

# **Characteristics of Businesses Disrupted by Building Damages from the HayWired Scenario Mainshock**

By Anne M. Wein, Jon Haveman, Cynthia Kroll, and Jeff Peters

Chapter V4 of

**The HayWired Earthquake Scenario—Societal Consequences**

Edited by Shane T. Detweiler and Anne M. Wein

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## Chapter V4

# Characteristics of Businesses Disrupted by Building Damages from the HayWired Scenario Mainshock

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## Abstract

A review of business characteristics associated with business vulnerability after a disaster (for example, type of business, location, sector, size, age, and owner demographics) accompanies a spatial analysis of business characteristics exposed to disruptive building damages in the HayWired scenario, San Francisco Bay region, California. The National Establishment Time-Series Database contains business and owner characteristics. Extensive and complete building damages from the HayWired scenario mainshock earthquake and fire hazards are used to estimate the percentage (or risk) of disruptive building damage by occupancy in census tracts. The spatial analysis of businesses in nine counties within the San Francisco Bay region with regard to building occupancy damage estimations provides a more nuanced assessment of business establishment and employment vulnerability than can be gleaned from building occupancy damage results alone. The analysis and literature are used to inform policies, mitigation approaches, and programs and implementations that could be helpful in the San Francisco Bay region after a large earthquake.

We estimate a 7–8 percent risk of disruptive building damage to business establishments and employment in the San Francisco Bay region; at least 40,000 establishments and 240,000 employees could be affected by extensive or complete damage at their workplaces. The risks vary by sector and range from 5–6 percent (for businesses in utility, other, finance and insurance, and management of companies sectors) to 10–11 percent (for establishments in the construction, education, and warehouse and transportation sectors and employment in the manufacturing sector). Business location strongly differentiates disruptive building damage risk for all types of businesses. About 25 percent of Alameda County businesses and employees could be affected by limited or restricted use of their buildings, and the risk increases to 35 and 40 percent in central Alameda and western Contra Costa Counties, respectively, because of their close proximity to the HayWired scenario epicenter. In Alameda County, risk of disruptive building damage by sector range from 15–19 percent (agricultural and utility businesses) to about 33–35 percent (construction and education businesses) and in central Alameda County, sectoral risks can be as large as

57 percent for public administration employment and 50 percent for construction business establishments. All Alameda County establishment and employment risks exceed risks in other counties; disruptive building risk in Contra Costa County is 12–13 percent, followed by 3–4 percent in Santa Clara County. Overall, the shares of business characteristics in Alameda County largely drives the result for the region. For example, the slightly larger regional risk to minority-owned businesses and branch-type establishments reflect a larger representation of these business characteristics in Alameda County.

The disaster research literature identifies the prevalent and vulnerable business characteristics of small size (measured either by number of employees or revenue). Small businesses (less than 50 employees) represent 98 percent of establishments and 60 percent of employment in the San Francisco Bay region. About 33 percent of establishments and 10 percent of employment have annual business revenues under \$100,000. Recent studies find that small businesses are underserved by disaster recovery resources and seek more innovative solutions. Larger businesses have more resources for disaster mitigation, preparedness, and recovery, and based on location in the HayWired scenario, they show slightly less disruption from building damage than medium- and small-sized businesses in the region, but not in each county. In Santa Clara County, large businesses face a greater risk of building damage, suggesting they are located in more hazardous places in the HayWired scenario or in more vulnerable buildings than small- and medium-sized businesses in the county.

Businesses in the retail sector have also been vulnerable after disasters, although retail sales may be maintained as customers switch to other retailers. Programs to ensure continued operations have assisted retail businesses impacted by disasters. Such programs will be important for the retail sector in the San Francisco Bay region, which has an above-average disruptive building damage risk and a larger composition of small businesses. Business establishments in the construction sector face larger disruptive building damage and are more likely to be small businesses—this may impede their ability to reap the benefits of reconstruction in the absence of programs ensuring their participation. Manufacturing businesses also face above-average disruptive building damage risk, and combined with the

difficulty of relocating fixed assets, may result in changes to the business base in Alameda County, requiring coordinated economic development. Transportation and warehouse establishments are disproportionately located in Alameda County and, therefore, the sector is at greater risk of disruptive building damage, which could create a need for public and private coordination around emergency and production supply networks. The risk to education establishments and employees is potentially exacerbated by fire following the HayWired scenario mainshock and reinforces the importance of fire prevention and safety management in schools with laboratories. Slightly larger disruptive building damage risk for minority-owned businesses is a reminder to follow up on programs for minority business owners. Male-minority-owned businesses are exposed to more risk in the HayWired scenario and female-owned businesses have been found to be more vulnerable after previous disasters.

After the direct benefit of constructing stronger buildings to reduce disruptive building risk, opportunities to improve business preparedness and recovery reside in interorganizational arrangements and programs.

## Introduction

Macroeconomic impacts, measured as national and regional Gross Domestic Product (GDP) losses, can mask business interruption at the microeconomic level (Dahlhamer and Tierney, 1998; duPont and Noy, 2015). Individual businesses may experience impacts of disasters in widely varying ways (Dahlhamer and Tierney, 1998). A disaster may interrupt businesses directly through

- Damages to buildings, contents, and inventory (Marquis and others, 2015), and
- Transportation and utility (electricity, water, gas, voice and data) service outages (for example, Webb and others, 2002; Scarinci, 2016),

and indirectly through

- Disruptions to downstream businesses in supply chains (Altnay and Ramirez, 2010),
- Damages to neighborhoods and safety perceptions that deter customers (Dahlhamer and Tierney, 1998; Chang and Falit-Baiamonte, 2002; [New Zealand] Department of Labour, 2011),
- Socioeconomic status of customers (Lam and others, 2012), and
- Staff issues<sup>1</sup> (Corey and Deitch, 2011; Seville and others, 2014).

<sup>1</sup>Staff issues include (1) difficulties finding qualified or suitable staff; (2) the additional burden of managing and supporting staff; and (3) reduced productivity caused by staff being stressed, emotionally drained, and burned out (Seville and others, 2014).

If a business is closed for any reason, it is vulnerable to losing market share (Alesch and others, 2001).

In this study of businesses in the San Francisco Bay region, we focus on building damages as the source of business disruption from the HayWired scenario earthquake. Of the businesses that reported physical damage after the 1989 Loma Prieta earthquake, 55 percent of them described it as disruptive or very disruptive (Wasileski and others, 2011). Building damage and relocation was a top issue for the Christchurch, New Zealand, business community for at least eight months after the magnitude (*M*) 6.3 Christchurch earthquake (Recover Canterbury, n.d.). The effects of other sources of business disruption for the HayWired scenario are examined in other chapters of this volume: neighborhood impacts by Wein, Belzer, and others (in prep., planned to be published as part of this volume); supply chain ripple effects by Sue Wing and others (in prep., planned to be published as part of this volume); and labor and transportation effects by Kroll and others (in prep., planned to be published as part of this volume).

Researchers have sought to identify pre-existing business and owner characteristics that make businesses vulnerable to failure or slow to recover after a disaster (for example, Webb and others, 2002; Marshall and others, 2015). The goals of such research are to inform policies and programs to increase the resilience of businesses before, during, and after disasters (for example, Alesch and others, 2001; Zhang and others, 2009; Hatton and others, 2012; Marshall and others, 2015). In this chapter, we draw upon this body of research and a detailed inventory of businesses to shed light on potential business vulnerability to building damages in the San Francisco Bay region after a hypothetical large earthquake on the Hayward Fault.

In the HayWired scenario, the Federal Emergency Management Agency's Hazus model is used to estimate building damages for building occupancy classes, which broadly defines the industrial sector and their building types (Seligson and others, 2018). Fire following earthquake damages (Scawthorn, 2018) are integrated as additional complete building damages (Johnson and others, in prep.; planned to be published as part of this volume). We assume extensive and complete building damage states are particularly disruptive because they approximate conditions of building use (that is, restricted use of yellow-tagged buildings and prohibited use of red-tagged buildings, respectively). We define the risk of disruptive building damage for businesses as the percentage of building square footage that is extensively or completely damaged in their occupancy class in their census tract. Using the National Establishment Time-Series (NETS) Database, a more detailed accounting of the businesses and owner characteristics with respect to building damage states in census tracts allows application of findings from earlier disasters to discuss business vulnerability factors for the HayWired scenario.

Therefore, this report combines a review of past disaster research on business vulnerability factors with a spatial analysis of San Francisco Bay region businesses to provide a more nuanced assessment of business vulnerability than is conveyed in Hazus occupancy class building damage results. The literature review summarizes business and owner characteristics in relation to business outcomes (for example, temporary or permanent closure

or partial recovery) after a natural disaster. The method section describes the approach to perform a spatial analysis, combining disruptive building damage (derived from Hazus results) with the detailed business establishment data available from NETS—that is, disruptive building damage risk for businesses and employees within a specific sector, geographical area, business size, business age, establishment type, and owner demographic. The results section tallies business characteristics regionally and identifies those at high risk of disruptive building damage from HayWired mainshock earthquake hazards with and without fire following the earthquake.<sup>1</sup> We relate these results to findings from the business demise and recovery literature to illuminate potential business vulnerability in the region after such an event. In the concluding sections, we acknowledge the gaps in the data and limitations of our method and refer to policy insights from prior studies to discuss opportunities to increase business resilience to an earthquake in the San Francisco Bay region.

## Literature on Business and Owner Characteristics

Drawing upon theoretical frameworks of business resilience, studies have considered the influences of business owner demographics (for example, Alesch and others, 2001; Marshall and others, 2015), business characteristics (for example, Zhang and others, 2009), and organizational attributes (for example, Lengnick-Hall and others, 2011; Doerfel and others, 2013). “Owner characteristics” include the education and business experience, gender, minority/majority designation, age, household resources, personal resilience, and industry and disaster experience of the business owner. “Business characteristics” include the business location, sector to which it belongs, establishment type, operation in an owned or leased building, size, market reach, labor source, business condition and growth, prior business experience in the industry, prior business experience with disasters, prior short-term disaster business closure, and prior cash flow issues. “Organizational resilience” is defined by Lengnick-Hall and others (2011) in terms of cognitive, behavioral, and contextual attributes of organizations and framed as the corporate cultural dimension of resilience by Sheffi (2005). Doerfel and others (2013) find resilience in interorganizational relations that (pre-disaster) form communities of practice and involve multiple ties with each type of supporting organization. Our literature review focuses on business and owner characteristics because only these types of data are tracked in the NETS data.

The literature spans different approaches and contexts that complicate conclusions about the characteristics influencing business demise or recovery after a disaster. These study differences include:

- Different definitions and measurements of business impacts—for example, the condition and experience of businesses (Wasileski and others, 2011), business demise (Marshall and others, 2015), or recovery relative to impact (Brown and others, 2014). See Stevenson and others (2018) for a discussion of a business recovery framework.
- Different time periods of measuring business status—for example, 8 months (Webb and others, 2002; [New Zealand] Department of Labour, 2011) or 8 years (Marshall and others, 2015) after an event, such that businesses are subjected to different influences on reopening within different time periods (Lam and others, 2012).
- Extent to which business closure is differentiated from temporary arrangements (for example, owner/employees working for another business), consolidation of the business at another location, or reopening under a different name (Hatton, 2015).
- Different geographical settings, such as rural versus urban (for example, Stevenson and others, 2011).
- Different types and sizes of disasters—earthquakes, floods, and cyclones (for example, Webb and others, 2002; Wasileski and others, 2011; Hsiang and Jina, 2014).
- Different ways of identifying survey participants, including random sampling (for example, Marshall and others, 2015) and drawing from recipients of disaster loans (for example, Scarinci, 2016) or members of a business alliance organization (for example, Recover Canterbury, n.d.).
- Treatment of background noise of business failure or other market trends in the absence of a disaster.
- Recognition of pre-existing economic conditions including regional economic structure, commercial and residential space vacancy rates, and insurance penetration.
- Documentation of support programs provided to businesses after each disaster. Examples include a temporary space to congregate businesses (Kroll and others, 1990), a subsidy to pay employees (Brown and others, 2014) versus a loan (Alesch and others, 2001; Webb and others, 2002), and other programs in response to monitored business issues (Recover Canterbury, n.d.).

## Business Owner Characteristics

Marshall and others (2015) provide a state-of-the-art literature review of small business owner demographics and their cognitive attributes. Based on research and intuition, they make a case to investigate a slate of owner characteristics: education and disaster experience, gender, race/ethnicity, veteran status, household size and disaster experience, and personal resilience with respect to business states (reopened, closed and reopened,

<sup>2</sup>This analysis addresses only building damages, rather than the impacts of roadway or utility damages on business activity. These additional impacts are discussed in more detail in other chapters of the HayWired scenario analysis, including by Kroll and others (in prep., planned to be published as part of this volume) and Johnson and others (in prep., planned to be published as part of this volume).

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and closed) eight years after Hurricane Katrina. They found the likelihood of business closure (with and without reopening) increased for female owners. They note consistency with Fothergill (1996) and Council of Economic Advisers (2015), who explain that women, in general, have a greater exposure to risk because of their social roles as caregivers, lack of mobility, and access to capital (for example, aid, savings, insurance, and wages) compared to their male counterparts.

The experience of prior damage to business owners' homes did not appear to predispose their business for recovery; rather, prior home damage was associated with an increased likelihood of immediate or eventual business closure (Marshall and others, 2015). Recovering from damage to a home may limit household resources for business recovery investments.

Marshall and others (2015) found the likelihood of business closure (without reopening) was increased for minority or veteran owners. They point out that whereas the effects of ethnicity and race on business survival and preparedness are inconclusive, African-American owned businesses (in the retail and service sectors, in particular) have been found to fail more often in general, a trend that could be exacerbated in a disaster. Compared to non-veteran owners, veteran owners had lower perceived business success (which was associated with increased likelihood of closure) and owned fewer businesses in the service sector (that had a lower likelihood of demise).

The business owner's personal resilience is thought to be an important factor in the owner's ability to cope with stress resulting from a natural disaster (Marshall and others, 2015). Marshall and others (2015) found that owner resilience was associated with increased likelihood of reopening then closing. This corresponds to Alesch and others' (2001) observations of extraordinary psycho-social resiliency that commonly gave in to post-disaster stress and pressures, eventually resulting in business failure.

Marshall and others (2015) surmise that the business owner's household may be both a source of resources that the business can draw upon or a source of competition for those resources. They found opposing relationships between business status and the owner's household size. Owners with larger households were more likely to close and remain closed (suggesting resource competition between a larger household and business) and less likely to reopen and close (suggesting that resources from the larger household were available for the business).

Furthermore, Marshall and others (2015) found that businesses with partnerships were less likely to close. However, if businesses with partnerships closed for a time and then reopened, they were more likely to close again (perhaps caused by a perception of having more resources initially in the partnership).

### Business Characteristics

Numerous business characteristics have been examined by researchers after a disaster. The vulnerabilities summarized here pertain to business location; sector; establishment type; size;

premise type (either owned or leased and [or] home based); age; experience with disruption; and pre-existing business conditions.

### Business Location

Business location differentiates impacts from hazard exposure, property and neighbor damages, and utility disruptions to businesses (Kroll and others, 1991; Tierney and Nigg, 1995; Tierney, 1997; Webb and others, 2002; Wasileski and others, 2011; Brown and others, 2014; Marshall and others, 2015). Location is also relevant where businesses are dependent on local customers ([New Zealand] Department of Labour, 2011; Whitman and others, 2013). In contrast, businesses with international markets have recovered more quickly (Webb and others, 2000), although there is evidence that Christchurch businesses needed to assure national and international customers that they were reliable sources despite the ongoing earthquakes (observed by A.M. Wein during a 2011 visit to Christchurch; Resilient Organizations, 2018).

### Business Sector

Business sector has been related to business demise and recovery status after a disaster. Businesses in the retail and wholesale sectors have fairly consistently been found to be more vulnerable to disaster damages and disruption, including that from earthquakes: Kroll and others (1990) and Wasileski and others (2011) discuss the 1989 Loma Prieta earthquake,<sup>3</sup> Webb and others (2002) discuss the 1997 Northridge earthquake, and Chang and Falit-Baiamonte (2002) discuss the 2001 Nisqually earthquake. The [New Zealand] Department of Labour (2011) and Statistics New Zealand (2012) showed employment declines in the wholesale and combined retail and accommodation/food sectors in the Canterbury region for more than a year after the most damaging 2011 M6.3 aftershock in Christchurch, New Zealand. Retail and wholesale sectors were not highlighted in Canterbury earthquake surveys of business impact and recovery (Brown and others, 2014), but the surveyed businesses in these sectors did not appear among the most impacted. The vulnerability of retail and wholesale has been explained by the competitive nature of the business and tendency for small retail businesses to depend on local customers and to occupy older buildings (Alesch and others, 2001; Chang and Falit-Baiamonte, 2002).

After Hurricane Katrina, Marshall and others (2015) found service businesses survived more often than goods-producing businesses that rely more on fixed assets. Similarly, Zhang and others (2009) classify professional, scientific, and technical services as low-vulnerability businesses and manufacturing and construction as moderate-vulnerability businesses. Businesses in manufacturing and construction sectors were noted to recover better than expected after the 1989 Loma Prieta earthquake

<sup>3</sup>However, business assistance muted the effect for retail.



(Wasileski and others, 2011). The construction sector has shown initial decline that can be followed by a building boom (Kroll and others, 1990; Statistics New Zealand, 2012) to place it among the most recovered sectors (Brown and others, 2015).<sup>4</sup> Reconstruction brings in construction workers that are new customers for food and accommodation sectors that suffer from decreases in tourism after a disaster (Brown and others, 2015). The number of tourists declined in Christchurch when hotel capacity was impacted and tourists were encouraged to visit other parts of New Zealand because of ongoing aftershocks (Orchiston and others, 2013). In central Italy, there was a drop in tourism that lasted nine months after the 1997 earthquake (Mazzocchi and Montini, 2001). After the 2014 South Napa earthquake, visitors to restaurants declined in the City of Napa for as long as six months (observed by A.M. Wein in 2016). Amongst business sectors that typically benefit from an influx of potential customers, only the arts, entertainment, and recreation sector did not gain from new construction worker customers in Christchurch—these businesses were the most impacted and the least recovered relative to impact (Brown and others, 2015).

