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Assessing Post-disaster Housing Needs to Inform Disaster Recovery Planning

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ABSTRACT

Residential damage from major disasters often displaces residents out of their homes and into temporary housing. Communities tend to rely on out-of-town contractors for post-disaster housing recovery, and these contractors also need temporary housing. The conflicting housing needs from the displaced residents and out-of-town contractors create pressure on the local available housing stock. Communities that prepare for temporary housing demand can minimize the impact on residents and expedite housing recovery efforts. This study uses simulation models to investigate the housing recovery of San Francisco after a hypothetical *M*7.2 earthquake. The earthquake is expected to significantly damage about 17,000 homes and displace their occupants. A peak demand for 4,000 out-of-town contractor crews following the earthquake is identified. The total temporary housing demand of 20,000 units can stress the local housing market and expose the displaced population to longer periods of housing instability. These results highlight the need to plan for a surge of out-of-town contractors and a shortage of temporary housing during the recovery phase.

Introduction

Temporary housing plays a pivotal role in the early stage of disaster recovery [1]. Providing temporary housing for the displaced population can reduce post-disaster population losses. With this goal in mind, communities typically develop plans to house displaced residents within municipal boundaries, ideally within their own neighborhoods [2]. However, displaced residents are not the only group in need of temporary housing after a disaster. Post-disaster reconstruction often relies on the recruitment of out-of-town contractors which may lead to the escalation of rental prices. This may force a portion of the displaced residents out of the rental market. Moreover, unappealing housing conditions limits the community's ability to attract and retain the needed workforce [3]. The competition for temporary housing sparks conflicts between out-of-town contractors and residents [4].

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The Federal Emergency Management Agency highlights the need for emergency managers and planners to maintain awareness of current housing stock within their jurisdiction and identify temporary housing needs prior to an incident [5]. However, the rare nature of large-scale disasters makes it hard to plan for them using empirical knowledge alone. In this context, computational simulations are powerful tools to inform planning. However, existing housing recovery models focus on the allocation of the existing workforce. What has not been addressed is the constraints on increasing the local workforce due to limited temporary housing which is also needed by the residents. In this study, we employ an agent-based housing recovery model to simulate the expected housing needs for displaced residents and out-of-town workers following a hypothetical *M*7.2 earthquake near San Francisco. We compare the housing needs to the expected post-disaster vacant units in the City of San Francisco to gain insights into the likelihood of a temporary housing shortage. These results can inform the pre-disaster planning to expedite housing recovery.

Methodology

We employ a five-step workflow to simulate post-earthquake housing recovery in the City of San Francisco, as shown in Figure 1. These steps, alongside detailed implementation flowcharts will be provided in an upcoming study by the authors [6]. Here, a brief description of the main aspects of the model is presented.

The first step is to simulate the hazard, i.e., a hypothetical *M*7.2 earthquake on the San Andreas fault. The SimCenter R2D tools are used to simulate 100 maps of the peak ground acceleration (PGA) on a 20x20 grid over San Francisco [7]. Next, we use the methodology developed by the Federal Emergency Management Agency to create a building inventory for San Francisco using Census data [8]. This process results in a synthetic inventory, including the occupancy (e.g., residential, or commercial), footprint area, replacement cost, and age of each building. For each map, we estimate the PGA intensity for each building in the inventory. Using PGA-based fragility functions [9], we estimate the expected damage, repair cost, and repair time for each building. We assume that the occupants of severely and completely damaged buildings are temporarily displaced. To simulate the reconstruction of each building, we use block-group level data to estimate the socioeconomic demographics of the households that occupy the buildings. Each household is assigned an income and a tenure. The model developed by [10] is used to determine the expected time needed for each household to raise the funding needed to repair their buildings, e.g., the repair cost. Once the household has obtained the financing needed, they procure a contractor. If the demand for contractors is high, out-of-town contractors are attracted to the city. The temporary housing needs of the displaced households and the out-of-town contractors and combined and compared to the expected number of vacant housing units in the city. If the demand for temporary housing exceeds the availability, a housing shortage is identified. This process is repeated for the 100 PGA maps to gain insights on the likelihood of a housing shortage.

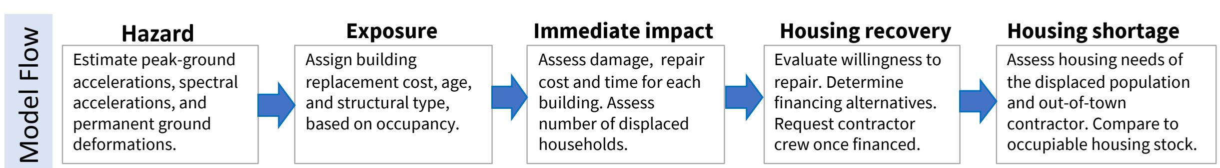

Figure 1. Workflow of computer models used to simulate post-earthquake housing recovery and the potential for temporary housing shortages.

