Earthquake Downtime due to Cordons

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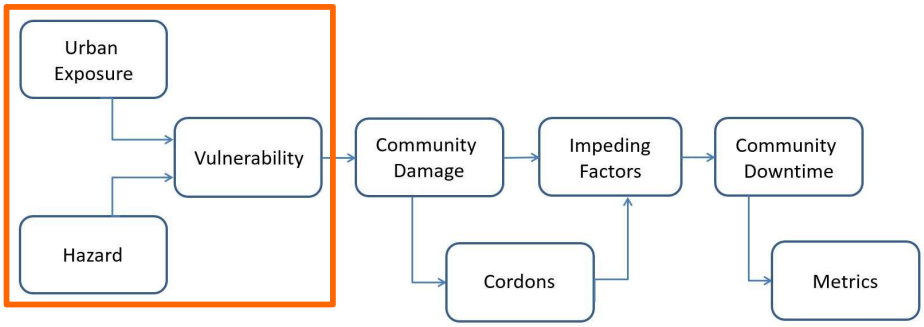
Stanford ENGINEERING | Civil & Environmental Engineering

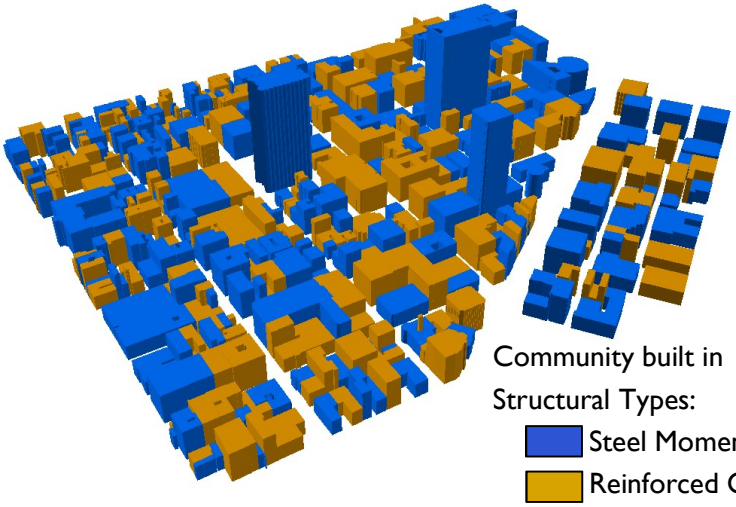
Motivation

- Premise: Spatial analysis of the context around individual buildings can improve downtime estimates and better inform decision makers
- Research focus: How do cordons around damaged tall buildings affect the downtime of the surrounding buildings?
- Today's purpose:
  - Present an overview of the community analysis framework
  - Highlight two areas for further discussion

Community Analysis Framework



Urban Exposure – Building Inventory



Community built in 1980

Structural Types:

- Steel Moment Frames (MF)
- Reinforced Concrete MFs

Building Heights:

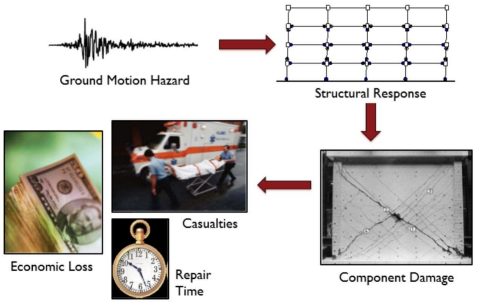
5 story, 10 story, 3x 40 story

Individual Building Analysis

- Performance-Based Earthquake Engineering Formulation (2000)

$$v(DV) = \iiint G\langle DV|DM\rangle |dG\langle DM|EDP\rangle |dG\langle EDP|IM\rangle d\lambda(IM)$$

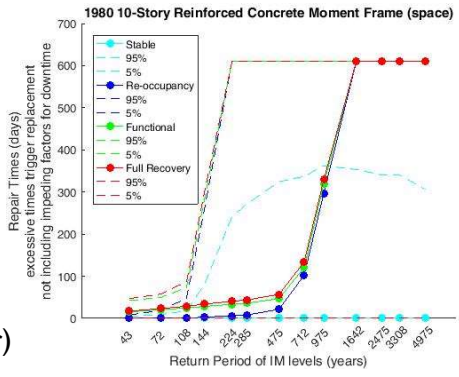
- FEMA P-58 (2012) used Monte Carlo simulation for integration
- REDi (2013) developed modifications for more realistic repair sequencing and downtime consideration