Zhang and others (2009) classify finance, insurance, and real estate businesses as moderately vulnerable. These businesses were considered to be better prepared, but not immune to earthquake impacts, surrounding damage, and transportation disruption after the Loma Prieta earthquake (Kroll and others, 1990). Brown and others (2014) rank finance and insurance businesses among the most recovered businesses relative to operations preceding the earthquakes and rank rental, hiring, and real estate businesses among the most recovered relative to impact (taking into account the level of impact as well as strength of business operations in the recovery period).

Business-oriented studies have had less to say about public and educational entities. The public administration sector was ranked among the least recovered entities in Christchurch, but one of the most recovered relative to size of impact (Brown and others, 2015). In Christchurch, the closure of hundreds of public schools affected 70,000 students and reopening of schools was delayed by water and wastewater services. Most schools reopened a month after the 2011 earthquake and school sites were shared to accommodate students from schools that remained closed (Earthquake Engineering Research Institute, 2011).

Continued operation of universities has depended on the restoration of other support services, including public schools. Tulane University was closed for a semester after Hurricane Katrina and reopening the university depended on the university's role in rebuilding support services, such as public schools, health services, and arranging for housing, as well as on the physical repairs (Cowen, 2007). During the hiatus, Tulane University helped students find education alternatives. In Christchurch, the University of Canterbury progressively reopened after 3–4 weeks using temporary (tent) structures onsite, off-site facilities, and

online instruction. The university suffered from loss of fee-paying international students. In the San Francisco Bay region, Comerio (2006) reports that the University of California, Berkeley, plans for a maximum closure of one month and Stanford University plans to reopen within one week after an earthquake.

## Business Establishment Type

Establishment type, as in headquarters, branch/affiliates, or stand-alone operations, indicate the range of resources and informed support and advice that may be available for managing business interruption. Headquarters typically have resources for emergency planning. Larger companies that have multiple sites in the region and nationally are able to shift operations (Comerio, 2006). The value of external advice from affiliates and headquarters was evident in Bowden's (2011) survey of four national companies when managers with "quake brain" had to make relocation decisions. In contrast, stand-alone businesses lack the benefit of preparedness guidance from headquarters, alternative sites, and (or) advice from others that are familiar with their business.

## Business Premises

Researchers have fairly consistently found that businesses that own their buildings fared better than renters (for example, Dahlhamer and Tierney, 1998; Chang and Falit-Baiamonte, 2002; Wasileski and others, 2011). Building ownership is an indicator of wealth for the business (Wasileski and others, 2011), whereas, as Comerio (2006) points out, resolving rental lease agreements can be a lengthy process. In contrast, Brown and others (2014) found that, in the Canterbury earthquakes, businesses that owned buildings fared worse than those that rented. Marquis and others (2015) shed light on the potential disadvantage of building ownership in Christchurch in the aftermath of the earthquake sequence, revealing unique issues and complexities for commercial building owners in relation to unexpected technical, legal, and financial challenges when making decisions about the future of their buildings and a paradoxical effect of insurance<sup>5</sup> on the recovery of Christchurch. In Brown and others' (2014) study on the Christchurch earthquakes, businesses that both owned and rented buildings recovered better, suggesting an advantage of having more options and more flexibility with multiple locations (Tierney, 1997).

Marshall and others (2015) found that home-based businesses had an advantage, perhaps because of better preparedness (for dual purposes) and because homes are built to higher codes than commercial spaces. Home-based businesses may be less likely to be located in built-up areas that are subject to concentrated neighborhood damage (see Wein, Belzer, and others, in prep.; planned to be published as part of this volume).

<sup>4</sup>Brown and others (2015) distinguish between recovery relative to operations preceding the earthquake and recovery relative to the size of impact. A sector that has not fully recovered to previous levels may still have recovered strongly relative to the level of impact experienced.

<sup>5</sup>The paradoxical effect refers to the expectation that insurance aids during recovery from a disaster, yet various insurance issues and challenges in Christchurch caused delays in repairs and rebuilding.

It is noteworthy that the number of people working from home is increasing but is more prevalent in some sectors than others. Working from home has been most prevalent in management, business, and financial occupations and has been increasing most rapidly for computer, engineering, and science occupations (Mateyka and others, 2012). In 2015, the U.S. Bureau of Labor Statistics (2016) measured 24 percent of workers are working from home in some capacity, including 30–40 percent of the management, business, and financial and professional service occupations, but fewer than 10 percent of production and transportation workers work from home.

## Business Size

Business size, measured by number of employees, wages, or revenues, is consistently found to be a factor in business recovery—small businesses are identified as more vulnerable to disasters than larger businesses (Dahlhamer and Tierney, 1998; Chang and Falit-Baiamonte, 2002). For example, small businesses had a lower probability of reopening in New Orleans after Hurricane Katrina (Lam and others, 2012). Small business size corresponds to less resources to prepare, fewer cash reserves, lower uptake of insurance, and a lack of access to government programs for recovery (Kroll and others, 1990; Webb and others, 2000; Alesch and others, 2001; Dunaway and Shaw, 2010; Collier and others, 2016). Wasileski and others (2011) caution that small business use of external aid may exacerbate the problem of debt.

Brown and others (2014) did not detect a small business size effect on business recovery, but small businesses were underrepresented in their sample. Although the five businesses in their survey that ceased operation had less than 50 employees (Brown and others, 2014), four of these businesses reopened under a new name (Tracy Hatton, Resilient Organizations, written communication, 2018). Also, the government earthquake support subsidy to compensate employees in Canterbury after the Christchurch earthquake was reportedly very helpful for keeping businesses going ([New Zealand] Department of Labour, 2011) and was taken up by relatively more small- and medium-sized businesses (Brown and others, 2015).

## Business Age

Some studies find evidence of the vulnerability of young business age caused by limited resources (including insurance), less experience, and smaller size (Dahlhamer and Tierney, 1998; Webb and others, 2002; Collier and others, 2016). However, results vary. No age effect was detected with respect to business recovery in Christchurch, but older businesses prevailed (Brown and others, 2014). Conversely, old businesses struggled more in Miami-Dade County, Florida, in the aftermath of Hurricane Andrew (Webb and others, 2002) and Scarinci (2016) gathered evidence that some smaller and newer businesses could relocate more easily than larger and more established businesses. Business age might align with experience, but younger businesses could

benefit from having an experienced owner, whereas older businesses headed by older proprietors may be less likely to survive (Brüderl and Ziegler, 1992). This could especially be the case where the level of damage requires extensive rebuilding and investment on the part of the owner, who may prefer to retire.

## Business Experience with Disruption

Marshall and others (2015) found positive effects from industry experience and business experience with disruption (including cash flow issues) on reopening, although, industry experience did not necessarily keep businesses from eventually closing. Scarinci's (2016) post-disaster preparedness investigation reinforced that small businesses can be inhibited by a lack of reflection caused by intense focus on recovery and even "amnesia" to wipe the horrible experience from business owners' minds.

## Pre-existing Business Conditions

Past studies have shown that disasters tend to intensify pre-existing business conditions (Marshall and others, 2015). Pre-disaster growth and financial condition have been identified as indicators of business survival and recovery (Dahlhamer and Tierney, 1998; Alesch and others, 2001; Webb and others, 2002). Positive owner perceptions of business success prior to Hurricane Katrina were associated with lower likelihood of demise (Marshall and others, 2015). Financial condition was the second strongest predictor of long-term recovery in Santa Cruz, Calif., after the Loma Prieta earthquake, but counterintuitively was found to have a negative effect (Webb and others, 2002).

## Methods

Past research, then, shows that a broad range of long-term effects are possible after a disaster relative to the severity of the event, and vary with the types of physical damage, particular circumstances of the economy, assistance provided, industry sector and mix, business size and age, establishment type, and other characteristics of business ownership. In the description of business characteristics in the San Francisco Bay region that follows this section, we highlight a few key factors that may contribute to business vulnerability, including location with respect to disruptive building damage, industry sector, business size, age, establishment type, and ethnic and gender characteristics of the business owner. None of these factors in themselves is a predictor of business outcomes, and indeed two different factors may interact to mitigate the effect a single characteristic might have (for example, a large retail business would have greater survival chances than a smaller one, but if heavily damaged relative to the smaller one, the survival likelihood of each could be reversed). Additionally, businesses facing compounding challenges are less likely to recover (Dahlhamer and Tierney, 1998). We analyze business characteristics for disruptive building risk in the HayWired

scenario to investigate whether an analysis of business and owner characteristics may illuminate the types of policies, mitigation approaches, or responses that could be helpful in the San Francisco Bay region. Next, we describe our methods for relating business characteristics to building damage estimates for the HayWired mainshock hazards of shaking, liquefaction, landslides, and fire.

## Data Sources

The NETS database is an annual collection of data pertaining to all of the business establishments in the United States between 1989 and 2013 sourced from Dunn and Bradstreet (Walls and Associates, 2011; Feldman, 2018). “Business” is broadly defined to include private for-profit and nonprofit organizations as well as government agencies (Barnatchez and others, 2017). In NETS, an establishment is a specific line of business at a specific location, and employment includes all workers at an establishment, potentially including proprietors, independent contractors, and temporary workers supplied by outside organizations (Barnatchez and others, 2017).<sup>6</sup>

Barnatchez and others (2017) review studies of comparable business datasets and conduct their own comparison of NETS data with that from more robust official data collection activities of U.S. statistical agencies. Using National NETS data for 1992–2014, they find that the correlation of NETS employment counts and U.S. Census Bureau County Business Patterns employment counts across U.S. counties can exceed 0.99; correlations across state-industry-size class cells are above 0.9 on restricted samples; and that zip-code-level correlations are also remarkably high. On the other hand, they find that NETS overrepresents establishments that have fewer than 10 employees, especially business sizes of 1.<sup>7</sup> A smaller, but significant, discrepancy is found for the largest establishments, but explained by large, public educational establishments that are difficult to identify as government owned, as well as establishments that mistakenly report firm employment numbers in NETS. Also relevant is the finding that post-2000 developments in U.S. mining, construction, and manufacturing employment do not appear to be well captured in NETS, possibly caused in part by industry labeling differences. When Barnatchez and others (2017) omit very small establishments (especially businesses of size 1), NETS agrees reasonably well with official datasets. The advantage of using NETS is that it does not require extensive proposal and security clearance processes and can be used outside of secure government facilities (Barnatchez and others, 2017).

<sup>6</sup>We do not know the extent to which the shadow economy (including nannies, gardeners, house cleaners, or day labor) is represented, but a Red Cross network of voluntary organizations estimated that about 450 nonprofit agencies provided some type of disaster service to 160,000 victims seeking help outside the regular channels compared to 130,000 families that received temporary housing assistance after the 1997 Northridge earthquake (Comerio [1998]).

<sup>7</sup>NETS imputes values for two-thirds of businesses that have less than 5 employees.

The data used for this analysis come from the 2014 version of the NETS dataset, and includes all of the business establishments in operation in the San Francisco Bay region as of January 2013. The San Francisco Bay region is defined as the following counties: Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco.

Business characteristic data in NETS used in this analysis include:

- Location,
- Size (number of employees, revenues),<sup>8</sup>
- Age,
- Establishment type, and
- Owner characteristics pertaining to gender and minority/<sup>9</sup> majority demographics.

Based on the discrepancies between datasets on business size, we also examined the distribution of businesses of size 1 (which may have 0 employees) across characteristics. Some additional characteristics were excluded because of many missing data entries. Even so, some location data had to be recalibrated, and some establishments were dropped from the dataset because location reporting concerns could not be resolved.<sup>10</sup> In all, the starting total of 627,856 establishments in the database was reduced to 570,659 when those with missing or unresolvable data were excluded.

The building damage data were sourced from the Seligson and others (2018) estimate of earthquake hazards and the Scawthorn (2018) estimate of fire hazards. The Hazus building damage states in a census tract are separated into: none, slight, moderate, extensive, and complete damage states. This analysis uses the percentage of building square footage that suffers the disruptive (extensive or complete) damage in each census tract for each occupancy class. Building damages are reported in Hazus by occupancy classes, which in turn are tied through a crosswalk to North American Industry Classification System (NAICS) codes, as shown in appendix 1. Fire damages were classified as complete damage, distributed to occupancy classes,

<sup>8</sup>Four establishments were dropped because they contained implausible data on either employment or revenues, most likely because they are headquarters with data that reflects activities at various establishments in other locations. The owner of the dataset did not respond to inquiries about these establishments. A much larger number of establishments were excluded because of missing records for revenue (mostly government offices) and age.

<sup>9</sup>Proprietor of non-European ancestry.

<sup>10</sup>The NETS data provided detailed geographic information on each establishment, including latitude and longitude, address, and level code. A level code indicates how the establishment was located by street, block, census tract, or zip code. Some establishments were not located in the level code indicated. Where possible, the establishment location was corrected and latitude and longitude were recalculated. For example, if an establishment was verified at the zip code level, but was not actually found to be located in the zip code indicated, the location for that establishment was moved to the indicated zip code centroid. 732 establishments with locations outside of the study area were relocated in the process of using zip code level codes. Relocating the remaining 35 establishments with insufficient data on their location was not attempted because it is a time-consuming manual process.

and integrated with the Hazus earthquake damages (appendix in Johnson and others, in prep.; planned to be published as part of this volume). The combination of earthquake hazard damages (Hazus) and fire following earthquake damages is referred to as “all hazards.”

## Algorithm

For counties in the San Francisco Bay region, we used an algorithm that counts business characteristics in each census tract by establishment and by numbers of employees. The counts are summed using the weight of the percentage of extensive and complete damage in the establishment’s census tract for the establishment’s occupancy class to calculate disruptive building damage risk to establishments and employees. Essentially, the risk is the percentage of establishments or employees that are in buildings that are extensively or completely damaged.

The steps are as follows:

1. Correct establishment location data in the 2013 NETS database for the San Francisco Bay region and assign it to a census tract using a geographical information system. Each business record contains the census tract, sector (6-digit NAICS code), employment, 2013 revenues, ownership (gender/race), and establishment type (headquarters/branch/stand alone).
2. Add further sector classifications to the business records. In this case, the 6-digit NAICS code is aligned with the Hazus occupancy classes and collapsed to the NAICS 2-digit industry code. Note that where there is no industry in the NAICS data field, the industry is classified as “other” and is subject to the average risk for all occupancies in the census tract.
3. Assign the sector risk measure to each record according to census tracts for both cases of earthquake hazards and all hazards to each establishment.
4. Use establishment-level risks assigned by census tract and occupancy class to aggregate into a measure of overall risk for each business characteristic.
  - A. The risk aggregation for business characteristics is performed for each sector (2-digit NAICS code) and all establishments (total) and aggregations are made across establishments using a weighted average of risk.
    - I. Weights for aggregating risk across characteristics are:
      - a. One for the risk aggregation by establishment.
      - b. Establishment employment for risk aggregated by employment.
  - B. The referenced business characteristics are the following:

- I. County (or subarea) in which the business is located,
- II. Number of employees in the establishment (various size categories),
- III. Age of the establishment in years (various age categories),
- IV. Overall revenues of the establishment (various revenue categories),
- V. Type of establishment (stand-alone, headquarters, or branch), and
- VI. Gender (male, female) and race/ethnicity (non-minority, minority) characteristics of the owner.

## Results

First, we summarize characteristics of San Francisco Bay region businesses and owners. We follow with the disruptive building risk results for businesses with these characteristics. Detailed results are presented in a set of tables in the appendixes, each set showing disruptive building damage risk results for each characteristic as equally weighted by establishment and weighted by number of employees in each establishment for the two cases of earthquake hazards only and all hazards (including fire following the earthquake).

### Business Characteristics in the San Francisco Bay Region

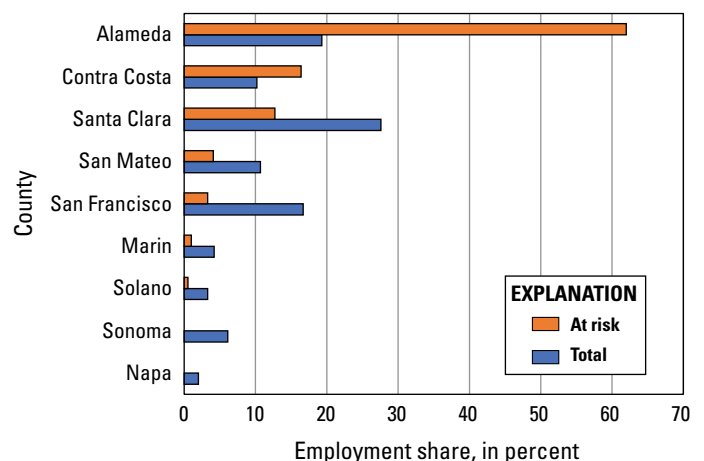
As of January 2013, the NETS data is summarized as follows:

1. *Establishments and employees.*—There are approximately 3,200,000 employees working in approximately 600,000 establishments in the dataset. Santa Clara County hosts the most businesses (24 percent of establishments; 28 percent of employment) followed by Alameda County (18 percent of establishments; 19 percent of employment).
2. *Distribution of employees by size of establishment.*—Within the region, 15 percent of employees are in businesses that have more than 500 employees (representing 0.1 percent of establishments); more than 60 percent of employees are in businesses that have less than 50 employees (representing 98 percent of establishments). Almost half of small business employees (almost 30 percent of all employees) work in businesses that have less than 5 employees (in 82 percent of establishments) and businesses of size 1 are 25 percent of establishments in the region. The remaining 25 percent of employees are in mid-sized business establishments that have 50–500 employees (representing 1 percent of establishments).

