Summary of Economic Impact Analyses and Policy Implications of the HayWired Scenario

By Stephen Levy, Anne M. Wein, and Cynthia Kroll

Chapter V1 of
The HayWired Earthquake Scenario—Societal Consequences
Edited by Shane T. Detweiler and Anne M. Wein

Scientific Investigations Report 2017–5013–R–W

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

Suggested citation:
Levy, S., Wein, A.M., and Kroll, C., 2020, Summary of economic impact analyses and policy implications of the HayWired scenario, chap. V1 *of* Detweiler, S.T., and Wein, A.M., eds., The HayWired earthquake scenario—Societal consequences: U.S. Geological Survey Scientific Investigations Report 2017–5013–R–W, 22 p., https://doi.org/10.3133/sir20175013v3.

ISSN 2328-0328 (online)

Contents

Figures

Tables

The HayWired Earthquake Scenario—Societal Consequences
Edited by Shane T. Detweiler and Anne M. Wein
Scientific Investigations Report 2017–5013–R–W
[Also see https://doi.org/10.3133/sir20175013v3]

Chapter V1

Summary of Economic Impact Analyses and Policy Implications of the HayWired Scenario

By Stephen Levy[1], Anne M. Wein[2], and Cynthia Kroll[3]

Introduction

The HayWired scenario examines a hypothetical earthquake sequence with a moment magnitude (M_w) 7.0 mainshock occurring on April 18, 2018, at 4:18 p.m. on the Hayward Fault in the east bay part of California's San Francisco Bay region. Economic and community impact analyses for the HayWired earthquake scenario paint a bleak picture of the consequences of an earthquake centered in Alameda County and affecting much of the nine-county San Francisco Bay region, which is home to about 7.8 million people. In this scenario, hundreds of thousands of San Francisco Bay region residents are affected by disruption to their families, homes, and jobs, raising questions:

- Is the San Francisco Bay region economy strong enough to withstand an event of this magnitude?
- Would the region's economy recover? How quickly?
- What are the key factors in determining how resilient the economy would be?
- Where are businesses and the people living or working in the region affected?

This subchapter summarizes a series of technical subchapters that look at the level of economic impact that could be expected from the HayWired earthquake scenario, how that impact would be distributed among geographic areas and types of businesses in the region, and how individual and policy decisions made before or applied after the event can change the overall impact immediately and over time. The economic analyses convey that whereas the overall economic losses can be overcome at a regional scale, policy interventions can be most important for addressing human challenges and location-specific challenges.

[1]Center for Continuing Study of the California Economy.

[2]U.S. Geological Survey.

[3]Metropolitan Transportation Commission and Association of Bay Area Governments, retired.

Overview of the HayWired Economic Analysis

The HayWired scenario is a collaborative effort led by the U.S. Geological Survey. Five studies were commissioned to identify the economic impacts and related policy implications of the HayWired earthquake scenario (see table 1). The full technical subchapters are published separately in this volume. Two studies focused on macroeconomic impacts—impacts on the levels of output, employment, and associated population movements in the San Francisco Bay region after the earthquake. Two studies focused on impacts for industry groups, business types by size and ownership, small geographic areas, and employee workplaces and homes. The final study, commissioned to inform both the economic analyses and the communities-at-risk analysis, focused on insurance coverage and related policy issues. The aim of these efforts is to inform policies, mitigation approaches, and programs that could be helpful in the San Francisco Bay region before and after a large earthquake like that in the HayWired scenario.

The assessments of economic impact were derived from estimates of physical damage to structures and infrastructure, such as transportation and telecommunication networks. Output and employment losses are the result of business interruptions caused by business and residential damages, transportation (highway and mass transit) disruptions, and telecommunications, water, and electric power outages.

Damaged homes, businesses, public facilities, utilities, and transportation and telecommunications infrastructure would need to be rebuilt and the speed of rebuilding would affect the amount and duration of economic losses. Temporary housing, business relocation, and restoration of services can help to reduce these losses.

Impacts can be important for policy purposes either because they are large or because they fall on individuals and organizations with limited ability to respond. For example, small businesses are slightly more likely to be disrupted by building damages compared to very large businesses in the HayWired scenario. Of greater significance, small businesses are also less able to prepare for and respond to a large earthquake compared to larger firms and organizations with multiple locations.

Table 1. Analyses of economic outcomes of the HayWired scenario.

[ABAG, Association of Bay Area Governments; MTC, San Francisco Bay Area Metropolitan Transportation Commission; USC, University of Southern California; USGS, U.S. Geological Survey]

Study title	Authors and affiliations	Method	Commissioner	Location in HayWired volume 3
Economic consequences of the HayWired earthquake scenario—Cyber and electricity network linkages and resilience	Ian Sue Wing (Boston University), Dan Wei and Adam Rose (USC), and Anne Wein (USGS)	Macroeconomic model of Gross Domestic Product losses in San Francisco Bay counties, the region, and the State of California during the first 6 months	HayWired project	Subchapter V2
The economic effects of the HayWired scenario using the Association of Bay Area Governments regional growth forecast	Cynthia Kroll, Bobby Lu, and Aksel Olsen (MTC and ABAG), and Anne Wein (USGS)	Macroeconomic model of Gross Regional Product, job, and population losses in subregions and the nine-county region compared to growth forecast over the next two decades	HayWired project	Subchapter V3
Characteristics of businesses disrupted by building damages from the HayWired scenario mainshock	Anne Wein (USGS), Jon Haveman (Marin Economic Consulting), Cynthia Kroll (MTC and ABAG), and Jeff Peters (USGS)	Spatial analysis of business exposure to building damage throughout the region by business characteristics	HayWired project	Subchapter V4
Spatial analysis of industries, employment, and commute flows in areas of concentrated damage from the HayWired earthquake scenario	Anne Wein (USGS), Dena Belzer (Strategic Economics), Cynthia Kroll (MTC and ABAG), Carline Au (Strategic Economics), Jamie Jones (USGS), Laurie Johnson (Laurie Johnson Consulting), Aksel Olsen (MTC and ABAG), and Jeff Peters (USGS)	Subarea and industrial sector exposures to concentrated damage and work-home relations between these areas in the region	HayWired project	Subchapter V5
Financial implications of the HayWired scenario	CoreLogic, Inc.	Insurance models of damage and coverage	California Earthquake Authority	Discussed in chapter U; published separately by CoreLogic, Inc. (2018)

There is a time dimension to these findings. Some impacts are large and short lived. Other impacts may last for many months or years. Recovery would vary across different types of businesses and residents and geographic parts of the region. Recovery would also depend on the scope of insurance coverage and the ability of the public and private sectors to raise funds for rebuilding.

In addition to identifying and quantifying economic impacts, the goal of this research is to identify policy responses that can prevent damage, reduce some of the impacts, and facilitate the recovery process. These involve forward-looking community and regional planning, actions that can be taken beforehand, such as retrofitting buildings and new building designs, and policies that speed up recovery, such as business continuity and preparation, adequate insurance, and other reconstruction funding mechanisms.

This report is organized as follows: (1) an overview of high-level findings, (2) a summary of each individual report, (3) a list of the major policy implications, and (4) a closing statement.

High-Level Findings from the HayWired Scenario

This section identifies and summarizes the high-level findings of the four HayWired scenario economic analyses. These findings also include relevant insurance analysis findings.

Macroeconomic Analyses

- Damages to hundreds of thousands of vulnerable buildings (residential, commercial, and industrial) and months to years of disrupted transportation systems

(for example, major highways and transit) result in job and production (output) losses similar to a moderate to severe recession.

- Job and output losses are concentrated in the areas of strongest shaking and liquefaction in Alameda and Contra Costa Counties.
- The cumulative output loss effects from transportation network and commuting flow interruptions could spread economic losses throughout the San Francisco Bay region and be as large as the output loss associated with building damage.
- Most of the economic losses occur within the first 6 months to one year after the M_w 7.0 earthquake of the HayWired scenario, although the losses continue for a few years beyond, and it takes many more years to rebuild damaged buildings and infrastructure.
- Bottlenecks from labor, material, and funding shortages and higher construction costs could stretch recovery times for several additional years. Such delays were found in Santa Rosa and Sonoma County after extensive wildfire damage to homes in 2017 (Li, 2018).
- The amount of economic losses and the time for recovery and rebuilding can be reduced by implementing mitigation and resilience measures such as those discussed in the policy implications section.

Geographic and Business Analyses

- Risk of building damage that limits or restricts building use varies greatly depending on location, with the largest impacts in central Alameda County and parts of Contra Costa County.
- In addition to business location, the type of building an industry tends to occupy affects its risk of building damage. For example, production and distribution industries are more concentrated in older buildings with less modern reinforcement and seismic safety design, and thus face higher risk of building damage.
- Beyond individual building damage risks, concentrated building damage (defined as more than 20 percent of building square footage extensively or completely damaged within neighborhoods or business districts) complicates response and recovery in these areas. Concentrated building damage in more than 10 percent of San Francisco Bay region census tracts is largely attributable to damages to (likely older) industrial/warehouse, retail/commercial, and multifamily residential buildings.
- Almost 200,000 employees (7.6 percent of jobs in the nine-county region) may work in damaged buildings with limited or restricted use, but the lives of more than 500,000 employees (14 percent) are potentially affected by concentrated damage in their business districts or residential neighborhoods, even if their work or homes are undamaged.

Insurance Analysis

- About 95 percent of homeowners have basic (including fire) residential property insurance coverage, but only about 10 percent of general residential property insurance holders in the nine-county region have an earthquake insurance policy.
- Statewide, only 8.5 percent of insured commercial properties have earthquake insurance coverage. Large commercial properties are insured, raising the overall share of square footage covered by insurance, such that smaller and less-resourced businesses are less likely to have property insurance and more likely to face shortfalls in recovery financing.
- CoreLogic, Inc., estimates $170 billion in damages for the HayWired earthquake scenario, of which $30.2 billion are insured. About 18 percent of the total damage estimate is insured—9 percent of estimated residential damage and 20 percent of estimated commercial damage. Of the insured damages,
  - About $21.2 billion are for the M_w 7.0 earthquake damages from ground shaking, liquefaction, and landslide;
  - $4 billion are for fire and sprinkler damage; and
  - $5 billion are for aftershock damages.
- These estimates do not include the insured losses for damage to the region's infrastructure and government buildings (which may be covered by self-insurance funds set aside by jurisdictions), workers compensation exposures, automobile lines of business, and indirect business interruption of such a major disaster.

Human Considerations

- Whereas economic losses are comparable to the effects of the first few years of a recession, the human challenges (emotional trauma, population displacement, and job losses) to many residents and businesses would be severe and the degree of severity would depend on preparation and post-earthquake actions.

