Oakland Resilience Initiative

Soft Story Apartment Retrofits

Executive Summary

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Acknowledgements

First and foremost, our team would like to acknowledge and thank the many people who made it possible for us to pursue our project. Our main contact and leading community partner was Victoria Salinas, who took the time throughout our project to sit down and talk with us, something that proved invaluable as we moved forward. In addition, we would like to thank City of Oakland affiliates, Sue Piper – who spoke with us regarding the outreach component of our project – and Tim Low. Tim provided us with information regarding the structural nature of the buildings that were being targeted by the program, without which we would have never been able to complete the risk analysis portion of our project.

Second, we would like to thank our contacts at ABAG, both Danielle Mieler and Dana Brechwald, who also provided our team with vital information regarding buildings types, and were able to guide us throughout the project as to how to proceed in specific areas.

Third, we would like to recognize our Stanford mentors throughout this project. Mary Lou Zoback spoke with us and sent us information concerning San Francisco's retrofit programs, which provided us with an ideal framework for how to best outline of scope of work. David Lallemant, after delivering a wonderful lecture to our Sustainable Cities class, came to speak with us about our project and our own thoughts on the notion of 'Resiliency.' David Medeiros, an expert in GIS mapping, helped us iterate on the design and content of our GIS map deliverables. Lastly, not only our project but the entire class would never had been possible without the guidance and tutelage of Professor Deland Chan, who on a weekly basis inspired us to do more with what we had available.

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I. Project Purpose

The City of Oakland's partnership with the 100 Resilient Cities initiative began when the City was selected by the Rockefeller Foundation to be a part of the 100 Resilient Cities Initiative. Through this program, Oakland, along with a potential 99 other cities from around the world, are collaborating with the 100 Resilient Cities Initiative with the goal of designing programs and policies to safeguard civilians from natural disaster and other critical urban stresses. With their Soft-Story Apartment Earthquake Retrofit program, the City of Oakland is focusing decreasing the likelihood that Oakland soft-story homes, homes with less structural support on the first story, will collapse or fall into disrepair in the event of an earthquake. Given that there are 1,400 homes and 22,000 units all designated as "soft-story" by the City of Oakland, the implementation and delivery of a mandatory retrofit, or structural reinforcement program is being carefully designed and formatted to meet the needs of the many community stakeholders.

During their initial pilot phase, the City's Oakland Resilience team must decide how to best allocate limited resources to expedite the retrofit process for the most critical or vulnerable areas. On this issue, Oakland Resilience planners are weighing notions of resilience with notions of sustainability. While it is certainly a resilience priority to retrofit as many soft-story homes as possible as soon as possible, this process must not come at the cost of the displacement of tenants throughout Oakland, or further economic stress to low-income families.

Through the Stanford Sustainable Cities course, our project team worked with the City of Oakland and the 100 Resilient Cities Initiative on developing their Soft-story Earthquake retrofit program, one such program to mitigate the damage caused to Oakland's inhabitants in the event of an Earthquake. The needs of the Oakland team in this early development phase were diverse in their nature, thus we adapted our contribution to help inform the future growth of the City's resilience effort. More specifically, our team focused on using existing outreach and survey data to create planning tools for the City of Oakland that were visual and communicative.

Of Oakland's self-identified seven areas of vulnerability, our contributions could be understood as primarily addressing the areas of community planning and capacity building, as well as housing. Our four contributions were the production of a GIS risk map, a FEMA structural analysis of a statistically typical soft-story building, communicative online media, and a profile analysis of demographic preferences of Oakland residents. Our goal with these deliverables was to 1) inform the city of areas of greatest risk and 2) package the data into visuals that would make relative risk more clearer to both planners and the community members.

II. Methodology

Our general approach to contribution was to utilize existing city outreach and technical material to create communicative data visualizations by applying analytical tools such as GIS, Matlab, and existing structural tools, such as the "Weak Story Tool" used in FEMA P-807.

IIa. FEMA Structural Analysis Methodology

For the structural analysis that we conducted, we began with data available from the "Soft-Story Screening Program" collected Summer of 2010. Tim Low, an Oakland Structural Engineer, sent this data as a spreadsheet containing information for 2598 potentially soft-story buildings about their structural properties: year of construction, area of construction, number of stories, structural system, material used, and a simple description of the length and location of walls in the first floor. To ground our structural analysis in established earthquake risk standards, we decided to use the *FEMA P-807 report, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings With Weak*

First Stories, which is a comprehensive study of wooden soft-story buildings that propose different levels of simplified structural analyses. As part of this initiative, an electronic tool, “Weak-Story Tool”, was implemented to apply the methods contained in the FEMA P-807 report, rendering the results that we used in our analyses.

Given the timeframe of the present study, we decided to analyze a selection of buildings which would represent the largest diversity of building typologies and structural characteristics that influence the structural vulnerability of soft-story buildings on Oakland. It was deemed from available data that our main indicators of structural vulnerability would be the year of construction, which is related to the wooden structural sheathing system (plaster, stucco, wood panel, etc) mainly used during that era due to existing standards, and the number of stories. Given that as part of the “Soft-Story Screening Program” the wooden wall sheathing information for each building was not compiled, our group used a standard (shown in Table 1) based on structural engineering practice to relate the year of construction with the sheathing assembly.

Table 1. Criteria used in this project to relate the year of construction with the sheathing configuration for the soft-story inventory of Oakland.