3. *Business sizes and sectors.*—Large establishments (>500 employees) are primarily in the public administration, utility, manufacturing, or information sectors. Sectors with the fewest employees in large establishments (>500 employees) include accommodation/food, retail, and construction. Sectors that have the largest share of employees in small businesses are administrative support and waste management; real estate, rental, and leasing; and management of companies. Businesses of size 1 are most prevalent in professional, scientific, and technical services (the share of businesses of size 1 in this sector is 163 percent of the regional share of establishments in this sector), followed by arts, entertainment, and recreation (144 percent of the regional share) and construction (133 percent of the regional share).
4. *Establishment revenues.*—One-third of businesses make less than \$100,000 (containing 10 percent of employees), and a total of 77 percent of establishments make less than \$250,000 (containing 28 percent of employees). Ninety-two percent of businesses of size 1 report revenues less than \$100,000. The establishments in the largest revenue category (\$2.5 million and above) contain 42 percent of all employees.
5. *Ages of business establishments.*—Most employees work for young or old companies: 25 percent of employees are in business establishments younger than 6 years (45 percent of establishments), and 34 percent of employees are in business establishments older than 26 years (13 percent of establishments).
6. *Establishment type.*—Most employees (77 percent) are in stand-alone companies (97.5 percent of establishments), followed by 20 percent of employees in headquarters (2 percent of establishments), and the remainder in branches (3 percent of employees; 0.5 percent of establishments).
7. *Owner characteristics.*—Most employees (90 percent) are in businesses that do not qualify as minority- or female-owned businesses (91 percent of establishments), 5 percent of employees work for establishments that are non-minority female-owned businesses (6 percent of establishments), and another 5 percent of employees work for minority male- or female-owned businesses (3 percent of establishments). Businesses of size 1 are disproportionately non-minority female owned and to a lesser degree, minority female owned.

described below reflect the geographic concentration of the shaking and fire damage of the HayWired scenario near the cities of Hayward and San Leandro in Alameda County. As illustrated in figure 1, Alameda County has 19 percent of the region's employment (as measured in the NETS dataset), but 62 percent of the employment that is at risk of disruptive building damage from the HayWired mainshock scenario. Contra Costa County has 10 percent of the region's jobs, but 16 percent of employment that is at risk of disruptive building damage. Santa Clara County, with the largest concentration of the region's employment (28 percent) has 13 percent of the region's employment that is at risk of disruptive building damage, whereas San Francisco and San Mateo Counties, with 17 and 11 percent of the region's employment, have 3 and 4 percent that are at risk of disruptive building damage, respectively.

The characteristics of business establishments at risk in each county differ by the sectoral mix of their businesses and the types of buildings that they occupy, as well as any other business characteristics that distinguish the mix of business establishments in each county. Note that, as shown in other economic analyses in this volume, business impacts increase and shift in their distributions when additional sources of disruption from the transportation, communication, water, and power systems, neighborhoods, and supply and customer chains (not covered in this chapter) are added to the analysis. This assessment differs from Hazus building losses and business output losses used in the macroeconomic computable general equilibrium and Regional Economic Models, Inc., analyses (Kroll and others, in prep. [planned to be published as part of this volume]; Sue Wing and others, in prep. [planned to be published as part of this volume]), but the overall results are consistent across analyses.



## Distribution of Employment at Risk across Counties

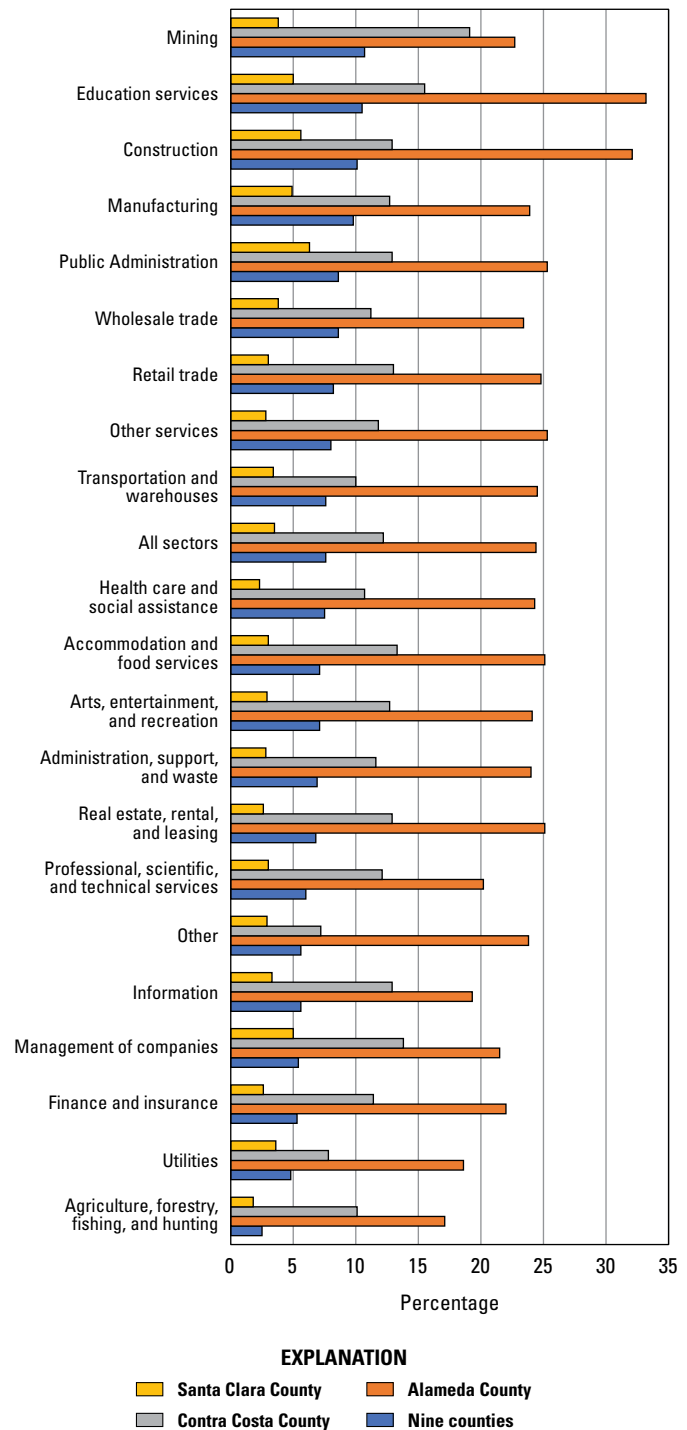
Because the building risks are shaped by the geography of the region and the earthquake event, we begin with a summary of the geographic characteristic. The results

**Figure 1.** Plot of the total and at-risk employment shares by county for the HayWired scenario mainshock earthquake in the San Francisco Bay region, California. Risk pertains to disruptive building damage from earthquake hazards and fire but does not include utility and transportation system impacts.

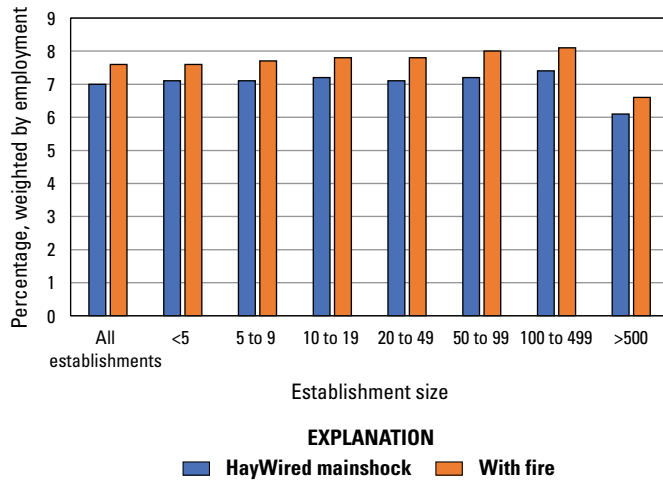
## Disruptive Building Damage Risk by Business Characteristics

Both business establishment and employment at risk portray the following results for business characteristics affected by disruptive building damage from all hazards.

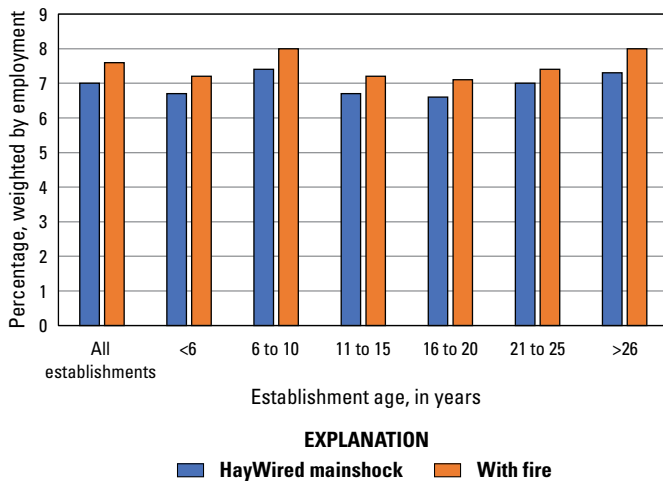
1. The risk of disruptive building damage from earthquake hazards could be greatest for businesses in the construction and manufacturing sectors. When fire hazards are included, mining and education could slightly surpass these sectors for the greatest risk of disruptive building damage (fig. 2). Businesses belonging to the agriculture/forestry/fishing/hunting and utility sectors show the lowest risk of disruptive building damage (relative to the number and size of establishments in those sectors) because of their more distant locations from the epicenter of the earthquake (for example, almost half of utility sector employees are employed in San Francisco County). However, when separated out by county, even these relatively low-risk sectors in Alameda County are at substantially greater risk of disruptive building damages than even the largest risk sectors for the San Francisco Bay region as a whole. The risk is accentuated further in subareas (appendix 4); as much as 57 percent of employment (in public administration) and 50 percent of establishments (in construction) could be at risk of disruptive building damage in central Alameda County.
2. For the most part, businesses in different size categories have similar risks of disruptive building damage. However, the largest businesses (500 or more employees) show a slightly lower level of risk, as shown in figure 3, because San Francisco and Santa Clara Counties have larger shares of large businesses and lower building damage risk. Overall, this means that smaller sized businesses may not be disproportionately damaged but are susceptible to the vulnerability of their size, as seen after prior disasters.
3. The disruptive building damage risk is distributed fairly evenly by establishment age (fig. 4) and the results reflect the greater risks in Alameda County. However, this does not suggest that risks and problems are evenly spread among firms of all ages. Firms may experience differential responses to disaster, as found by previous researchers (see discussion above).
4. The lowest revenue businesses (less than \$100,000) are slightly more likely to be at risk of disruptive building damage, relative to all other revenue categories, but the differences are quite small (see fig. 5). This implies that riskier buildings may house a disproportionate share of businesses that have a lower revenue base overall to cope with the disruptive event. Contrary to the regional result, the percentage of employment shares of high-revenue businesses affected by disruptive building damage is larger in Santa Clara County when compared to other counties in the region. This is because Santa Clara County hosts more businesses in the largest revenue category compared to the other counties.



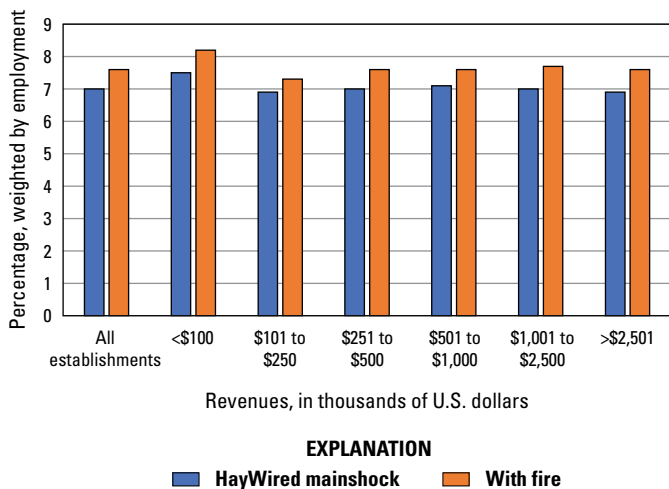
**Figure 2.** Plot of at-risk employment share by industry sector for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for the three riskiest counties (Santa Clara, Contra Costa, and Alameda Counties) and the total sector employment in the nine-county region. Data are ordered by decreasing risk to all counties (from top to bottom). The impacts of fire in the HayWired scenario are included, but utility and transportation system impacts are not.



**Figure 3.** Plot of at-risk employment share by establishment size (number of employees) for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for scenarios with and without fire following the earthquake. The analysis is relative to the total for the nine-county region, excluding damage beyond the bay region. Utility and transportation system impacts are not included.



**Figure 4.** Plot of at-risk employment share by establishment age for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for scenarios with and without fire following the earthquake. The analysis is relative to the total for the nine-county region, excluding damage beyond the bay region. Utility and transportation system impacts are not included.



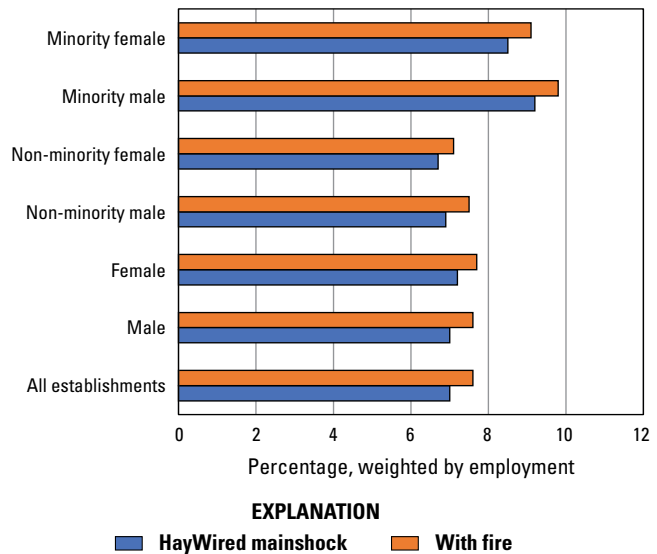
**Figure 5.** Plot of at-risk employment share by establishment revenue for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for scenarios with and without fire following the earthquake. The analysis is relative to the total for the nine-county region, excluding damage beyond the bay region. Utility and transportation systems impacts are not included.



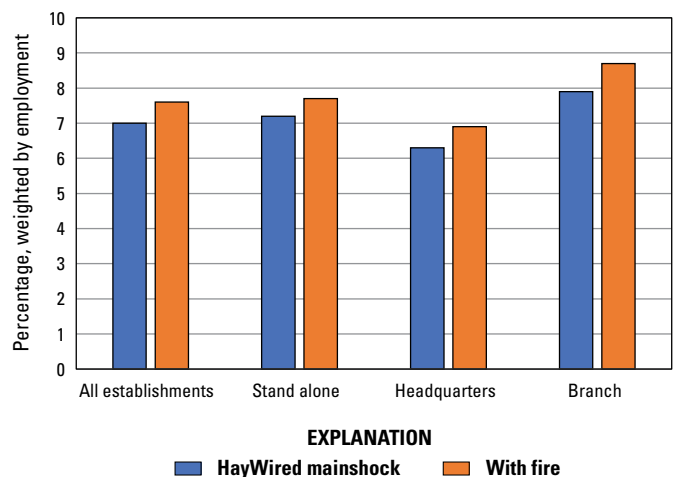
## 12 The HayWired Earthquake Scenario—Societal Consequences

5. Disruptive building damage risk by business ownership characteristics differ marginally from the overall ownership profile of establishments in the region. Minority-owned businesses are at a slightly greater risk of disruptive building damage—over 9 percent, compared to 6 to 8 percent of all establishments and non-minority-owned establishments (fig. 6). This is because relatively more minority-owned establishments are located in the most heavily impacted county, Alameda County (4.6 percent of establishments and 7 percent of employment), and the sectors to which these businesses belong experience larger risk of disruptive building damage. We see relatively more minority-owned businesses in the manufacturing, wholesale trade, and transportation and warehouse sectors, which sustain more disruptive building damage risk. Whereas some research has shown minority-owned establishments to be more vulnerable than other businesses, we should not assume this is necessarily the case in the San Francisco Bay region, as many successful start-ups in the region are minority owned.
6. There are relatively more employees in branches in Alameda and Contra Costa Counties and branch businesses in the region are at a slightly greater risk of disruptive building damage based on their location and building type (fig. 7). These businesses may be resilient in the short term as relates to company survival because they may have other options for production outside of the area or be able to reestablish supply networks more quickly. Contrary to regional results, Santa Clara County has a larger share of headquarters that have a slightly greater risk among all establishment types.

The regional average disruptive building damage risk for all business and owner characteristic categories that have above-average risk is shown in figure 8. Note that the risks for earthquake hazards and all hazards are averaged in two ways: the average across business establishments and a weighted (by employment) average of business establishments. Overwhelmingly, the risk of disruptive building damage from HayWired earthquake hazards and fire befalls at least 25 percent of the business establishments in Alameda County and 12 percent of establishments in Contra Costa County. Within subareas, the average building risk rises to about 40 and 35 percent in central Alameda County and western Contra Costa County, respectively (appendix 4). For Alameda and Contra Costa Counties and most of the other characteristics in figure 8, the risk is larger for establishments than employment—meaning that relatively fewer employees are in the riskier buildings in this earthquake scenario. An exception is in the mining sector (albeit represents a very small share, 0.08 percent, of the region’s employment), where employment-related risk (about 10 percent) is noticeably larger than establishment risk (about 7.5 percent).

