

INTEGRATING EQUITY AND COMMUNITY PERSPECTIVES IN SEISMIC RETROFIT DECISIONS

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Natural Hazards Workshop 2026 Researches Meeting

Housing, Mobility, and Climate Risk



School of Industrial Engineering

Motivation

The built facilities play an important role in shaping how communities experience risk.

(Chang et al., 2014; Dargin & Mostafavi, 2020; Jasanoff, 1993)

U.S. Geological Survey estimates indicate a substantial probability of a major earthquake affecting Southern California in the coming decades. (Field et al., 2014)

Los Angeles has over 1,600 non-ductile reinforced-concrete buildings. These buildings are also called “killer buildings” due to the risk they pose in seismic events.

(Anagnos et al., 2008; Comerio & Anagnos, 2012; Seymour et al., 2009)

Los Angeles Times

L.A. County moves to require quake retrofits as Turkey-Syria death toll exceeds 50,000

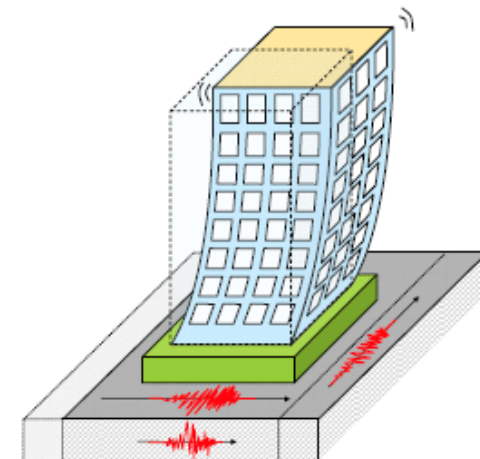
Rebecca Ellis, Rong-Gong Lin II · 13 min read · Feb 28, 2023

Los Angeles Times

Many older L.A. buildings could collapse in an earthquake

Rong-Gong Lin II, Rosanna Xia, Doug Smith · 16 min read · Oct 12, 2013

Non-ductile reinforced concrete buildings (NDRCB) are risky due to their brittle design (they are unable to deform and dissipate energy)



Non-ductile reinforced concrete buildings are “killer buildings”



Photo: Gary B. Edstrom, Kaiser Permanente Building after the 1994 Northridge Earthquake. Public domain, via Wikimedia Commons.



Photo: San Fernando VA Hospital, Sylmar – non-ductile RC hospital buildings that collapsed in the 1971 San Fernando earthquake, killing 49 patients and staff (USGS / LA Times).

There is no standardized framework for incorporating community-elicited service priorities in seismic retrofit decisions of civic infrastructure