The San Francisco Bay Region Economy

The nine-county San Francisco Bay region accounts for a growing share of the U.S. economy, reaching almost 3 percent of the Nation's jobs and almost 4 percent of the Nation's output in 2017. The region has close to 4 million wage and salary jobs, of which 30 percent are in the east bay, where the HayWired scenario damages are concentrated. The region is home to Silicon Valley, which has seen several waves of industry innovation and expansion in high tech, multimedia, and social media over the past four decades, and the city of San Francisco, once the financial center of the west coast, is now a hub for high-tech services and social media and has played a key role in incubating new companies over the past two decades. Alameda and Contra Costa Counties, the two east bay counties, provide somewhat more affordable housing for many of the workers who commute to San Francisco and the south bay. One strength of the east bay economy has been its diversity, with some spillover of jobs from Silicon Valley and San Francisco, but also a concentration of regional and local serving and support services for residents and businesses. Oakland, the region's third largest city, is in the heart of the east bay and is a Federal job center for the region; the east bay also has a high concentration of trade and construction jobs. The San Francisco Bay region has a multiethnic, multilingual, and mobile population—more than 30 percent of the population is foreign born. With nine counties and 101 cities, the San Francisco Bay region has developed innovative ways to address the seismic risks faced daily, but also faces challenges in finding effective policies that can be adopted by small and large, rich and poor jurisdictions throughout the region.

Macroeconomic Impacts and Economic Resilience Analysis—The First 6 Months

The subchapter "Economic Consequences of the HayWired Earthquake Scenario" evaluates the economic impacts from the HayWired earthquake scenario on the economies of the San Francisco Bay region and California State using a computable general equilibrium (CGE) simulation model. A CGE model is commonly used for estimation of business interruption losses measured as Gross Domestic Product (GDP). It uses real-world sector purchasing data in a system of equations that describe the general equilibrium balance of different elements of an economy. As such, business interruption losses ripple through supply and customer chains.

In the 6-month period after the M_w 7.0 HayWired scenario earthquake, total GDP losses are estimated to be $43.2 billion (2014 U.S. dollars) for the State of California—that is, 4.2 percent of the State's baseline GDP for that period. The GDP losses are primarily caused by property damages; individual GDP losses from water, power, or telecommunication outages do not exceed $900 million.

However, this loss could be reduced by 42 percent to $25.3 billion if economic resilience measures are implemented after the damages and outages have occurred. Implementation of economic resilience measures after the disaster is in contrast to mitigation investments to reduce damages before a disaster. Evaluation of these resilience measures, which include business continuity planning, is a major contribution of this study. The sidebar below provides a summary of the types of measures evaluated.

Economic Resilience Measures

1. Resilience measures that speed restoration of services. These include:
    - A. Input substitution, such as fixed back-up power (batteries and generators) for telecommunications equipment and fuel management plans for water utilities in case of an electric power outage.
    - B. Inventories of portable telecommunication equipment to temporarily add capacity in telecommunications networks.
2. Resilience measures that work around the supplier disruption to maintain production of goods and services. These include:
    - A. Conservation of critical inputs (for example, recycling water).
    - B. Input substitution that replaces an unavailable good or service (for example, using a plain old telephone service in place of Voice over Internet Protocol service, or vice versa).
    - C. Resource isolation to allow the proportion of the production or sales processes that can continue without utility services. For example, much of agricultural production does not require electricity.
3. Resilience measures that use resources beyond normal use to serve more customers. Two examples are:
    - A. Production recapture (rescheduling) is the ability of businesses to recoup lost production by working overtime or extra shifts once their operational capability is restored and their critical inputs and employees are available. This is a viable option for short-term disruptions, where customers are less likely to cancel orders from their standard suppliers.
    - B. Relocation of businesses, including teleworking from other locations (for example, shared workplaces or homes).

Table 2 illustrates resilience measures that reduce estimated unmet demand for telecommunication services. They may include

- fixed backup power (batteries and generators) to substitute for electric power supply disruption in the short term,
- user behavior management (including texting instead of talking) to temporarily conserve available bandwidth,
- longer lasting resilience measures when carriers truck in portable equipment and fuel to speed restoration.

For example, in Alameda County, the service disruption in the base case results in 5.1 percent unmet customer demand over 6 months. If the fixed back-up power measure alone is adopted, unmet demand drops to 4.4 percent. The table shows the impact of each resilience measure separately, but if all measures are adopted, unmet demand drops to 0.8 percent in Alameda County. In turn, the resilience measures reduce the GDP losses from telecommunication service outages from $350 million to $40 million.

Regarding property damages, the most effective resilience measure is shown to be catching up on lost production (38 percent reduction in GDP losses) followed by telework (6 percent reduction in GDP losses). Results of the modeling without and with resilience are shown in table 3. As shown below, the hardest hit county of Alameda has a decline of $12.7 billion (or 23.5 percent) with no resilience measures and a decline of $7.45 billion (or 13.8 percent) with all resilience measures. Both Alameda and Santa Clara Counties suffer from $7 billion GDP losses once resilience is incorporated. The study found that the overall economic impacts were smaller than the peak national percentage of GDP losses in two consecutive quarters of the Great Recession that began in 4th quarter of 2007, except for Alameda County alone, and smaller than the region's peak percentage of GDP losses, except for Alameda and Santa Clara Counties alone. Therefore, the predicted economic impacts of the HayWired scenario earthquake would result in a recession in the San Francisco Bay region, but not a multiyear global impact like the Great Depression of the 1930s.

Longer Term Macroeconomic Analysis—Effects of a Major Earthquake on the Region's Future

The subchapter "The Economic Effects of the HayWired Scenario Using the Association of Bay Area Governments Regional Growth Forecast" examines how the long-term trajectory of the region's economy could be altered by a major earthquake along the Hayward Fault for the nine-county San Francisco Bay region. In this analysis, the following subregions are defined:

- the east bay is Alameda and Contra Costa Counties,

Table 2. Summary of data and voice telecommunications disruptions resulting from the HayWired earthquake scenario for the base case and resilience cases on a 6-month basis for the five most disrupted counties in the San Francisco Bay region, California.

[Values are percentages of unmet customer service demand]

County	Base case (no resilience measures)	Supplier resilience measures		Customer resilience measures			All resilience measures
		Fixed back-up power	Fuel/portable equipment	User behavior management	Input substitution	Production and sale isolation	
Alameda	5.1	4.4	3.0	4.7	2.8	2.1	0.8
Contra Costa	3.6	3.1	1.7	2.8	1.9	1.1	0.3
San Francisco	1.9	1.6	1.5	1.7	1.3	1.0	0.5
San Mateo	2.3	1.9	1.6	2.2	1.4	1.1	0.4
Santa Clara	3.7	3.1	1.7	2.9	2.0	1.4	0.4

Table 3. Total Gross Domestic Product changes without and with all resilience measures in the 6 months after the HayWired earthquake scenario in the San Francisco Bay region and California.

[Values in billions of 2012 U.S. dollars. %, percent]

Loss category	Alameda County	Contra Costa County	San Francisco County	San Mateo County	Santa Clara County	Rest of San Francisco Bay region[1]	Rest of California	California total
No resilience	−12.7	−3.6	−2.5	−3.6	−13.1	−2.1	−6.5	−44.2
	−23.5%	−11.4%	−4.0%	−8.4%	−11.2%	−1.3%	−1.0%	−4.2%
With resilience	−7.45	−2.11	−1.31	−2.02	−7.23	−1.23	−3.94	−25.3
	−13.8%	−3.4%	−2.1%	−4.6%	−6.2%	−0.8%	−0.6%	−2.4%

[1]Marin, Napa, Sonoma, and Solano Counties.

- the north bay is Napa, Solano, and Sonoma Counties,
- the west bay is Marin, San Francisco, and San Mateo Counties, and
- the south bay is Santa Clara County.

The Association of Bay Area Governments (ABAG) and Metropolitan Transportation Commission analysis, using the Regional Economic Models, Inc. (REMI) model, translates sector output losses from building damage, commute flow interruption, and other factors into disruptions in business activity and then into estimates of the impact on the 2017 ABAG projection of jobs, regional output, and population. The analysis also considers sensitivities of effects to varying recovery times for trade and manufacturing sectors, housing cost increases, and population responses in terms of migration. Government disaster funds and insurance payouts counteract some of these effects.

The economic impacts are primarily caused by output losses from building damages and commute flow interruptions from transportation (Bay Area Rapid Transit [BART] and highways) disruptions that may last months to a few years. The analysis shows an economy that would experience substantial damages and losses in the short term. In the first year after the earthquake, assumed to occur in 2018, employment would drop by approximately half a million jobs (table 4) and Gross Regional Product would decline by 8 percent relative to the growth projected in 2017. The decline in output from commute flow interruption more than doubles the employment and population loss. Although building damage is the major contributor to employment loss from building damage in the east bay, where damage is greatest, commute flow interruptions in the west and south bay affect employment to a much greater degree than employment loss from building damages.

Government spending and new investments over a 9- to 10-year period have a stimulating effect on the economy that can counteract some of the job and population losses. If total impacts and stimulus effects are combined, the region's net employment loss in the first year is still more than 496,000 jobs—a 10 percent decrease compared to the regional baseline forecast. Results show a regional economy that could experience a deep recession with more severe effects in the most strongly affected area. Much of the economy could recover to the pre-earthquake growth path within a few years, but parts of the San Francisco Bay region do not recover to pre-earthquake employment levels until about 7 years later (2025). The region returns to within about 1 percent of the 2017 projected employment track by 2025 (fig. 1).

To put this in perspective, the HayWired economic impact analysis described here shows employment losses experienced in the east bay that are much sharper and deeper than during recent recessions, but with a faster rate of recovery than from either the dot-com recession of 2001 or the financial-crisis-related Great Recession that reached a trough in mid-2009. Figure 2 compares the effects of the HayWired scenario on employment with the effects of the last three recessions on east bay employment.

The speed of recovery would be helped by the continued economic strength of the Nation as a whole and other parts of the San Francisco Bay region, and by the assumption that individual firms recover rather than relocate. Employment losses in the San Francisco Bay region are of a magnitude similar to that experienced in the dot-com recession, but it ultimately took the region much longer to recover the jobs lost in the dot-com recession than the recovery illustrated in the HayWired scenario economic analysis drawn from the REMI model. In the dot-com bust, the region lost its main engine of growth. In contrast, effects from the HayWired scenario are more diversified among sectors, public money is invested in the recovery, and many businesses in undamaged parts of the region continue to operate.

All sectors experience jobs losses in the first few years after the HayWired earthquake scenario mainshock, relative to growth that would have occurred without the earthquake (fig. 3). The construction sector is one of the first to be stimulated by year three, as recovery spending picks up after initial delays (as were experienced after the Christchurch, New Zealand, earthquake in 2011), and other sectors return to normal. The accommodations and food services sector has the largest employment loss in 2018, at almost 59,000 lost jobs (19 percent), followed by the professional, scientific, and technical services sector (44,000 lost jobs, or 7 percent), the retail trade sector (43,000 lost jobs, or 10 percent), and the

Table 4. Total employment difference from all effects of the HayWired scenario mainshock relative to the undisrupted Association of Bay Area Governments' 2017 projection for the San Francisco Bay region, California.