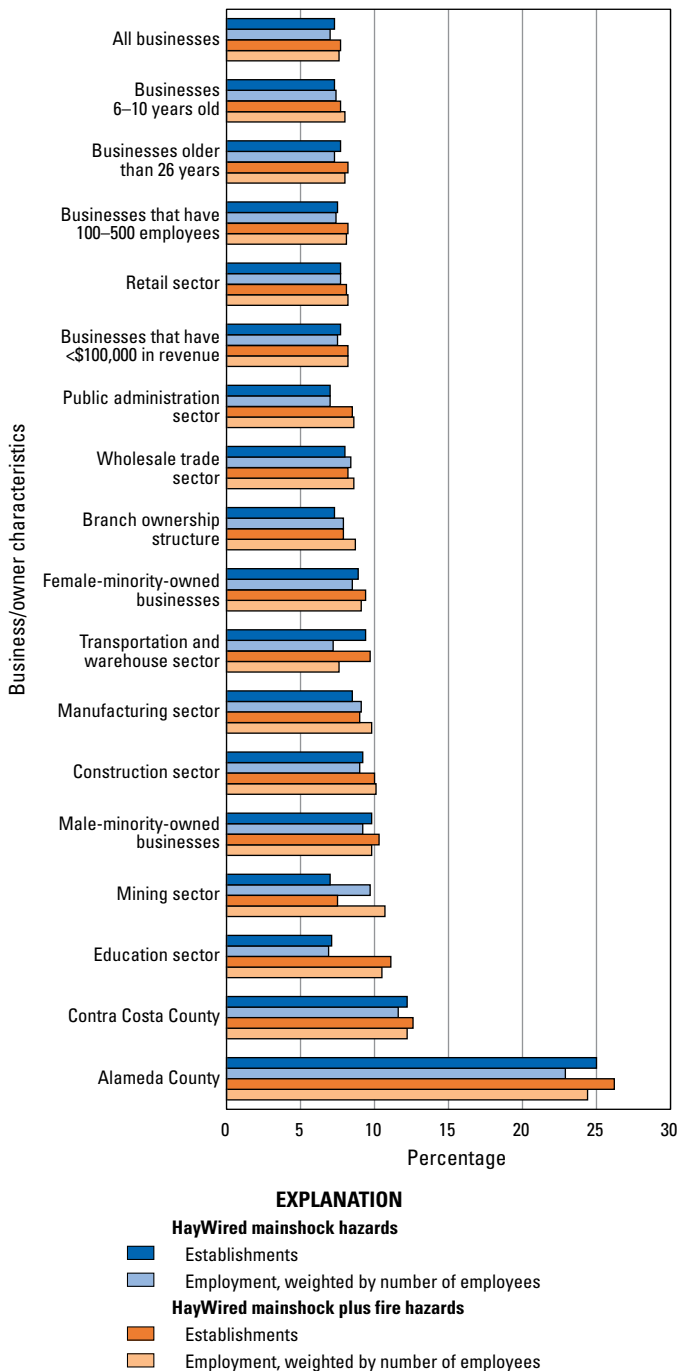


**Figure 6.** Plot of at-risk employment share by business-owner demographics for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for scenarios with and without fire following the earthquake. The analysis is relative to the total for the nine-county region, excluding damage beyond the bay region. Utility and transportation system impacts are not included.



**Figure 7.** Plot of at-risk employment share by establishment type for the HayWired mainshock earthquake scenario in the San Francisco Bay region, California. Data are shown for scenarios with and without fire following the earthquake. The analysis is relative to the total for the nine-county region, excluding damage beyond the bay region. Utility and transportation system impacts are not included.





**Figure 8.** Plot of the business characteristics with the largest disruptive building damage risk in the HayWired scenario in the San Francisco Bay region, California. Risk is calculated both as percentage of establishments and percentage of employment with disruptive building damage. Data are shown for hazard scenarios with and without fire following the earthquake. Utility and transportation system impacts are not included.

After location, most of the business characteristic categories that have larger disruptive building damage risk in the region are sectors reflecting the performance of the building types they occupy and the geographical distribution of employment in those sectors. Integrating location and sector, the largest disruptive building damage risk for the HayWired mainshock earthquake all-hazard case are for establishments and employees working in construction in Alameda County (affecting about 32 percent of those employees and 35 percent of those establishments from earthquake hazards alone) (tables 2.25 and 2.31 of appendix 2). Mining is the industry at most risk of disruptive building damage in Contra Costa County, showing 16–19 percent risk to mining establishments and employment (fig. 2), although this industry is very small in the bay region. The disproportionate effect of fire damage in Alameda and Contra Costa Counties on the education sector is evident in the increased establishment risk from 7 to over 10 percent.

Minority-owned businesses, particularly male-minority-owned businesses, have larger disruptive building damage risk compared to businesses with different owner demographics. Other business characteristics featured in figure 8 pertain to size (smallest revenue or mid-sized businesses) and age (businesses 6–10 years old), but the differences in these average characteristic risks in the region are negligible.

## Study Limitations

Our analysis is limited to data tracked by NETS and to building damages as the only source of disruption. Some discrepancies in the NETS database were identified in the method section. The NETS data do not measure some characteristics that have been found to differentiate business vulnerability, such as owner experience in the industry, business experience with disruption and disasters, owned versus leased premises, market reach, or home-based businesses. The data in NETS on establishment pre-disaster performance were also not adequate for this analysis.<sup>11</sup> Age of business, which is analyzed in the data, may act as a partial proxy for some of these or related characteristics (such as experience in the industry and long-term performance).

The resolution of Hazus building data at the census-tract scale does not match the available business data by establishment. Future work could more tightly associate building damages to business establishment data and results could be sensitive to increasing the resolution of the damage estimation. Building data is captured by UrbanSim (<http://www.urbansim.com>), but crosswalks between Hazus damage estimation to the buildings

<sup>11</sup>We considered two other variables in the NETS data that we thought might indicate the condition of the business prior to disaster. We found the establishment-based payment performance (PayDex)—how quickly bills are paid—to be a useful statistic. The SalesGrowthPeer data could have been useful, but are considered unreliable. In both cases, there were too many missing entries in the database.

would be needed. Current efforts to develop tools that increase the resolution of damage estimates to buildings within census tracts (for example, those by SimCenter, available at <https://simcenter.designsafe-ci.org/research-tools/pbe-application>) would avoid introducing errors from the crosswalks.

The building damage state results are estimated using Hazus (Seligson and others, 2018) and a distribution of burned building square footage (Scawthorn, 2018) to occupancy classes using 1994 Northridge earthquake fire data (see appendix of Johnson and others, in prep.; planned to be published as part of this volume). Hazus representation of construction offices as manufactured buildings and fires in school laboratories after the Northridge earthquake are influencing the results for the HayWired scenario.

By only considering disruptive building damage, we underestimate the risk of business disruption from concentrations of damage in neighborhoods. Neighborhood damage and home-to-workplace relation effects are examined by Wein, Belzer, and others (in prep.; planned to be published as part of this volume). Their study uses subareas, defined by contiguous city boundaries, containing census tracts with concentrated building damages. We also calculate disruptive building damage risk for subareas using the Hazus building damage and NETS data; results are available in appendix 4.

Utility outage geographies are not analyzed here. Dahlhamer and Tierney (1998) called attention to effects of utility disruptions and Kachali and others (2015) also identified them as a significant factor impacting organizations in Canterbury, New Zealand, after the 2011 earthquakes. Across utilities and transportation, the duration of electric power outages has been found to most adversely affect business productivity (Tierney and Nigg, 1995; Wasileski and others, 2011), and for manufacturing businesses in particular (Kajitani and Tatano, 2009). Brown and others (2014) noted that 30 percent of businesses were able to operate without power, water, and (or) wastewater services at their site for short durations or by relocation, such that businesses tended to underestimate their ability to operate without these services. Various utility restoration curves are available by county for the HayWired scenario (see Jones and others, this volume). Utility and transportation disruptions include initial widespread electrical power outages, days to weeks of disrupted voice and data services, months of water supply outages in Alameda, Contra Costa, and San Mateo Counties, months of highway bridge repairs, and years of rapid transit service disruptions along the east bay corridor.

## Policy Discussion and Conclusion

In conclusion, we consider the implications of our results in conjunction with what is known about business vulnerability after a disaster, as well as policy and program ideas and implementations that can influence business outcomes. Here, we consider findings for business location and various sectors that show the largest disruptive building damage risks. We also discuss characteristics that were found to be associated with vulnerable establishments in previous disasters, such as small businesses and various business-owner characteristics.

## Risk from Business Location

First and foremost, location (primarily Alameda County and secondarily Contra Costa County) most strongly differentiates disruptive building damage risk for all types of businesses. Many of the programs and resources developed to address post-event impacts of the earthquake and related issues in the San Francisco Bay region would need to be centered in the areas of greatest impact, but also cannot disregard the range of impacts to and needs of businesses outside the high-damage zones. Preparatory actions, however, should be widespread, because the HayWired scenario is only one of many possible earthquakes that could affect the bay region.

## Sector Risk and Vulnerability

Large disruptive building damage risk reflects low-performing building types that certain industries tend to occupy and the concentration of certain industries in heavily impacted areas. In the HayWired scenario, these industries are manufacturing, transportation and warehousing, wholesale and retail, construction, and education (caused by fire only). Although employment-weighted risk in the mining sector is relatively large, we do not draw any conclusions for this small sector of a few thousand employees.

Marshall and others (2015) propose targeting businesses in the goods sectors (that have fixed assets, such as equipment and inventory) with pre-disaster assistance. Post-disaster, manufacturing businesses with disruptive building damage may be more difficult to relocate in the region. There could be larger risk of long-term displacement from property owners that choose to rebuild to a higher value use (see Wein, Belzer, and others, in prep.; planned to be published as part of this volume). Although manufacturing has tended to recover in the wake of reconstruction, establishments may not remain in devastated areas. The region's proposed Priority Production Area program (see Kroll and Jaramillo, 2017) could include pre-disaster planning for preserving space for critical industries. Coordinated economic development in the most heavily impacted areas also may be needed to provide a viable business base after the event.

The large presence of the transportation and warehouse sector in Alameda County leads to a larger risk of disruptive building damage for the sector in the region, particularly for establishments (as opposed to where the employees work). The establishments are important to supply networks. The public sector will need to work cooperatively with private logistics 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. Growing automation in the sector and the use of drones and autonomous delivery equipment (for example, electric carts) may provide an opportunity for supporting supply networks to residents and businesses in the region. Advanced planning would be needed to ensure this type of equipment is licensed to operate in a post-earthquake setting and to establish enough redundancy in logistics operations to adapt to areas

with downtime. However, even if this approach addresses the delivery problem around damaged roadways, stored goods will be lost on damaged sites and logistics functions may be disrupted or require relocation.

Wholesale and retail businesses fairly consistently show vulnerability after disasters. In the HayWired scenario, retail has both larger disruptive building damage risk and a contingent of small businesses (see below). Retail businesses have not emerged as vulnerable when there has been local government intervention, for example, to provide a space for businesses to congregate near their customers (for example, Kroll and others, 1990) or (government-funded) employee subsidies after the 2011 Christchurch earthquake. Assistance of this type may be particularly critical where damage is extensive and widespread.

The presence of small businesses in the construction sector (33 percent of the construction sector's employees are in businesses that have less than 5 employees) potentially compounds the vulnerability of these types of businesses with disruptive building damage. Although, construction businesses could benefit from rebuilding, Zhang and others (2009) caution that many of the smaller, local contractors miss out on reconstruction when they are still recovering themselves, are unable to take on large jobs, or both. Pre-registration of construction firms and coordination of programs to help in business recovery and to encourage the use of local firms in reconstruction could help local construction firms survive the challenges posed by the damage.

Fire increases the risk for all sectors, but disproportionately affects education. The effect on the education sector is an artifact of the 1994 Northridge fire-following-earthquake data that was used to distribute burned buildings for the HayWired scenario. Reportedly, school laboratories were the source of fires in schools. Safety management of hazardous materials can address how materials are stored and how to best separate materials to prevent potentially volatile mixtures in earthquake-prone areas.

## Small Business Vulnerability

Small businesses are a significant source of local employment and add to the economic vitality of a community (Zhang and others, 2009). Our business type analysis showed that the largest businesses (500 or more employees) are somewhat less likely than businesses with 500 or fewer employees to be located in the riskiest locations or building types in the HayWired scenario. The literature (summarized in the "Literature on Business and Owner Characteristics" section) suggests that among businesses where damage occurs, those with less than 50 employees are more likely to close, perhaps because they are less diversified in locations and lack assets and financial cushions to allow for recovery. However, small businesses also may be more flexible in terms of response alternatives, providing opportunities to maintain or grow the business after a disaster.

In the NETS database, businesses that have fewer than 50 employees make up 98 percent of establishments and

have 60 percent of the employees in the San Francisco Bay region; half of those employees work in establishments that have less than 5 employees. Another measure of business size is revenue: 33 percent of establishments and 10 percent of employment are in the lowest revenue category (<\$100,000).

In the bay region, small businesses account for a large share of administration, support and waste, and other services sectors (99.6 percent of sector establishments have less than 50 employees). The largest numbers of small businesses in the bay region are in these two sectors plus the professional, technical, and scientific services sector. The businesses in professional, technical, and scientific services show a slight advantage of lower disruptive building damage risk from the HayWired scenario because the industry is more concentrated in office buildings on the San Francisco Peninsula (as opposed to the east bay, which is closer to the Hayward Fault). They could benefit from increased demand for engineering, accounting, and legal services (for example, Recover Canterbury, n.d.), and they could have more mobility and flexibility for working from home. Lister (2017) reports that the professional, scientific, and technical service sector has the largest percentage of telecommuters, corroborating the mobility of the assets in this service sector.

Small business revenue vulnerability would be compounded by disruptive building damage in Alameda and Contra Costa Counties. For the region, businesses in the lowest revenue category are among those with slightly larger disruptive building damage risk. Small Business Administration loans that increase debt are not likely to be attractive or obtainable (because of restrictive criteria) by low-revenue businesses (Collier and others, 2016). Lam and others (2012) conclude that small businesses need assistance within 6–9 months of disruption. Business recovery funding gaps (for small and young businesses, in particular) require small, rapidly deployed loans and grants to provide a bridge for small businesses between the time when a disaster strikes and when State and Federal funds first become available, as well as after they are no longer available (Collier and others, 2016; Federal Reserve Banks, 2017).

Research has found that small business owners may not know what can be done to prepare for earthquakes. Alesch and others (2001) identify business management practices to reduce business exposure and vulnerability to disaster. These include diversifying the organization's customer base, diversifying the location of the organization's inventory, protecting organizational electronic and hard-copy data, and having multiple business outlets (for example, multiple locations and [or] e-commerce). More recently, the effects of Hurricane Sandy underscored that computer system and document/file recovery were most costly and time consuming for small businesses (Scarinci, 2016). Regarding building and content risk, insurance helps to protect equity and lease arrangements can be checked for repair responsibility and timing. Other considerations include coping with psychological stress, entrepreneurial skill to adapt to changes in the business environment, and support from family, friends, and employees.

Preparedness planning and testing is seen to decrease with business size (Scarinci, 2016). Small business preparedness actions tend to be limited to safety (for example, acquiring first aid kits) and fall short for business continuity (for example, relocation plans, generators for emergency power, training and drills, and structural assessment) (Webb and others, 2000). The actions that small businesses take are less complicated, less expensive, and protect against a range of emergencies rather than actions that are technically difficult, more expensive, and time consuming (Webb and others, 2000). Lindell and others (2006) promote the need for policies, such as incentives, that encourage small businesses to engage in emergency planning. Marshall and others (2015) add that policies intended to reduce small business demise should concurrently consider the interrelatedness of family needs, demands, and resources with those of the affected business. Overall, Marshall and others (2015) propose that small business vulnerability be mitigated with policies that target the characteristics of small businesses that make them vulnerable.

## **Business Owner Vulnerability**

Minority-owned businesses are associated with slightly larger disruptive building damage risk in the HayWired scenario. The risk for minority-owned businesses is a reflection of the concentration of minority-owned businesses in Alameda County relative to the rest of the bay region and relatively larger representation in manufacturing and wholesale trade sectors. This illuminates the proposal of Marshall and others (2015) for policy support and educational assistance for disaster preparedness that targets minority-, female-, and veteran-owned business. They note that, even though the Small Business Administration has targeted disaster programs for these groups, more awareness and education may be necessary. Given limited resources, one approach may be to intensify outreach to small businesses in sectors with greater building occupancy type vulnerabilities.

## **Other Vulnerable Business Characteristics**

The risk of disruptive building damage is strongly differentiated by location relative to the earthquake, and secondarily by sector according to building performance. We found slight differences in the risk for other business characteristics, but the vulnerability still remains for those businesses located in riskiest locations and building types. Just because our methodology could not support analyses of other potentially vulnerable business characteristics does not mean they are unimportant. Other considerations from the literature pertaining to disruptive building damages include:

- Leased business spaces. The business owner is subjected to the building owner's decisions about rebuilding, affecting business relocation planning, especially for single-location businesses. Education of commercial building owners on the likely needs and possible services to offer tenants after an event could reduce tenants' vulnerability.

- Owner resilience and prior disaster experience. Businesses whose owners lack this kind of experience may be more vulnerable. Targeted education and shared experiences from those with prior disaster experience could assist inexperienced business owners to become more informed and better prepared.
- Businesses in decline can have that trend exacerbated by a disaster and may need additional business and financial planning assistance to make decisions about whether to continue the business after the event.
- Business culture may affect business vulnerability—this topic has not been explored in this chapter.

Finally, recall that direct building damage is only one source of business disruption. Vulnerable business characteristics are relevant to other sources of disruption, such as utility outages. Wein, Belzer, and others (in prep.; planned to be published as part of this volume) consider how businesses are impacted by damages in their neighborhoods. Business establishments without strong support systems (for example, sole proprietorships and [or] dependence on a displaced customer base) will be particularly vulnerable regardless of the sector, business age, business size, or business-owner characteristics. Policy development can consider how to coordinate programs to address geographical, sectoral, and other vulnerable characteristics of establishments and firms.

## **Turning Risk into Opportunity**

Stronger buildings and codes directly reduce disruptive building risk. Interorganizational arrangements and programs present opportunities to improve business preparedness and recovery. With the widespread distribution of risk across firms of small, medium, and large sizes, preparedness and resources will vary in the region. Programs like the California State-led Outsmart Disaster Business Resilience Challenge (visit <https://outsmartdisaster.com/be-resilient/at-work/resilient-business-challenge> for more information), which grew out of the HayWired scenario, encourages businesses to take the next challenge to “outsmart disaster”—whether it be at a business level, collaboration with their community, or demonstration of innovative practices for businesses in the State. Outsmart Disaster encourages larger businesses to look beyond themselves and provide preparedness assistance to the smaller neighborhood businesses on which they depend. In support of this incentive, Dunaway and Shaw (2010) found that participation in a collaborative partnership was correlated with motivation to prepare. Post-disaster, Aldrich (2012) makes the case for the role of social capital. After the 2014 South Napa earthquake, the tight-knit small business community in the City of Napa lent support to each other, and the community as a whole rallied to provide financial support to businesses in need (Almufit and others, 2016). Stevenson and others (2014) document how organizations managed and utilized



networks to reduce the impacts of the Canterbury earthquake sequence (2010–14) and to adapt to altered post-earthquake environments. For example, similar and competitive businesses assisted each other by sharing functional space.

