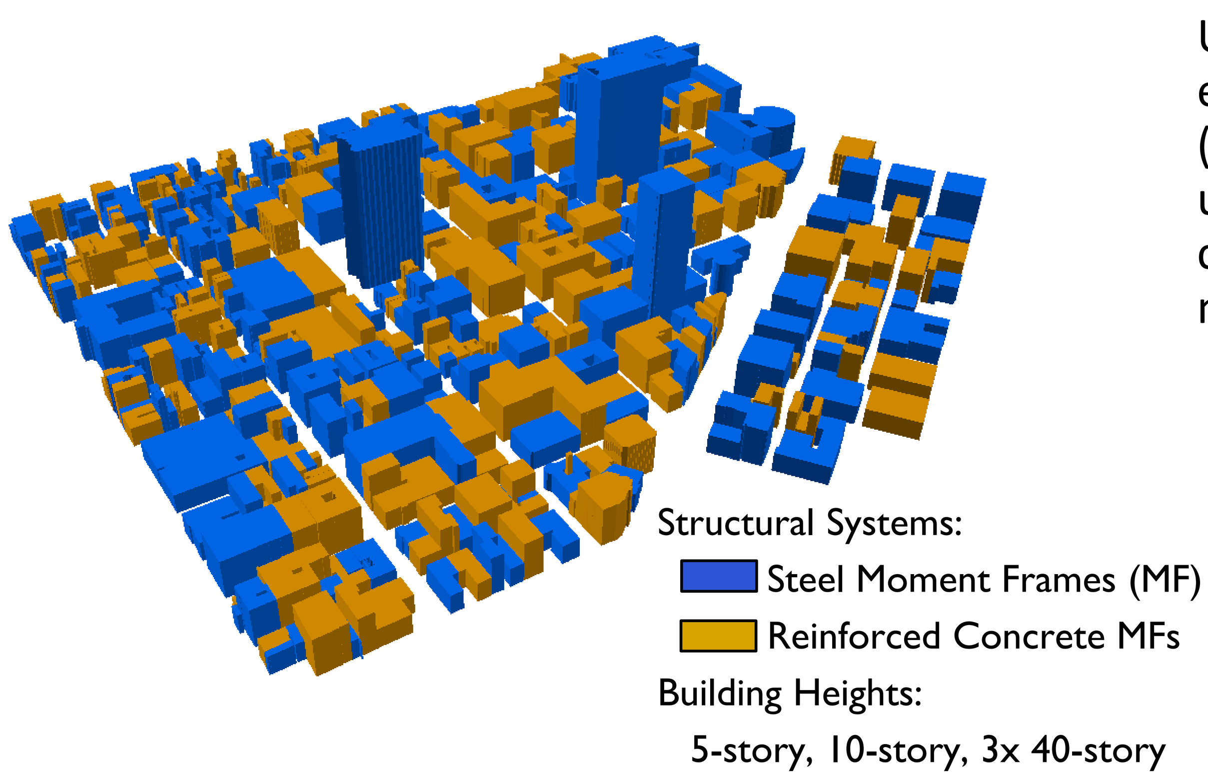


Output

The decision variable of interest is building downtime in the community (measured in time*unit, e.g. months*office sqft), which is the sum of individual building downtimes due to damage and/or access restrictions.

Network analysis provides actionable metrics, such as identifying the buildings that are expected to induce the most cordon-related downtime.