Research Gaps

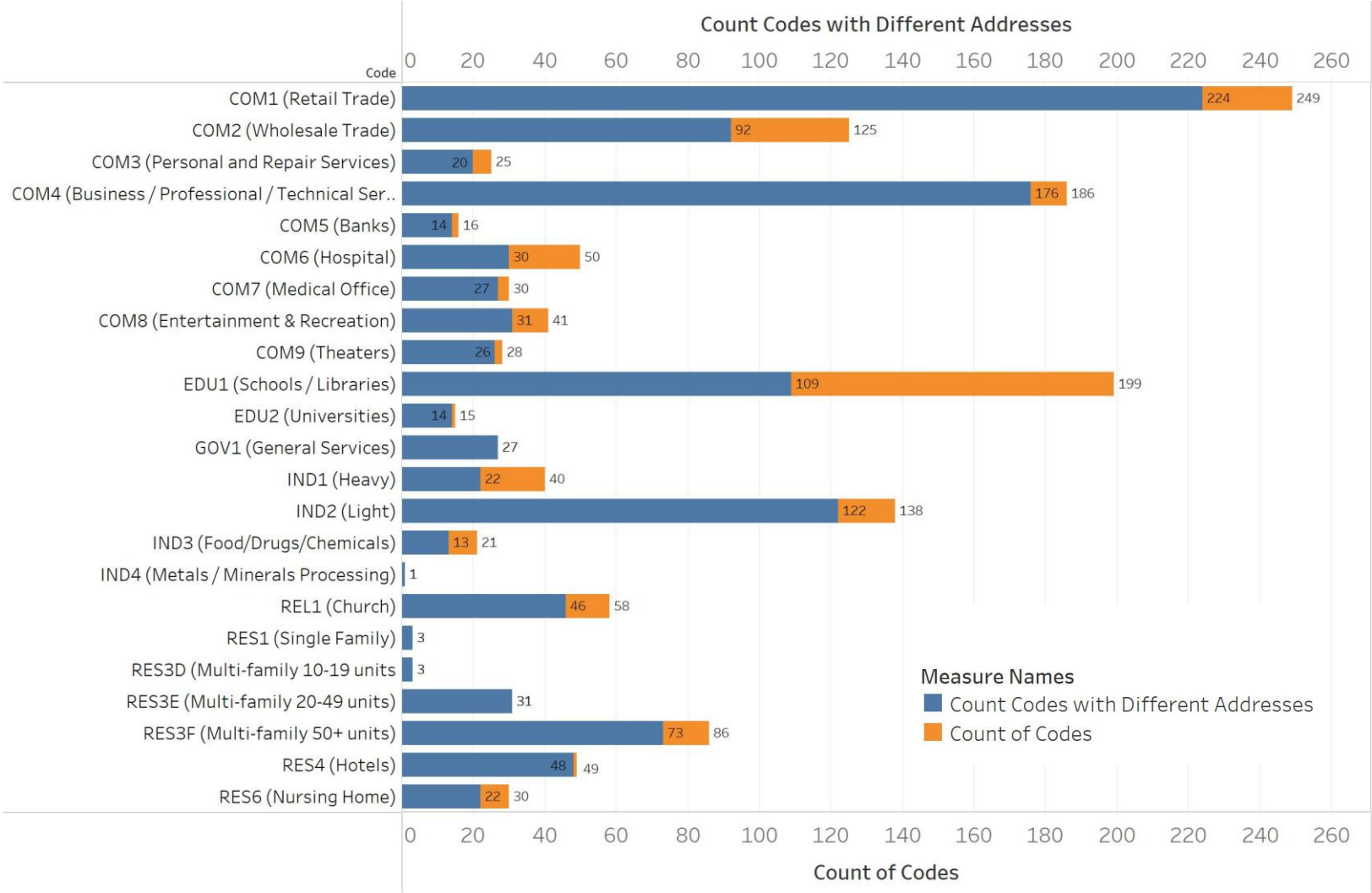
There is limited guidance for prioritizing vulnerable buildings when they differ not only in physical vulnerability, but also in the public functions they support and the populations that depend on them.

(Liel & Deierlein, 2012, 2013; NIST Community Resilience Program, 2020; Sarin, 1983; Zhang et al., 2024)

Many prioritization decisions are made with limited direct input from the communities that will be most affected by the disruption. (Egbelakin et al., 2011; Hardy, 2021).

There is no widely used standardized framework for incorporating community-elicited service priorities and preference heterogeneity into seismic retrofit decision-making. (Aven, 2023; Räsänen et al., 2020; Jasanoff, 1993)

Los Angeles has over 1500 risky buildings



In Los Angeles there are a lot of civic infrastructure that needs seismic retrofits

There are a lot of civic infrastructure

1. Bank
2. Community Center
3. Daycare
4. EMS
5. Fire Station
6. Gas Station
7. Government Offices
8. Grocery Store
9. Hardware Store
10. Hospital
11. Hotel / Motel
12. Laundromat
13. Library
14. Nursing Home / Assisted Living Facility
15. Office Building
16. Pharmacy
17. Places of Worship
18. Police Station
19. Recreational Facilities (theater, concert hall, gyms)
20. School
21. Public Transit Station (Bus / Train Station)
22. Urgent Care / Health Clinic
23. Veterinary Clinic

Survey design and distribution

- Targeted low-income individuals (household income less than \$100k) in Los Angeles County.
- Fielded the survey in April 2026 by Dynata. Translated into Spanish by native speakers.
- Types of questions in the survey
 - Frequency of use of the service questions (6 questions for each respondent)
 - Demographic questions (gender, race, education level, household size, number of children, housing burden). These were asked in the end to reduce discomfort, and their completion did not impact compensation.
 - Earthquake relevant questions
 - Earthquake preparedness
 - Earthquake experience
 - Best-worst scaling questions (12 questions for each respondent)
 - Balanced incomplete block design with randomization across 140 task list.