Zhang and others (2009) promote coordination between business and local government regarding exchanges of information about hazards, business buildings and structures, employees, business linkages, and response and recovery needs. For example, the 2018 California Assembly Bill AB–2681 sought to require local communities to inventory potentially vulnerable buildings. Although the bill was vetoed by the governor, some cities in the bay region are already creating such inventories. For those communities that have inventoried vulnerable buildings, it might help to also inventory the uses of those buildings (for example, commercial versus residential) and to understand if specific business types or sectors are concentrated in vulnerable buildings and to plan for potentially disruptive building risk. Local government can plan for temporary business locations, restoring transportation and utility systems, expediting building inspection and permitting, and other support for local businesses facing external competition (Zhang and others, 2009).

Recovery funding for small businesses is an innovation opportunity in community development (Collier and others, 2016; Federal Reserve Banks, 2017). Beyond suggestions to make changes to the Small Business Administration loan policy (Collier and others, 2016), cross-sector and 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) (Federal Reserve Banks, 2017). Small businesses could be incentivized to become eligible for post-disaster funding that fits their needs during the critical time periods by implementing preparedness actions (Collier and others, 2016).

Doerfel and others (2013) find, more generally, that resource-vulnerable businesses exhibit diverse interorganizational relations that are associated with low resilience after a disaster because the relations lack redundancy. Post-disaster, Doerfel and others (2013) suggest that businesses can increase resilience (access to resources and information) by building pre-disaster interorganizational relations. Examples include building communities of practice (for example, professional associations, similar types of business functions), establishing relations with cross-community entities (that is, suppliers, clients, different types of businesses, banks, endowment or funding sources, nonprofits, and city government), and having multiple ties with each type of these supporting organizations. Scarinci (2016) reports that new small business alliances developed after Hurricane Sandy helped businesses by facilitating the sharing of information and resources and assisting with loan applications. Based on the finding of inhibited learning after a disaster, implementing programs for small business preparedness with recovery resources and assistance could improve business resilience from its pre-disaster state.

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## **Appendixes 1–4**

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## Appendix 1. Crosswalk between Hazus Occupancy Classes and NAICS Categories

In order to evaluate risk to San Francisco Bay region businesses, we needed to first convert results for Hazus occupancy classes to results for North American Industry Classification System (NAICS) codes. Risk values have been estimated using Hazus for occupancy classes. The following table provides a mapping to translate those risks to NAICS codes. The table lists the NAICS code and the equivalent Hazus occupancy class (Federal Emergency Management Agency, 2002).

A single NAICS code may map to several Hazus occupancy classes. In this case, a new Hazus occupancy class is created that combines the several classes in the mapping. The new combined occupancy class is created simply by adding together the total and extensive and complete damaged square footage in each class for the geographic unit. The sum of the extensive complete damage square footage is then divided by the sum of the total square footage.

**Table 1.1.** Mapping of NAICS codes to Hazus occupancy classes.

[Table derived from Sue Wing and others (in prep.; planned to be published as part of this volume). NAICS, North American Industry Classification System]

Sector description	NAICS code <sup>1</sup>	Hazus occupancy class
Agriculture, forestry, fishing and hunting	11	AGR1
Oil and gas extraction	211	IND4
Coal mining	2121	IND4
Other mining	212–213 except for 2121	IND4
Electric power generation, transmission, and distribution	2211	COM4
Natural gas distribution	2212	COM4
Water, sewage, and other systems	2213	COM4
Construction		IND6
Heavy industry	313, 321, 322, 327, 332, 333, 336	IND1
Light industry	314, 315, 316, 323, 326, part of 334 (except for 334111, 334112, 334411, 334412, 334413), 335, 337, 339, 511, 516	IND2
Petroleum refineries	32411	IND3
Food, drug, and chemicals	311, 312, 324 except for 32411, 325	IND3
Primary metal manufacturing	331	IND4
Electronic computer manufacturing	334111	IND5
Computer storage device manufacturing	334112	IND5
Semiconductor and related device manufacturing	334413	IND5
Other high-technology-related manufacturing	334411, 334412	IND5
Wholesale trade, warehousing, and storage	42	COM2
Retail trade	44–45	COM1
Air transportation	481	COM4
Rail transportation	482	COM4
Water transportation	483	COM4
Truck transportation	484	COM2
Transit and ground passengers	485	COM4
Pipeline transportation	486	COM4
Sightseeing transportation	487 and 488	COM4
Couriers and messengers	492	COM4
Publishing, motion picture, and broadcasting	511, 512, 515	IND2, COM4
Internet publishing and broadcasting	51913	COM4
Telecommunications	517	COM8
Data processing, hosting, and related services	518	COM4
Other information services	51911–2	COM4
Finance, insurance, real estate, and leasing	52, 53	COM4, COM5
Computer systems design and related services	5415	COM4
Other professional scientific and technical services	54 except for 5415	COM4
Other business services	55, 56	COM4
Educational services	6111, 6112–3, 6114–7	EDU1, EDU2
Ambulatory health care and hospitals	621, 622	COM6, COM7
Nursing home/social assistance	623, 624	RES6, COM3
Arts, entertainment, and recreation	711–713, 722	COM8
Accommodations	721	RES4
Repair and maintenance	811	COM3
Personal services/private households	812, 814	COM3
Religious, grantmaking, and similar organizations	813	REL1
Government and non-NAICS	92	GOV1, GOV2

<sup>1</sup>See the NAICS website (available at <https://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2017>) for examples of establishments in the various NAICS sectors.

## **Appendix 2. Building Damage Risk Results for the HayWired Scenario, San Francisco Bay Region**

This appendix contains four sets of tables of HayWired building damage risk for business characteristics in the San Francisco Bay region with respect to the sector to which the businesses belong. The four sets pertain to two different ways of calculating the risk: (1) average across establishments and (2) employment weighted average; risk is also calculated for two different sets of extensive and complete (disruptive) building damages: (1) from earthquake hazards only (no fire) and (2) from earthquake

plus fire hazards. Within each set, business characteristics are summarized by county, business size, revenue, ownership structure, and owner demographics. There are two tables for each characteristic; the first table presents risk calculations and the second table shows the distribution of establishments or employees in the categories of interest. The business distribution table is not repeated for fire hazard risk (third and fourth sets) because the distribution of business characteristics stays the same.

## Disruptive Building Damage Risk from Earthquake Hazards for Establishments in the HayWired Scenario

**Table 2.1.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by county and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments in 9 counties	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	3.2	17.8	9.8	0.7	0.0	1.5	1.4	2.1	0.0	0.0
Mining	7.0	27.7	16.3	1.0	0.1	1.3	4.5	3.0	0.2	0.0
Utilities	4.5	19.1	10.0	0.9	0.0	1.6	1.8	2.7	0.1	0.0
Construction	9.2	33.3	14.2	1.0	0.0	1.3	2.2	3.8	0.2	0.0
Manufacturing	8.5	27.1	13.3	1.1	0.0	1.9	2.9	3.8	0.3	0.0
Wholesale trade	8.0	25.5	11.4	1.0	0.0	1.8	2.5	3.0	0.2	0.0
Retail trade	7.7	25.2	12.7	0.9	0.0	1.4	2.2	2.7	0.3	0.0
Transportation and warehouses	9.4	25.8	11.9	1.1	0.0	1.6	2.2	3.0	0.2	0.0
Information	6.7	23.9	13.8	0.9	0.0	1.5	2.4	2.4	0.2	0.0
Finance and insurance	6.2	24.0	11.1	0.9	0.0	1.3	2.3	2.2	0.2	0.0
Real estate, rental, leasing	7.2	25.2	11.5	1.0	0.0	1.3	2.2	2.3	0.2	0.0
Professional, scientific, and technical services	6.7	23.0	12.1	0.9	0.0	1.4	2.2	2.4	0.2	0.0
Management of companies	6.1	21.8	12.7	0.9	0.0	1.3	2.1	2.2	0.3	0.0
Administration, support, and waste	6.6	24.2	11.7	0.8	0.0	1.1	1.9	2.2	0.1	0.0
Education services	7.1	22.2	11.5	0.9	0.0	1.2	2.2	2.1	0.4	0.0
Health care and social assistance	7.1	23.8	11.8	0.9	0.0	1.0	1.8	2.1	0.3	0.0
Arts, entertainment, and recreation	7.5	25.3	13.1	0.9	0.0	1.3	2.1	2.3	0.2	0.0
Accommodation and food services	7.3	24.8	13.0	0.8	0.0	1.3	1.9	2.7	0.4	0.0
Other services	7.6	24.8	11.5	1.0	0.0	1.3	2.2	2.3	0.4	0.0
Public administration	7.0	20.7	12.7	0.7	0.0	1.7	2.1	3.8	0.5	0.0
Other	5.6	21.0	7.9	0.7	0.0	1.3	1.8	2.3	0.0	0.0
Total	7.3	25.0	12.2	0.9	0.0	1.3	2.1	2.5	0.2	0.0

**Table 2.2.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by county and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	5,002	9.7	10.2	5.2	13.8	5.2	7.1	14.1	7.7	27.1
Mining	240	12.1	14.2	7.9	0.8	13.8	11.7	21.3	7.5	10.8
Utilities	596	11.6	11.2	6.4	2.0	18.8	13.4	22.5	2.9	11.2
Construction	45,328	17.1	15.6	5.8	2.5	9.9	11.5	22.0	5.1	10.4
Manufacturing	20,899	20.9	9.0	4.3	3.7	10.6	10.1	29.7	3.1	8.7
Wholesale trade	23,316	21.4	11.4	4.8	3.7	13.1	10.5	23.0	3.7	8.3
Retail trade	43,904	20.1	12.3	5.1	2.5	15.0	9.7	22.1	5.0	8.2
Transportation and warehouses	9,938	25.7	13.6	3.4	2.1	9.8	14.6	18.8	5.8	6.1
Information	15,155	17.5	9.4	7.1	1.2	20.0	10.5	26.2	2.7	5.4
Finance and insurance	25,675	14.8	13.8	6.4	1.4	16.9	12.3	26.0	3.0	5.4
Real estate, rental, leasing	25,765	17.9	14.1	5.7	1.8	14.2	11.1	24.1	4.4	6.7
Professional, scientific, and technical services	92,391	17.7	12.6	6.7	1.6	16.9	10.2	25.0	3.0	6.1
Management of companies	1,701	15.3	12.7	5.4	1.2	22.9	12.6	22.6	2.9	4.3
Administration, support, and waste	113,786	16.6	13.1	5.8	1.8	12.5	10.9	27.8	4.5	6.8
Education services	9,802	21.4	12.0	6.1	1.8	13.8	9.7	24.8	3.7	6.8
Health care and social assistance	47,398	19.9	12.9	5.9	1.8	15.2	9.8	23.7	4.0	6.9
Arts, entertainment, and recreation	11,472	19.4	12.3	7.1	2.3	17.5	8.9	20.0	4.5	7.8
Accommodation and food services	21,452	19.3	10.8	4.3	2.3	21.5	10.1	20.8	4.0	6.8
Other services	55,809	20.5	13.7	4.7	1.9	14.1	10.2	22.8	5.1	7.2
Public administration	587	19.4	13.6	6.1	2.4	15.7	12.1	14.7	6.5	9.5
Other	443	16.3	14.4	4.7	1.6	18.7	9.3	26.0	3.6	5.4
Total	570,659	18.4	12.8	5.7	2.2	14.4	10.5	24.4	4.2	7.4

**Table 2.3.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by number of employees and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	3.2	3.4	2.6	1.8	3.1	0.9	1.0	
Mining	7.0	7.1	8.1	4.8	4.0	5.2	13.0	
Utilities	4.5	4.1	3.4	6.0	7.1	8.6	5.5	6.3
Construction	9.2	9.2	9.0	9.0	9.4	9.8	9.8	3.6
Manufacturing	8.5	8.4	8.5	8.2	8.7	9.4	10.1	7.3
Wholesale trade	8.0	7.9	8.3	8.5	8.4	9.4	10.2	5.4
Retail trade	7.7	7.8	7.2	7.2	6.9	7.7	8.1	8.5
Transportation and warehouses	9.4	9.6	8.7	7.9	7.6	6.8	8.1	1.6
Information	6.7	7.0	5.5	6.8	5.1	4.6	6.1	4.7
Finance and insurance	6.2	6.3	5.8	5.5	5.2	5.0	5.2	3.5
Real estate, rental, leasing	7.2	7.2	7.1	7.1	6.8	7.8	5.5	2.4
Professional, scientific, and technical services	6.7	6.8	6.2	6.3	5.6	5.4	4.7	4.1
Management of companies	6.1	6.1	5.6	6.9	4.3	4.8	1.2	4.2
Administration, support, and waste	6.6	6.6	5.6	6.9	7.3	7.1	8.1	6.4
Education services	7.1	7.0	7.3	7.4	7.5	6.3	8.6	5.7
Health care and social assistance	7.1	7.1	6.9	7.5	7.9	8.3	7.2	6.9
Arts, entertainment, and recreation	7.5	7.6	6.9	7.4	5.8	6.5	6.8	6.8
Accommodation and food services	7.3	7.5	7.3	7.2	6.6	6.0	4.2	6.0
Other services	7.6	7.7	7.3	7.3	7.0	5.3	4.5	9.7
Public administration	7.0	6.9	10.4	2.8	4.3	10.7	8.6	4.4
Other	5.6	5.7	5.1	3.3	7.5	1.5		
Total	7.3	7.3	7.1	7.3	7.1	7.2	7.5	5.9

**Table 2.4.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by number of employees and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	5,002	84.8	8.0	3.9	2.3	0.7	0.4	
Mining	240	68.3	17.1	5.8	5.4	1.7	1.7	
Utilities	596	64.8	13.4	10.7	5.9	2.5	2.2	0.5
Construction	45,328	84.4	7.8	3.9	2.7	0.7	0.4	0.0
Manufacturing	20,899	63.0	15.3	8.9	7.2	2.8	2.4	0.4
Wholesale trade	23,316	76.5	12.2	6.1	3.5	1.1	0.6	0.0
Retail trade	43,904	83.0	10.1	3.9	1.9	0.7	0.3	0.0
Transportation and warehouses	9,938	83.1	8.2	4.2	3.1	0.8	0.5	0.0
Information	15,155	79.7	9.3	4.7	3.4	1.5	1.2	0.2
Finance and insurance	25,675	87.5	6.7	2.9	1.9	0.6	0.4	0.1
Real estate, rental, leasing	25,765	86.9	7.4	3.0	1.8	0.7	0.2	0.0
Professional, scientific, and technical services	92,391	85.4	7.4	3.7	2.3	0.8	0.4	0.0
Management of companies	1,701	94.1	2.9	1.1	1.1	0.4	0.2	0.1
Administration, support, and waste	113,786	95.1	2.8	1.0	0.7	0.3	0.1	0.0
Education services	9,802	57.3	24.0	8.3	6.4	2.7	1.1	0.2
Health care and social assistance	47,398	71.5	20.3	4.6	2.3	0.8	0.4	0.1
Arts, entertainment, and recreation	11,472	79.2	11.8	4.3	2.8	1.4	0.5	0.1
Accommodation and food services	21,452	33.7	37.0	18.5	8.3	1.8	0.7	0.0
Other services	55,809	86.8	8.4	2.9	1.5	0.3	0.1	0.0
Public administration	587	39.0	11.6	9.0	14.8	11.8	11.1	2.7
Other	443	84.2	7.7	4.7	2.7	0.7		
Total	570,659	82.2	9.9	4.1	2.4	0.8	0.4	0.1



**Table 2.5.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by establishment age (in years) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across all establishments	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	3.2	4.0	3.6	3.0	2.4	2.2	1.9
Mining	7.0	9.7	5.7	5.1	5.2	7.5	6.6
Utilities	4.5	4.5	5.8	2.4	3.5	3.5	5.9
Construction	9.2	9.5	9.2	9.1	8.4	8.6	8.9
Manufacturing	8.5	8.2	8.3	7.8	8.1	7.9	9.7
Wholesale trade	8.0	7.8	8.1	8.1	8.4	8.0	8.3
Retail trade	7.7	7.7	7.7	7.8	7.1	7.4	8.0
Transportation and warehouses	9.4	10.2	9.5	8.6	7.4	7.1	7.9
Information	6.7	6.7	6.9	6.4	6.9	6.7	7.2
Finance and insurance	6.2	6.1	6.6	6.1	5.9	5.9	6.7
Real estate, rental, leasing	7.2	6.8	7.7	7.5	7.4	7.6	7.0
Professional, scientific, and technical services	6.7	6.7	6.8	6.6	6.7	6.8	6.9
Management of companies	6.1	6.1	6.4	4.6	7.0	7.1	5.7
Administration, support, and waste	6.6	6.6	6.7	6.1	6.5	6.9	7.1
Education services	7.1	7.1	7.2	7.3	7.2	6.7	7.2
Health care and social assistance	7.1	6.9	7.3	7.2	6.9	7.1	7.5
Arts, entertainment, and recreation	7.5	7.7	7.6	6.8	6.8	7.6	7.3
Accommodation and food services	7.3	7.2	7.6	7.3	7.1	6.9	7.2
Other services	7.6	7.3	7.5	7.9	8.1	8.0	8.0
Public administration	7.0	8.1	3.6	8.6	3.7	12.0	6.1
Other	5.6	5.2	4.1	6.6	6.8	7.3	5.7
Total	7.3	7.2	7.3	7.2	7.2	7.3	7.7