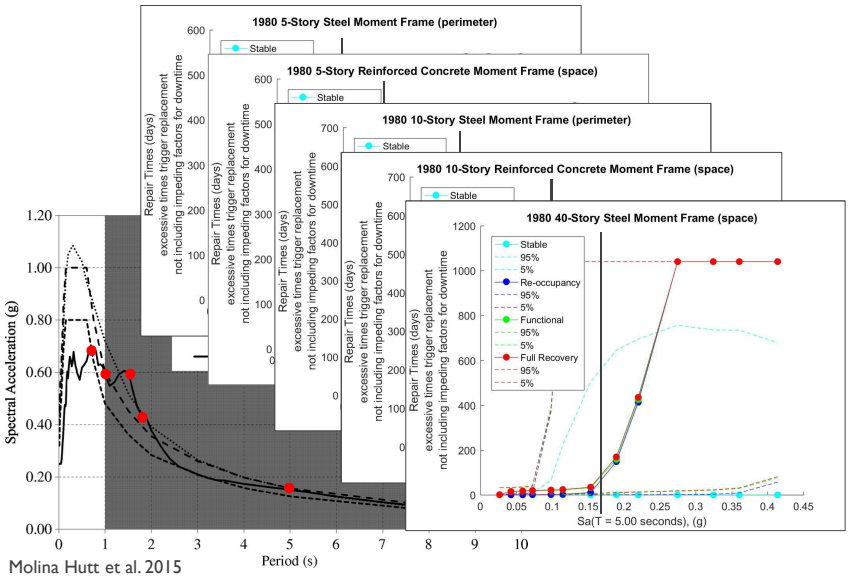
Courtesy of: Haselton and Hamburger

Vulnerability – Archetype Profiles

- Building stock inventory is mapped to archetype profiles
- SP3 software uses FEMA P-58 and REDi to generate repair times for n realizations across multiple IM
- Provides a multi-attribute sample pool (repair times, residual drift, max repair class, collapse indicator)

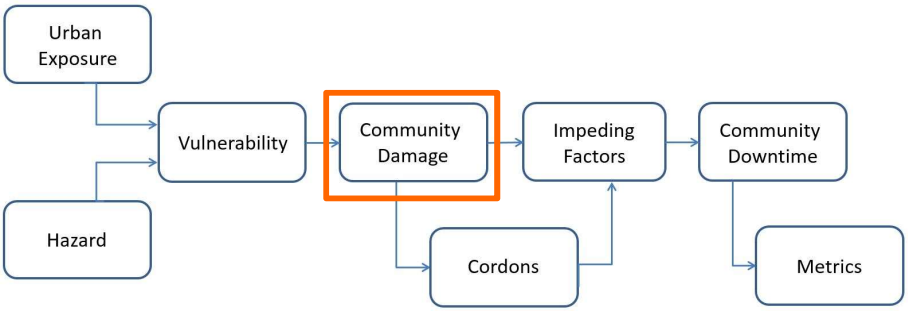


Combining Hazard and Archetype Profiles

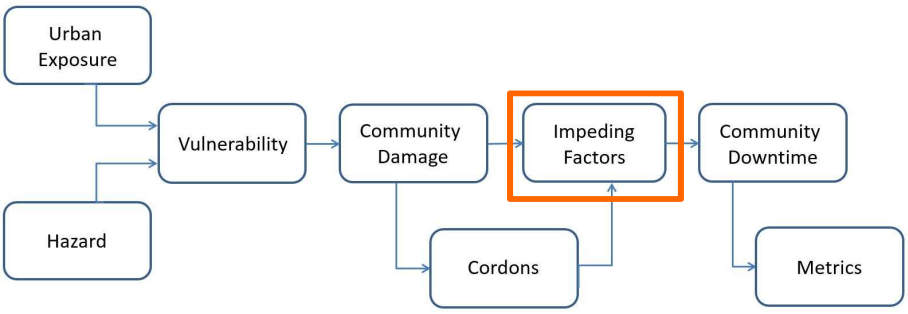


Molina Hutt et al. 2015

Individual Building Damage Across a Community

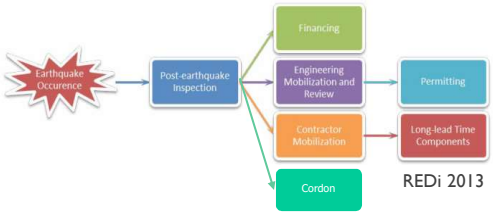


Reframe Impeding Factors

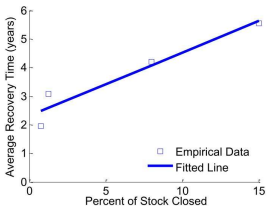


REDi Impeding Factors

- REDi uses sequences of impeding factors for delays prior to repair initiation
- Does not include cordon related delays
- REDi is designed for individual building analysis, and does not incorporate community-wide inflation for downtime