	Interior sheathing	**Exterior sheathing**
Pre-1950	Plaster	Stucco
1950-1970	Gypsum wallboard	Stucco
Post 1970	Gypsum wallboard	Plywood or OSB with stucco

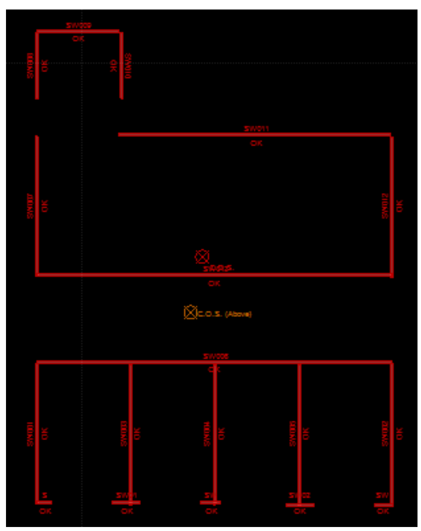
With a preliminary statistical analysis of the soft-story screening data, we were able to determine that the most common soft story apartments were three story stories, (median, mean and mode all equal to 3 stories), with second most common being two stories. As a result, an initial structural analysis was conducted on four actual buildings, two, three story buildings and two, two story buildings.

Table 2. Vulnerability indicators of the 4 cases of study.

	Year	N Stories
Building 1	1952	3
Building 2	1965	2
Building 3	1919	3
Building 4	1956	2

After choosing our study cases, our team analyzed the buildings using the previously introduced “Weak-Story tool”. Given that only the wall distributions on the first story was available, the wall distributions of other stories were inferred from the distribution of the first story, images of Google Earth and Street View. Fig. 2 shows the layout of the wall distribution of Building 1.

Fig. 2. Wall distribution of the first story of Building 1.



Additionally, the soil type information, required to calculate the force demands on our selected buildings, was extracted from USGS *“Soil Type and Shaking Hazard in the San Francisco Bay Area”* (http://earthquake.usgs.gov/regional/nca/soiltype/). For this analysis, a 20% *Targeted Drift Limit Probability of Exceedance* was used (this was recommended in FEMA 807 (table 1-1) to be consistent with *“current seismic standards for existing buildings”*), a hazard level corresponding to a *Maximum Considered Earthquake* hazard defined in ASCE/SEI 7-05, and a Performance Level of *Onset of Strength Loss* corresponding to the FEMA 807 Guidelines’ default performance objectives.

With these structural analyses, we hoped to understand quantitatively how much stronger these most commonly found soft-story buildings needed to be to withstand the expected earthquake without falling into disrepair.

IIb. Demographic Analysis Methodology

To create an in-depth demographic analysis of the preferences of the Oakland community, we utilized information from the City of Oakland’s Retrofit Survey, which asked participants how they would prioritize resources and funding as well as how they felt about existing policies on price-sharing of retrofit costs. Although the survey is still in progress, we were able to perform a preliminary analysis on a database of 297 responses that we obtained from our partners from the City of Oakland.

From Victoria Salinas and Sue Piper, we received the raw survey responses and a summary of responses which detailed the distribution of responses for each question. To push existing analysis one step further, we applied MatLab to filter and discover underlying trends in the data by crossing content from different questions. By implementing “if, then” logic statements via MatLab, we were able to understand how each category of respondent was answering each question. In example, we asked “how much *monthly rent increase* was acceptable to *tenants* depending on the *percentage of income spent on rent*.**”** As a result of the application of MatLab to the data set, we were able to discover how much tenants who pay 10-20% of their income on rent would spend on retrofit costs per month and compare those preferences to the cost preferences of tenants who spend more than 50% on rent.

Described below are the questions we used MatLab to answer:

1. What was the distribution of tenants based on the percentage of income they spent on rent?
2. How much *monthly rent increase* was acceptable to *tenants* depending on the *percentage of income spent on rent***.**
3. *What type of buildings should be prioritized* (Question 4) according to *landlords and tenants* (Question 8), depending on the *percentage of income spent on rent* (Question 9), for the case of tenants.
4. What is the *level of acceptable damage* (re-interpretation of Question 7) for *tenants* (Question 8) depending on the *time they expect to remain in the building* (Question 20)?
5. How likely are *landlords* (Question 8) to *retrofit voluntary, by law, or with financial incentives* (Question 14)?
6. What was the *outreach strategy* (Question 25) that captured more *people who were likely to be engaged in the program* (Question 1)?
7. What is most important factor to *landlords* (Question 8) in their *decision to retrofit* (Question 15**)**?

IIc. GIS Mapping Methodology

Based on the initial survey analysis provided to us by the Oakland Resilience team, we were able to determine that a majority of community members felt the City should prioritize retrofits based on vulnerability of tenants. Thus we decided to create a composite risk map, with parcels of high social and economic vulnerability overlayed with the locations of soft-story homes. This composite GIS risk map would serve to highlight to planners and the community which soft-story homes were in the most socially and economically vulnerable areas. To portray how many living units were in areas of socially and economically vulnerable areas, we used ArcScene to project living units as a vertical height on a 3-dimensional map along with the existing vulnerability layers.

