Tracking the Progression of Retrofits for the Los Angeles Soft Story Ordinance: Effect of Socioeconomic Factors and Inequities in Temporal Seismic Risk Reduction

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Introduction

Since its implementation in 2015, the Los Angeles Soft-Story Ordinance has led to large numbers of retrofits of multi-story wood-frame buildings with soft, weak or open front (SWOF) wall lines. The Ordinance aims to reduce the collapse risk of such buildings by mitigating the formation of a single-story mechanism caused by differences in strength and stiffness of adjacent stories. Although other cities and municipalities such as Pasadena and San Francisco have enacted similar measures, the geographic scale and diversity of affected residents pale in comparison to the Los Angeles Ordinance. With retrofit costs ranging from $60,000 to $130,000 for mid-size buildings and as much as $350,000 for large apartments [1], the associated financial burden is a major impediment to attaining full compliance. Although owners can apply for the California Capital Access Program [2] for assistance in recovering the cost of the retrofit, there are no current programs that offer up-front subsidies.

Previous research on wood-frame buildings have quantified the effect of retrofit on collapse risk [3,4], evaluated the effect of alternative soft-story retrofit schemes on system performance [4,5], and analyzed the cost-benefit of the Los Angeles Soft-Story Ordinance through regional-scale seismic loss assessments [6]. All of these were based on static scenarios that do not account for temporal shifts in performance and subsequent risk reduction based on retrofit progress. Moreover, the implications of potential socioeconomic inequalities to the reduction in seismic risk have not been studied. Recent studies [7] have started to identify the socioeconomic disparities in energy retrofit programs, but there has been no comprehensive study conducted on seismic retrofits.

This study examines various trends in the progress of retrofits under the Los Angeles Soft-Story Ordinance. Both temporal and geographic trends are analyzed in addition to potential disparities in the pace of retrofit based on income, race, and educational attainment. The trajectory of seismic risk reduction under the Ordinance is quantified through a seismic loss assessment of existing and retrofitted SWOF buildings in the City based on a hypothetical **M** 7.1 Puente Hills event. The implications of inequalities in the risk reduction are analyzed through disaggregation of the trajectories by the aforementioned socioeconomic characteristics.

Description of the Data

Data on retrofit progress and compliance were obtained from the Los Angeles Department of Building and Safety (LADBS) [8], including the building occupancy type, number of units per building, date of order to comply, and dates on which each compliance status was achieved. The compliance status of each building is classified into three levels under the LADBS retrofit program: *Level 1* - Submit proof of previous retrofit, or plans to retrofit or demolish, *Level 2* - Obtain permit to start construction or demolition, and *Level 3* - Complete construction (fully retrofitted). The exact locations of buildings were verified using permit records accessed via the Los Angeles Open Data portal [9]. Buildings without permit records were not considered in this study. The breakdown of soft-story buildings with respect to each compliance level is shown in Table 1. It can be seen that there is a significant delay in the retrofit of condominiums and non multi-unit dwellings when compared to the entire inventory. Furthermore, a higher percentage of units have attained Levels 2 and 3 compliance in comparison with that of individual buildings, again suggesting that multi-unit dwellings have progressed further in terms of retrofit completion compared to Other types of buildings.

Table 1. Distribution of Soft-Story Compliance Status (Raw counts in parentheses)

	Level 1	Level 2	Level 3
Total buildings	37.2%* (4383)	22.6% (2659)	40.3% (4659)
Apartments	36.5% (3983)	22.1% (2412)	41.4% (4526)
Condominiums	45.9% (369)	27.2% (219)	26.9% (216)
Other (Non multi-unit)	50.8% (31)	45.9% (28)	3.3% (2)
Number of units	30.8% (49054)	25.8% (41041)	43.4% (69075).

*Percentages relative to the sum of each category

The spatial distribution of soft-story buildings at each level is shown in Figure 1 below, although trends are not readily apparent due to the sheer number of buildings displayed. The histogram of time to achieve each compliance level from the date of the order to comply is shown in Figure 2. Lower compliance levels tend to have a much shorter duration to meet compliance. An interesting observation is that the time to Levels 2 and 3 compliance have a “normal-like” distribution whereas the histogram for Level 1 compliance has much more of a “left skew.”