**Table 2.6.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by establishment age (in years) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	5,002	35.8	20.4	13.7	6.7	2.4	21.0
Mining	240	30.8	22.5	13.8	8.8	2.5	21.7
Utilities	596	45.6	17.1	16.1	3.5	1.3	16.3
Construction	45,328	45.3	19.4	9.7	5.4	4.0	16.2
Manufacturing	20,899	28.7	19.8	11.7	9.1	5.3	25.3
Wholesale trade	23,316	41.4	19.2	9.9	7.0	4.6	17.9
Retail trade	43,904	37.1	19.9	11.7	8.3	4.3	18.7
Transportation and warehouses	9,938	47.4	21.2	10.7	5.5	3.2	12.0
Information	15,155	48.6	20.8	13.1	6.9	2.8	7.8
Finance and insurance	25,675	48.8	21.1	12.2	4.8	2.9	10.2
Real estate, rental, leasing	25,765	41.8	19.9	11.5	5.8	3.9	17.2
Professional, scientific, and technical services	92,391	44.8	19.9	11.5	7.5	4.3	11.9
Management of companies	1,701	65.1	23.5	6.4	1.7	0.9	2.4
Administration, support, and waste	113,786	59.2	26.6	8.4	1.9	1.0	2.9
Education services	9,802	45.2	18.9	11.4	6.5	3.5	14.5
Health care and social assistance	47,398	39.3	19.3	11.7	7.6	5.3	16.7
Arts, entertainment, and recreation	11,472	44.5	20.2	12.1	6.8	3.4	13.1
Accommodation and food services	21,452	35.6	20.5	11.4	8.9	5.0	18.5
Other services	55,809	40.4	18.1	12.0	7.1	4.2	18.2
Public administration	587	43.8	6.6	6.8	3.7	2.2	36.8
Other	443	43.8	14.9	36.8	2.3	1.1	1.1
Total	570,659	45.3	21.1	10.9	6.0	3.6	13.2

**Table 2.7.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	3.2	4.0	2.3	2.1	2.2	2.5	1.4
Mining	7.0	6.5	6.8	9.4	7.0	4.9	5.9
Utilities	4.5	4.2	3.8	2.6	4.4	7.1	6.6
Construction	9.2	9.6	9.0	8.9	9.0	9.0	9.3
Manufacturing	8.5	8.7	8.5	7.9	8.3	8.7	8.9
Wholesale trade	8.0	8.4	8.0	7.4	8.2	8.4	9.1
Retail trade	7.7	7.7	7.9	7.5	7.6	7.5	7.5
Transportation and warehouses	9.4	9.7	9.6	7.9	8.9	8.3	8.7
Information	6.7	7.6	6.5	6.0	5.6	5.7	5.0
Finance and insurance	6.2	6.8	6.3	5.9	6.4	5.1	5.7
Real estate, rental, leasing	7.2	7.3	7.1	7.3	7.5	6.9	6.6
Professional, scientific, and technical services	6.7	7.3	6.4	6.3	5.9	6.0	5.3
Management of companies	6.1	4.5	6.2	5.6	6.1	7.3	3.0
Administration, support, and waste	6.6	7.7	6.0	6.2	6.6	7.3	6.7
Education services	7.1	7.0	7.2	7.1	7.7	6.8	7.1
Health care and social assistance	7.1	8.0	6.8	6.8	6.8	7.7	7.9
Arts, entertainment, and recreation	7.5	7.9	7.1	6.4	7.0	5.4	6.5
Accommodation and food services	7.3	7.8	7.4	7.3	6.7	5.6	5.4
Other services	7.6	7.7	7.5	7.6	8.0	7.1	6.1
Public administration	7.0	7.1	4.7				
Other	5.6	5.7	3.4	1.1	1.4	3.3	0.7
Total	7.3	7.7	6.9	7.1	7.3	7.2	7.4

**Table 2.8.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	5,002	56.5	28.3	6.9	4.5	2.3	1.5
Mining	240	14.6	30.4	20.0	16.3	10.0	8.8
Utilities	596	30.2	24.3	10.1	12.6	4.4	18.5
Construction	45,328	30.3	43.7	11.8	6.7	4.1	3.4
Manufacturing	20,899	23.6	30.0	14.4	11.7	8.6	11.8
Wholesale trade	23,316	10.9	32.3	26.9	13.1	8.4	8.3
Retail trade	43,904	30.9	38.5	14.5	8.5	4.5	3.2
Transportation and warehouses	9,938	31.6	46.1	10.3	5.2	3.8	2.9
Information	15,155	41.4	35.8	8.2	5.2	4.3	5.0
Finance and insurance	25,675	7.4	64.6	16.5	5.0	3.5	3.0
Real estate, rental, leasing	25,765	12.9	66.7	11.7	4.8	2.3	1.5
Professional, scientific, and technical services	92,391	43.1	36.9	9.0	5.0	3.4	2.6
Management of companies	1,701	3.4	87.2	4.1	1.8	1.6	1.9
Administration, support, and waste	113,786	31.8	61.7	3.2	2.0	0.8	0.6
Education services	9,802	44.6	18.6	17.2	7.9	5.8	5.8
Health care and social assistance	47,398	23.3	43.4	23.4	5.5	2.7	1.7
Arts, entertainment, and recreation	11,472	55.8	30.5	6.1	3.4	2.1	2.0
Accommodation and food services	21,452	15.3	31.4	38.5	9.2	4.3	1.4
Other services	55,809	63.5	23.3	6.8	3.3	1.9	1.0
Public administration	587	99.1	0.3		0.2	0.3	
Other	443	96.8	1.1	0.5	0.9	0.2	0.5
Total	570,659	33.3	43.4	12.0	5.4	3.2	2.7

**Table 2.9.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by type of establishment and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	3.2	3.2	4.6	3.6
Mining	7.0	7.0	7.9	0.4
Utilities	4.5	4.3	8.5	5.2
Construction	9.2	9.2	11.4	13.2
Manufacturing	8.5	8.5	8.5	8.9
Wholesale trade	8.0	8.0	9.4	8.0
Retail trade	7.7	7.7	7.0	7.7
Transportation and warehouses	9.4	9.4	9.2	9.3
Information	6.7	6.8	5.3	5.1
Finance and insurance	6.2	6.3	4.8	5.1
Real estate, rental, leasing	7.2	7.2	6.2	7.5
Professional, scientific, and technical services	6.7	6.7	5.8	6.5
Management of companies	6.1	6.1	4.3	12.1
Administration, support, and waste	6.6	6.6	7.0	8.5
Education services	7.1	7.1	6.9	7.1
Health care and social assistance	7.1	7.1	7.7	6.7
Arts, entertainment, and recreation	7.5	7.5	5.3	5.9
Accommodation and food services	7.3	7.3	7.5	7.4
Other services	7.6	7.6	7.5	5.7
Public administration	7.0	6.9	6.8	8.3
Other	5.6	5.6	4.6	
Total	7.3	7.3	7.3	7.3

**Table 2.10.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by type of establishment and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	5,002	98.7	1.2	0.2
Mining	240	89.2	9.6	1.3
Utilities	596	91.9	6.4	1.7
Construction	45,328	98.8	1.1	0.2
Manufacturing	20,899	93.1	6.2	0.6
Wholesale trade	23,316	94.8	4.4	0.8
Retail trade	43,904	96.1	2.6	1.3
Transportation and warehouses	9,938	96.9	2.4	0.7
Information	15,155	96.2	3.3	0.5
Finance and insurance	25,675	96.6	2.6	0.8
Real estate, rental, leasing	25,765	97.1	2.2	0.7
Professional, scientific, and technical services	92,391	97.6	2.0	0.4
Management of companies	1,701	96.1	3.6	0.2
Administration, support, and waste	113,786	99.4	0.4	0.1
Education services	9,802	94.8	3.6	1.5
Health care and social assistance	47,398	97.6	1.8	0.6
Arts, entertainment, and recreation	11,472	98.2	1.2	0.6
Accommodation and food services	21,452	97.0	2.7	0.3
Other services	55,809	98.6	1.1	0.4
Public administration	587	59.8	24.7	15.5
Other	443	99.1	0.9	
Total	570,659	97.6	1.9	0.5

**Table 2.11.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by business owner demographics and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	3.2	3.2	3.9	3.2	3.9	3.6	3.9
Mining	7.0	7.0	7.0	7.0	6.4	7.1	7.5
Utilities	4.5	4.4	9.3	4.1	5.4	18.4	23.0
Construction	9.2	9.2	10.1	9.1	9.5	12.5	11.3
Manufacturing	8.5	8.4	9.4	8.3	9.1	10.7	10.3
Wholesale trade	8.0	8.0	8.4	7.9	7.9	10.9	9.7
Retail trade	7.7	7.8	7.4	7.7	7.1	9.3	8.9
Transportation and warehouses	9.4	9.3	10.0	9.3	9.9	10.6	10.1
Information	6.7	6.7	7.7	6.6	7.5	8.4	8.5
Finance and insurance	6.2	6.2	7.4	6.2	7.1	9.3	8.3
Real estate, rental, leasing	7.2	7.2	7.3	7.2	6.6	8.8	10.3
Professional, scientific, and technical services	6.7	6.7	7.0	6.6	6.7	8.6	8.0
Management of companies	6.1	6.1	4.4	6.1	5.0	6.1	2.4
Administration, support, and waste	6.6	6.5	7.9	6.5	7.5	9.6	8.9
Education services	7.1	7.1	7.2	7.1	7.0	9.1	8.4
Health care and social assistance	7.1	7.1	7.7	7.1	7.6	8.6	8.2
Arts, entertainment, and recreation	7.5	7.6	6.3	7.6	6.1	9.4	7.9
Accommodation and food services	7.3	7.2	7.6	7.2	7.3	9.3	8.4
Other services	7.6	7.6	8.0	7.6	7.8	10.1	8.8
Public administration	7.0	7.1	0.0	7.1	0.0		
Other	5.6	5.5	6.3	5.5	7.0	4.8	4.1
Total	7.3	7.2	7.7	7.2	7.3	9.8	8.9

**Table 2.12.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by business owner demographics and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	5,002	93.0	7.0	92.2	6.4	0.8	0.6
Mining	240	95.8	4.2	94.2	2.1	1.7	2.1
Utilities	596	97.0	3.0	95.0	2.3	2.0	0.7
Construction	45,328	97.0	3.0	94.6	2.1	2.4	0.9
Manufacturing	20,899	89.0	11.0	84.9	7.9	4.1	3.1
Wholesale trade	23,316	90.8	9.2	87.8	6.7	3.0	2.5
Retail trade	43,904	88.4	11.6	86.2	9.2	2.2	2.4
Transportation and warehouses	9,938	94.8	5.2	91.7	3.6	3.1	1.6
Information	15,155	93.8	6.2	92.1	4.9	1.7	1.3
Finance and insurance	25,675	95.8	4.2	94.8	3.3	1.0	0.9
Real estate, rental, leasing	25,765	94.0	6.0	93.0	4.9	1.1	1.1
Professional, scientific, and technical services	92,391	89.3	10.7	86.9	8.5	2.4	2.2
Management of companies	1,701	99.2	0.8	98.8	0.6	0.4	0.2
Administration, support, and waste	113,786	97.3	2.7	96.6	2.0	0.7	0.7
Education services	9,802	90.3	9.7	89.4	8.3	0.9	1.4
Health care and social assistance	47,398	91.5	8.5	90.5	7.0	1.0	1.6
Arts, entertainment, and recreation	11,472	91.2	8.8	90.3	7.8	0.9	1.0
Accommodation and food services	21,452	91.9	8.1	88.6	5.7	3.3	2.4
Other services	55,809	91.0	9.0	89.4	7.0	1.6	2.0
Public administration	587	99.8	0.2	99.8	0.2		
Other	443	91.9	8.1	88.3	6.3	3.6	1.8
Total	570,659	92.8	7.2	91.0	5.6	1.7	1.6



## Disruptive Building Damage Risk from Earthquake Hazards for Employment

**Table 2.13.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by county and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees in 9 counties	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	2.4	16.0	10.1	0.6	0.0	1.5	1.8	1.8	0.0	0.0
Mining	9.7	21.7	17.4	1.8	0.1	1.8	4.1	3.3	0.1	0.0
Utilities	4.6	18.0	7.5	0.9	0.0	0.7	3.5	3.4	0.0	0.0
Construction	9.0	29.7	12.2	1.4	0.1	2.0	3.2	4.5	0.3	0.0
Manufacturing	9.1	22.5	12.2	1.4	0.0	2.6	3.4	4.5	0.2	0.0
Wholesale trade	8.4	22.9	10.9	1.2	0.1	2.3	3.2	3.6	0.2	0.0
Retail trade	7.7	23.8	12.4	1.0	0.0	1.5	2.3	2.7	0.4	0.0
Transportation and warehouses	7.2	23.7	9.6	1.5	0.1	2.4	1.8	3.1	0.3	0.0
Information	5.2	18.4	12.5	1.1	0.1	1.8	3.3	3.0	0.1	0.0
Finance and insurance	5.1	21.2	11.0	1.1	0.1	1.2	3.6	2.3	0.2	0.0
Real estate, rental, leasing	6.6	24.4	12.5	1.0	0.0	1.3	2.6	2.4	0.2	0.0
Professional, scientific, and technical services	5.6	19.4	11.7	0.9	0.0	1.5	3.0	2.7	0.2	0.0
Management of companies	5.2	20.8	13.4	0.8	0.0	1.1	2.7	4.8	0.3	0.0
Administration, support, and waste	6.6	23.2	11.3	0.9	0.0	1.2	2.1	2.5	0.1	0.0
Education services	6.9	23.9	11.2	0.9	0.0	1.0	2.1	2.2	0.3	0.0
Health care and social assistance	7.1	23.1	10.2	1.0	0.0	1.2	1.7	2.0	0.3	0.0
Arts, entertainment, and recreation	6.7	23.1	12.2	1.2	0.0	1.5	2.0	2.6	0.2	0.0
Accommodation and food services	6.7	23.8	12.8	0.9	0.0	1.4	2.0	2.5	0.3	0.0
Other services	7.3	23.7	11.1	1.1	0.0	1.3	2.4	2.3	0.3	0.0
Public administration	7.0	21.4	11.7	0.5	0.1	1.2	1.6	4.8	0.2	0.0
Other	4.9	21.5	6.7	0.5	0.0	1.1	1.6	2.4	0.0	0.0
Total	7.0	22.9	11.6	1.0	0.0	1.5	2.6	3.1	0.2	0.0

**Table 2.14.** Distribution of employment (in percent) in the San Francisco Bay region, California, by county and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	20,740	7.4	7.5	3.3	19.6	4.1	6.2	15.4	9.3	27.2
Mining	2,451	7.8	41.5	5.9	0.2	7.0	5.2	11.9	12.9	7.6
Utilities	11,069	16.4	8.8	5.0	0.9	45.8	5.0	12.7	1.5	4.0
Construction	207,224	18.8	13.7	4.7	2.5	9.9	11.8	24.2	5.9	8.5
Manufacturing	370,952	27.1	5.4	1.3	2.2	5.0	7.9	43.8	1.7	5.4
Wholesale trade	146,761	25.6	8.0	3.1	3.0	11.1	10.9	28.0	3.2	7.0
Retail trade	201,716	21.9	11.6	4.4	2.2	15.8	10.3	21.3	4.4	8.1
Transportation and warehouses	60,505	21.2	9.3	2.9	2.2	9.7	30.1	15.4	4.4	4.9
Information	153,971	14.5	4.2	3.7	0.6	19.8	15.9	37.2	0.9	3.2
Finance and insurance	145,999	11.2	12.3	6.8	1.2	31.2	15.4	16.1	2.3	3.5
Real estate, rental, leasing	113,725	15.9	12.3	4.8	1.7	24.4	9.8	22.3	3.3	5.6
Professional, scientific, and technical services	446,889	15.8	8.7	4.1	1.0	21.0	9.7	34.3	1.6	3.8
Management of companies	7,595	8.6	7.2	3.6	0.7	24.3	9.3	39.0	4.7	2.7
Administration, support, and waste	341,069	17.7	11.8	4.6	1.4	17.6	10.2	26.7	3.8	6.2
Education services	112,573	20.0	9.7	4.8	2.0	19.1	8.3	22.9	3.8	9.4
Health care and social assistance	311,315	21.1	12.9	5.1	2.0	14.7	10.7	22.9	3.7	6.8
Arts, entertainment, and recreation	68,028	17.4	12.7	6.0	3.2	16.7	9.3	23.6	3.2	7.8
Accommodation and food services	235,814	17.5	11.1	4.4	3.1	23.7	9.5	20.3	3.8	6.5
Other services	195,238	20.8	12.3	4.3	1.8	16.7	10.1	22.5	4.8	6.7
Public administration	37,625	19.6	9.5	7.1	1.3	16.4	11.2	25.2	6.3	3.4
Other	1,644	15.0	9.3	4.7	0.6	23.1	11.9	26.6	3.2	5.5
Total	3,192,903	19.3	10.2	4.2	2.0	16.7	10.7	27.6	3.3	6.1

**Table 2.15.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by establishment size (number of employees) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	2.4	3.2	2.5	1.7	3.2	0.9	1.1	
Mining	9.7	7.1	8.6	3.9	3.6	5.2	14.7	
Utilities	4.6	3.8	3.2	6.2	6.8	9.9	4.3	2.9
Construction	9.0	9.1	9.0	9.0	9.5	9.9	9.0	4.7
Manufacturing	9.1	8.3	8.5	8.2	8.8	9.4	10.1	8.9
Wholesale trade	8.4	7.8	8.5	8.6	8.5	9.5	9.6	4.9
Retail trade	7.7	7.8	7.2	7.1	6.9	7.9	8.2	10.5
Transportation and warehouses	7.2	9.4	8.8	7.8	7.8	6.9	8.1	1.3
Information	5.2	6.9	5.6	6.7	5.0	4.5	6.1	4.0
Finance and insurance	5.1	6.3	5.8	5.3	5.1	4.9	5.5	3.2
Real estate, rental, leasing	6.6	7.1	7.1	7.1	7.0	8.2	5.6	1.3
Professional, scientific, and technical services	5.6	6.7	6.1	6.2	5.5	5.4	4.4	4.1
Management of companies	5.2	6.1	5.6	6.6	3.5	4.6	1.4	5.6
Administration, support, and waste	6.6	6.3	5.7	6.9	7.0	6.9	8.1	7.0
Education services	6.9	7.0	7.3	7.4	7.3	6.4	8.1	5.2
Health care and social assistance	7.1	7.0	6.9	7.5	8.0	8.6	7.2	5.9
Arts, entertainment, and recreation	6.7	7.4	6.9	7.4	5.7	6.8	6.0	6.5
Accommodation and food services	6.7	7.5	7.3	7.2	6.6	5.9	3.9	9.0
Other services	7.3	7.6	7.3	7.3	6.8	5.3	4.1	12.7
Public administration	7.0	7.0	9.7	2.8	4.4	9.7	9.2	5.3
Other	4.9	5.7	6.2	3.0	6.6	1.5		
Total	7.0	7.1	7.1	7.2	7.1	7.2	7.4	6.1