To render the social and economic vulnerability layer in the GIS software, we obtained and extracted available ABAG analysis on at risk communities across the Bay Area. For each region in Oakland, ABAG factored in the following criteria into a composite vulnerability score:

1. Income level
2. Transportation Dependence
3. Percent of Income spent on rent
4. Age
5. Transportation Cost Burden
6. Housing Cost Burden

After transferring this data our GIS database, we coded areas with an ABAG score of high risk by shading those regions as darker than areas of relatively lower risk, which were shaded lighter grey. We then added a parcel layer which added geography and street names to the vulnerability scores, as well as the locations of the soft-story homes. In ArcScene we were able to use number of units as a three dimensional scaling factor, so that each building had a height that corresponded to occupancy.

To highlight particular regions of Oakland that were of heightened relative risk, we broke up the GIS map into 3 additional maps that show specific regions and the soft-story homes in the area. These 3 regions have been designated as: 1) the area around Lake Merritt, which has a high concentration of soft story homes, 2) The eastern portion of the city, which has few soft stories but covers a large portion of the map, 3) Regions of exceptionally high risk, located further away from Lake Meritt.

IId. Online Outreach Methodology

In addition to the use of analytical tools to extract demographic preferences from the City of Oakland's survey data, we assisted with the City's efforts to connect to soft-story residents, owners, and business affiliates. Through the help of Chief Resilience officer Victoria Salinas, we were able to attend and co-facilitate two community meetings and hear what community members thought about the mandatory retrofit program. Also of interest to the city was how these community members felt city resources should be allocated, as well as how they wanted to be involved with the program.

Attendees, we learned, had been contacted in a variety of ways, from printed flyers which were sent to every address to online media posts via the Yahoo groups that the City of Oakland connected to. Of particular note during these community meetings was collective desire for a single resource, a "one-stop-shop" for the retrofit process.

After speaking to Sue Piper, the City of Oakland's Outreach coordinator, about ways to expand the reach of the retrofit program and spread the word about the mandatory retrofit process, our project team decided that the development of other online outreach tools would be a contribution that would help fulfill community members' desire for a "one-stop-shop" resource and allow for the City of Oakland to reach a greater audience. The creation of an outreach page on Facebook was one such online outreach tool that our team helped generate. The primary objectives of the Facebook page was to increase awareness of community meetings and increase the proliferation of outreach materials. We found that Facebook was suited for this purpose, and we populated the page with critical links to resources in the Oakland Retrofit website. Photos that detailed Oakland's location of soft-story homes were also added to increase awareness.

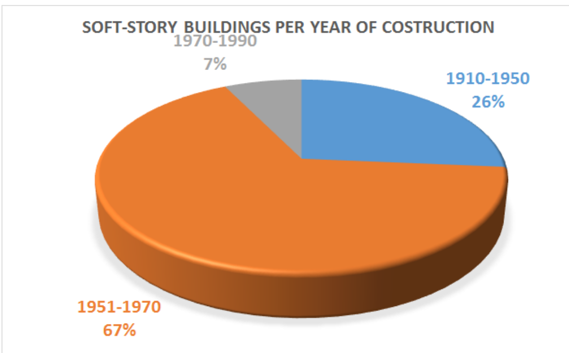
The creation of a website was our project team's attempt to create a concentrated resource detailing the retrofitting process and motivating retrofitting in soft-story apartments. With the SquareSpace design platform, we were hoping to create an approachable forum for discussion and resources. Although many documents we have created were designed for use by planners, we generalized design so that dedicated tenant and homeowners could easily find resources detailing the essentials of retrofitting.

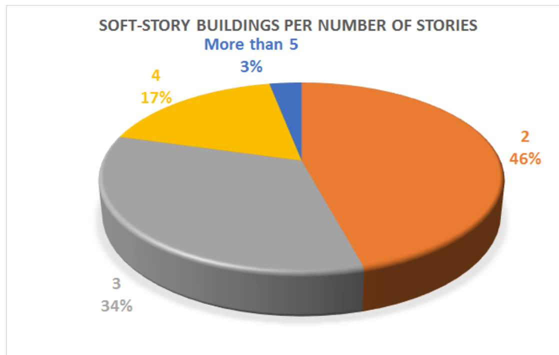
III. Findings

IIIa. FEMA Structural Analysis Results

Fig. 1 shows the distribution of soft-story buildings in Oakland according to the year of construction and number of stories. It is interesting to note that almost two thirds of the soft-story building inventory were constructed in the period from 1951 to 1970, a period when most wooden buildings had a sheathing configuration consisting of gypsum wallboard as interior sheathing and stucco as exterior sheathing. Roughly a quarter of the soft-story inventory were constructed prior 1950, an era when wooden buildings were mostly characterized by a interior sheathing of plaster on wood lath and an interior sheathing of stucco. It is relevant to make that distinction since both sheathing configurations behave structurally different; gypsum wallboards typically sustain large deformations, while plaster on wood lath can to a lesser degree (less ductility). This difference might exacerbate the vulnerability of older buildings. Another interesting fact from fig. 1 is that nearly 80% of soft-story buildings in Oakland have 2 or 3 stories.

Fig. 1. Distribution of soft-story inventory of Oakland according to vulnerability indicators. Left: Year of Construction. Right: Number of Stories





As mentioned in the FEMA Structural Analysis Methodology section, our team decided to analyze 4 buildings from the soft-story inventory, with vulnerability indicators summarized in table 2. Three of them were built between 1951 and 1970 and one prior to 1950. Two of them were two stories and the other two were three stories.

Table 1. Criteria used to relate the year of construction with the sheathing configuration in Oakland

	Interior sheathing	**Exterior sheathing**
Pre-1950	Plaster	Stucco
1950-1970	Gypsum wallboard	Stucco
Post 1970	Gypsum wallboard	Plywood or OSB with stucco

Table 2. Vulnerability indicators of the 4 cases of study.