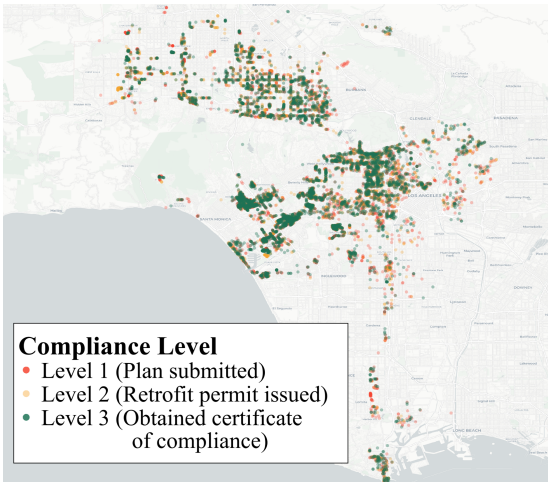

Figure 1. Spatial distribution of soft-story buildings at each compliance level

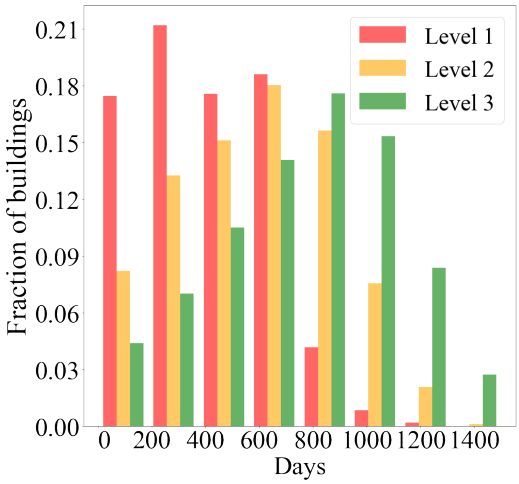

Figure 2. Histogram of duration (from date of order to comply) to achieve each compliance level

Analysis of Socioeconomic Trends

The median income, race (including Hispanic/Latino population), and educational attainment in terms of percent high school graduates were obtained from US Census data [10]. Each soft-story building was assigned the corresponding characteristics by performing a spatial join at the census tract level. For a representative profile of the overall distribution, the inventory of soft-story buildings was divided into four quartiles for each category. The median duration to achieve Level 3 (fully retrofitted) from the date of order to comply was found for each socioeconomic quartile (Table 2). In general, the duration tends to decrease with increasing quartiles of median income, percent white, and percent high school graduate population.

It should be noted that this trend is reversed for percent Hispanic/Latino population, where the 4th quartile with the highest Hispanic/Latino proportion exhibits the greatest median duration. In terms of racial groups, individual race profiles specific to percent African American and Asian population did not display any significant association with the duration to comply and were not analyzed in further detail. The difference in median duration between the 1st and 4th quartiles of all other sociodemographic profiles was at least 50 days, with a difference of more than 3 months for percent high school graduates.

Table 2. Median duration (days) to achieve Level 3 per quartile

Quartile	1st	2nd	3rd	4th
Median income	807	783	781	754
Percent white	834.5	787	782	765.5
Percent African American	781	795	767	789
Percent Asian	792	788.5	747	802
Percent Hispanic/Latino	737.5	770	800	822
Percent high school graduate	865	801.5	777	761

Trajectories of the proportion of Level 3-compliant buildings with respect to the time since order to comply are shown in Figure 3 for percent Hispanic/Latino and percent high school graduates, profiles which had the greatest difference in median duration between the 1st and 4th quartiles. There exists a considerable gap between quartiles with the highest Hispanic/Latino population and the lowest percent of high school graduates and the adjacent quartiles; these quartiles have a compliance proportion that is 10.1% and 13.8% lower than the next quartiles, respectively. The apparent gaps highlight the need for increased support in underserved communities that fall in these quartiles; not only do they have the longest duration to achieve compliance, but they also have the lowest proportion of fully retrofitted buildings.