[ABAG, Association of Bay Area Governments; %, percent]

Subregion	2018 (year of earthquake)	2019 (1 year after)	2022 (4 years after)	2027 (9 years after)	2040 (22 years after)
East bay	−238,518	−74,107	−48,398	−736	−3,149
North bay	−22,844	−10,136	−12,164	−780	−1,224
West bay	−145,844	−25,566	−25,422	−1,058	−3,619
South bay	−107,998	−22,300	−9,622	1,635	−2,380
San Francisco Bay region	−515,204	−132,108	−95,606	−940	−10,373
Regional percentage compared to ABAG 2017 projection	−10.1%	−2.6%	−1.9%	<0.1%	−0.2%

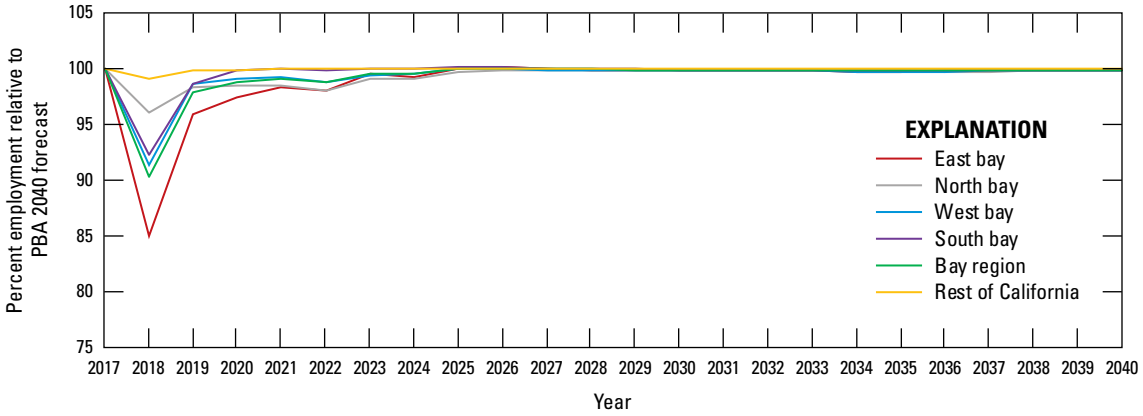

Figure 1. Line graph showing the percentage of employment difference resulting from the HayWired earthquake scenario in the San Francisco Bay region, California, by subregion compared to Association of Bay Area Governments (ABAG) regional and statewide projections. PBA 2040 is the ABAG Plan Bay Area 2040 forecast.

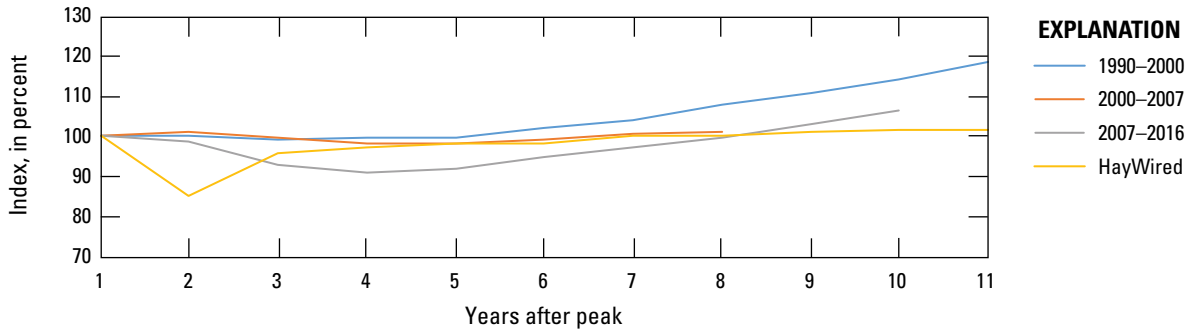

Figure 2. Line graph showing the recovery progression for the three most recent recessions from prerecession peak to peak of recovery or next upturn for the east bay subregion of the San Francisco Bay region, California, compared to job projection in the HayWired scenario. One hundred percent represents the peak before each downturn. Data from Kroll and others (this volume), based on California Employment Development Department data and, for HayWired projections through 2027, Association of Bay Area Governments Planning and Research Department REMI model version 1.7.8, adjusted control NC3RC1. REMI refers to models produced by Regional Economic Models, Inc.

administrative and waste management services sector (32,000 lost jobs, or 10 percent). Nevertheless, the region returns to a strong growth path within less than a decade, and by 2040, regionwide employment is only 10,000 below projections without the earthquake.

Although the initial net effect of the earthquake on population is smaller than employment effects relative to the regional growth projection, the population effects last longer in this analysis—the population in the region is below the ABAG projection without an earthquake for more than a decade. The population in the San Francisco Bay region decreases by about 145,000 in 2018 relative to projections, of which 83,000 occurs in the east and north bay. Population net loss in the east bay after the HayWired scenario earthquake includes those who move for economic reasons and those who retire, who are assumed in the analysis to choose not to rebuild but instead leave the area. These changes continue to have a small effect on the region's population throughout the forecast—the "economic" portion of the population returns as the jobs return, but the "noneconomic" departures (such as retirees) take longer to return, if ever. By 2040, the population in the San Francisco Bay region remains a net loss of about 21,000 people compared to the regional control forecast; see figure 4. These declines are small in percentage terms (around 4 percent at the peak in 2022, and only 0.2 percent compared to the 2040 forecast) compared to the 7.8 million regional residents in 2018 and projected 9.5 million residents in 2040, according to "Plan Bay Area 2040" (ABAG Planning and Research Department, 2016; Kroll and others, 2017).

Varying public spending and other assumptions affect the model results, and policies assumed before and after the earthquake may also determine the outcomes for individuals, communities, and the region as a whole. For example, sensitivity testing of an increase in postdisaster construction

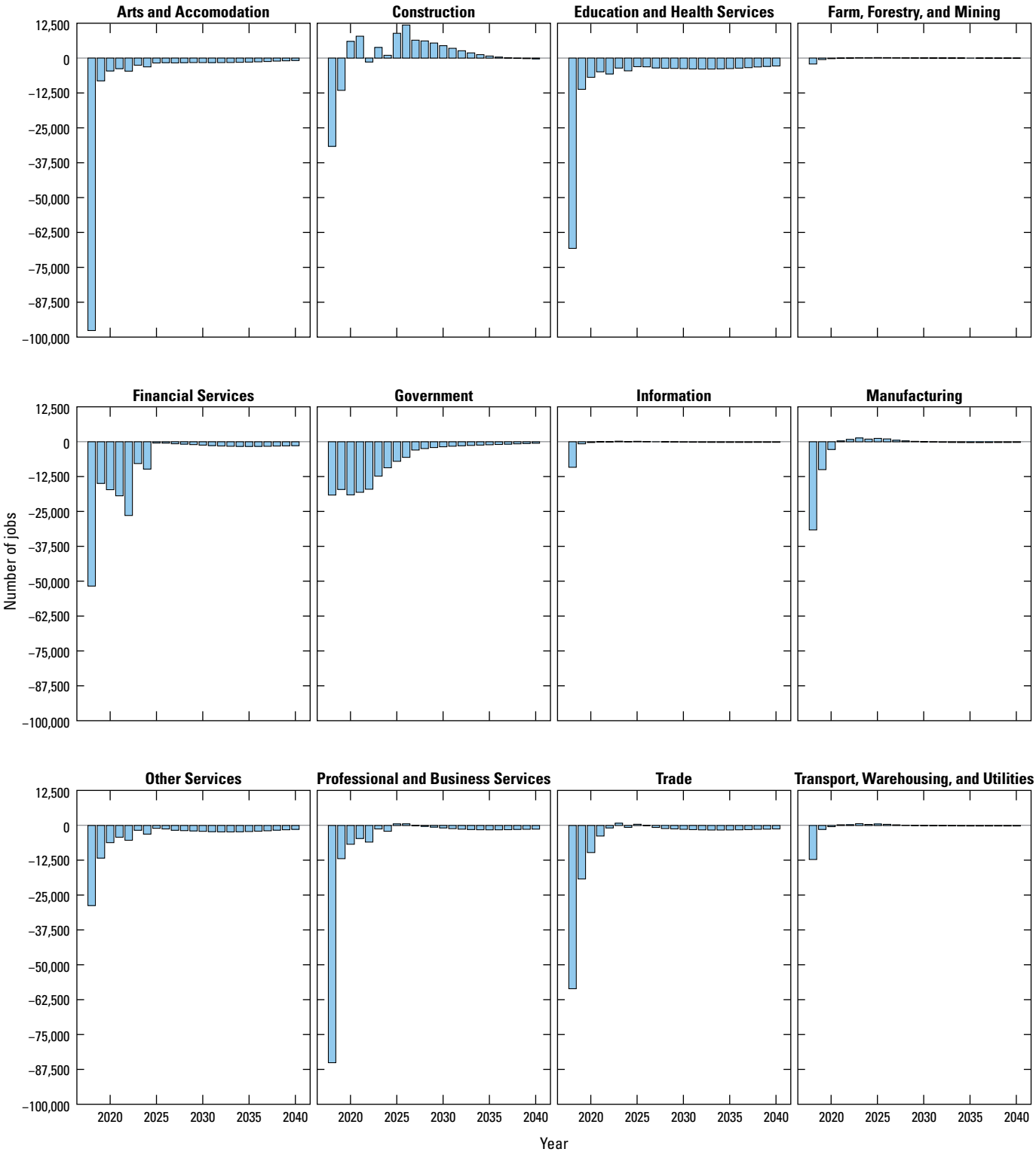

Figure 3. Bar graphs showing San Francisco Bay region, California, employment change projections after the HayWired scenario mainshock (in 2018) through 2040 by major North American Industry Classification System industrial sector. Employment is plotted relative to Association of Bay Area Governments regional growth projections.