	Year	**N Stories**
Building 1	1952	3
Building 2	1965	2
Building 3	1919	3
Building 4	1956	2

The results of the analysis are shown in the table 3. We can notice that in all 4 buildings analyzed the strengths of the buildings are far below the level of intensity they need to resist. According to these analyses, it can be concluded that these buildings need to be retrofitted to increase their capacity to resist earthquakes according to current earthquake engineering practices, which would mean that they would have to improve their lateral strength in ranges that go from 70% to 200% to comply with the performance objective adopted in this report.

Table 3. Comparison between demands and capacities of the Study Cases.

	Intensity Sa (g)	Strength Sa (g)
Building 1	1.97	0.86
Building 2	1.67	0.79
Building 3	1.74	1.05
Building 4	1.52	0.58

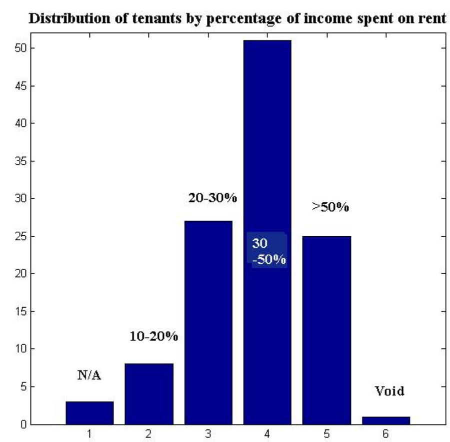
These results are comparable to building damage recorded in the 1989 Loma Prieta Earthquake, which caused extensive damage and collapse to soft-story buildings in San Francisco (Fig. 3) that share many structural similarities with the buildings in Oakland such as number of stories and year of construction.

Fig. 3. Collapse of a soft-story low-rise building after Loma-Prieta earthquake in San Francisco.

Even though these analyses seem to be conclusive about the need of the retrofitting program, our team has to recognize that further analysis using more detailed information of the structural characteristics of the buildings (distribution of walls in all the stories, details connections among structural elements, slab thicknesses, column geometries, soil slopes, reinforced concrete soil-retaining walls, and so on) would give a more thorough understanding of the buildings' structural vulnerabilities.

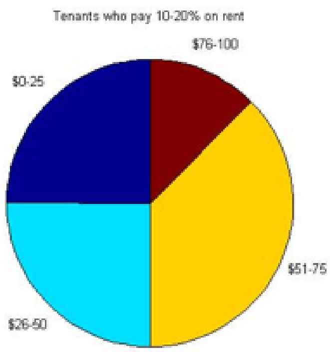
IIIb. Demographic Analysis Findings

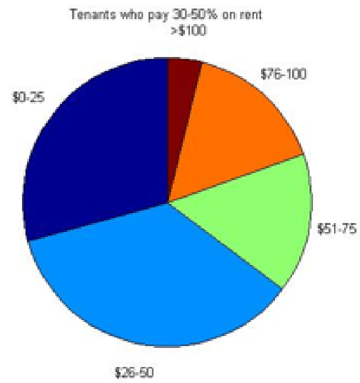
1. What was the distribution of tenants based on the percentage of income they spent on rent?

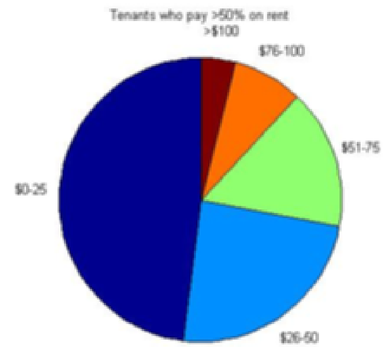


As shown in this figure, a majority of tenants spend 30-50% of their income on rent.

2. How much *monthly rent increase* was acceptable to *tenants* depending on the *percentage of income spent on rent*?



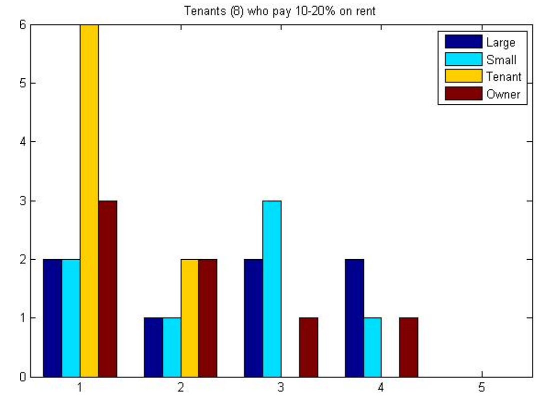




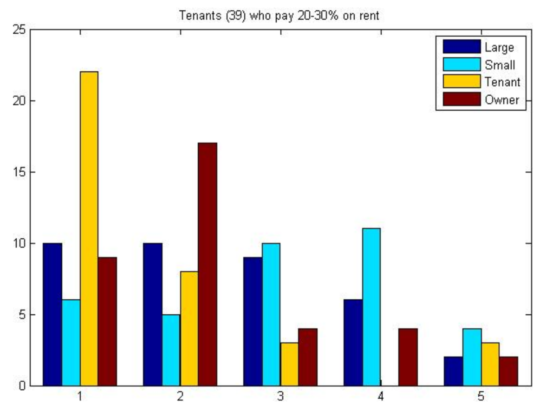
As observed across multiple tenant categories, most tenants are not willing to pay more than $50 (monthly rent increase) on seismic retrofits.