**Table 2.16.** Distribution of employment (in percent) in the San Francisco Bay region, California, by establishment size (number of employees) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	20,740	36.6	11.7	11.6	15.4	11.5	13.3	
Mining	2,451	14.5	11.0	8.0	14.3	9.5	42.7	
Utilities	11,069	7.1	4.5	7.3	9.2	9.9	19.9	42.1
Construction	207,224	32.6	10.7	10.8	16.6	9.8	14.5	5.0
Manufacturing	370,952	7.7	5.5	6.4	11.9	10.6	25.5	32.4
Wholesale trade	146,761	25.5	11.9	12.3	16.1	11.4	16.5	6.4
Retail trade	201,716	36.4	13.5	10.7	11.9	10.3	11.5	5.7
Transportation and warehouses	60,505	28.0	8.6	8.6	14.3	8.9	14.5	17.1
Information	153,971	14.8	5.6	5.8	9.7	10.0	21.1	32.9
Finance and insurance	145,999	32.5	7.2	6.3	9.2	7.1	11.9	25.7
Real estate, rental, leasing	113,725	43.1	9.9	8.6	11.5	10.5	7.3	9.1
Professional, scientific, and technical services	446,889	30.5	9.5	9.7	13.3	10.3	13.6	13.1
Management of companies	7,595	43.8	3.7	2.9	7.4	5.8	10.5	25.9
Administration, support, and waste	341,069	59.3	5.3	4.2	6.3	5.4	7.1	12.4
Education services	112,573	8.9	13.4	9.1	16.9	15.6	16.9	19.2
Health care and social assistance	311,315	27.2	18.1	8.7	9.9	8.3	10.6	17.3
Arts, entertainment, and recreation	68,028	24.4	12.3	9.3	13.4	15.2	15.8	9.5
Accommodation and food services	235,814	7.6	24.6	21.2	21.5	10.6	10.6	3.8
Other services	195,238	49.5	14.7	10.5	11.7	5.7	4.7	3.2
Public administration	37,625	1.7	1.0	1.9	7.2	13.1	32.1	42.9
Other	1,644	40.5	13.0	15.6	17.8	13.1		
Total	3,192,903	28.8	11.1	9.2	12.5	9.5	13.8	15.1

**Table 2.17.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by establishment age (in years) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	2.4	4.0	3.7	2.8	1.2	1.7	1.5
Mining	9.7	10.4	6.0	5.1	2.9	5.4	11.7
Utilities	4.6	5.0	7.4	3.0	5.5	2.7	4.3
Construction	9.0	9.4	8.8	9.3	6.8	9.6	9.1
Manufacturing	9.1	8.2	13.9	6.1	7.5	7.9	9.3
Wholesale trade	8.4	7.5	7.3	8.6	9.7	7.8	8.9
Retail trade	7.7	8.1	8.7	7.9	6.8	7.8	7.3
Transportation and warehouses	7.2	9.5	8.1	7.4	7.3	6.6	5.8
Information	5.2	5.4	4.9	5.4	4.0	5.5	6.4
Finance and insurance	5.1	5.7	5.7	5.9	5.2	5.8	4.3
Real estate, rental, leasing	6.6	6.5	5.4	8.1	7.6	6.3	6.9
Professional, scientific, and technical services	5.6	5.1	5.9	6.1	6.4	5.6	5.5
Management of companies	5.2	5.4	5.0	3.4	5.8	7.4	2.8
Administration, support, and waste	6.6	6.4	6.1	5.5	6.4	7.2	7.9
Education services	6.9	7.0	7.8	7.9	6.4	6.4	6.6
Health care and social assistance	7.1	6.8	7.4	7.6	7.4	6.1	7.0
Arts, entertainment, and recreation	6.7	7.3	5.9	5.3	6.9	5.5	7.2
Accommodation and food services	6.7	6.9	7.4	6.3	6.8	6.6	6.1
Other services	7.3	6.7	7.1	7.4	7.0	7.9	7.8
Public administration	7.0	8.8	2.6	10.2	7.0	6.1	6.9
Other	4.9	5.4	3.0	5.3	6.8	9.0	5.2
Total	7.0	6.7	7.4	6.7	6.6	7.0	7.3

**Table 2.18.** Distribution of employment (in percent) in the San Francisco Bay region, California, by establishment age (in years) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	20,740	18.9	13.3	10.1	8.4	3.3	46.0
Mining	2,451	10.4	9.5	5.5	8.2	5.1	61.2
Utilities	11,069	16.1	6.5	5.1	2.7	0.7	69.0
Construction	207,224	22.5	13.5	8.9	7.8	6.2	41.0
Manufacturing	370,952	8.5	12.3	11.4	10.8	6.9	50.1
Wholesale trade	146,761	18.3	14.4	10.9	9.1	7.2	40.1
Retail trade	201,716	23.6	16.6	10.6	9.2	4.7	35.4
Transportation and warehouses	60,505	20.4	15.7	8.6	5.9	4.5	44.8
Information	153,971	22.2	13.4	14.8	22.9	3.3	23.4
Finance and insurance	145,999	23.6	14.3	8.4	8.8	6.0	38.9
Real estate, rental, leasing	113,725	27.2	22.5	10.5	6.1	6.1	27.6
Professional, scientific, and technical services	446,889	30.9	16.2	14.7	11.1	6.3	20.8
Management of companies	7,595	39.9	16.8	10.1	1.6	19.1	12.5
Administration, support, and waste	341,069	40.5	21.9	8.8	5.4	2.5	20.7
Education services	112,573	24.2	10.2	6.5	4.5	2.5	52.1
Health care and social assistance	311,315	24.6	13.8	9.4	7.8	4.6	39.7
Arts, entertainment, and recreation	68,028	23.5	15.0	11.7	9.6	4.8	35.3
Accommodation and food services	235,814	29.3	19.2	11.9	11.2	5.0	23.4
Other services	195,238	28.7	14.0	10.9	7.9	4.4	34.0
Public administration	37,625	9.7	3.5	3.2	8.4	2.3	72.9
Other	1,644	51.4	19.9	25.5	0.6	0.5	2.1
Total	3,192,903	25.0	15.5	10.8	9.3	5.1	34.2

**Table 2.19.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	2.4	4.1	2.3	2.1	2.2	2.5	1.1
Mining	9.7	10.0	6.4	10.4	6.4	4.3	11.5
Utilities	4.6	4.0	3.1	2.5	3.6	10.5	4.5
Construction	9.0	9.6	9.0	8.8	9.2	9.0	8.9
Manufacturing	9.1	8.4	8.7	8.2	8.0	8.7	9.4
Wholesale trade	8.4	8.3	8.1	7.3	8.3	8.1	8.7
Retail trade	7.7	7.7	7.8	7.2	7.4	7.3	8.1
Transportation and warehouses	7.2	9.4	9.3	7.4	8.1	7.8	5.6
Information	5.2	7.5	6.6	6.5	5.7	6.1	4.7
Finance and insurance	5.1	6.9	6.3	5.9	6.1	4.9	4.3
Real estate, rental, leasing	6.6	7.1	7.0	7.2	5.6	7.4	5.8
Professional, scientific, and technical services	5.6	7.3	6.5	6.4	5.8	6.0	4.7
Management of companies	5.2	4.6	6.1	5.4	5.2	6.5	4.2
Administration, support, and waste	6.6	7.5	5.9	5.9	6.8	7.5	7.1
Education services	6.9	7.0	7.4	7.2	7.5	7.0	6.6
Health care and social assistance	7.1	7.9	6.9	6.9	7.1	7.6	7.0
Arts, entertainment, and recreation	6.7	7.9	7.3	5.9	7.1	5.2	6.5
Accommodation and food services	6.7	7.6	7.4	7.4	6.8	5.7	5.5
Other services	7.3	7.6	7.2	7.3	7.9	6.8	6.9
Public administration	7.0	7.0	4.1				
Other	4.9	5.2	3.3	0.8	1.3	3.3	0.7
Total	7.0	7.5	6.9	7.0	7.1	7.0	6.9

**Table 2.20.** Distribution of employment (in percent) in the San Francisco Bay region, California, by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	20,740	21.2	17.3	10.3	12.3	13.9	25.1
Mining	2,451	2.4	6.5	5.8	9.5	12.3	63.5
Utilities	11,069	2.1	3.6	2.0	4.2	3.2	84.9
Construction	207,224	7.2	20.0	8.6	10.0	12.1	42.2
Manufacturing	370,952	2.0	4.2	3.6	5.0	7.1	78.0
Wholesale trade	146,761	2.1	9.6	11.3	10.5	12.1	54.4
Retail trade	201,716	8.9	18.7	11.6	11.1	11.7	38.0
Transportation and warehouses	60,505	8.0	18.1	8.4	8.3	11.2	46.0
Information	153,971	6.2	8.5	4.2	4.6	7.1	69.4
Finance and insurance	145,999	1.6	23.0	10.0	5.8	7.5	52.0
Real estate, rental, leasing	113,725	3.8	34.8	12.3	13.7	11.4	24.0
Professional, scientific, and technical services	446,889	10.3	17.1	8.2	8.4	11.1	44.9
Management of companies	7,595	1.0	40.7	3.5	2.3	5.6	46.8
Administration, support, and waste	341,069	13.9	44.8	5.2	5.5	5.7	25.0
Education services	112,573	6.3	6.8	10.4	8.8	12.4	55.3
Health care and social assistance	311,315	5.9	20.9	18.3	9.2	9.5	36.3
Arts, entertainment, and recreation	68,028	15.7	18.9	8.6	8.9	11.1	36.7
Accommodation and food services	235,814	2.3	13.0	32.9	17.1	16.1	18.5
Other services	195,238	32.9	21.4	11.5	9.8	10.0	14.3
Public administration	37,625	99.8	0.0		0.0	0.1	
Other	1,644	92.4	0.9	0.5	0.9	1.5	3.8
Total	3,192,903	9.6	18.8	10.7	8.7	9.9	42.2



**Table 2.21.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by type of establishment and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	2.4	2.4	2.8	10.1
Mining	9.7	8.1	12.3	0.3
Utilities	4.6	4.1	4.7	9.2
Construction	9.0	9.0	8.7	12.2
Manufacturing	9.1	10.5	7.3	10.7
Wholesale trade	8.4	8.0	9.4	10.4
Retail trade	7.7	7.8	6.9	9.2
Transportation and warehouses	7.2	7.0	7.9	8.6
Information	5.2	6.1	4.1	5.0
Finance and insurance	5.1	5.5	4.1	5.4
Real estate, rental, leasing	6.6	6.7	6.0	6.1
Professional, scientific, and technical services	5.6	5.8	4.6	9.4
Management of companies	5.2	5.0	5.5	9.9
Administration, support, and waste	6.6	6.5	6.6	11.7
Education services	6.9	6.9	6.6	7.8
Health care and social assistance	7.1	7.6	5.4	4.9
Arts, entertainment, and recreation	6.7	7.0	4.4	4.1
Accommodation and food services	6.7	6.6	8.1	6.2
Other services	7.3	7.4	6.3	6.4
Public administration	7.0	7.3	7.1	6.6
Other	4.9	4.9	4.0	
Total	7.0	7.2	6.3	7.9

**Table 2.22.** Distribution of employment (in percent) in the San Francisco Bay region, California, by type of establishment and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	20,740	92.3	7.5	0.2
Mining	2,451	60.7	38.1	1.3
Utilities	11,069	43.2	53.2	3.6
Construction	207,224	87.6	11.5	0.9
Manufacturing	370,952	54.6	43.2	2.2
Wholesale trade	146,761	75.5	22.9	1.6
Retail trade	201,716	80.6	14.0	5.4
Transportation and warehouses	60,505	83.2	15.3	1.5
Information	153,971	58.0	41.0	1.0
Finance and insurance	145,999	67.9	29.7	2.4
Real estate, rental, leasing	113,725	85.6	11.5	2.8
Professional, scientific, and technical services	446,889	80.2	17.5	2.3
Management of companies	7,595	68.5	30.9	0.6
Administration, support, and waste	341,069	92.0	7.3	0.7
Education services	112,573	61.4	33.4	5.2
Health care and social assistance	311,315	78.2	18.4	3.4
Arts, entertainment, and recreation	68,028	88.5	8.0	3.5
Accommodation and food services	235,814	91.9	7.3	0.8
Other services	195,238	92.9	6.0	1.1
Public administration	37,625	15.7	60.3	24.1
Other	1,644	99.6	0.4	
Total	3,192,903	77.5	20.0	2.4

**Table 2.23.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by business owner demographics and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	2.4	2.3	4.0	2.3	3.5	1.1	5.9
Mining	9.7	10.6	0.8	10.6	0.2	10.1	3.0
Utilities	4.6	4.6	3.0	4.5	2.2	26.5	6.7
Construction	9.0	8.9	11.4	8.8	10.7	9.7	12.7
Manufacturing	9.1	9.1	10.0	9.0	9.9	11.3	10.3
Wholesale trade	8.4	8.3	9.2	8.1	9.3	12.9	8.8
Retail trade	7.7	7.7	7.9	7.7	7.1	8.8	10.9
Transportation and warehouses	7.2	7.2	7.7	7.0	7.5	12.0	8.0
Information	5.2	5.2	6.3	5.2	5.8	6.8	8.0
Finance and insurance	5.1	5.1	7.1	5.0	7.0	9.4	7.3
Real estate, rental, leasing	6.6	6.6	6.7	6.6	6.0	6.4	9.4
Professional, scientific, and technical services	5.6	5.7	5.3	5.6	4.6	7.5	7.2
Management of companies	5.2	5.2	4.4	5.2	4.9	4.6	2.4
Administration, support, and waste	6.6	6.5	7.1	6.5	6.9	8.7	7.4
Education services	6.9	6.9	6.2	6.9	6.3	8.5	5.9
Health care and social assistance	7.1	7.0	7.4	7.0	7.3	11.1	8.0
Arts, entertainment, and recreation	6.7	6.7	7.6	6.7	7.9	6.7	5.8
Accommodation and food services	6.7	6.7	6.9	6.7	6.1	7.1	8.5
Other services	7.3	7.3	7.6	7.2	7.3	9.1	8.5
Public administration	7.0	7.0	0.0	7.0	0.0		
Other	4.9	4.8	7.5	4.9	9.1	2.5	4.6
Total	7.0	7.0	7.2	6.9	6.7	9.2	8.5

**Table 2.24.** Distribution of employment (in percent) in the San Francisco Bay region, California, by business owner demographics and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	Male	Female	Minority		Non-minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	20,740	93.3	6.7	91.6	5.2	1.7	1.5
Mining	2,451	91.1	8.9	90.6	7.1	0.4	1.8
Utilities	11,069	97.0	3.0	96.4	2.5	0.6	0.5
Construction	207,224	94.6	5.4	90.4	3.6	4.2	1.8
Manufacturing	370,952	94.2	5.8	90.6	3.8	3.6	2.0
Wholesale trade	146,761	91.0	9.0	86.3	5.7	4.7	3.3
Retail trade	201,716	91.0	9.0	88.3	7.0	2.7	2.0
Transportation and warehouses	60,505	93.9	6.1	90.2	3.8	3.7	2.3
Information	153,971	96.4	3.6	94.5	2.7	2.0	0.9
Finance and insurance	145,999	97.1	2.9	96.2	2.2	0.9	0.7
Real estate, rental, leasing	113,725	94.3	5.7	93.0	4.5	1.3	1.1
Professional, scientific, and technical services	446,889	85.2	14.8	80.8	10.9	4.4	3.9
Management of companies	7,595	99.6	0.4	98.9	0.3	0.8	0.1
Administration, support, and waste	341,069	92.3	7.7	89.4	4.7	2.9	3.0
Education services	112,573	96.8	3.2	96.4	2.7	0.4	0.5
Health care and social assistance	311,315	94.0	6.0	93.3	4.9	0.8	1.1
Arts, entertainment, and recreation	68,028	95.2	4.8	94.3	4.2	0.8	0.6
Accommodation and food services	235,814	94.1	5.9	91.0	4.0	3.1	1.9
Other services	195,238	92.6	7.4	90.7	5.4	1.9	2.0
Public administration	37,625	100.0	0.0	100.0	0.0		
Other	1,644	95.0	5.0	92.8	3.3	2.3	1.7
Total	3,192,903	92.7	7.3	90.0	5.2	2.7	2.0

## Disruptive Building Damage Risk from Earthquake and Fire Hazards for Establishments

See section on “Disruptive Building Damage Risk from Earthquake Hazards for Establishments” for distribution tables.