Analysis of Geographic Trends

For a higher-level analysis that examines all three compliance levels, the retrofit progress of each census tract was assessed by computing the mean of the compliance level of all constituent soft-story buildings, which are shown in Figure 4. Whereas tracts with high levels of compliance (2.7 or greater) are distributed fairly evenly, low compliance levels (near 1.0) are concentrated around tracts with low-income and low percentage of high school graduates. Analysis of tracts with a mean compliance Level of 1 (i.e. minimal progress) shows that 65.0% have a median income below that of Los Angeles County ($62,910), and that 71.6% of such tracts had a median high school graduate population lower than that of Los Angeles County (80.4%). The spatial distribution of these tracts are shown in Figure 5; the tracts are concentrated in Eastside and South Los Angeles.

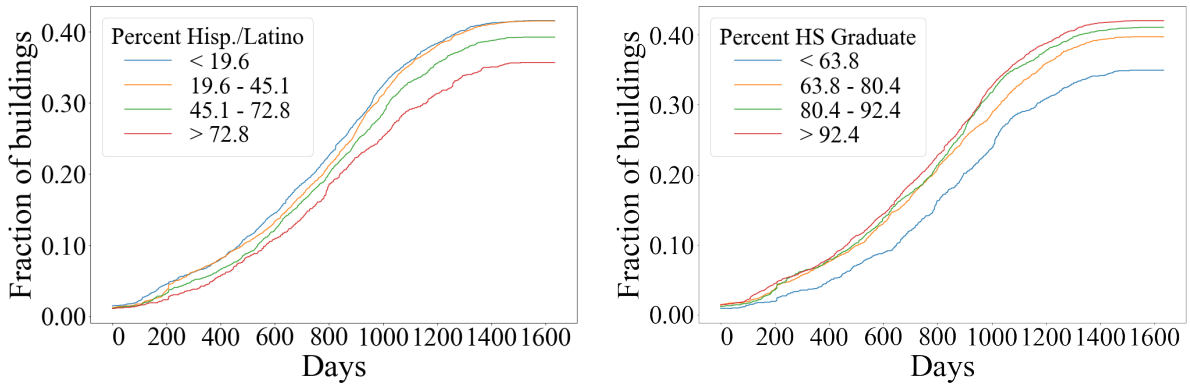

Figure 3. Trajectories (based on the time since the order to comply) of Level 3-complaint (fully retrofitted) buildings disaggregated by (a) percent Hispanic/Latino population and (b) percent high school graduates

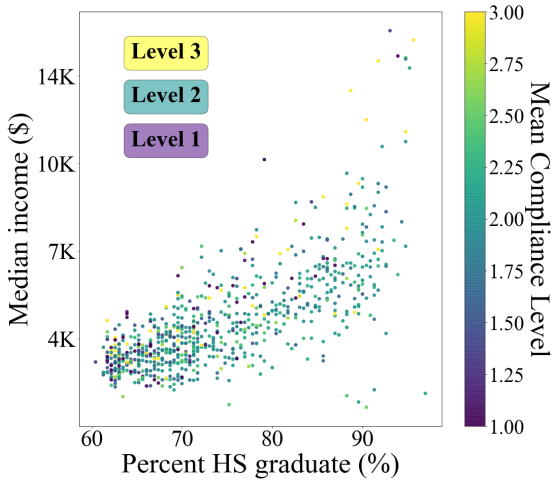

Figure 4. Distribution of mean compliance level per census tract

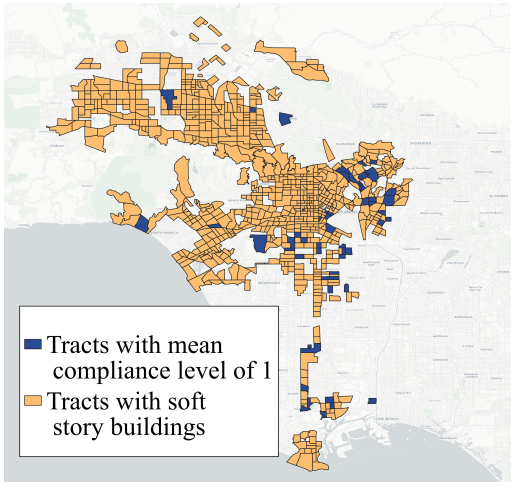

Figure 5. Location of census tracts with a mean compliance of Level 1

Temporal reduction in scenario-based losses based on hypothetical Mw 7.1 Puente Hills event