Case Study

The portfolio generated using the procedure in [8] results in 124,564 single-family houses in the city of San Francisco. Using data from the American Community Survey, we estimate that 18,626 housing units in San Francisco are vacant and could be rented by displaced persons or out-of-town contractors after an earthquake. A housing unit is either a single-family house or a multi-bedroom apartment. We assume that vacant rental homes remain available for renting after the disaster, i.e., the owners do not occupy or sell them. Data from the ArcGIS Business Analyst [11] suggests that about 3,000 persons in San Francisco work as contractors who primarily work on single-family homes. Assuming a three-member crew, we estimate the local workforce to be 1,000 contractor crews. That is, 1,000 homes can be repaired simultaneously without assistance from out-of-town contractors. We note that this is a conservative assumption, and that when more than three construction workers are required for one damaged single-family home the potential shortage of temporary housing for local displaced people and out-of-town contractors is to be worse. We consider two scenarios in terms of the number of out-of-town contractors in the city. The 'baseline scenario' recovery relies solely on the local workforce. In the 'ideal' scenario, out-of-town contractors will supply the demand that exceeds the local workforce availability. This scenario leads to the highest possible recovery speed, hence it is called 'ideal.' In addition, we investigate the impacts to the housing demand of these two scenarios.

Figure 2 shows two sets of results. The left panel shows the average number of homes waiting for repairs over time. The averages are calculated from the 100 simulations of hazards, damages, losses, and recovery. The dashed line shows that without out-of-town contractors the reconstruction speed is slow. This is because the number of workers becomes a bottleneck to recovery. The solid line shows the results considering that as many workers as needed will come into the city. In this case, recovery progresses much faster within the first couple years but slows down later. The change in the recovery speed, i.e., the slope of the curve, is due to recovery being bottlenecked by factors other than the number of workers. The panel on the right in Figure 2 shows the average temporary housing needs in each scenario. The demand at time t=0 represents the displaced population only. In the 'Baseline' scenario this is the total demand. In the 'Ideal' scenario the housing demand is eventually compounded by the housing needs of out-of-town contractors as they move into the city for employment opportunities in the reconstruction sector. The results show that the 'Ideal' scenario leads to a peak housing demand which is considerably higher, i.e., extra 3,000 units, than the 'Baseline' scenario. However, this increased demand within the first year after the earthquake is counterbalanced by a substantial decrease in the total demand for housing in the following years. These results indicate that if a community can afford the extra housing needs within the first year it has substantial payoffs in the long run, highlighting the importance of planning to be able to accommodate out-of-town workers soon after a large earthquake.

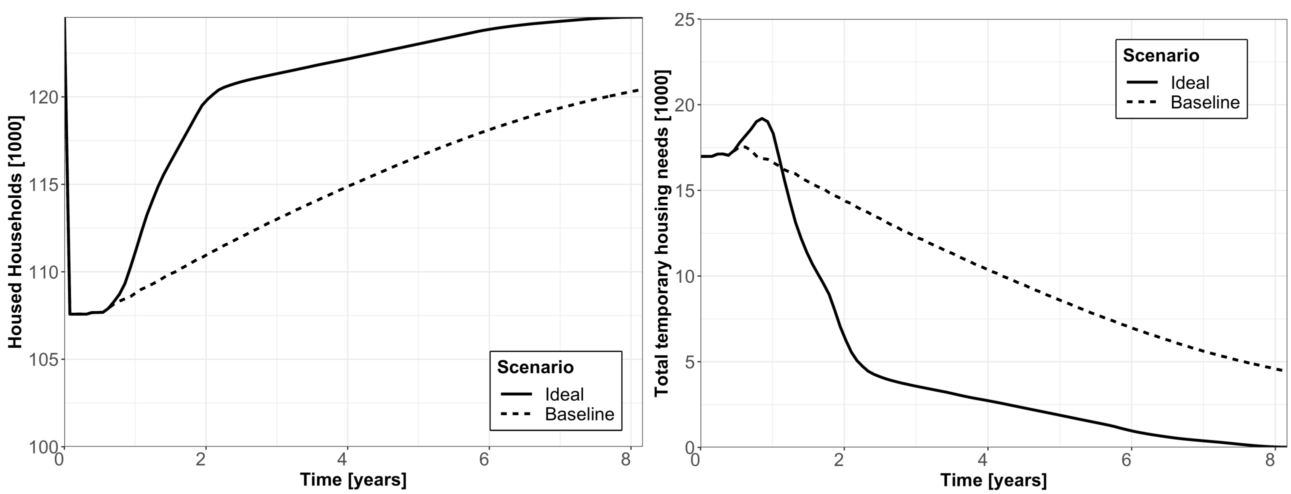

Figure 2. Cases study results. On the left, the number of housed households after the earthquake is shown. On the right, the expected demand for temporary housing.