3. *What type of buildings should be prioritized* (Question 4) according to *landlords and tenants* (Question 8), depending on the *percentage of income spent on rent* (Question 9), for the case of tenants?

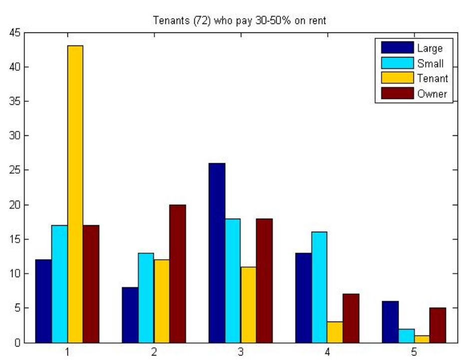
The following figures show tenants' prioritization preferences, with 1 being the highest priority and colors representing buildings that are large, small, with low-income tenants, or with low-income owners.



6-7 Tenants who pay 10-20% on rent would like the city to make subsidizing low-income tenants a top priority.

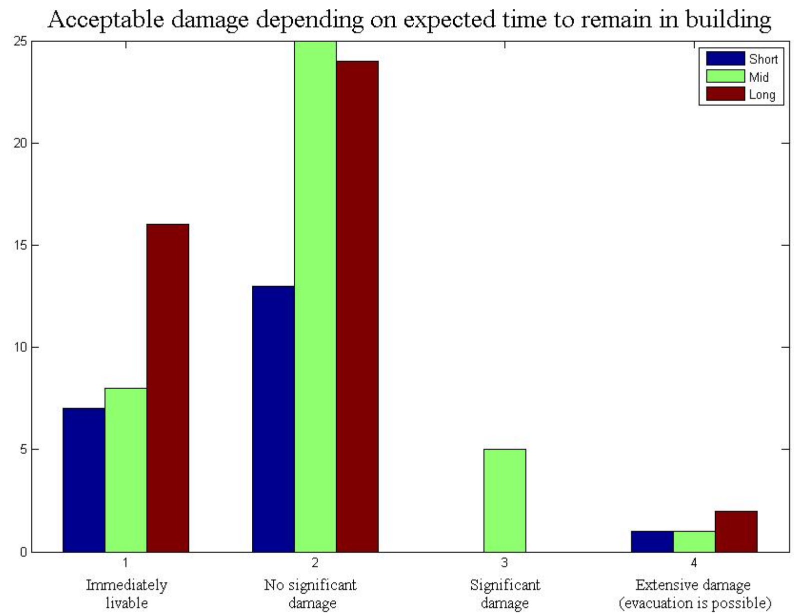


20-25 Tenants who pay 20-30% on rent would like the city to make subsidizing low-income tenants a top priority.



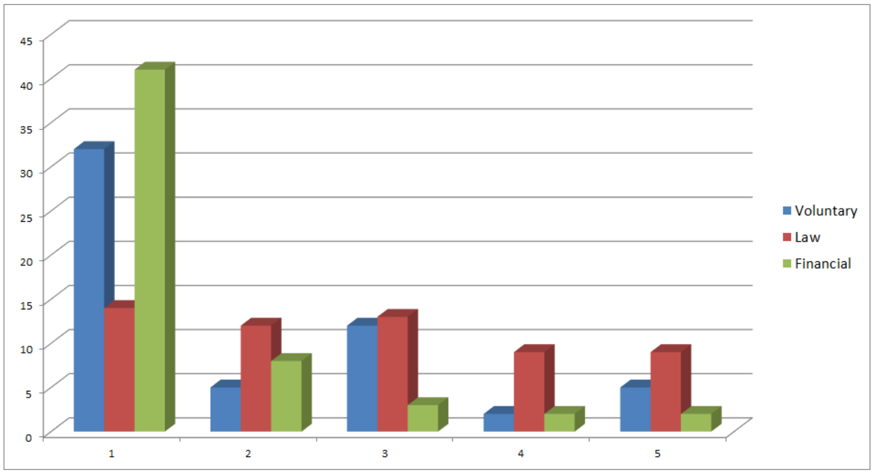
40-45 Tenants who pay 30-50% on rent would like the city to make subsidizing low-income tenant a top priority.

4. What is the *level of acceptable damage* (re-interpretation of Question 7) for *tenants* (Question 8) depending on the *time they expect to remain in the building* (Question 20)?