Best-worst scaling design allows for comprehensive way to rank these civic infrastructure

Best-Worst Scaling with Balanced Incomplete Block Design

Best-Worst Scaling: Show people small sets of items and ask them to pick the **most** and **least** important

Balanced Incomplete Block Design: Each item appears the same number of times, every pair of items together appears together λ times $\rightarrow$ to ensure we can use smaller sets but still create a definitive ranking of items in the list

BIBD conditions: $bk = vr$ and $\lambda(v - 1) = r(k - 1)$

v items, set size k , number of blocks b , appearances per item r , pair co-occurrence λ .

Best-worst scaling method allows for prioritization ranking without cognitive burden

Best-worst scaling question

For each set of services shown, please select the one service that is most important for the community to have working during and immediately after a disaster (most important) and the one that is the least important (least important).

Please select one option for "Most" and one for "Least." You cannot select the same service for both.

	Grocery Store	Pharmacy	Community Center	Urgent Care / Health Clinic
Most important / disruptive if unavailable	☐	☐	☐	☐
Least important / disruptive if unavailable	☐	☐	☐	☐

There are many ways to analyze the survey results to produce a prioritization ranking of civic infrastructure

500 Responses → 449 after filtering

Best – Worst Score

- Descriptive service ranking.
- Does not model respondent heterogeneity or repeated choices.

Multinomial Logit Model

- Estimates average relative performances and supported rankings.
- Assumes preferences are the same across respondents.

Mixed-Logit Model

- Estimates average preferences and respondent-level variation.
- Shows heterogeneity but does not explain its source.

Interaction Model

- Explains preference differences using respondent characteristics.
- More complex and dependent on the reference group sizes.

Best-worst score to estimate overall service ranking

Full Results (449 respondents after filtering the Qualtrics bot filter and attention question)

Civic Infrastructure	Shown	Most	Least	Not Picked	Net Margin	BWScore
Hospital	954	679	35	240	644	0.67505241
Urgent Care / Health Clinic	899	563	28	308	535	0.59510567
Grocery Store	958	494	62	402	432	0.45093946
Fire Station	913	413	30	470	383	0.41949617
EMS	884	404	83	397	321	0.36312217
Police Station	966	401	85	480	316	0.32712215
Pharmacy	883	298	50	535	248	0.2808607
Gas Station	856	240	132	484	108	0.12616822
Bank	896	210	174	512	36	0.04017857
Nursing Home / Assisted Living Facility	957	194	166	597	28	0.0292581

