Variability of Business Characteristics Exposed to Building Damages from Earthquakes in the San Francisco Bay Area

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Abstract

Understanding the exposure of business characteristics like its location, sector, size, age, and owner demographics and structure to building damages from an earthquake can inform business continuity planning and broader community and regional programs and policies for business recovery. A baseline analysis was performed for the HayWired scenario (Wein, Haveman and others, 2019) using business characteristic data from the National Establishment Time Series (NETS) which showed that location and sector are strong differentiators of disruptive building damage risk, while minority ownership, branch ownership structure, and low revenue are other above average differentiators. The HayWired analysis was limited by damage information at the census tract scale for occupancy classes (per the Federal Emergency Management Agency Hazus software). In this study, we expand the analysis to multiple earthquake scenarios and apply machine learning techniques to generate building level assessments instead of census tract level. Association of business characteristics with building damages by location increases the analysis resolution providing more nuanced understanding and analyzing across multiple scenarios shows the variability of business characteristic exposure to different earthquakes for the region and across communities. Anne Wein, Jon Haveman, Cynthia Kroll, Jeff Peters. 2019. Characteristics of Businesses disrupted by Building Damages from the HayWired Scenario Mainshock, in press.

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Abstract

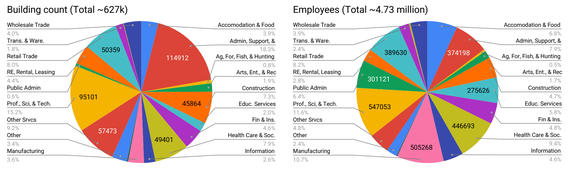
Understanding the exposure of business characteristics like its location, sector, size, age, and owner demographics and structure to building damages from an earthquake can inform business continuity planning and broader community and regional programs and policies for business recovery. A baseline analysis was performed for the HayWired scenario (Wein, Haveman et. al., 2019) using business characteristic data from the National Establishment Time Series (NETS) which showed that location and sector are strong differentiators of disruptive building damage risk, while minority ownership, branch ownership structure, and low revenue are other above average differentiators. The HayWired analysis was limited by damage information at the census tract scale for occupancy classes (per the Federal Emergency Management Agency HAZUS software). In this study, we expand the analysis to multiple earthquake scenarios and apply machine learning techniques to generate building level assessments instead of census tract level. Association of business characteristics with building damages by location increases the analysis resolution providing more nuanced understanding and analyzing across multiple scenarios shows the variability of business characteristic exposure to different earthquakes for the region and across communities.

Introduction

Individual businesses are an integral part of communities and influence their recovery after disasters. Business interruption may occur from a variety of factors including damages to buildings, content and inventory, disruption of utility services, supply chain, transportation networks, and unavailability of employees or customers. This study investigates the risk of building damage which can limit its use for business, in order to identify how business characteristics relate to seismic vulnerability of their buildings.

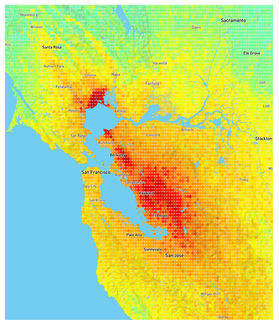
This analysis in the San Francisco bay area increases the spatial resolution of the Wein, Haveman et. al. (2019) study that identified business and owner characteristics at risk of extensive or complete building damage by census tract in the HayWired scenario. We analyze building damages at the building level, and expand to two additional earthquake scenarios - an M7.0 earthquake on the Hayward fault, and an M7.0 earthquake on the San Andreas fault.