REDi 2013



Burton et al. 2017

Impeding Factor	Building	Mitigation Measure	Other Conditions	θ	β
Inspection	All Facilities	BORP Equivalent	-	1 day	0.54
	Essential Facility	-	-	2 days	0.54
	Non-Essential Facility	-	-	5 days	0.54
Engineering Mobilization & Review/Re-Design	All Facilities	Engineer on Contract	Max Structural RC = 1	2 weeks	0.32
			Max Structural RC = 3	4 weeks	0.54
			Max Structural RC = 3*	42 weeks	0.45
		-	Max Structural RC = 1	6 weeks	0.40
			Max Structural RC = 3	12 weeks	0.40
			Max Structural RC = 3 *	50 weeks	0.32
	≥ 20 Stories	GC on Contract	Max RC = 3	7 weeks	0.35
		-	Max RC = 1	28 weeks	0.30
			Max RC = 3	40 weeks	0.31
Permitting	All Facilities	-	Max Structural RC = 1	1 week	0.86
		-	Max. Structural RC = 3	8 weeks	0.32

*This curve should be used if loss analysis reveals a need for a complete re-design

REDi 2013

Reframing Impeding Factors

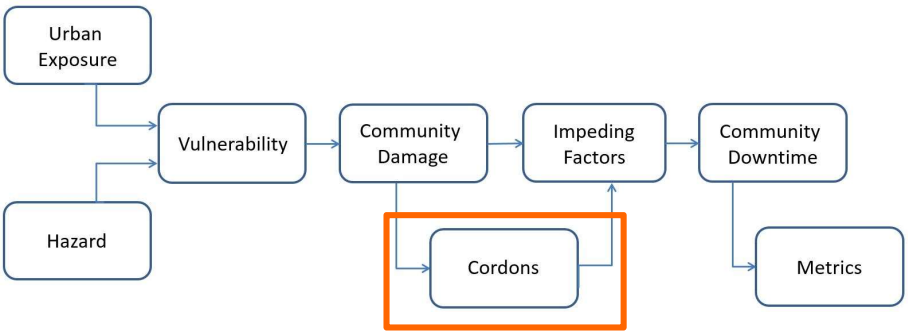
- Conceptually, the median and dispersion parameters for impeding factor curves can be scaled as necessary

- What data is available for informing this impeding factor inflation model?

- Are REDi's current impeding factors appropriate for representing Christchurch and Wellington's recovery?
  - Inspection, Financing, Engineering Mob. + Review, Contractor Mob., Permitting

- How would cordons interact with the other impeding factors?
  - Current factors are either in series or in parallel

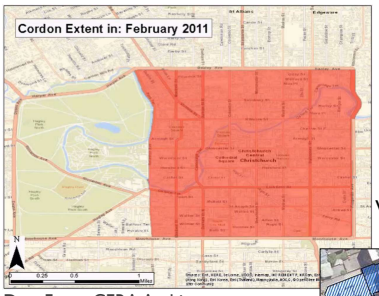
Cordon Analysis



Cordon Strategies

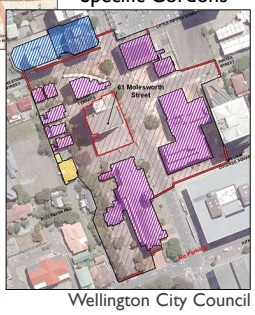
- Past earthquakes have produced a wide array of potential emergency response and cordoning strategies, based on local decisions

Christchurch – Preliminary Cordon



Data From: CERA Archive

Wellington – Building Specific Cordons



Wellington City Council

- Understanding the ramifications of various cordoning choices would be more useful to decision-makers than a predictive model

Cordon Strategies

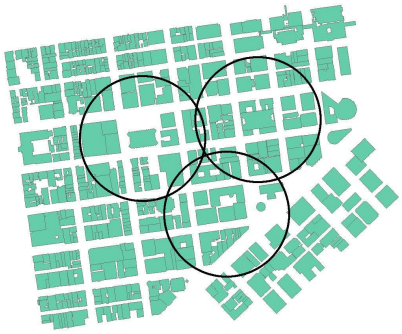
- Aftershock collapse capacities are best characterized by residual drift
- Framework uses residual drift thresholds to trigger cordons

- Preliminary cordon assumptions:
  - Only considered for tall buildings
  - Cordon radius = building height