Hypothetical Community

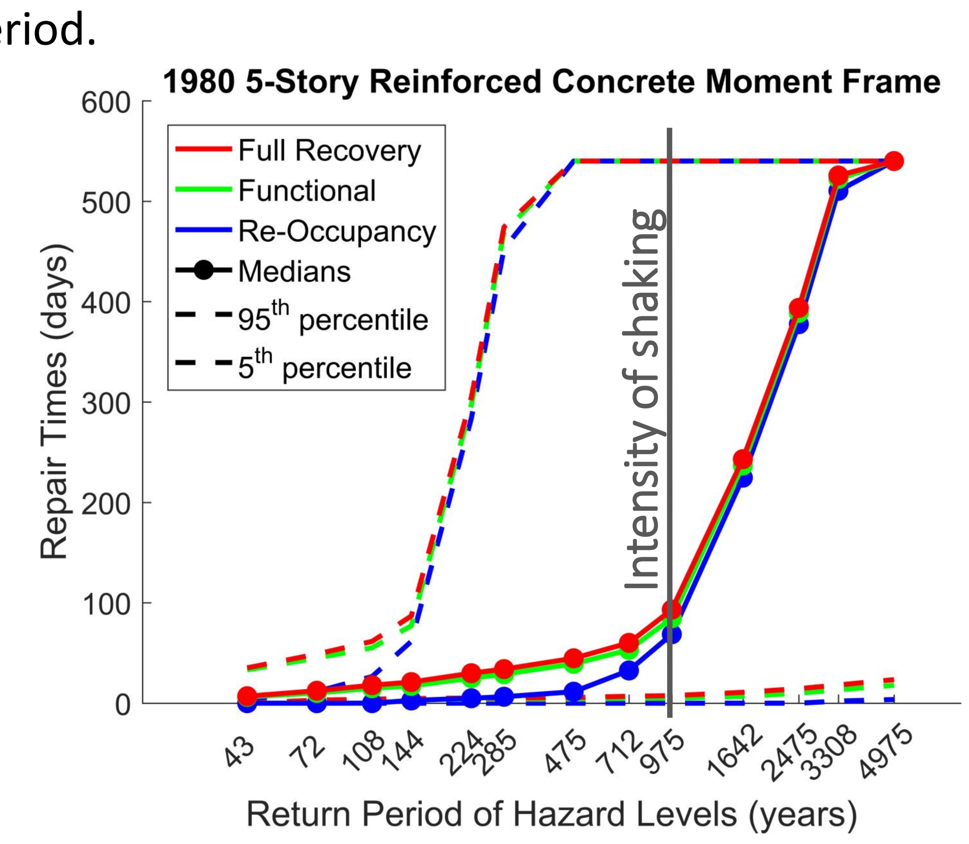


Set of Earthquake Scenarios

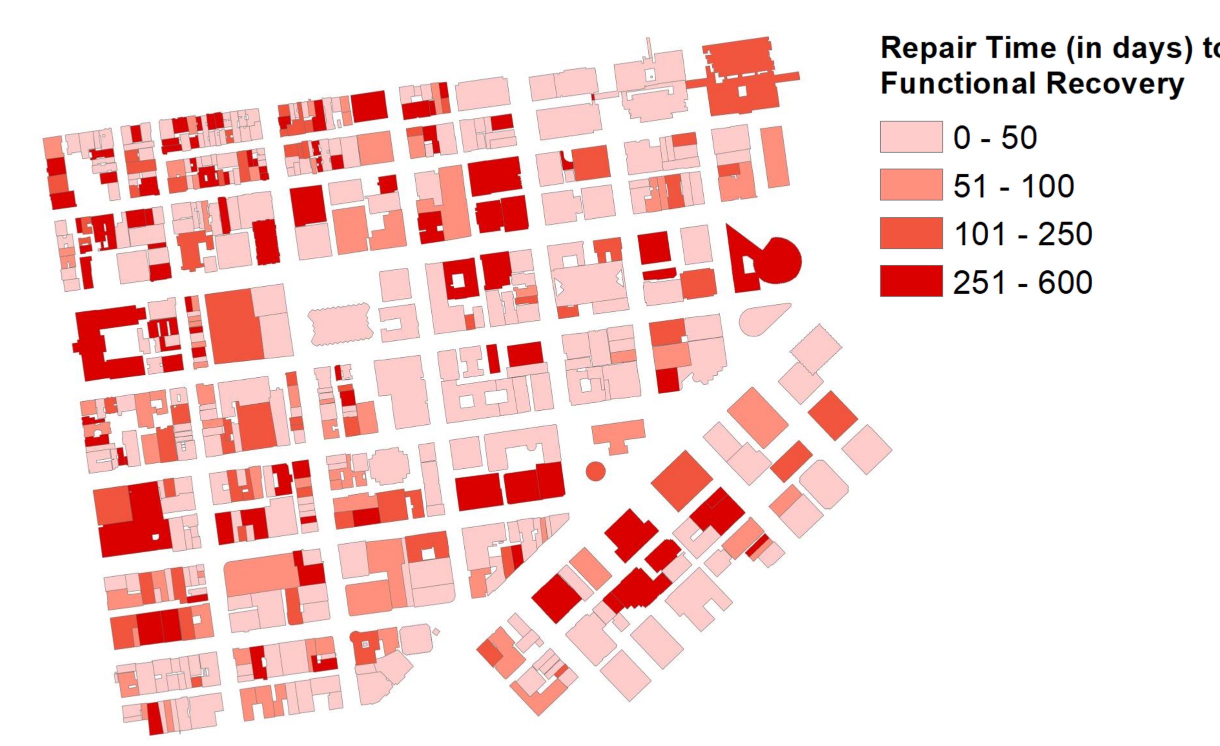
The spatially distributed response spectra for each earthquake rupture scenario serve as the basis for community-wide realizations of damage in buildings.