The business and owner characteristics data in San Francisco Bay area is obtained from the National Establishment Time-Series (NETS) data set. A summary of buildings and employment by industry sectors in the dataset is shown below -



Ground motion generation

Ground motions are generated for two M7.0 scenarios, one each on San Andreas and Hayward faults on a 0.01° latitude by 0.01° longitude grid, using GEM (2019) OpenQuake engine. Ground-motion prediction equations from NGA-West2 are used along with Jayaram and Baker (2009) spatial correlation model to generate ground motion realizations from the fault ruptures. One of the realizations is randomly selected. Damage analysis is also performed on the USGS M7.05 HayWired scenario for comparison with the previous study. The realizations of Peak Ground Accelerations from the two scenarios and the HayWired scenario are shown below -

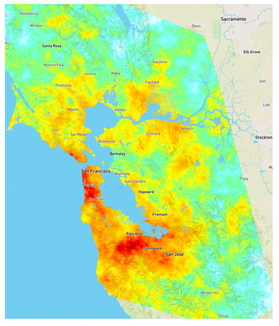


M7.05 HayWired scenario from USGS

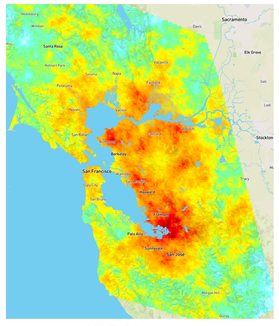
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong
POTENTIAL DAMAGE	none	none	none	Very light	Light
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI

Scale based upon Worden et al. (2012)

Very strong	Severe	Violent	Extreme
Moderate	Mod./Heavy	Heavy	Very Heavy
22	40	75	>139
20	*41*	*86*	*>178*
VII	VIII	IX	X+



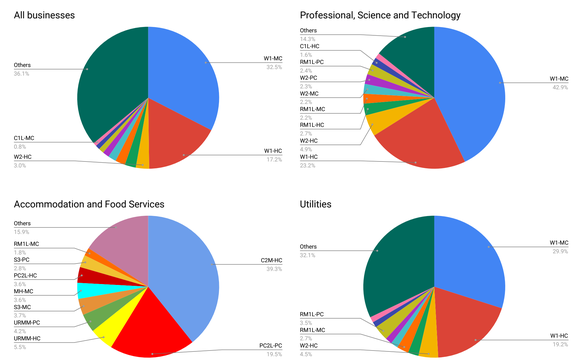
M7.0 San Andreas



M7.0 Hayward

Exposure and vulnerability functions

Business locations from NETS database are associated with buildings based on one-to-one nearest neighbor search with buildings data from the tax assessor's office. HAZUS building type and code level are applied to buildings based on their construction material and year.

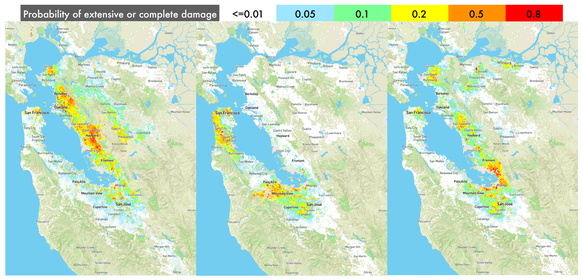


W1	Wood, light frame (<= 5000 sq. ft.), 1-2 stories	PC2L	Precast concrete frames, low 1-3 stories
W2	Wood, commercial and industrial (> 5000 sq. ft.)	URMM	Unreinforced masonry bearing walls, mid 2+ stories
RM1L	Reinforced masonry, 1-3 stories	S3	Steel light frame
C1L	Concrete moment frame, low 1-3 stories	MH	Mobile homes
C2M	Concrete shear walls, mid 4-7 stories		

PC - Pre 1941 MC - 1941-1974 HC - 1975-

Building damage estimation

Ground motions are interpolated to business building locations from the realizations using cubic interpolation. HAZUS fragility functions are used according to assigned building type and code level. The probability of extensive or complete damage at business locations in each of the three scenarios is shown below -