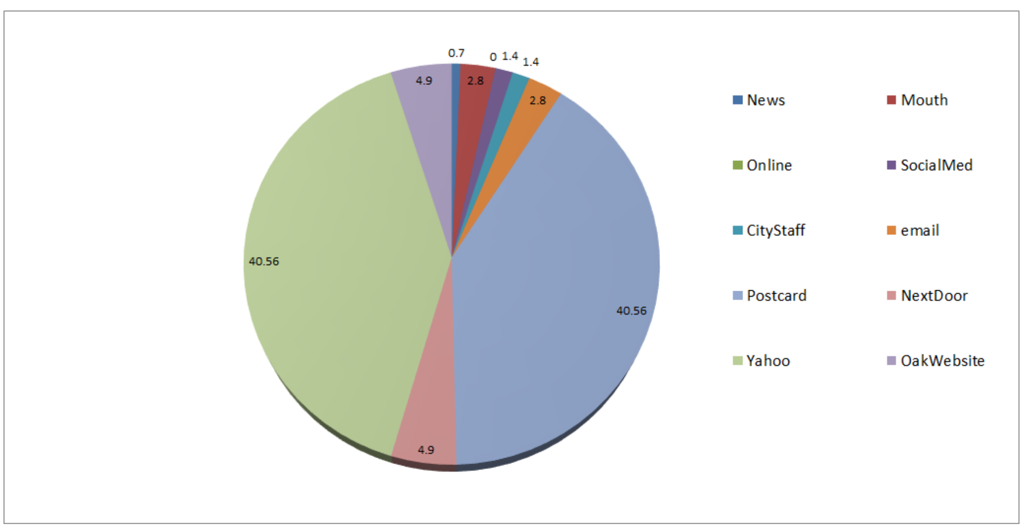
As shown in the figure, most tenants prefer that no significant damage occur to the building after an earthquake, and would tolerate damage to utilities, over the best, safest option 1, in which public utilities in a building are immediately available. We believe that this an indicator that as of now community members are prioritizing cost concerns over complete safety.

5. How likely are *landlords* (Question 8) to *retrofit voluntary, by law, or with financial incentives* (Question 14)?



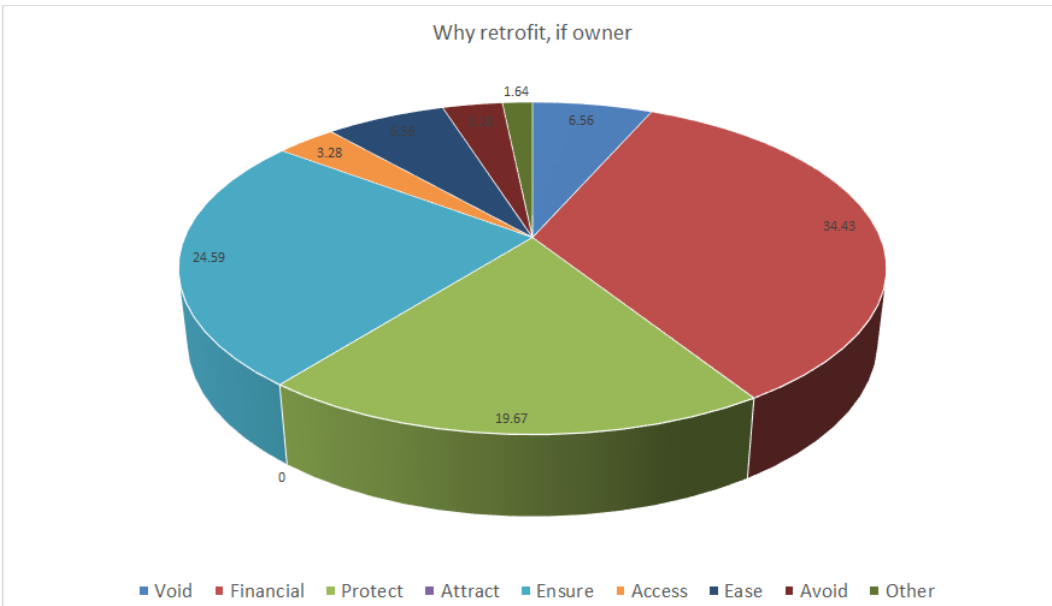
The following figure, with 1 being the highest likelihood and color representing the type of incentive, shows how landlords are willing to make improvements (because of factors address below, such as protecting their investment), but at the same time are strongly encouraged by potential financial incentives that may be offered by the City.

6. What was the *outreach strategy* (Question 25) that captured more *people who were likely to be engaged in the program* (Question 1)?



When filtering only those stakeholders that want to stay involved in the program, the outreach strategies that seem to have the greatest impact are the Yahoo Groups, which seem to be an active networking tool in the community, and the physical postcard.

7. What is most important factor to *landlords* (Question 8) in their *decision to retrofit* (Question 15)?



The figure shows how three reasons dominate owners' decision to retrofit, namely: financial incentives offered by the City or private sector; protect my investment; ensure renters are safe from harm in a major disaster (identified in the chart with only the main verb).