Vulnerability

Urban exposure is linked to the hazard via vulnerability profiles for each archetype. The profiles contain multi-dimensional parameters (e.g. repair times and residual drift) from each Monte Carlo result used for FEMA P-58[3] and REDi[4] analyses at a range of intensities, characterized by the spectral acceleration at the building's first-mode period.



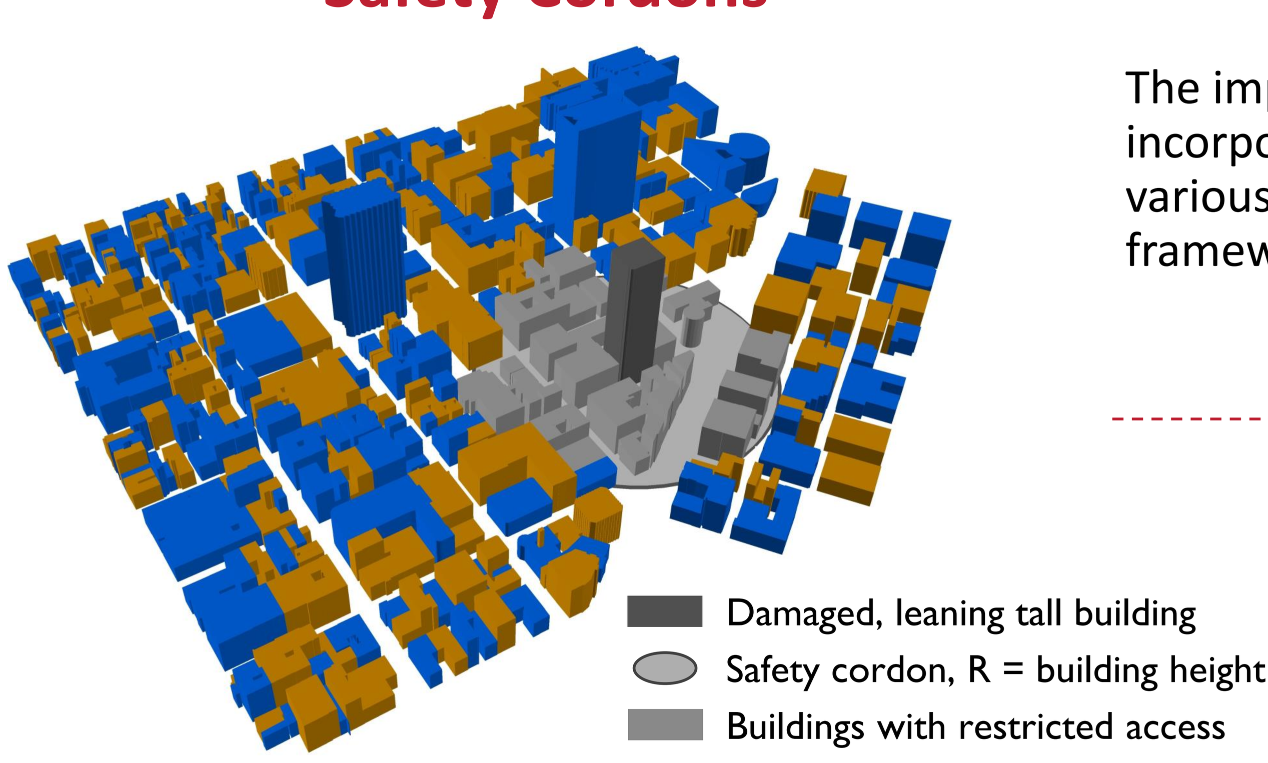
Community Damage



A set of damage and repair parameters is randomly sampled from the appropriate archetype profile for each building in the community, given the shaking intensity dictated by the earthquake scenario.

Note: only one dimension (the repair time required to reach the functional recovery state) is shown above.