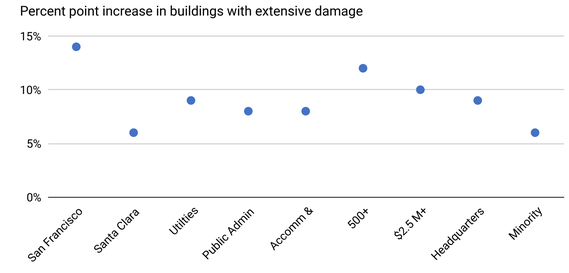


HayWired scenario M7.0 San Andreas M7.0 Hayward

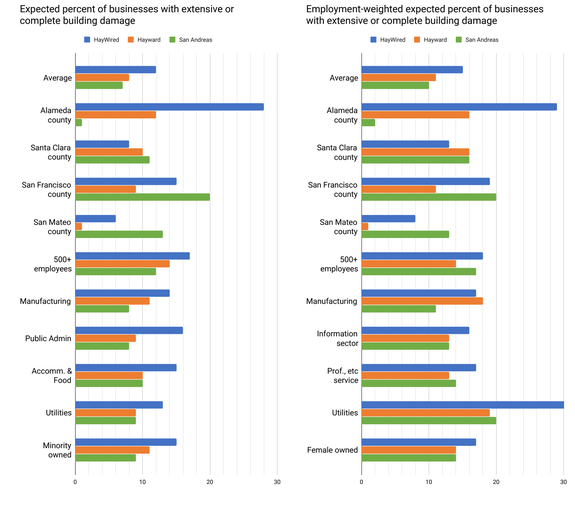
Comparison of HayWired results

A comparison was made between the current study and the previous study by Wein, Haveman, et. al. (2019) for the business characteristics of vulnerable buildings in the HayWired scenario. The previous study used 2005 building exposure data at a census tract level from HAZUS, while the current study used 2019 building inventory data from the tax assessor's office.

- Buildings with extensive damage increased from 7.3% to 11.7%, although liquefaction was not included in this study.
- San Francisco county experienced highest change in percent of buildings with extensive damage from 1.3% to 15%.



Comparison among scenarios



Discussion

- Across all scenarios -
  - Percent of buildings with extensive damage increases with business age, revenues, and size.
  - Percent of buildings with extensive damage for minority owned businesses exceeded that of non-minority owned businesses.
  - Accommodation and food, and Other sectors are in top 4 sectors for building damage.
- Among the top 4 industry sectors with highest percent of buildings with damage, manufacturing and public administration are most impacted in the two Hayward fault scenarios, while information and utilities are most impacted in the San Andreas scenario.
- Weighing percent of buildings with extensive damage by employment -
  - elevates employee risk for all three scenarios in Santa Clara county, for manufacturing, public administration, wholesale, and utilities, and for female-owned businesses.
  - maintains the trend for size, revenue, and minority-owned business characteristics.

Conclusions and limitations

- The county in which a business is located is the strongest differentiator of building damage across all scenarios.
- Accommodation and food services is one of the most impacted sectors across all scenarios, with manufacturing and public administration also impacted in Hayward fault scenarios, and information and utilities impacted in San Andreas scenario.
- More work is needed to identify the contributions of updated building inventory and differences in fragility functions toward the increase in building damage in this study compared to the previous study. This was especially the case for the expected percent of employees affected by damage to utility buildings in San Francisco - estimated at 53% for the HayWired scenario.
- Future work could include combinations of business characteristics, e.g., size, sector, and ownership.
- The approach presented in this study can be used to inform data-driven policies by identifying industry sectors or business characteristics that are more vulnerable to business disruption or closure, and highlighting areas of improvement to increase resilience, thus ensuring that communities are able to bounce back faster in future disasters.

References

Jayaram N. and Baker J.W. (2009). "*Correlation model for spatially-distributed ground-motion intensities,*" Earthquake Engineering and Structural Dynamics, 38(15), 1687-1708.

Wein A., Haveman J., Kroll C., Peters J. (2019). "*Characteristics of businesses disrupted by building damages from the HayWired scenario mainshock,*" in press.

GEM (2019). "*The OpenQuake-engine User Manual* ,"Global Earthquake Model (GEM) Open- Quake Manual for Engine version 3.7.0.