- What are appropriate cordon protocols?
  - Cordon triggers
  - Cordon extents

Cordon Extent and Duration

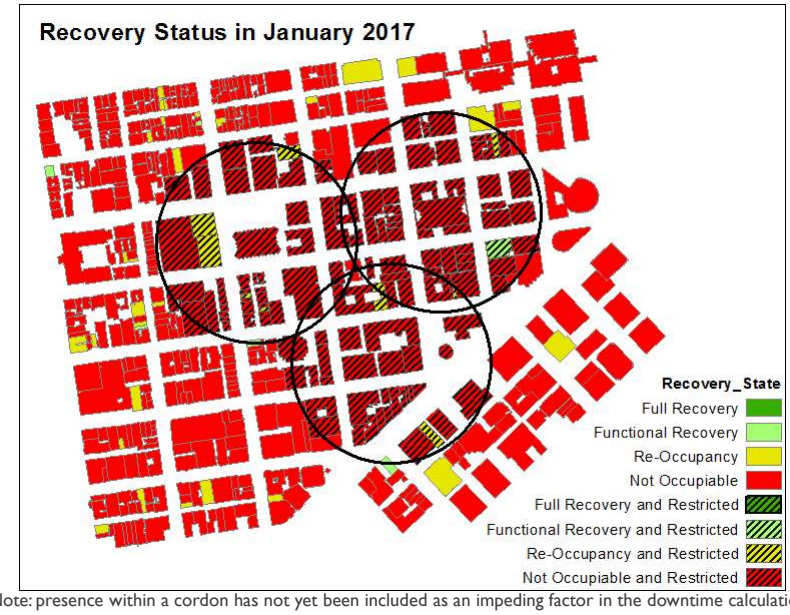
- Spatial analysis for identifying buildings within the cordons
  - Cordon duration is included in the downtime as an impeding factor



- Cordons are removed once the tall building is stabilized, either through structural/ external cladding repair or after demolition is complete

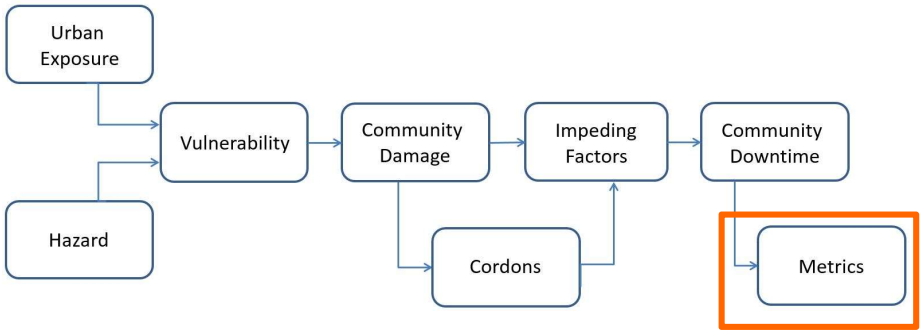
Cordon Duration Includes:	No Cordon Necessary	Significant Damage (>Res. Drift Threshold)	Excessive Damage based on Residual Drift or Cost/Time	Collapse
Inspection	✓	✓	✓	✓
Repair/Demolish Decision		✓	✓	
Mobilize Contractor		✓		
Repair Time to Stable Status		✓		
Mobilize Demolition Crew			✓	✓
Demolition			✓	✓

Recovery Through Time

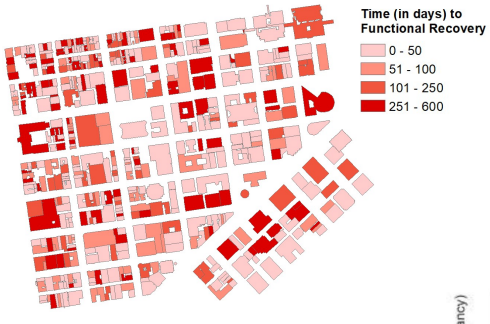


Note: presence within a cordon has not yet been included as an impeding factor in the downtime calculation

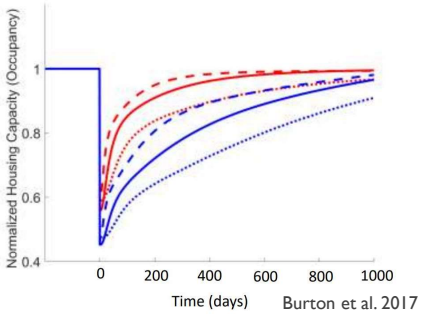
Quantify Metrics



Aggregating for Community Recovery Curves



- The recovery times are known for each building
- Each building's capacity contributes to the cumulative community capacity



Burton et al. 2017

- The cumulative recovery process is captured by community recovery curves
- Curves can be compared for sensitivity analysis for policy interventions

Conclusion

- Community analysis framework incorporates individual building analysis via Monte Carlo simulation from archetype profiles
- Data is needed to inform the reframing of the impeding factors
- Cordon strategies need to be considered