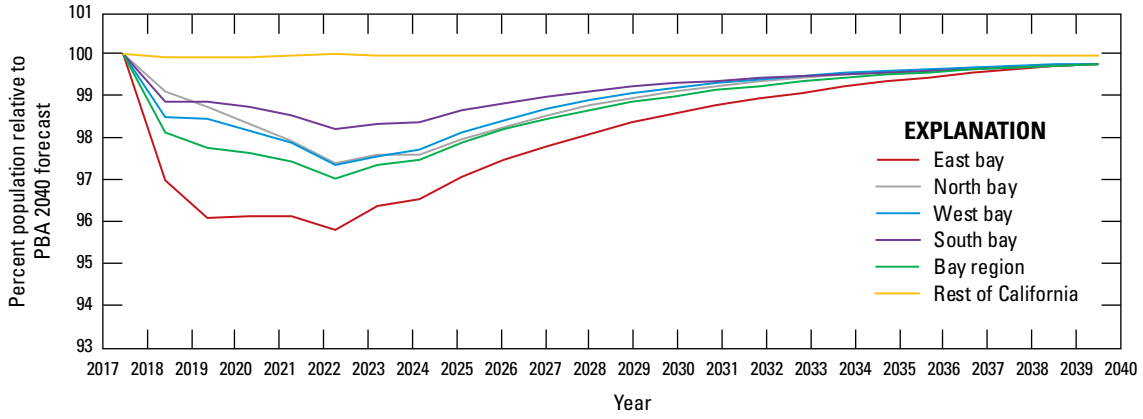

Figure 4. Line graph showing population curves in the HayWired scenario for the San Francisco Bay region, California, relative to the Association of Bay Area Governments (ABAG) regional and statewide projections. PBA 2040 is the ABAG Plan Bay Area 2040 forecast.

costs and an inadequate supply of construction workers significantly slows down recovery.[4] The pace and level of spending in response to the earthquake and the source of funds for rebuilding also influence the pace and level of recovery in the region.

How Business Characteristics and Location affect Vulnerability and Outcomes

The subchapter "Characteristics of Businesses Disrupted by Building Damages from the HayWired Scenario Mainshock" analyzes attributes of businesses vulnerable to limited or restricted use of their buildings as a result of extensive and complete damage (as determined by the Hazus-MH 2.1 loss-estimation software) from the HayWired scenario. The risk of disruptive building damage is estimated for business establishments by location, industry, size, structure, and ownership. For example, business establishment risk by location is the percentage of business establishments with disruptive building damage in a county divided by the total number of establishments in that county. Through a background review of past research, this chapter also recognized significant differences in the ability of various businesses and owners to prepare for and respond to an earthquake. Both the background research and the vulnerability findings suggested the value of exploring policies and programs to mitigate the impacts of an earthquake of the HayWired scenario magnitude for certain business characteristics.

Above average disruptive building damage risk for business establishment characteristics is shown in figure 5. The key finding is that location is the most distinctive attribute for this risk and a driver of other smaller risk differences.

- Alameda County establishments face the highest risk (25 percent of establishments), followed by Contra Costa County.
- Business establishments in the construction sector have a slightly higher risk resulting from greater concentration in the east bay and the building types occupied by construction firms. This is important in light of the current construction worker shortage, recovery challenges of small San Francisco Bay region construction businesses, and increased construction costs that delay overall recovery, as shown in the macroeconomic analysis.
- The largest businesses (with 500 or more employees) have a slightly lower level of risk of building damage, which could result from occupancy of modern buildings or location in less affected areas in this scenario. In contrast, smaller revenue (below $100,000) businesses appear more likely to suffer disruptive building damage and also have fewer resources to help in recovery.
- Minority-owned small businesses are slightly more likely to be in areas where buildings are at greater risk of disruptive damage—more than 9 percent, compared to the range of 6 to 8 percent for non-minority-owned establishments. This result reflects the presence of relatively more minority-owned establishments (4.6 percent of establishments and 7 percent of employment) in Alameda County, the most affected county, and

[4]The issue of construction worker availability is addressed more fully by Littlehale (2019).

in the sectors of manufacturing and wholesale trade, which have more disruptive building damage risk associated with location and building types. Some research has shown minority-owned establishments to be more vulnerable than other businesses for a variety of reasons relating to resources and networks. In this case, identifying these businesses as "vulnerable" is largely because of the vulnerability of the sectors and locations of these businesses. The situation for these establishments should not be confused with many of the most successful, well-capitalized, minority- or immigrant-owned businesses that started up in the San Francisco Bay region.

- If the risk to businesses is weighted by employment numbers at the establishments, manufacturing sector risk increases from 8.5 to 9.1 percent. Conversely, employment-weighted risk is less than establishment risk in Alameda County (22.9 percent) and the warehouse/transportation sector risk drops from 9.4 to 7.2 percent, meaning that fewer employees are in the riskier buildings for those characteristics.

- Fire hazard increases disruptive building damage risk most for businesses in Alameda County and for education and public administration sector businesses. The vulnerability of education and public administration sector businesses reflects the allocation of burned buildings to sectors based on the 1995 Northridge earthquake fire data—the distribution among building occupancy could be quite different in the San Francisco Bay region.

Geographic Concentrations of Impacts and their Interactions—A Spatial Analysis

Traditional macroeconomic impact analysis of building and infrastructure damage assessments provides an aggregate estimate of effects the HayWired scenario could have on the regional economy. Yet macroeconomic analysis does not adequately capture the fact that these effects are spread unevenly across counties and subregions nor the effects of the spatial relations between jobs and homes. The subchapter "Spatial Analysis of Industries, Employment, and Commute Flows in Areas of Concentrated Damage from the HayWired Earthquake Scenario" provides a geographical examination of potential disruption, focusing specifically on areas with concentrated building damage, and considers effects on both employee workplaces (by industry group) and homes (by single-family/duplex, multifamily, or group-living type).

Concentrated Building Damages

The total number of census tracts where the percentage of extensive or complete building damage is concentrated—greater than 20 percent from earthquake and fire hazards—is 173, out of a total of nearly 1,600. There are seven subareas in the region that contain these tracts (fig. 6), which make up about 11 percent of the total number of tracts in the nine-county San Francisco Bay region. The 173 tracts are primarily located in Alameda and Contra Costa Counties, with fire impacts also concentrated in Marin and Solano Counties. The cities of Hayward and San Leandro have older downtown cores with concentrations of vulnerable building

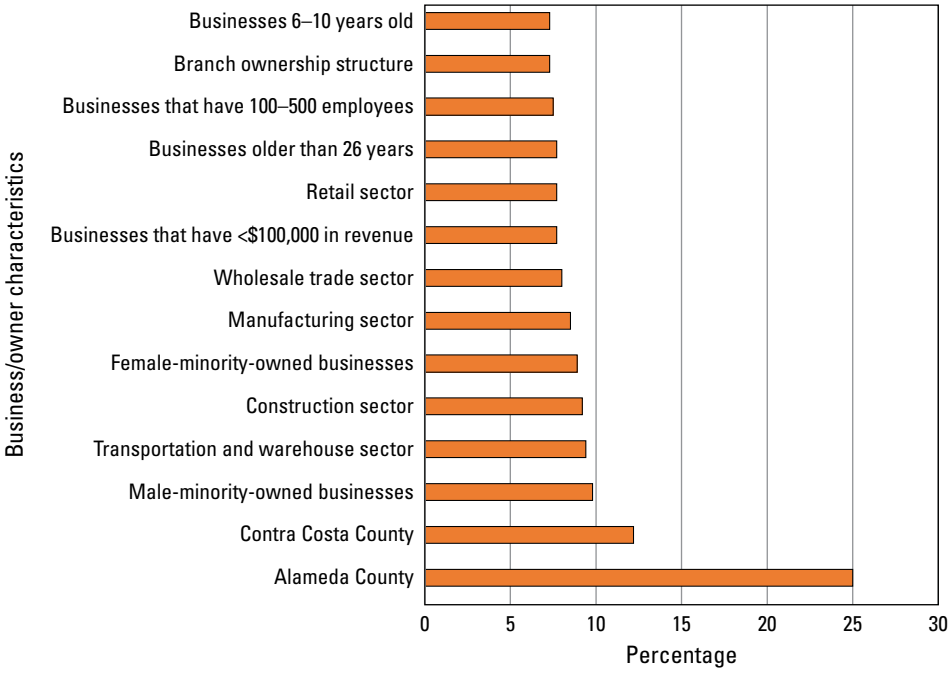

Figure 5. Plot showing business characteristics with average and larger risk of disruptive building damage from earthquake hazards in the HayWired scenario in the San Francisco Bay region, California.

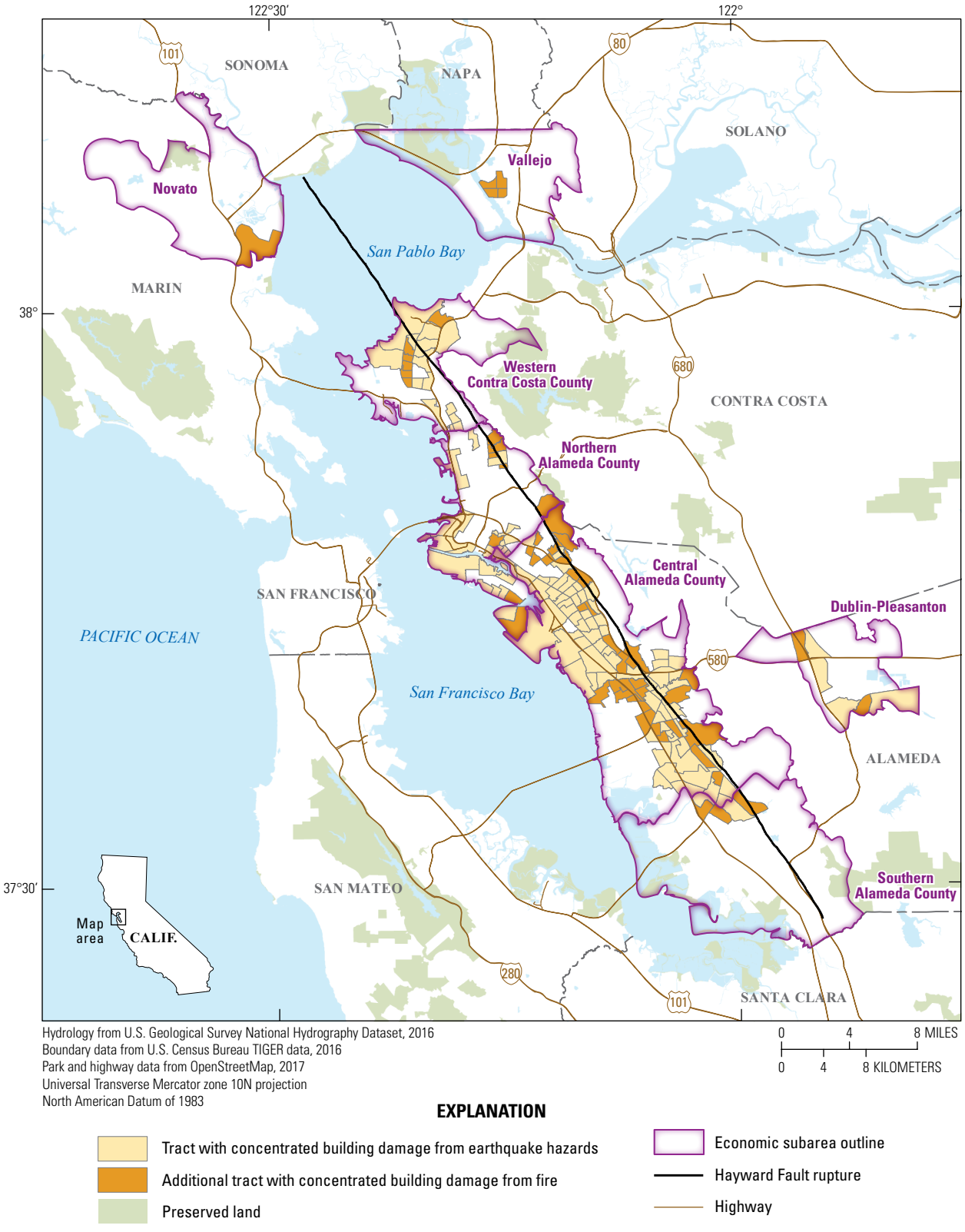

Figure 6. Map of the San Francisco Bay region, California, showing census tracts with concentrated damage in subareas as a result of hazards caused by the HayWired scenario mainshock on the Hayward Fault. Census tracts with concentrated damage are defined as tracts with 20 percent or more of their total building square footage in extensive or complete damage according to the Hazus analysis.

stock that are heavily damaged in the HayWired scenario. Downtown Oakland and San Francisco, which have some even older buildings are spared of the most intense shaking in the HayWired scenario (but could be highly vulnerable in a different earthquake scenario).