Figure 3 provides another two sets of results aimed at informing planning. The left-hand side plot shows the expected peak demand for out-of-town contractors. The demand is nearly 4,000 contractor crews, i.e., 12,000 contractors, at around one year after the earthquake. As the recovery progresses, this demand quickly decreases to about 2,000 within one and a half years since the earthquake. Within two years since the event the demand has declined to a point where the local workforce of 1,000 contractor crews is sufficient. Finally, the plot on the right-hand side in Figure 3 shows the probability of a housing shortage in the City of San Francisco following the hypothetical *M*7.2 earthquake. This probability is calculated as:

$$P_s(t) = \frac{1}{N}\sum_{i=1}^{N} \mathbf{1}(D(t)_i > V_i) \qquad (1)$$

where **1** is an indicator function that returns the unity if the condition is true and zero otherwise, *D(t)* is the temporary housing needs of the displaced population and out-of-town contractors, and *V* is the number of vacant units in the community. The index *i* represents each housing recovery simulation and *N*=100. The 'Ideal' scenario leads to an increased probability of a housing shortage in the short-term but make it unlikely that a housing shortage will still be observed after two years since the event. In combination, the results in this study demonstrate that the housing recovery in San Francisco following the *M*7.2 earthquake will attract out-of-town contractors and their housing needs will have substantial impact on the local housing market, i.e., increasing the competition for a limited number of vacant housing units. However, there are bigger benefits of having the city's reconstruction assisted by out-of-town contractors. Pre-established actions could be devised to provide adequate housing for all in need, helping the city expedite recovery without forcing displaced residents into subpar temporary housing conditions.

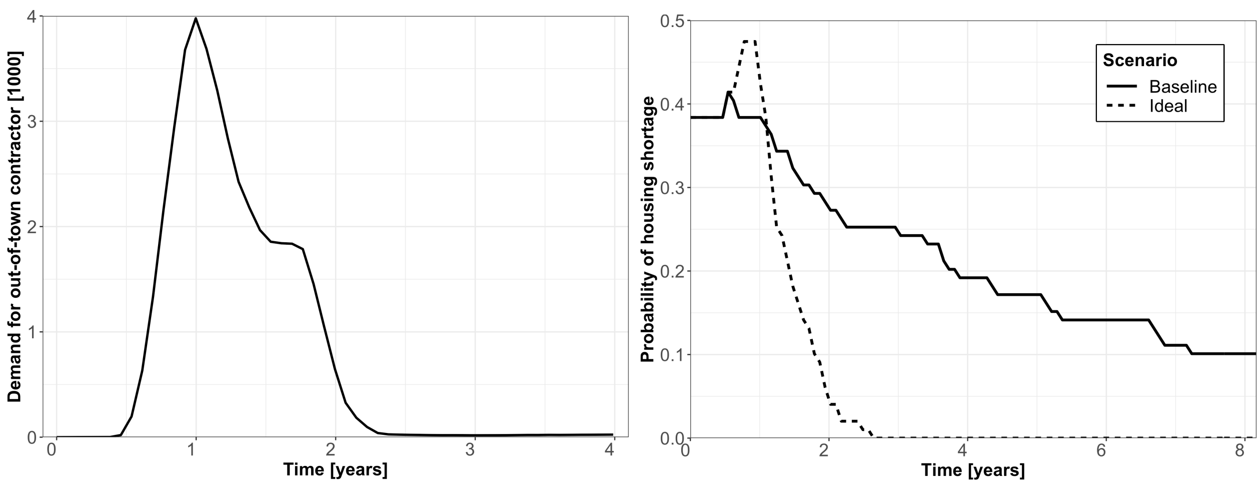

Figure 3. Case study results. On the left, the average demand for out-of-town contractors following the *M*7.2 earthquake. On the right, the probability that the existing vacant housing in San Francisco is not enough to supply the demand for post-earthquake temporary housing.

Conclusions

This study uses computational simulation models to investigate the housing recovery of the city of San Francisco after a hypothetical *M*7.2 earthquake on San Andreas Fault. We consider two scenarios: 'baseline scenario' and 'ideal scenario.' For the 'ideal scenario', We identify a peak demand of 4,000 out-of-town contractor crews needed for housing repairs and reconstruction following the earthquake. The estimated total temporary housing needs of 20,000 units are likely to stress the local housing market and expose the displaced population to longer periods of housing instability. Compared to the 'baseline scenario,' The recovery progresses much faster in the 'ideal scenario' in which as many contractors as needed come to rebuild the city. However, the total temporary housing needs of the 'ideal scenario' are significantly higher than those of the 'baseline scenario.' The comparisons between the 'baseline scenario' and 'ideal scenario' on temporary housing needs and recovery speeds highlight the importance for communities and recovery planners to prepare for a surge in temporary housing demand caused by out-of-town contractors. With proper pre-established actions, the communities can expedite housing recovery efforts with minimal adverse impacts on the residents.

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