Multinomial logit model to estimate overall service ranking

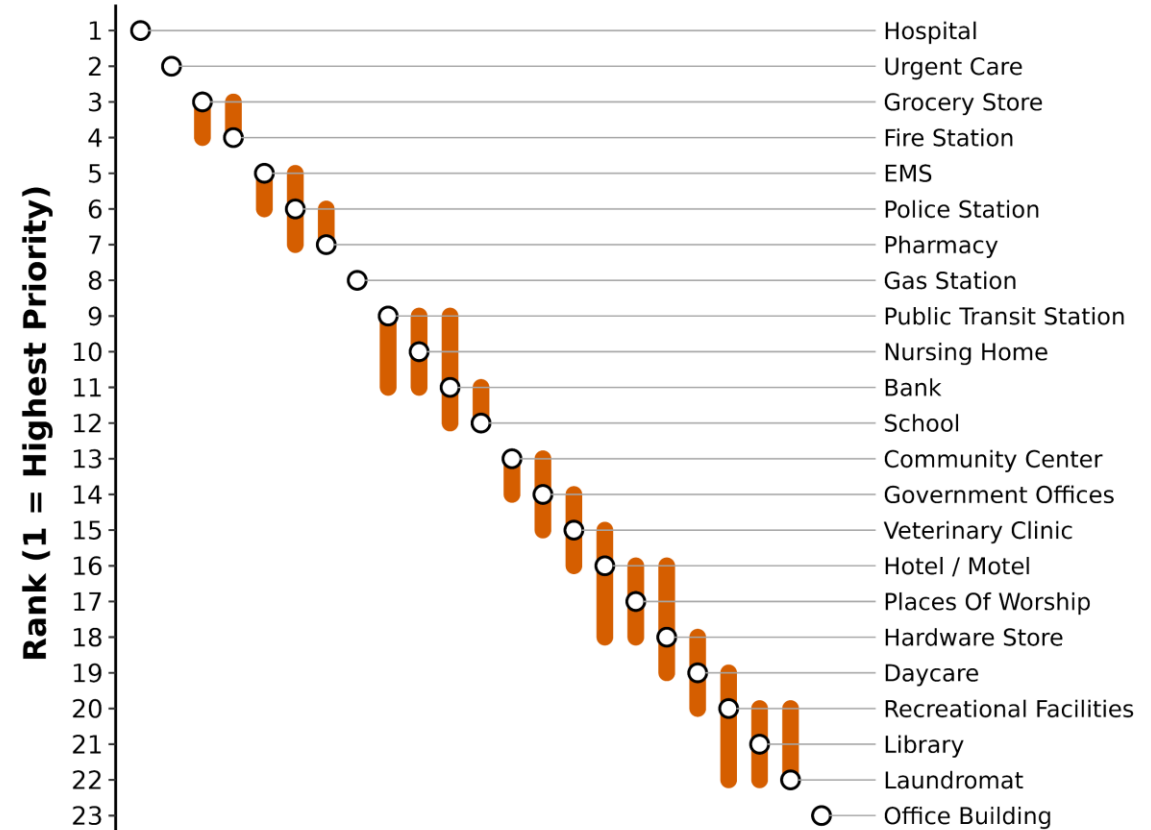
The multinomial logit model gives us the average relative priority of any service across all respondents.

We use Bank as reference and multinomial-logit rank of services is relative to Bank. → The higher the difference of a service from the Bank, the higher the rank.