Concentrated Building Damages and Sectors

Industrial/warehouse, retail/commercial, and multifamily buildings (commonly low-cost rentals) largely affect neighborhood damage concentrations from all HayWired scenario hazards. Fire following earthquake is a primary cause of concentrated damage to multifamily buildings. Group-living occupancies, most prevalent in the northern Alameda County subarea, are also vulnerable to extensive or complete damage, but represent only a very small share of residential square footage. One item to note is that efforts by the University of California to strengthen their dormitories may have helped mitigate this vulnerability identified in the Hazus analysis; this would not address vulnerability in other types of older, privately owned group facilities or in correctional facilities. Office and single-family/duplex buildings generally perform well with respect to damage, but the businesses and households occupying these buildings may still be affected by their location in neighborhoods of more vulnerable, generally older, buildings.

Household serving industries are also affected by and are closely tied to the households that they serve. Predominantly single-family/duplex residential neighborhoods would have trouble reestablishing themselves without household services (for example, schools) available. Conversely, household serving industries could be affected if their customers—the households they serve—are displaced by significant multifamily residential damage.

Home and Workplace Relations

Home and workplace relations are defined as one of the following: employees (1) live and work in areas with concentrated damage, (2) live in areas with concentrated damage but work in areas with less-concentrated damage, (3) work in areas with concentrated damage but live in areas with less-concentrated damage, or (4) live and work in areas with less-concentrated damage (fig. 7). In the case of earthquake and fire hazards, about 15 percent of the nine-county San Francisco Bay region employees are affected by one of the first three relations. Of the 96,000 employees who live and work in tracts with concentrated damage, 70 percent do so in the same subarea, and 57 percent of employees that live and (or) work in the same subarea do so in central Alameda County.

With nearly 420,000 employees living and (or) working in at least one tract with concentrated damage in the nine-county region, job losses or relocation and employed resident displacement have the potential to geographically widen business impacts in addition to commuter interruption analyzed in the REMI model. Approximately 81,000 of these employees commuted to jobs in tracts with less-concentrated damage in Alameda County (Alameda County remainder in fig. 8). Further afield, around 50,500 employees commute to San Francisco and about 32,500 employees commute to Santa Clara County. Employment districts, such as downtown San Francisco and some cities in Santa Clara County, could be adversely affected if many of the people who work in these locations are stranded by the earthquake; lose their homes, utility services, and (or) community services (for example, schools are closed); are stressed by living conditions and home repairs; and (or) can no longer get to work because of transportation disruptions. Since the fire hazard disproportionately affects residences and concentrates damages in Marin and Solano Counties, some businesses could struggle to fill jobs, as their preexisting and potential workforce no longer has housing accessible to jobs, similar to the outcome of the 2017 Santa Rosa fires.

Conversely, of the 232,000 people working in areas with concentrated damage, half of these workers (114,000) are coming from less damaged residential neighborhoods in the remainder of Alameda and Contra Costa Counties (white areas within those counties in fig. 6). These workers could lose their jobs or be out of work for an extended period without a paycheck and could even relocate. Telework from home may be possible; office work generally has more flexibility for telework, but this is a less viable option for some of the 90,000 employees living in tracts with less-concentrated damage and working in the goods producing and trade, transportation, and utility industries located in tracts with concentrated damage.

These neighborhood impacts, along with extended transportation disruptions, could have consequences well beyond the direct effects to individual businesses and households. In addition to the direct loss of jobs from damage and commuting disruption, a large earthquake on the Hayward Fault could:

1. Accelerate the exit of declining industries;
2. Exacerbate the already precarious position of specialized industrial clusters in older manufacturing areas and move manufacturing to more affordable places, creating ripple effects to suppliers, customers, research and development, and headquarter operations; and
3. Accelerate the gradual conversion of industrial to higher uses in mixed land uses and the region's identified priority development areas, where concentrations of housing and office uses are planned, dislocating jobs.

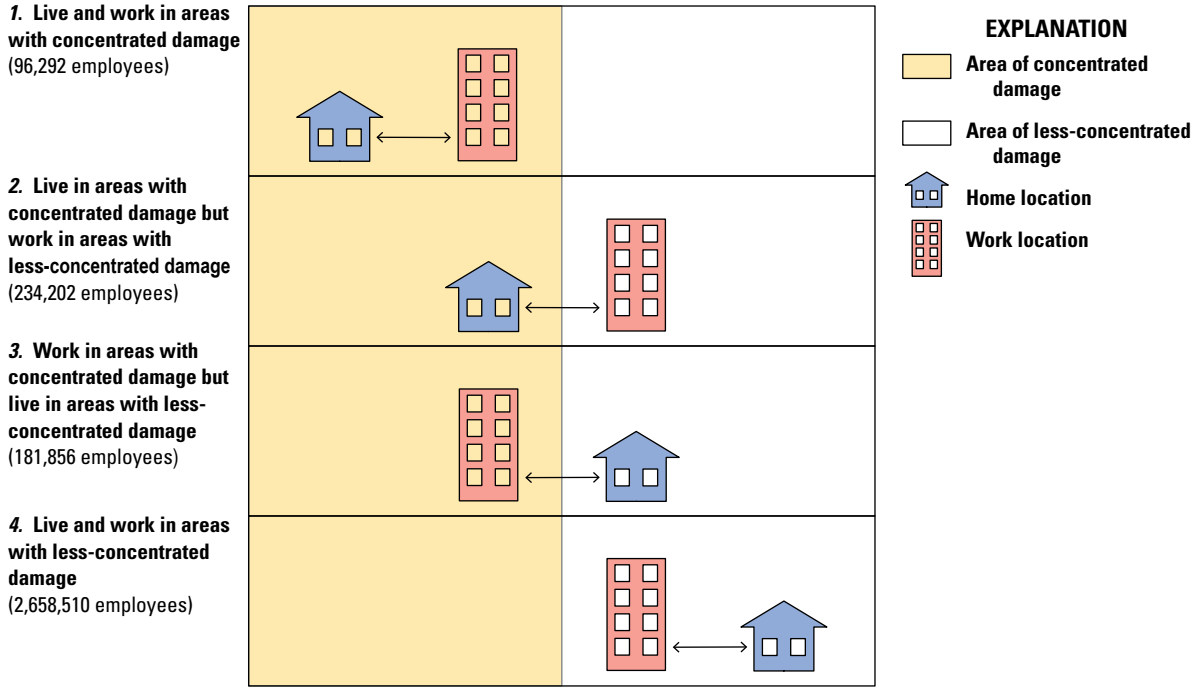

Figure 7. Cartoon showing possible home-workplace relations associated with areas of concentrated and less-concentrated damage resulting from the HayWired scenario mainshock in the San Francisco Bay region, California.

Construction Sector Stressors and Opportunities

Both the macroeconomic and business focused studies single out the unique situation of the construction industry before and after the HayWired scenario mainshock. The earthquake brings both stressors and opportunities in the sector.

- Many local construction firms are small businesses located in the east bay, in buildings that are at risk of extensive or complete damage, or in areas of concentrated damage.
- Demand for construction industry services will soar after the earthquake, after an initial slowdown, to repair and rebuild damaged structures, drawing new construction workers to the area.
- In 2018 (the year of the scenario earthquake), as well as in more recent years, the industry has already been dealing with a very tight labor market, unable to find all of the workers needed to fulfill demand for new housing construction. This labor shortage is exacerbated by rising demand for construction workers after the earthquake.
- The labor shortage and rising demand lead homeowners, businesses, and public agencies to face higher prices, with some effects on the pace of recovery. This may be further exacerbated by the transportation disruptions described above.
- Because of the damage to local businesses, the increased demand for construction work will not necessarily strengthen the existing base of smaller construction firms, which would be unable to quickly take advantage of new opportunities and, once recovered, could face extensive competition from outside firms.