For the loss reduction analysis, 32 archetypes developed by Burton et al. [4] based on a survey of 3,000 buildings in Los Angeles were considered. These archetypes account for differences in first-story layouts, number of stories, and types of interior walls; details on the geometry and seismic weight of each archetype is summarized in Burton et al. Tables 1 and 2 [4]. The surveyed buildings comprise roughly 27% of the building inventory in this paper; archetypes were randomly assigned to the rest of the inventory to reflect the proportions of each archetype in the survey. As part of a cost-benefit analysis, Yi et al. [6] developed intensity-based economic loss curves for each archetype before and after retrofit using the Seismic Performance Prediction Program (SP3) based on FEMA P-58 methodology. Two types of earthquake induced losses were considered for each archetype: direct losses caused by damage to buildings and fatality losses. These loss curves were coupled with the spatial distribution of shaking intensities for a hypothetical **M** 7.1 Puente Hills event obtained from Yi et al. [6] to assess the scenario-based losses. The total induced losses for a given day after the implementation of the Soft-Story Ordinance was calculated by assigning the loss to each building based on whether it had achieved Level 3 compliance.

The trajectory of loss reduction is shown in Figure 6. Each point on the curve represents a fraction (or percentage) of the dollar loss relative to the existing inventory that would be induced if the same **M** 7.1 event occurs on any given day after the implementation of the Soft-Story Ordinance. With 40.3% of the building inventory currently having undergone retrofit, there has been an overall 7.9% reduction in losses. A complete retrofit of all buildings is predicted to result in a 17.5% reduction in losses.

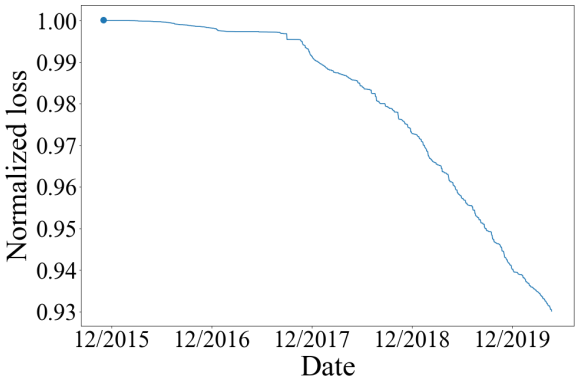

Figure 6. Trajectory of normalized loss reduction (based on Mw 7.1 Puente Hills Event)

The trajectories of loss reduction normalized with respect to the initial loss are shown in Figure 7. The risk reduction among the four median income quartiles is fairly evenly distributed. There is an evident gap for the quartile with the highest Hispanic/Latino population, which has a risk reduction of 5.32% that is 19.6% lower (relatively) than a reduction of 6.73% for the adjacent quartile as of August 2020. For percent white

population, the risk reduction of the two lowest quartiles are relatively 19.6% and 12.3% lower than that of the next quartiles respectively. There is a similar trend for the percent high school graduates, with corresponding relative differences of 14.2% and 11.5%. The top two quartiles are clustered for these two socioeconomic factors.