Pairwise p-values were adjusted using the Benjamini-Hochberg procedure.

Statistically Supported Service Rankings

Points show estimated ranks; vertical bars show ranks that cannot be statistically distinguished



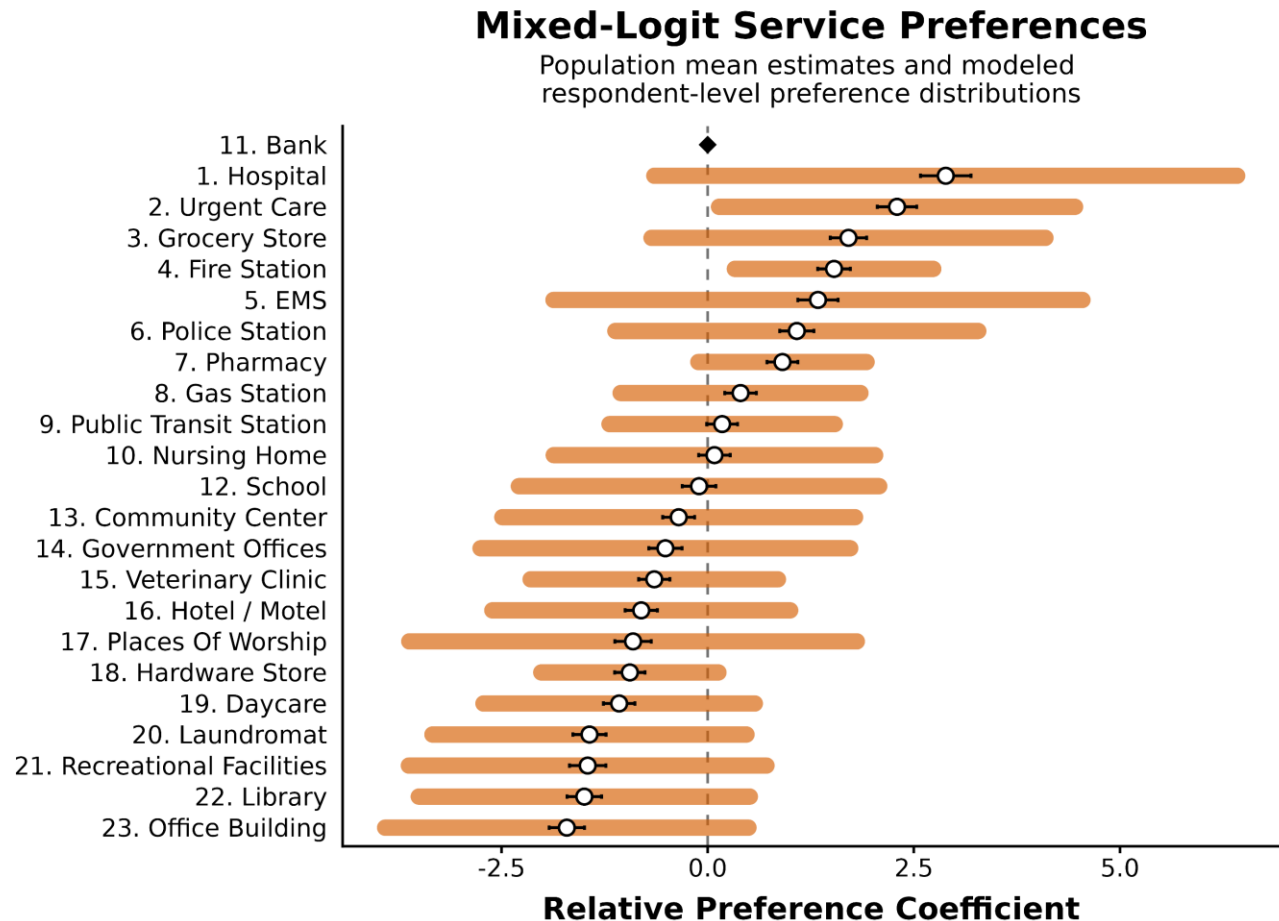
Services are ordered by their multinomial-logit coefficients.