IIIc. GIS Risk Maps

Fig. 4: Vulnerability and Soft Story Unit Density in East Oakland

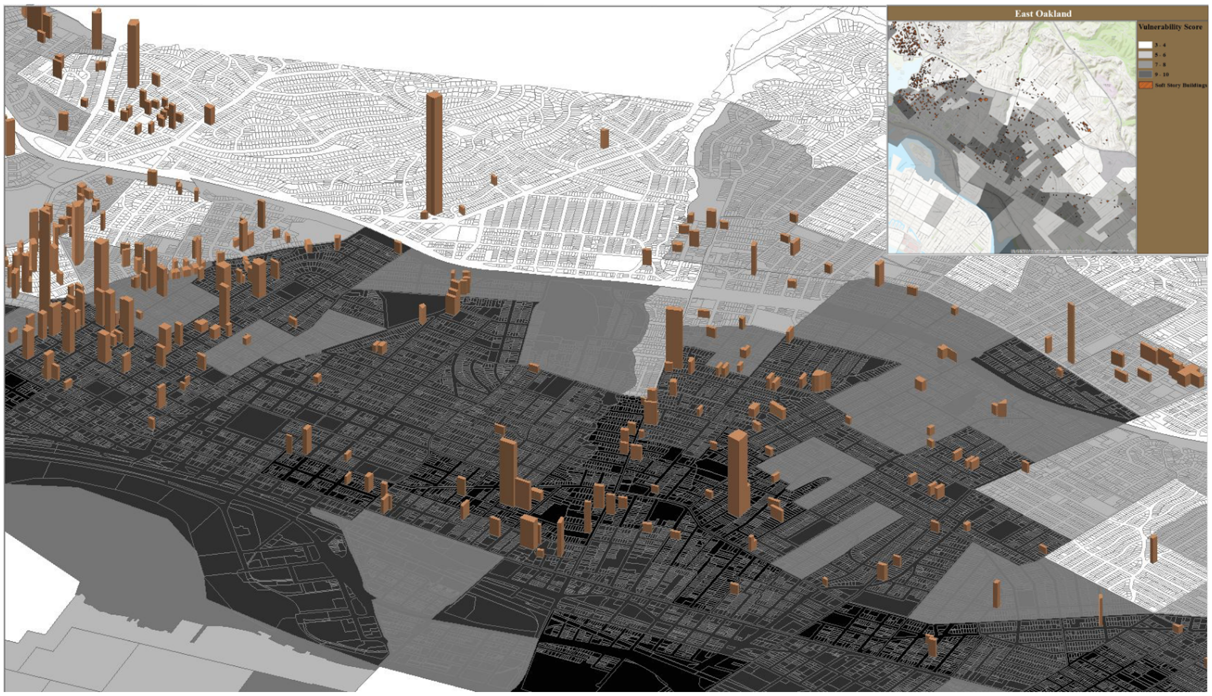


Fig. 5: Vulnerability and Soft Story Unit Density in the Lake Merritt Area

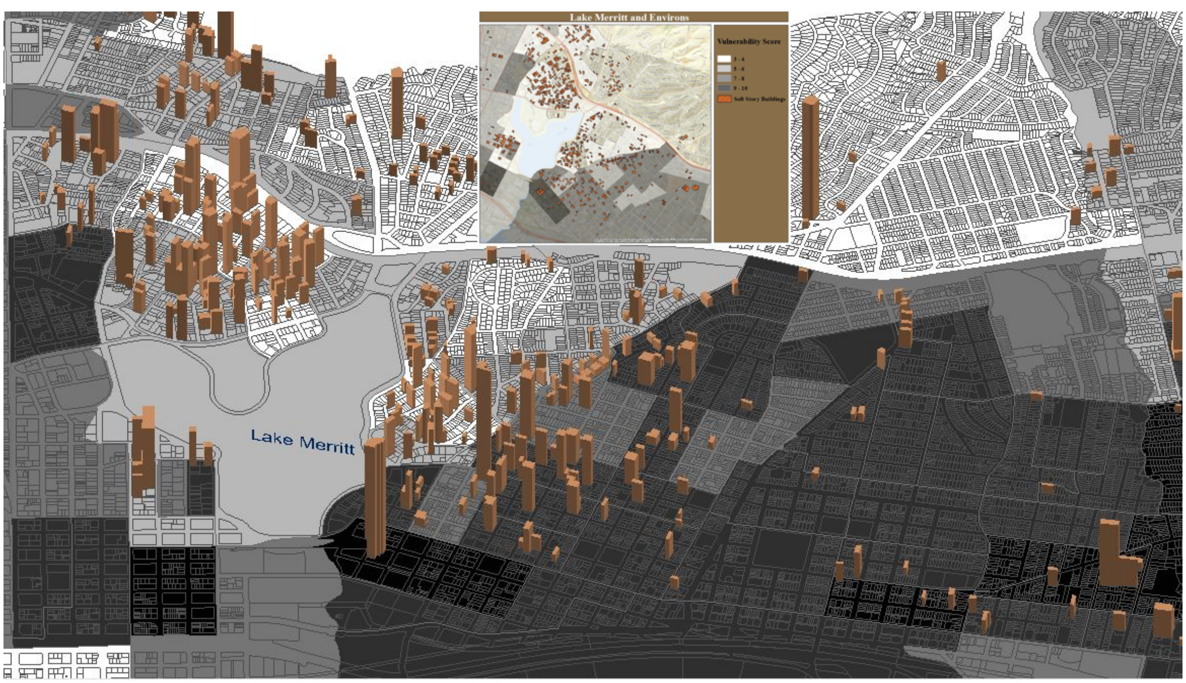
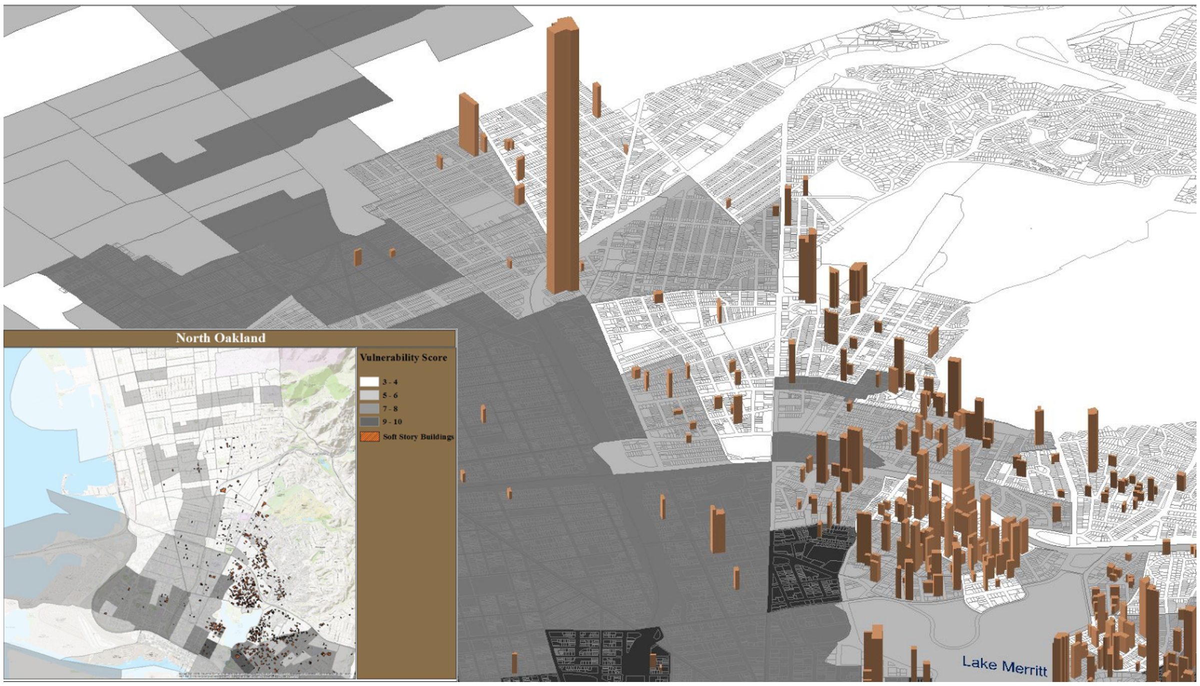