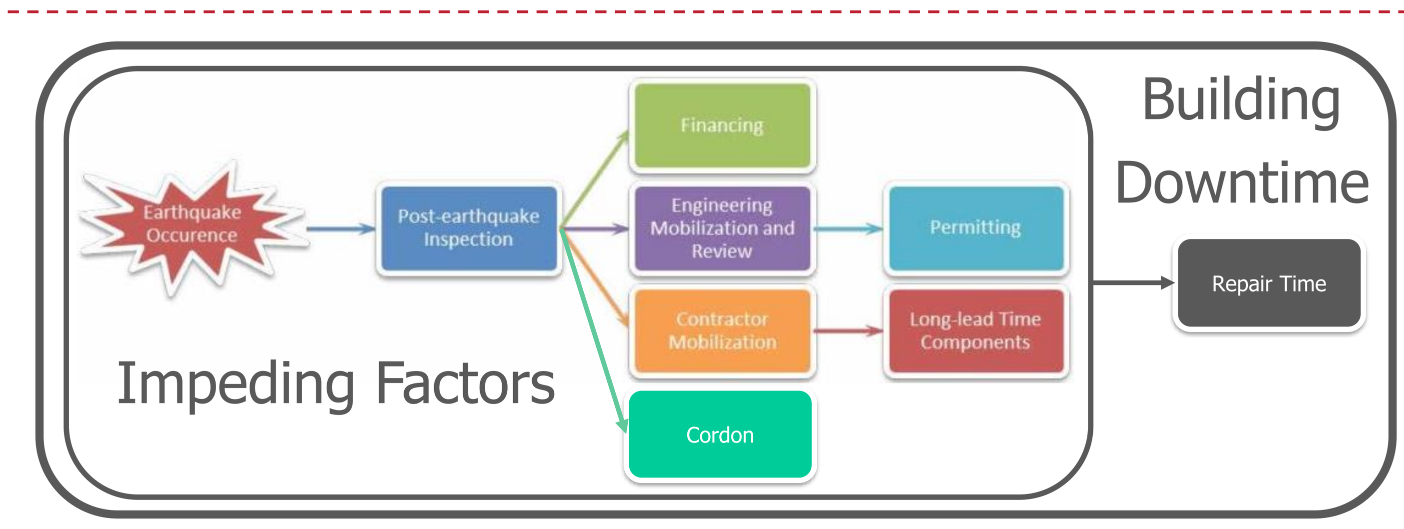
Safety Cordons



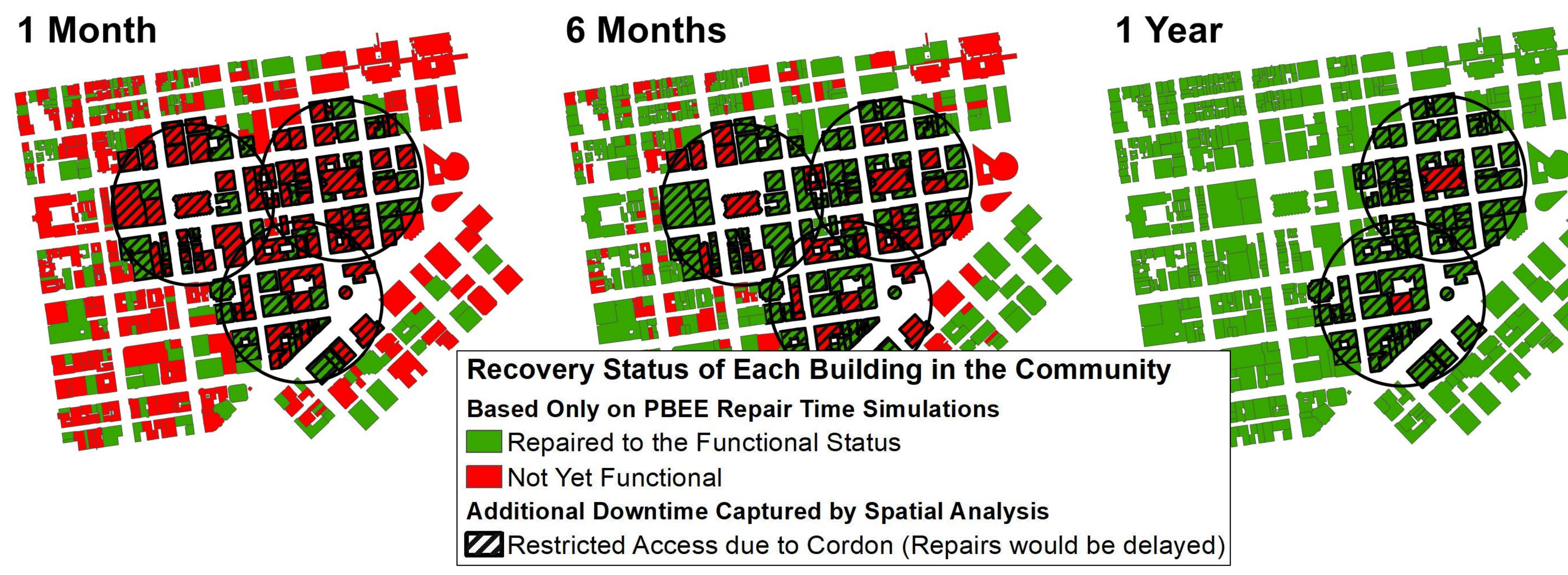
Safety cordons are established around damaged tall buildings, using residual drift thresholds as a proxy for probability of collapse in an aftershock. The duration is based on repair time until the building is stable.

Impeding Factors

The impeding factor framework is borrowed from REDi[4] to incorporate variability in the time needed to facilitate various logistics prior to initiating building repairs. The framework is modified to include delays due to cordons.



Community Downtime



The incorporation of access restrictions leads to a more realistic prediction of the total downtime. The green hatched buildings shown here represent the underestimation when the buildings are modeled in isolation.

Conclusion

By incorporating access restrictions around damaged tall buildings, as observed in Christchurch, New Zealand, this recovery framework seeks to capture a dimension of community recovery that is not considered in building-level Performance-Based Earthquake Engineering assessments. This more holistic methodology can provide further insights to policy-makers who are seeking to make their communities more seismically resilient.

Acknowledgements

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References

[1] San Francisco Planning and Urban Research Association (SPUR), "The resilient city: defining what San Francisco needs from its seismic mitigation policies," San Francisco, CA, 2009.
[2] FEMA, "HAZUS-MH 2.1 Technical Manual," Washington, D.C., 2012.
[3] FEMA, "FEMA P-58: Seismic Performance Assessment of Buildings," Washington, D.C., 2012.
[4] I. Almufti and M. Willford, "REDi Rating System: Resilience-based Earthquake Design Initiative for the Next Generation of Buildings," ARUP, San Francisco, CA, 2013.