Pairwise p-values were adjusted using the Benjamini-Hochberg procedure.

Mixed logit model to test respondent preference heterogeneity

The mixed logit model allows selected service coefficients to vary across respondents. So, we can answer:

1. What is the average priority of each service?
2. How much disagreement or heterogeneity exists across respondents?



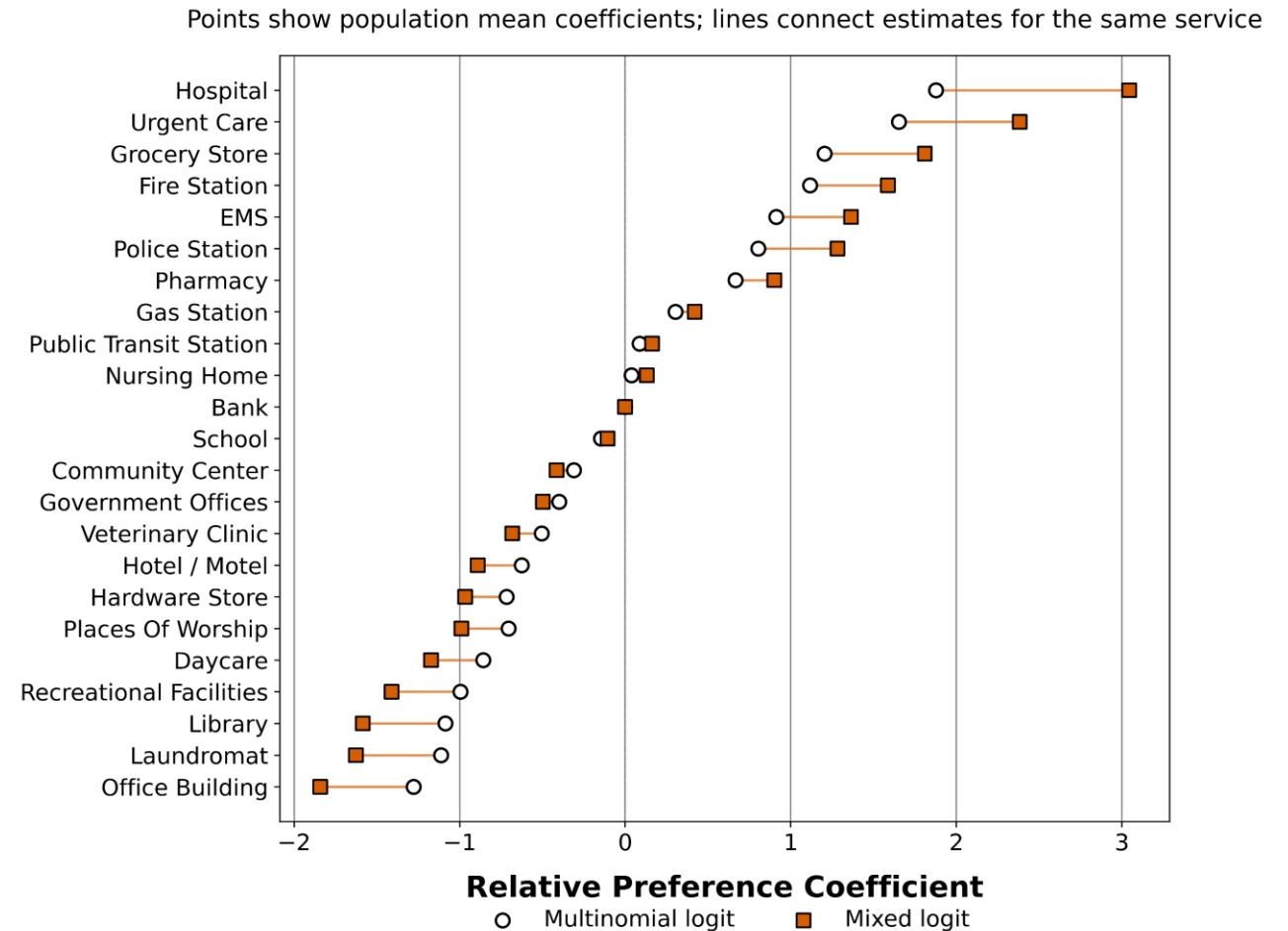
White points and thin black intervals show population-mean coefficients and their 95% confidence intervals.
Thick orange intervals show the approximate central 95% of the modeled respondent coefficient distribution (mean $\pm$ 1.96 random SD). Bank is fixed at zero.

Model Comparison: Mixed logit model performs better

Comparison of MNL and Mixed-Logit Estimates

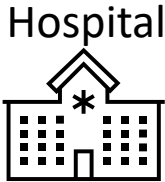
The comparison between multinomial logit and mixed-logit model shows there is heterogeneity between our respondents' preferences.

Model	AIC
Multinomial Logit Model	20,810.05
Mixed Logit Model	19,575.62

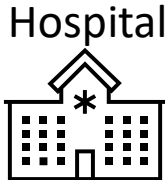


Interaction models to determine whether preferences differ across demographic and earthquake experience groups

Moderate earthquake experience > No/minor earthquake experience



More than 50% of income on housing > Less than 30% of income on housing



Hispanic/Latino Respondents > White Respondents



Interaction models to determine whether preferences differ across demographic and earthquake experience groups

White Respondents > Black / African American Respondents



Black / African American Respondents > White Respondents



Household without children > Households with children



Households with children > Households without children



Graduate or professional degree > College or associate degree

Public Transit Station



Conclusions

Best-worst scaling provides a way to prioritize list of services without putting too much burden on the respondents.

Hospitals and urgent care are the most important services to keep in operation during and after a disaster.

Grocery stores are ranked either as important or more important than emergency services.

Demographic characteristics and the level of earthquake experiences has significant impact on the value of some civic infrastructure.

Future work

Evaluating whether the frequency of use or visit of certain services impacts the prioritization rankings.

Geographic analysis of prioritization rankings → Does living in an area with higher density of buildings that needs retrofitting cause differences in rankings

Expanding the analysis into Northern California (Bay Area), Oregon, and Washington

Acknowledgements



National
Science
Foundation

**Strengthening American Infrastructure
(SAI) – Award Number: 2228559**

Project Team Members:

David Johnson, Purdue University
Edwin Dielming Patino, Purdue University
Julio Alfonso Ramirez, Purdue University
Yanyu Ma, Purdue University
Holly Wang, Michigan State University
Shirley Dyke, Purdue University

THANK YOU

Questions?

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