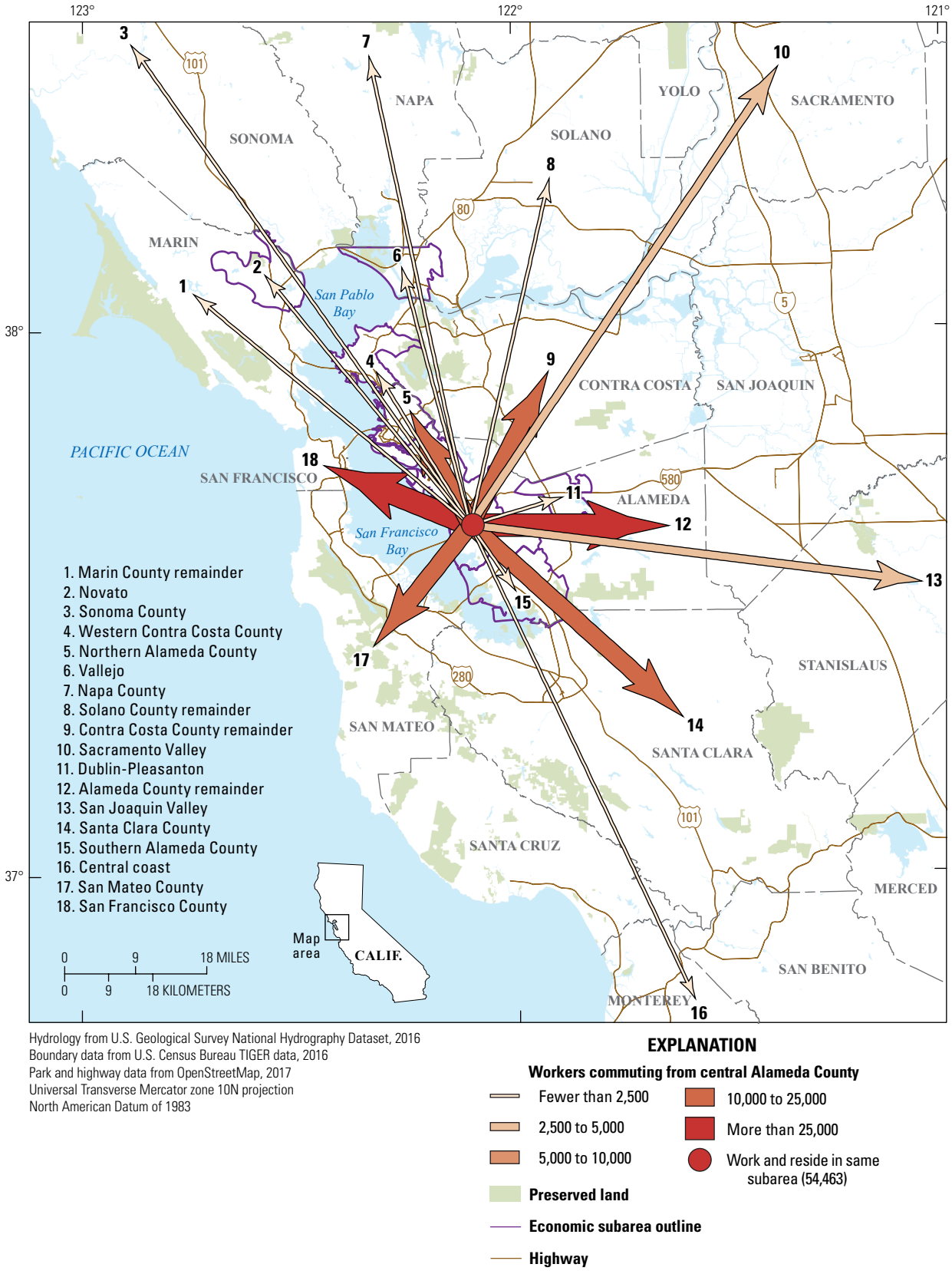

Figure 8. Map showing employed resident flow out of areas of concentrated damage resulting from the HayWired scenario mainshock for the central Alameda County subarea, California. Areas with "remainder" in the name are parts of counties outside the defined subareas, and other counties that do not have areas of concentrated damage are also included. More distant counties are aggregated into larger subregions: Sacramento Valley (Sacramento and Yolo Counties), San Joaquin Valley (Merced, San Joaquin, and Stanislaus Counties), and the central coast (Monterey, San Benito, and Santa Cruz Counties).

Policy Implications Related to the Economic Analyses

Public policy is a critical aspect of addressing the economic effects and the disruptions for workers and residents of an event like the HayWired scenario. Public policies include investments or planning that happen before a major event, as well as those that speed recovery and minimize disruptions after an earthquake occurs. Although the five reports identified critical vulnerabilities and causes, and in some cases, policies, the discussion that follows draws additionally on literature reviewed for the study and on the discussion during the HayWired Economic Consequences for Policy Interpretation workshop jointly hosted by the Association of Bay Area Governments and U.S. Geological Survey that was held on August 28, 2018.

Planning Ahead

- About $80 billion has already been invested in seismic strengthening of infrastructure and buildings since the 1989 Loma Prieta earthquake (Brocher and others, 2018). This money has likely reduced future economic impacts because HayWired economic analyses show the largest economic impacts are caused by building damage and transportation disruption. Continuing to retrofit or replace older structures and improve seismic building codes would continue to reduce potential economic impacts. Another study could use economic models developed for the HayWired scenario to quantify benefits of stronger structures.
- Designing and building to prevent fire ignitions and to be fire resistant would reduce not only earthquake-related hazards but also those related to wildland and urban wildfires. For example, 50 percent of buildings built using 2008 fire codes versus 18 percent of buildings built before 2008 survived the 2018 Camp Fire in Paradise, California. Impacts from fire spread can be further reduced if cities, regions, and the State have identified and planned for means of fighting fires in cases where water distribution has been interrupted.
- The advanced creation of policy and procedures about restricting access once damage occurs could anticipate potential tensions between keeping people safe versus allowing business owners into damaged buildings to get what they need, and efficiency of demolition behind a cordon versus business resumption in safe buildings in heavily damaged areas.
- The vulnerability of local household-serving businesses like food services, retail, and healthcare can have long-term effects on neighborhood resilience. Planning for neighborhood response and accommodating temporary business relocation needs in advance, as well as providing temporary facilities and support services for businesses and customers after the event, can help to mitigate the otherwise widespread losses that can be expected for businesses in these sectors.
- The impacts of building and inventory loss can be reduced by cooperative responses among businesses and neighbors and even between more and less heavily damaged areas. Efforts to build networking ties, including small business alliances, before the event can make it easier to develop these cooperative responses in a crisis period. Advance planning, including identification or development of communications and planning tools, can also improve the logistics of managing cooperative responses once an event occurs.
- In general, the points on inventory and supply chain issues raised in the previous two points could be addressed by reducing supply bottlenecks for responders and local businesses. As experienced after the north bay wildfires in 2017 and 2018, the increased demand for construction workers can be difficult to meet while the sector is experiencing challenges (such as labor shortages). There is already a current urgency for construction capability in the San Francisco Bay region to build more housing and for funded and approved transportation infrastructure projects. Loss of construction capacity or increases in construction costs because of high demand would slow the ability to recover, similar to the experience in Sonoma County after the 2017 wildfires. Long-term planning for resilience in the construction industry by major employers, trade organizations, educational institutions, and local, State, and Federal government can improve the industry's ability to respond to catastrophic events.[5] For example, preregistration of small construction firms within the region for disaster reconstruction could improve their participation. As the use of modular units in construction expands in the bay region, it would be useful to evaluate to what extent this approach eases delays and whether it would be an effective way of speeding reconstruction after a major earthquake.
- Even with a more robust regional construction sector, the scale of damage required by a major earthquake would tax the San Francisco Bay region's capacity to rebuild. Advanced planning for temporary expansion of the construction workforce can help to limit bottlenecks. Such approaches could include developing a national network of firms specialized in recovery, identifying in advance ways to provide housing and support services for the temporary construction workforce that would be needed, and planning for emergency measures, such as easing parking restrictions on mobile homes and recreational vehicles to house the temporary workforce as well as displaced residents and businesses.

[5]Recommendations for improving the availability of trades workers is addressed by Littlehale (2019); Li (2018) further discusses the rebuilding challenges in the San Francisco Bay region after a major earthquake.

- Expedited permitting would help enable rebuilding to happen in the time period shown in the San Francisco Bay region economic recovery model. In Sonoma County following the 2017 fires, for example, emergency ordinances eased physical and occupancy restrictions on temporary housing, extended existing permits, and included a simplified design review process.[6] Advanced planning for future contingencies (including draft ordinances outlining procedures for emergency situations) would better prepare jurisdictions to address rebuilding efforts from a comprehensive perspective, and effective retrofit programs could reduce the need in the first place.
- Regional and local jurisdictions would need to be prepared beforehand to launch a planning process that brings together local property owners and residents to discuss their needs as alternative travel patterns, land uses, and land use intensity are considered. Resources could be prepared in advance to instruct local jurisdictions on how best to document damage and register households and business owners needing or receiving assistance.
- State government and local jurisdictions may need to plan together to determine how the sales tax and property tax revenue losses of a widespread event could be shared and ensure that the local governments most in need of revenue for recovery have access to necessary resources. This could involve developing a reserve fund through contributions from State and local sources or an insurance program to cover lost revenues in affected areas.
- Similar to planning for sea level rise and fires, regional planners can take earthquake risk into account in land use and resilience planning. Land use decisions and earthquake planning can be integrated into regional responses to climate change. This approach could recognize the overlapping areas of projected sea level rise and geological risks of liquefaction during an earthquake.
- Major disruption of land use and routes may be an opportunity for improving planning, for example, to reduce greenhouse gas emissions and minimize risks from future earthquakes. Restored travel routes could be improved to address preexisting congestion and access concerns, and where appropriate, rebuilding could happen in some cases at higher densities to improve the viability of public transit use, especially in areas that already planned for this type of transition. In addition, future regional planning can examine reallocating planned land uses away from earthquake risk areas, as is being considered with regard to future building in high fire-risk areas.
- Policies for pre- and post-earthquake preparations can take into account opportunities presented by planning for the 21-county northern California megaregion. One opportunity is around goods movement. Megaregion goods movement studies by the regional agencies identify opportunities for expanding logistics and wholesale functions beyond the core San Francisco Bay region, and for diversifying the geographic location of tech-related manufacturing and services (Metropolitan Transportation Commission, 2019). Another opportunity is in expanding housing opportunities supported by new car-free commute options. For example, the San Francisco Bay Area Planning and Urban Research Association (SPUR) (www.spur.org) encourages a megaregional perspective on future growth, which would improve residential and business opportunities by building on growth generated by bay region businesses and connecting parts of the megaregion through new transportation investments.

The Role of Employers

The role of employers is also of key importance.

- Inclusion of major employers, such as those in the technology sector and in the health industries, at all stages—in advanced planning, initial responses, and recovery—can augment the resources available when most needed (such as emergency supplies and mental health services) and also ensure that employees, suppliers, and other linked sectors are informed about immediate and possible long-term effects as an event unfolds.
- Employers can prepare for neighborhood effects on their business operations and critical infrastructure, impacts on employee living situations, work relocation plans with respect to their customers and employee residences, particular vulnerabilities of their sector, and their role in neighborhood resilience and recovery. This preparation could benefit from being done cooperatively with similar types of businesses and within the context of city or regionwide resilience plans, to be able to address the differing needs of businesses of different sizes and sectors.
- Advanced planning in areas vulnerable to heavy damage can reduce the impacts of restricted access after an earthquake by locating critical assets (for example, emergency operations centers, police services, and fire services) and backing up business assets (for example, servers) outside these areas.

[6]See, for example, chapter 40 of the Sonoma County code of ordinances, titled Sonoma Complex Fire Disaster Recovery, available at https://library.municode.com/ca/sonoma_county/codes/code_of_ordinances?nodeId=CH40SOCOFIDIRE (last accessed September 11, 2020).

Policies Effective After the Earthquake

- Businesses can make up for output losses by implementing business continuity measures, including shifting production in time (to catch up on lost production) and space (to alternative locations), and having backup alternatives for power, water, and telecommunication services.
- A quick recovery in overall employment depends heavily on investment for rebuilding homes, nonresidential buildings, and infrastructure. The robust level of recovery spending assumed in the economic forecast analysis drops the east bay job deficit from 15 percent to below 3 percent in 2 years and brings the east bay to within 1 percent of projected employment levels within 5 years. The public sector plays a critical role in this, not only providing a portion of the funding, but also providing the means for clearance of debris, safety checks, issuance of new permits, and continuity of services (such as schools).
- Private lenders can work with local officials, regional representatives, business organizations, and their borrowers to provide ways of stabilizing businesses and homeowners through postponed loan payments and expedited new loans.
- Restoration of the telecommunications sector is also a major factor in allowing many economic sectors to restore their operations. As seen in the sensitivity tests, if telecommunications are not sufficiently repaired to provide for remote work, then the losses from transportation disruptions could be much more severe.
- The public sector would need to work cooperatively with private logistic firms to ensure the delivery of necessary emergency supplies at the outset, to ease supply bottlenecks for local producers during recovery, and to maintain pathways for distributing final products.