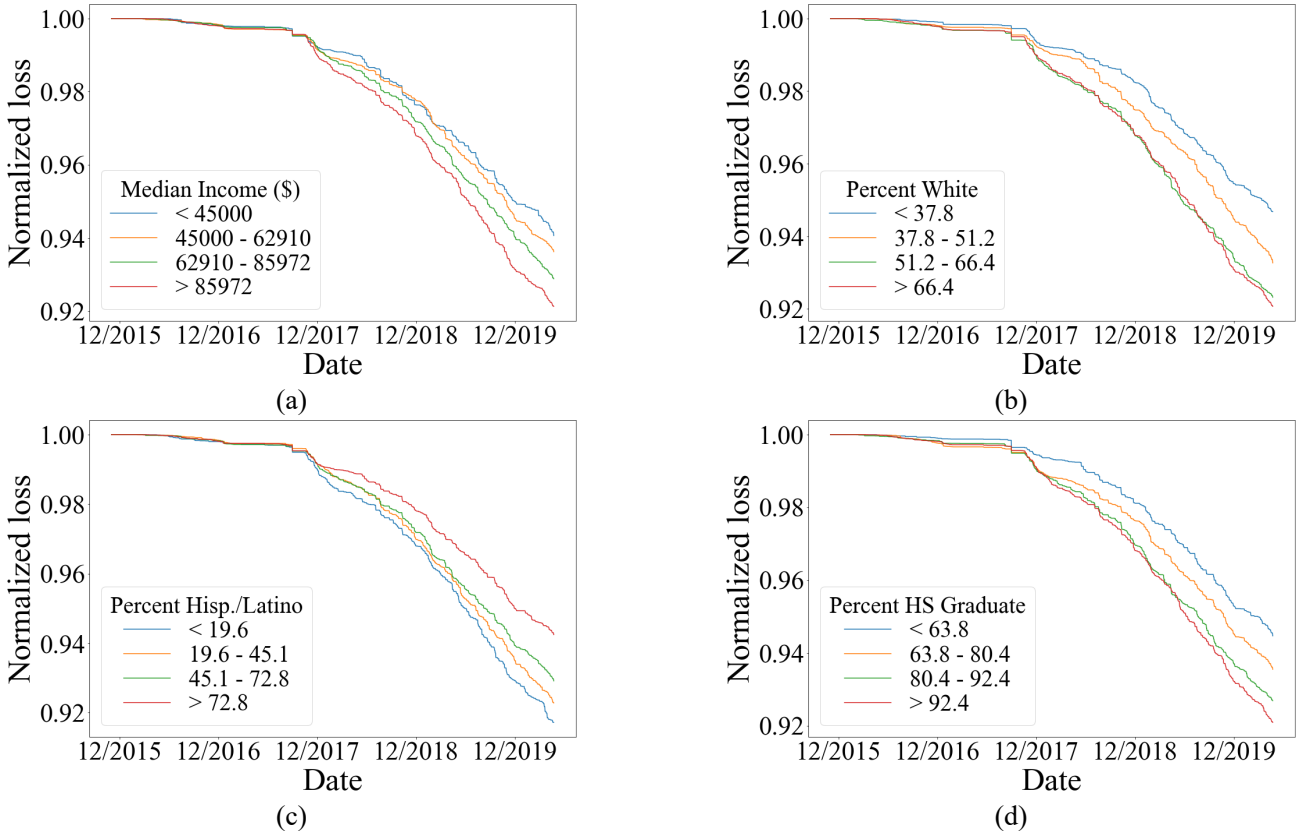

Figure 7. Trajectories of loss reduction (normalized by initial loss) disaggregated by (a) median income (b) percent white population (c) percent Hispanic/Latino population and (d) percent high school graduates

Conclusion

Temporal and geographic trends in the progress of retrofits under the Los Angeles Soft-Story Ordinance and potential disparities in retrofit caused by socioeconomic inequalities were analyzed based on spatial joins using data from LADBS and the US Census. Higher median income, percent white population, percent high school graduate population, and lower percent Hispanic/Latino population were associated with shorter durations to achieve full retrofit as well as higher proportions of fully retrofitted buildings. For the risk reduction analyzed using the hypothetical **M** 7.1 Puente Hills event, these factors resulted in a greater rate of reduction. The trends were distinct with the trajectories of one quartile rarely crossing that of others, and lags were consistently present for the highest quartile of percent Hispanic/Latino population. With all three compliance levels in consideration, it was observed that higher compliance levels tend to have longer durations to comply, and communities with the lowest overall compliance were concentrated in Eastside and South Los Angeles.

Acknowledgements

I would like to express my deep gratitude to Professor Henry V. Burton (UCLA) and Zhengxiang Yi (Ph.D. Candidate, UCLA) for their continued support and guidance.

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