Fig. 6: Vulnerability and Soft Story Unit Density in North Oakland



As mentioned in the Methodology section, our mapping deliverable divides Oakland into three regions: East Oakland, Lake Merritt and Environs, and North Oakland. Respectively, these regions go from most to least vulnerable.

East Oakland has the most vulnerable communities and even areas east and southeast of the Lake Merritt area faces a similar disadvantage. East Oakland does not have nearly the same unit density as Lake Merritt, although areas east from the waterfront do share similar pockets of soft story buildings. A hypothesis for this finding would be that the region nearer to Lake Merritt was developed in a similar era, using a similar construction model. Regardless, based on our community results it would seem that they would like the City to target funding and engagement with those most vulnerable to earthquake hazard. For this reason, we recommend that the City focus extensively on supporting the communities in East Oakland with engagement and finance.

In contrast, communities that may not appear immediately vulnerable to earthquake hazard are the relatively affluent neighborhoods surrounding Lake Merritt. However, this area has the highest density of soft story units in Oakland. Given that this region is relatively stable, our recommendation would be to reach out a few weeks before the retrofitting program becomes mandatory with information communicating the drastic nature of the issue and suggestions that make the process of completing and financing the retrofit seem simple, a worthy investment (for landlords) and financially feasible (for tenants).

North Oakland seems the least vulnerable in the case of a major earthquake. Other than clumps of density in the surrounding Lake Merritt area, the soft story units are relatively small compared to East Oakland and Lake Merritt. Additionally, they are spread in areas of small to moderate levels of community vulnerability. Because North Oakland is not vulnerable relative to its neighboring communities, we would recommend an engagement strategy similar to our strategy for the region around Lake Merritt.

Of course, there are outliers for all of these general trends that deserve individualized attention. There are two that jumped out of us are in North Oakland and Lake Merritt, regions previously described as well-suited to deal with the impending retrofitting process. However, these sets of properties both have high unit density and a level of vulnerability higher than the areas surrounding them. With the largest number of units in Oakland, the property located center-North on the North Oakland map is an apartment complex spanning several blocks. All units are owned by the same landlord and each individual building seem similar (if not identical) to the rest. This may make the retrofitting solution simpler than if the properties were more varied. Additionally, dependent upon the person it may prove more efficient to interact with one stakeholder with a huge responsibility for improving resilience as opposed to several, smaller stakeholders. Finally, the properties at the Southeast corner of Lake Merritt deserve special attention. The region that starts here and extends eastward for a few more miles combines the vulnerability of East Oakland and the density of area surrounding Lake Merritt, making this the community most at risk to earthquake hazards. As the City seeks to deal with the issue of improving the resiliency of soft story occupants, we suggest making this area the focal point going forward.

IIId. Examples of Online Media Development

Link to website: https://oaklandsoftstory.squarespace.com

Homepage of Project Website

IV. Recommendations

Our main findings and recommendations are summarized below. These recommendations could also be considered as future projects for Stanford community partners!

1. **From the FEMA Analysis:** Communicate to planners that a majority of soft-story buildings, 2-3 story buildings will need a 70-200% increase in lateral strength to withstand an expected earthquake.

2. **From the Demographic Analysis**
   a. Potentially make an upper limit of retrofit costs $50 per month for low income residents, what survey respondents indicated as their preference.
   b. When appealing to landowners to retrofit, the most effective arguments are financial incentives, rather than legal.
   c. When engaging the community, we recommend continued use of printed media and online outreach.

3. **From the GIS Mapping:** Concentrate resources to specific communities of high social and economic risk, areas such as East Oakland and immediately surrounding Lake Merritt. Specific addresses of large unit buildings in these areas are possible to obtain with the GIS maps.

4. **From Online Media Outreach:** We recommend further integration of multiple sources of information, i.e. connecting the Facebook page to the Yahoo groups and Oakland Website to the Facebook or Yahoo groups.