The Relation with Housing

- Temporary housing services would be crucial in maintaining the labor force needed to keep ongoing businesses in operation and support the labor force needed for reconstruction. Preparedness, response, and recovery plans would need to recognize population movements and long-term displacement as central components of earthquake resilience. Organizations would need to plan for emergency, interim, and temporary housing, as well as registering households in need, and also recognize the dynamics of these phenomena over time and space. Identification of successful efforts in previous disasters may make it easier to respond effectively after an event.
- The San Francisco Bay region is in a critical situation in 2018 and 2019 with respect to housing supply, as is much of urban California. Had the HayWired scenario actually occurred in April 2018, the housing losses and resulting rising prices could have been a drag on the economy for years. Recent experience with wildfires has shown that vulnerability to disaster does not discriminate by income or cultural group. However, the housing stock most vulnerable to earthquake damage—old multifamily units—is disproportionately occupied by households in the lower half of the income scale, as is discussed in a separate chapter in this volume that focuses on communities at risk. This emphasizes the importance of building more new housing for all income groups now, as well as being prepared with policies that support the replacement of the low-cost stock that is likely to be lost in a major earthquake event.

The Role of Insurance

- Investment in recovery is not only the responsibility of the public sector. In the sensitivity analysis, private insurance payments have a small effect on the outcome because these payments cover such a small share of the total damage. Were a larger share of homes and buildings covered by insurance, recovery would be better resourced, and displacement and outmigration could be less. Judging from past experience, close cooperation between assistance agencies, such as the Federal Emergency Management Agency and the California Governor's Office of Emergency Services, and private insurers may be needed to ensure the timely consideration and payment of claims.
- Regional agencies and local government could mount a campaign to educate public and private entities about earthquake insurance coverage and common issues, including underinsurance, interpreting insurance policy language, and policy changes, as well as recommend new approaches to insurance that might better meet the needs of households in risky locations. The context could be extended to fire and flood insurance and influences of sea level rise and climate change.
- Contingent business interruption insurance is important to cover losses from indirect causes, such as reduced patronage when business is inaccessible to customers because of cordons, checkpoints, or fear. Review of how existing policies supported businesses after disaster interruption in previous events would help to suggest modifications in the design of the product.
- Recovery funding for small businesses is an innovation opportunity in community development. Beyond suggestions to make changes to the Small Business

Administration's loan policy, cross-sector and (or) cross-agency collaboration can support and guide small businesses by providing individualized small business risk assessments and a small grant to help implement recommendations (for example, adequate insurance coverage, digitizing records, or adding a generator). Small businesses could be incentivized to become eligible for postdisaster funding that fits their needs during critical time periods by implementing preparedness actions. By the nature of many small businesses, needs also relate to family needs. The Federal Emergency Management Agency and the U.S. Economic Development Administration could be among the organizations collaborating with the Small Business Administration to provide support for small businesses with regional and subregional economic development organizations and to coordinate small businesses recovery with broader local, neighborhood, and regional needs.

- Resilience preparation, innovation, and entrepreneurship are action areas of the San Francisco Bay region's recently adopted Economic Action Plan—part of the Comprehensive Economic Development Strategy endorsed by the U.S. Economic Development Administration in fall 2018—and these action areas are likewise under discussion in the preparation of Plan Bay Area 2050. This provides a framework for linking actions in innovation and entrepreneurship with efforts to make the region's local economies recover quicker and stronger in the event of a major disaster.

Closing Statement

Macroeconomic analyses of the HayWired scenario focused on changes in employment and output levels in the San Francisco Bay region. Although these losses can be substantial, similar to a recession, the findings point to much larger and more challenging disruptions in the lives of residents who live near the Hayward Fault. The residents and communities with the highest levels of impact are expected to rebuild and recover slower than the recovery of a diverse and large economy, such as the nine-county San Francisco Bay region. The impacts on humans would be more devastating than the impacts on the economy.

Whether the focus is on the economy or the disruptions in the lives of residents, all of the studies identify effects that can be reduced by advanced planning, including actions that can be taken in advance of the earthquake and in post-earthquake recovery policies. Various policies imply actions by all levels of government but also stress the importance of business-led policies. Moreover, coordination among employers, governments, and neighborhood groups would minimize earthquake impacts.

The region now faces the challenge of planning for risks of sea level rise, wildfires, and other climate change effects, in addition to challenges posed by a large earthquake. This suggests that land use and transportation planning for the San Francisco Bay region and, indeed, the 21-county northern California megaregion, can help in minimizing human and economic disruptions by integrating all of these risks into future rounds of planning and policies.

References Cited

Association of Bay Area Governments Planning and Research Department, 2016, Regional forecast for Plan Bay Area 2040: Association of Bay Area Governments, 25 p.

Brocher, T.M., Gefeke, K., Boatwright, J., and Knudsen, K.L., 2018, Reported investments in earthquake mitigation top $73 to $80 billion in the San Francisco Bay Area, California, since the 1989 Loma Prieta earthquake: U.S. Geological Survey Open-File Report 2018–1168, 18 p., https://doi.org/10.3133/ofr20181168.

CoreLogic, Inc., 2018, Financial implications of the HayWired scenario: CoreLogic, Inc., Special Report, accessed February 11, 2019, at https://www.corelogic.com/downloadable-docs/corelogic_haywired-scenario_r5.pdf.

Kroll, C., Jaramillo, J., Lu, S., Olsen, A., and Wong, H., 2017, Regional forecast of jobs, population and housing; Plan Bay Area 2040—Final supplemental report: Association of Bay Area Governments and Metropolitan Transportation Commission, 32 p., [available at http://2040.planbayarea.org/sites/default/files/2017-07/Regional%20Forecast%20Supplemental%20%20Report_Final_7-2017_0.pdf as of April 29, 2020].

Li, R., 2018, Labor shortage could cripple Bay Area rebuilding after next big quake: San Francisco Chronicle, October 17, 2018, accessed September 8, 2020, at https://www.sfchronicle.com/business/article/Labor-shortage-could-cripple-Bay-Area-rebuilding-13312821.php#.

Littlehale, S., 2019, Rebuilding California—The Golden State's Housing Workforce Reckoning: Smart Cities Prevail, 49 p., accessed February 25, 2020, at https://www.smartcitiesprevail.org/wp-content/uploads/2019/01/SCP_HousingReport.0118_2.pdf.

Metropolitan Transportation Commission, 2019, Northern California Megaregion Goods Movement Study executive summary: Metropolitan Transportation Commission, 21 p., accessed September 24, 2020, at https://mtc.ca.gov/sites/default/files/Northern_California_Megaregion_Goods_Movement_Study.pdf.

Reflections on the COVID-19 Pandemic, June 2020

By Cynthia Kroll, Stephen Levy, and Anne M. Wein

The Coronavirus Disease 2019 (COVID-19) pandemic began during the completion of the economic analysis of the HayWired scenario. Though the analysis is complete, there are a number of implications for the analysis, as well as policies towards earthquake preparedness, that might be learned from the COVID-19 pandemic experience in the San Francisco Bay region. In particular, we highlight the importance of earthquake preparedness and the opportunity to reduce our vulnerabilities to future earthquakes while recovering from this pandemic.

Pandemics and Earthquakes are Different Types of Disasters

It is important to keep in mind some of the differences between the COVID-19 pandemic and the effect of an earthquake or other spatially contained disaster. A disaster such as the HayWired scenario earthquake causes localized devastation to lives and livelihoods. The most vulnerable areas have higher shares of aged multifamily housing, industrial, and commercial buildings. These areas tend to be occupied by the households and businesses with the fewest resources for response and recovery, increasing the risk to both low- and middle-wage jobs and likely increasing the income gap between high- and low-income households. The HayWired scenario highlights a potential loss of more minority-owned businesses that have fewer resources available for recovery. From the regional, state, and national perspective, the HayWired event will stimulate additional economic activity as rebuilding occurs. Some of the lost economic output will be shifted geographically to other business, nonprofit, or government branches, shortening the duration of the aggregate effects, even as it creates short- and (or) long-term challenges for the recovery near the earthquake's epicenter—one area's loss may be another area's gain. Impacts on local and state government coffers will vary widely. A few jurisdictions may lose a very high share of revenue, but the effect is not universal across the state level, and even San Francisco Bay region jurisdictions more distant from the epicenter may remain fiscally sound.

The COVID-19 pandemic is a very different case, where much of the global economy was put into a policy-induced decline—a self-imposed "coma," as some have described (Krugman, 2020)—but there has been no physical damage to buildings, utilities, and transportation systems. In the pandemic, entire segments of the economy (for example, cultural events, sports, many personal services, and real estate) shut down almost completely, and any economic activity that depended on transportation, whether the airline or cruise ship industry or the oil industry, has been heavily dampened. Closures of schools and dependent care centers have affected the productivity of the workforce; this has also occurred after earthquakes, but the options for handling the situation differ. Sectors with large numbers of low-wage employees with minimal resources have experienced the greatest challenges. Furthermore, the social unrest that has emerged during the pandemic, sparked initially by the death of an unarmed black man at the hands of police, underlines the fragility of low-income and minority communities when economies become stressed.

During the pandemic, the lack of physical damage has made it easier for some types of local services (for example, restaurants and retail) to shift to other methods of delivery, including mail order, take-out, and pick-up options (McGrath, 2020). Yet sales have dropped sharply despite these efforts and some business have closed, although the experience varies widely depending on the type of business. If the effects of the pandemic on the economy and employment are long lasting, there may be excess commercial space rather than a loss of space as in an earthquake or wildland fire. In addition, residential rents may decrease, in contrast to expected rental increases and a construction boom in the HayWired scenario. This could occur from the pandemic because of the number of recently unemployed people, or because high-wage workers are given the option to telecommute from remote locations, easing the pressure on bay region housing markets. Housing prices may also drop if more homes go into forbearance or foreclosure. Revenue losses from the pandemic are expected to be much more universal for state and local governments, as tax revenues from sales, income, and capital gains decline.

In both the HayWired scenario and COVID-19 pandemic, the timeline for recovery is uncertain. History tells us that for a large earthquake, recovery takes years. Will COVID-19 be the same? Much of the uncertainty around HayWired scenario recovery is based on how quickly and how much funding is available for rebuilding, as well as around the frequency and level of damage of aftershocks over time—making recovery a moving target. With COVID-19, we face even greater uncertainty over the trajectory of impact (human, social, and economic) and recovery capacity and timelines, which are intertwined with health, behavioral, and political issues. Projections for loss of life from COVID-19 vary by factors of ten or more and depend in part on the results of health and safety guidelines ranging from shelter-in-place to social distancing and testing for exposure and spread. Uncertainty abounds as sectors of the economy are reopened on varying

timetables and under different guidelines throughout the country. When a new normal after COVID-19 will be reached and what that new normal will be are also unknown. Will telework continue, thus reducing transportation and fuel demand? Will development of successful treatments or a vaccine allow us to reduce social distancing and reopen additional segments of the economy? Will some industries, such as restaurants, entertainment/leisure, or either small or major retail outlets ever recover? Will the societal inequities exacerbated by the pandemic be addressed by changes in policy?

COVID-19 Pandemic Experience Can Inform the HayWired Scenario Analysis

The COVID-19 pandemic experience could inform both the HayWired scenario regional and spatial analyses of impacts. Sectors that rely primarily on knowledge workers have shown great versatility for continuing to operate, even as public transportation use dropped by 90 or 95 percent throughout the region as a whole (Bay Area Rapid Transit, 2020). Major San Francisco Bay region employers, like Google and Facebook, took early action to direct all employees to work from home (Elias, 2020; Eadicicco, 2020). Government offices have also continued to provide some professional services through telecommuting employees as well as keeping workers in critical positions, like maintenance, on the job. Work has continued via telework at a higher level compared to the assumptions made in the HayWired scenario analysis.

The resilience of some of these sectors even in the face of total shelter-in-place policies is consistent with the assumptions discussed in the macroeconomic analyses of the HayWired scenario. A longer run analysis of the effects of the pandemic over the next 2 years may help to highlight the resilience measures that could also operate after an earthquake across other sectors over time, such as production rescheduling, inventory management, conservation, and input substitution. Yet some repurposing of spaces for immediate business and housing needs, or adaptations of production processes and delivery services to meet changed demands, could be very different after an earthquake as compared to the broad pandemic, including the need to find new locations to accommodate for building damage and concentrated damages in business districts. Planning for and adjusting to spatial economic shifts around stranded assets (for example, underutilized commercial space with work from home) from the pandemic may also inform shifts from heavily damaged areas and their recovery.

At the same time, the COVID-19 situation raises supply chain questions that could affect the kinds of analyses done for the HayWired scenario. Even with no physical disruption to transportation, communications, production, or logistics facilities as in the case of a major earthquake, supply bottlenecks abound (for example, for personal protective equipment [Asian Development Bank, 2020] and ventilators [Ranney and others, 2020]). Distribution networks have been slow to adapt to shifts in the sources of demand—for example, although grocery shelves are sometimes empty of basic staples and food banks lack enough capacity to meet the growing demand, animals are being euthanized and crops plowed under because the normal distribution network has broken down (Yaffe-Bellany and Corkery, 2020; Blake and Walljasper, 2020). After an earthquake, supplies for personal hygiene, medical equipment, medication, and many types of grocery staples may suddenly be in increased demand. Companies that are still operating will continue to have a steady demand for inputs, but disrupted businesses will sharply decrease orders. Even households that did some advance preparation may find that the resupply of basic necessities recovers much more slowly than anticipated. The pace of recovery after an earthquake will be affected by how quickly logistics challenges, as well as physical damage, can be addressed for the supply chain.

Important Policy Lessons

Although mitigation investments have reduced seismic risk in the bay region, the impacts of the ongoing COVID-19 pandemic and the insights from the HayWired scenario economic analyses herein remind us that much more is needed to anticipate, plan, and prepare for earthquakes. The HayWired scenario volume 3 includes information and suggestions for actions that help prepare residents, businesses, nonprofit, and government organizations to reduce the potential severity and duration of economic impacts of a future earthquake. The experience of responding to the COVID-19 pandemic has lessons that could be used to inform policy about both preparing for a major earthquake and recovering from the pandemic itself.

Advance Preparedness and Mitigation

The pandemic has highlighted the importance of preparedness. The San Francisco Bay region and California have reacted quickly and transparently to the challenges faced by the COVID-19 pandemic. The global experience underlines the costs of being unprepared, and even the bay region was not fully ready for the types of unprecedented actions required to respond to the pandemic. With the gradual approach of the virus' spread to the bay region, counties had time to develop strategies and, to date, have deflected some potential impacts, particularly on the healthcare system (Ho, 2020; Kahn and Marinucci, 2020). In contrast, there will be no gradual onset of a major earthquake, and once it arrives, we will have lost the time needed to make preparations. We know with some certainty that the bay region will experience effects from a large earthquake, possibly in the not-so-distant future, which will challenge our healthcare systems, supply chains, and many economic sectors. Actions are needed to improve resilience before an event to lower potential damage, and advance planning for post-event response is needed to anticipate and avoid missteps that may otherwise characterize the implementation of well-intentioned responses (Federal Emergency Management Agency, 2016; M.C. Comerio, written commun., 2020). Taking steps to understand the needs and challenges of

low-income and minority communities now can better prepare these communities to plan for and provide recovery efforts that address the needs of all residents (Markhvida and others, 2020).

A COVID-19 Recovery Plan Can Spur Earthquake Preparedness

Another policy consideration is that recovery steps that will be taken to tighten supply chains and restore our economy during and after the pandemic can also become investments in physical improvements and strategic plans needed to strengthen our resilience to seismic risks. There are two main ways a COVID-19 recovery program can be helpful in earthquake preparedness.

1. Stimulus packages to spur economic recovery from the pandemic-induced recession can include support for infrastructure investments that also increase earthquake or fire resilience, such as retrofitting buildings, strengthening transportation and other infrastructure, and improving our telecommunications capacity.

2. The pandemic has increased the urgency for building housing to alleviate overcrowding and homelessness—two conditions that accelerate the spread of the virus but are also of critical concern to the region's economic health and its post-earthquake resilience. Building more housing, particularly affordable housing for low- and moderate-income and essential workers, is already a critical challenge in the bay region, and one that will increase with new regional housing-needs targets from the State that focus on reducing the number of cost-burdened and overcrowded households (Kirkeby, 2020).

A Final Thought

In the midst of the current human and economic pain from the COVID-19 crisis, it is tempting to address one crisis at a time, and to postpone preparing for the one that could happen tomorrow—or in 30 years. We believe that would be a lost opportunity if we do not tie the lessons of loss and resources for recovery from one event toward improving resilience in a later event.

Acknowledgments

This section gained from the insights of several reviewers, including Jeff Bellisario of the Bay Area Council Economic Institute, Dena Belzer of Strategic Economics, Mary Comerio of the Department of Architecture at the University of California, Berkeley, Kara Gross of the Silicon Valley Economic Development Alliance, Lynn von Koch Liebert of Housing and Consumer Services at the California Business, Consumer Services, and Housing Agency, Jon Haveman of Marin Economics, and Adam Rose of the Center for Risk and Economic Analysis of Terrorism Events (CREATE) of the Sol Price School of Public Policy at the University of Southern California. Several of their suggested policy implications were incorporated into the final text.

References Cited

Asian Development Bank, 2020, Global shortage of personal protective equipment amid COVID-1—Supply chains, bottlenecks, and policy implications: Asian Development Bank Brief no. 130, accessed June 25, 2020, at https://www.adb.org/sites/default/files/publication/579121/ppe-covid-19-supply-chains-bottlenecks-policy.pdf.

Bay Area Rapid Transit, 2020, BART updates related to the coronavirus: Bay Area Rapid Transit website, accessed April 22, 2020, at https://www.bart.gov/news/articles/2020/news20200225.

Blake, M., and Walljasper, C., 2020, California farmer plows under lettuce after coronavirus shutters restaurant market: Reuters Business News, April 15, 2020, accessed May 8, 2020, at https://www.reuters.com/article/us-health-coronavirus-usa-lettuce/california-farmer-plows-under-lettuce-after-coronavirus-shutters-restaurant-market-idUSKCN21Y02M.

Eadicicco, L., 2020, Facebook is reportedly giving every employee a $1,000 bonus to help them work remotely during the coronavirus outbreak: Business Insider, March 17, 2020, accessed April 22, 2020, at https://www.businessinsider.com/facebook-gives-employees-1000-dollar-bonus-coronavirus-2020-3.

Elias, J., 2020, Google tells more than 100,000 North American employees to stay home amid coronavirus fears: CNBC, March 10, 2020, accessed April 22, 2020, at https://www.cnbc.com/2020/03/10/google-tells-all-north-american-employees-to-stay-home.html.

Federal Emergency Management Agency, 2016, National Disaster Recovery Framework [2d ed.]: U.S. Department of Homeland Security, 53 p., accessed June 25, 2020, at https://www.fema.gov/media-library-data/1466014998123-4bec8550930f774269e0c5968b120ba2/National_Disaster_Recovery_Framework2nd.pdf.

Ho, C., 2020, Bay Area hospitals hope they won't have to choose who to save in coronavirus pandemic: San Francisco Chronicle, March 13, 2020, accessed June 25, 2020, at https://www.sfchronicle.com/business/article/Bay-Area-hospitals-hope-they-won-t-have-to-15128063.php.

Kahn, D., and Marinucci, C., 2020, Bend it like the Bay Area—Doctors see flatter curve after 2 weeks of social isolation: Politico LLC, March 30, 2020, accessed June 25, 2020, at https://www.politico.com/states/california/story/2020/03/30/bend-it-like-the-bay-area-doctors-see-flatter-curve-after-2-weeks-of-social-isolation-1269663.

Kirkeby, M., 2020, Final regional housing needs determination: California Department of Housing and Community Development memo to Therese McMillan, Executive Director of the Association of Bay Area Governments, on June 9, 2020.

Krugman, P., 2020, The Covid-19 Slump Has Arrived: New York Times, April 2, 2020, accessed April 22, 2020, at https://www.nytimes.com/2020/04/02/opinion/coronavirus-economy-stimulus.html.

Markhvida, M., Walsh, B., Hallegatte, S., Baker, J., 2020, Quantification of disaster impacts through household well-being losses: Nature Sustainability, v. 3, p. 538–547, https://doi.org/10.1038/s41893-020-0508-7.

McGrath, K., 2020, Curbside pickup options from restaurants and retailers: U.S. News and World Report Money, March 20, 2020, accessed April 22, 2020, at https://money.usnews.com/money/blogs/my-money/articles/curbside-pickup-options-from-restaurants-and-retailers.

Ranney, M.L., Griffeth, V., and Jha, A.K., 2020, Critical supply shortages—The need for ventilators and personal protective equipment during the Covid-19 pandemic: New England Journal of Medicine Perspectives, v. 382, 3 p., https://www.nejm.org/doi/full/10.1056/NEJMp2006141.

Yaffe-Bellany, D., and Corkery, M., Dumped milk, smashed eggs, plowed vegetables—Food waste of the pandemic: New York Times, April 11, 2020, accessed May 8, 2020, at https://www.nytimes.com/2020/04/11/business/coronavirus-destroying-food.html.