**Table 2.25.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by county and NAICS 2-digit sector.

[See table 2.2 for the distribution of establishments by county. NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments in 9 counties	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	3.3	18.6	9.8	0.7	0.0	1.5	1.5	2.1	0.3	0.0
Mining	7.5	28.8	17.1	2.0	0.1	1.3	4.7	3.3	0.6	0.0
Utilities	4.7	19.9	10.3	1.0	0.0	1.7	1.8	2.9	0.2	0.0
Construction	10.0	35.5	14.8	2.3	0.1	1.5	2.6	4.5	1.3	0.0
Manufacturing	9.0	28.3	13.7	2.0	0.0	2.0	3.2	4.2	1.2	0.0
Wholesale trade	8.2	25.9	11.6	1.3	0.0	1.9	2.6	3.1	0.4	0.0
Retail trade	8.1	26.3	13.1	1.4	0.0	1.4	2.4	3.0	1.0	0.0
Transportation and warehouses	9.7	26.7	12.2	1.4	0.1	1.7	2.4	3.3	0.6	0.0
Information	7.1	24.8	14.2	1.3	0.0	1.5	2.6	2.7	0.7	0.0
Finance and insurance	6.5	24.8	11.5	1.3	0.0	1.3	2.5	2.4	0.7	0.0
Real estate, rental, leasing	7.5	25.9	11.8	1.3	0.0	1.3	2.3	2.5	0.6	0.0
Professional, scientific, and technical services	7.0	23.7	12.4	1.2	0.0	1.4	2.4	2.6	0.6	0.0
Management of companies	6.3	22.5	13.1	1.0	0.0	1.3	2.2	2.4	0.5	0.0
Administration, support, and waste	6.8	25.0	11.9	1.1	0.0	1.2	2.0	2.4	0.4	0.0
Education services	11.1	32.4	15.3	5.2	0.1	1.5	4.0	4.8	3.6	0.1
Health care and social assistance	7.6	25.0	12.3	1.3	0.0	1.1	2.0	2.4	0.8	0.0
Arts, entertainment, and recreation	7.8	26.2	13.5	1.3	0.0	1.3	2.2	2.6	0.8	0.0
Accommodation and food services	7.7	26.0	13.5	1.4	0.0	1.3	2.2	3.0	1.0	0.0
Other services	8.3	26.3	12.2	1.7	0.0	1.3	2.5	2.8	1.6	0.0
Public administration	8.5	23.4	14.4	1.1	0.1	1.7	2.7	5.0	7.1	0.0
Other	6.4	23.9	8.5	2.1	0.0	1.4	2.2	2.9	0.8	0.0
Total	7.7	26.2	12.6	1.5	0.0	1.4	2.4	2.9	0.9	0.0

**Table 2.26.** Establishment risk (in percent) from earthquakes and fire in the HayWired scenario by number of employees and NAICS 2-digit sector.

[See table 2.4 for the distribution of establishments by number of employees. NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	3.3	3.5	2.7	1.8	3.3	1.0	1.2	
Mining	7.5	7.4	8.7	6.2	4.2	5.9	14.4	
Utilities	4.7	4.3	3.6	6.3	7.4	8.9	5.9	6.4
Construction	10.0	10.0	9.8	10.1	10.8	11.2	11.3	5.5
Manufacturing	9.0	8.9	9.1	8.8	9.3	10.1	10.7	7.9
Wholesale trade	8.2	8.0	8.5	8.7	8.6	9.6	10.5	5.5
Retail trade	8.1	8.2	7.7	7.6	7.3	8.1	8.6	9.1
Transportation and warehouses	9.7	10.0	9.2	8.2	7.9	7.3	8.6	1.9
Information	7.1	7.3	5.8	7.2	5.5	5.0	6.4	5.1
Finance and insurance	6.5	6.6	6.1	5.7	5.5	5.3	5.5	3.6
Real estate, rental, leasing	7.5	7.5	7.4	7.4	7.1	8.0	5.9	2.5
Professional, scientific, and technical services	7.0	7.1	6.5	6.6	6.0	5.8	5.0	4.4
Management of companies	6.3	6.3	5.9	7.2	4.5	4.9	1.3	4.3
Administration, support, and waste	6.8	6.8	5.8	7.2	7.7	7.5	8.5	6.8
Education services	11.1	10.8	11.3	11.6	11.6	11.0	12.1	7.7
Health care and social assistance	7.6	7.6	7.3	7.9	8.4	8.7	7.5	7.4
Arts, entertainment, and recreation	7.8	8.0	7.2	7.8	6.2	6.9	7.2	7.3
Accommodation and food services	7.7	8.0	7.7	7.6	7.0	6.5	4.7	7.2
Other services	8.3	8.3	7.9	8.0	7.7	6.1	5.1	10.2
Public administration	8.5	8.6	12.0	4.4	4.8	12.0	10.3	5.8
Other	6.4	6.6	5.9	3.9	7.9	1.9		
Total	7.7	7.7	7.7	7.9	7.8	8.0	8.2	6.4

**Table 2.27.** Establishment risk (in percent) from earthquakes and fire hazards in the HayWired scenario by establishment age (in years) and NAICS 2-digit sector.

[See table 2.6 for the distribution of establishments by establishment age. NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	3.3	4.2	3.7	3.1	2.5	2.3	2.0
Mining	7.5	10.1	6.1	5.3	6.1	7.9	7.1
Utilities	4.7	4.7	6.1	2.5	3.8	3.7	6.1
Construction	10.0	10.3	10.0	10.0	9.2	9.4	9.7
Manufacturing	9.0	8.7	8.9	8.2	8.6	8.4	10.2
Wholesale trade	8.2	8.0	8.2	8.3	8.6	8.2	8.5
Retail trade	8.1	8.2	8.2	8.2	7.5	7.8	8.4
Transportation and warehouses	9.7	10.6	9.9	9.0	7.7	7.4	8.2
Information	7.1	7.0	7.2	6.7	7.2	7.1	7.6
Finance and insurance	6.5	6.4	6.9	6.3	6.1	6.1	7.0
Real estate, rental, leasing	7.5	7.1	8.0	7.8	7.7	7.8	7.2
Professional, scientific, and technical services	7.0	7.0	7.1	6.9	6.9	7.1	7.1
Management of companies	6.3	6.3	6.6	4.8	7.2	7.5	5.9
Administration, support, and waste	6.8	6.8	6.9	6.4	6.8	7.2	7.4
Education services	11.1	11.0	11.5	11.3	11.1	10.4	10.6
Health care and social assistance	7.6	7.4	7.7	7.6	7.3	7.6	7.9
Arts, entertainment, and recreation	7.8	8.1	8.0	7.2	7.1	7.9	7.6
Accommodation and food services	7.7	7.6	8.0	7.8	7.5	7.4	7.6
Other services	8.3	8.0	8.1	8.5	8.6	8.4	8.6
Public administration	8.5	10.1	4.8	9.4	4.6	15.4	6.9
Other	6.4	6.0	4.8	7.5	7.6	8.1	6.1
Total	7.7	7.6	7.7	7.6	7.6	7.8	8.2

**Table 2.28.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[See table 2.8 for the distribution of establishments by revenue. NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	3.3	4.2	2.3	2.1	2.2	2.6	1.4
Mining	7.5	6.8	7.1	9.9	7.3	5.4	7.2
Utilities	4.7	4.4	4.0	2.7	4.5	7.3	6.9
Construction	10.0	10.4	9.8	9.7	9.9	10.1	10.6
Manufacturing	9.0	9.2	9.0	8.4	8.9	9.2	9.6
Wholesale trade	8.2	8.6	8.1	7.6	8.3	8.6	9.4
Retail trade	8.1	8.1	8.3	7.9	8.1	7.9	8.0
Transportation and warehouses	9.7	10.0	10.0	8.3	9.3	8.7	9.1
Information	7.1	7.9	6.8	6.3	6.0	6.1	5.3
Finance and insurance	6.5	7.1	6.6	6.2	6.6	5.4	6.0
Real estate, rental, leasing	7.5	7.5	7.4	7.6	7.8	7.2	6.9
Professional, scientific, and technical services	7.0	7.6	6.7	6.6	6.2	6.3	5.6
Management of companies	6.3	4.7	6.4	5.8	6.4	7.7	3.1
Administration, support, and waste	6.8	8.0	6.3	6.5	6.8	7.6	7.1
Education services	11.1	10.9	11.2	11.0	11.4	11.4	11.0
Health care and social assistance	7.6	8.4	7.3	7.3	7.2	8.1	8.3
Arts, entertainment, and recreation	7.8	8.3	7.4	6.7	7.4	5.8	6.9
Accommodation and food services	7.7	8.3	7.9	7.7	7.2	6.1	6.0
Other services	8.3	8.3	8.2	8.3	8.6	7.8	6.8
Public administration	8.5	8.5	5.7				
Other	6.4	6.6	3.9	1.3	1.4	3.3	1.1
Total	7.7	8.2	7.3	7.6	7.8	7.8	8.0



**Table 2.29.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by type of establishment and NAICS 2-digit sector.

[See table 2.10 for the distribution of establishments by type. NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	3.3	3.3	4.6	3.6
Mining	7.5	7.5	8.5	0.4
Utilities	4.7	4.4	8.8	5.6
Construction	10.0	10.0	13.0	14.2
Manufacturing	9.0	9.0	9.1	9.4
Wholesale trade	8.2	8.1	9.6	8.2
Retail trade	8.1	8.2	7.4	8.2
Transportation and warehouses	9.7	9.7	9.6	9.7
Information	7.1	7.1	5.6	5.3
Finance and insurance	6.5	6.6	5.1	5.4
Real estate, rental, leasing	7.5	7.5	6.5	7.9
Professional, scientific, and technical services	7.0	7.0	6.2	6.9
Management of companies	6.3	6.4	4.4	13.2
Administration, support, and waste	6.8	6.8	7.3	8.9
Education services	11.1	11.1	10.8	10.7
Health care and social assistance	7.6	7.6	8.1	7.3
Arts, entertainment, and recreation	7.8	7.9	5.7	6.3
Accommodation and food services	7.7	7.7	7.9	8.0
Other services	8.3	8.3	8.1	6.2
Public administration	8.5	8.5	7.9	9.8
Other	6.4	6.5	5.4	
Total	7.7	7.7	7.8	7.9

**Table 2.30.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by business owner demographics and NAICS 2-digit sector.

[See table 2.12 for the distribution of establishments by business owner demographics. NAICS, North American Industry Classification System]

NAICS sector	Average risk across all establishments	Male	Female	Non-Minority		Minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	3.3	3.3	4.1	3.3	4.1	3.6	4.2
Mining	7.5	7.5	7.2	7.5	6.6	7.3	7.8
Utilities	4.7	4.6	9.5	4.3	5.5	18.8	23.3
Construction	10.0	10.0	11.1	9.9	10.4	13.6	12.7
Manufacturing	9.0	8.9	9.9	8.8	9.6	11.3	10.9
Wholesale trade	8.2	8.2	8.6	8.1	8.1	11.2	10.0
Retail trade	8.1	8.2	7.8	8.1	7.4	9.8	9.4
Transportation and warehouses	9.7	9.7	10.3	9.7	10.2	11.1	10.5
Information	7.1	7.0	8.0	7.0	7.8	8.9	8.9
Finance and insurance	6.5	6.5	7.7	6.4	7.4	9.6	8.8
Real estate, rental, leasing	7.5	7.5	7.6	7.4	6.9	9.3	10.6
Professional, scientific, and technical services	7.0	7.0	7.3	6.9	7.0	9.0	8.4
Management of companies	6.3	6.3	4.6	6.3	5.2	6.3	2.7
Administration, support, and waste	6.8	6.8	8.2	6.8	7.8	9.9	9.3
Education services	11.1	11.0	11.2	11.0	10.9	13.1	12.9
Health care and social assistance	7.6	7.5	8.1	7.5	8.0	9.2	8.7
Arts, entertainment, and recreation	7.8	7.9	6.6	7.9	6.4	9.9	8.2
Accommodation and food services	7.7	7.7	8.0	7.6	7.7	9.8	8.9
Other services	8.3	8.3	8.3	8.2	8.1	10.5	9.2
Public administration	8.5	8.5	0.0	8.5	0.0		
Other	6.4	6.4	7.4	6.4	8.2	5.8	4.6
Total	7.7	7.7	8.1	7.6	7.8	10.3	9.4

## Disruptive Building Damage Risk from Earthquake and Fire Hazards for Employment

See section on “Disruptive Building Damage Risk from Earthquakes for Establishments” for distribution tables.

**Table 2.31.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by county and NAICS 2-digit sector.

[See table 2.14 for the distribution of employment by county. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees in 9 counties	County								
		Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Agriculture, forestry, fishing, and hunting	2.5	17.1	10.1	0.6	0.0	1.5	1.9	1.8	0.1	0.0
Mining	10.7	22.7	19.1	3.8	0.1	1.8	4.3	3.8	0.2	0.0
Utilities	4.8	18.6	7.8	1.0	0.0	0.7	3.7	3.6	0.0	0.0
Construction	10.1	32.1	12.9	4.0	0.1	2.2	3.7	5.6	2.6	0.0
Manufacturing	9.8	23.9	12.7	2.9	0.0	2.6	3.8	4.9	0.7	0.0
Wholesale trade	8.6	23.4	11.2	1.5	0.1	2.3	3.3	3.8	0.3	0.0
Retail trade	8.2	24.8	13.0	1.4	0.0	1.5	2.5	3.0	0.8	0.0
Transportation and warehouses	7.6	24.5	10.0	2.2	0.1	2.4	2.0	3.4	0.6	0.0
Information	5.6	19.3	12.9	1.9	0.1	1.8	3.5	3.3	0.7	0.0
Finance and insurance	5.3	22.0	11.4	1.4	0.1	1.2	3.7	2.6	0.5	0.0
Real estate, rental, leasing	6.8	25.1	12.9	1.3	0.0	1.4	2.8	2.6	0.5	0.0
Professional, scientific, and technical services	6.0	20.2	12.1	1.5	0.0	1.5	3.2	3.0	0.7	0.0
Management of companies	5.4	21.5	13.8	1.0	0.0	1.2	2.8	5.0	0.3	0.0
Administration, support, and waste	6.9	24.0	11.6	1.3	0.0	1.3	2.3	2.8	0.5	0.0
Education services	10.5	33.2	15.5	4.9	0.1	1.9	3.8	5.0	4.9	0.1
Health care and social assistance	7.5	24.3	10.7	1.4	0.0	1.2	1.9	2.3	0.8	0.0
Arts, entertainment, and recreation	7.1	24.1	12.7	1.8	0.1	1.5	2.2	2.9	1.3	0.0
Accommodation and food services	7.1	25.1	13.3	1.3	0.0	1.5	2.3	3.0	0.7	0.0
Other services	8.0	25.3	11.8	2.0	0.0	1.3	2.7	2.8	1.7	0.0
Public administration	8.6	25.3	12.9	0.6	0.1	1.2	2.1	6.3	5.0	0.0
Other	5.6	23.8	7.2	1.0	0.0	1.1	2.2	2.9	0.5	0.0
Total	7.6	24.4	12.2	1.8	0.0	1.5	2.9	3.5	1.2	0.0

**Table 2.32.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by number of employees and NAICS 2-digit sector.

[See table 2.16 for the distribution of employment by number of employees. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<5	5–9	10–19	20–49	50–99	100–499	>500
Agriculture, forestry, fishing, and hunting	2.5	3.3	2.7	1.8	3.3	1.0	1.3	
Mining	10.7	7.4	9.2	5.5	3.8	5.8	16.2	
Utilities	4.8	4.0	3.4	6.4	7.0	10.2	4.7	3.0
Construction	10.1	9.9	9.8	10.1	10.8	11.2	10.5	6.7
Manufacturing	9.8	8.8	9.1	8.8	9.4	10.1	10.8	9.6
Wholesale trade	8.6	8.0	8.7	8.8	8.7	9.7	9.9	5.1
Retail trade	8.2	8.2	7.6	7.6	7.4	8.3	8.7	10.9
Transportation and warehouses	7.6	9.7	9.2	8.2	8.1	7.4	8.6	1.6
Information	5.6	7.2	5.9	7.1	5.4	4.8	6.4	4.3
Finance and insurance	5.3	6.6	6.1	5.6	5.3	5.1	5.8	3.3
Real estate, rental, leasing	6.8	7.4	7.5	7.4	7.3	8.4	5.8	1.4
Professional, scientific, and technical services	6.0	6.9	6.4	6.5	5.9	5.8	4.8	4.3
Management of companies	5.4	6.3	5.8	6.9	3.7	4.8	1.7	5.7
Administration, support, and waste	6.9	6.6	5.9	7.3	7.4	7.3	8.5	7.3
Education services	10.5	10.8	11.2	11.6	11.4	11.2	11.3	7.3
Health care and social assistance	7.5	7.4	7.3	7.9	8.4	9.0	7.6	6.4
Arts, entertainment, and recreation	7.1	7.7	7.2	7.7	6.1	7.2	6.5	7.1
Accommodation and food services	7.1	8.0	7.7	7.5	7.0	6.4	4.3	10.0
Other services	8.0	8.3	7.9	8.1	7.5	6.2	4.7	13.2
Public administration	8.6	8.7	11.1	4.6	4.9	11.1	10.8	7.1
Other	5.6	6.5	7.1	3.5	7.0	1.8		
Total	7.6	7.6	7.7	7.8	7.8	8.0	8.1	6.6

**Table 2.33.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by establishment age (in years) and NAICS 2-digit sector.

[See table 2.18 for the distribution of employment by establishment age. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<6	6–10	11–15	16–20	21–25	>26
Agriculture, forestry, fishing, and hunting	2.5	4.1	3.9	3.1	1.3	1.7	1.6
Mining	10.7	10.8	6.4	5.3	4.3	6.0	12.9
Utilities	4.8	5.1	7.7	3.3	6.0	2.9	4.5
Construction	10.1	10.2	10.0	10.4	8.0	10.6	10.4
Manufacturing	9.8	8.8	14.7	6.7	8.2	8.5	10.0
Wholesale trade	8.6	7.7	7.4	8.8	9.9	8.0	9.2
Retail trade	8.2	8.5	9.1	8.3	7.3	8.2	7.7
Transportation and warehouses	7.6	9.9	8.5	7.8	7.6	6.9	6.2
Information	5.6	5.8	5.2	5.8	4.2	5.8	6.8
Finance and insurance	5.3	5.9	6.0	6.1	5.3	6.2	4.5
Real estate, rental, leasing	6.8	6.8	5.6	8.4	7.9	6.5	7.1
Professional, scientific, and technical services	6.0	5.4	6.2	6.5	6.7	5.9	5.8
Management of companies	5.4	5.7	5.1	3.5	6.0	7.6	2.9
Administration, support, and waste	6.9	6.6	6.4	5.7	6.8	7.6	8.3
Education services	10.5	10.9	13.4	11.4	10.0	10.1	9.7
Health care and social assistance	7.5	7.3	7.8	8.0	7.9	6.5	7.5
Arts, entertainment, and recreation	7.1	7.6	6.2	5.7	7.2	5.8	7.7
Accommodation and food services	7.1	7.2	7.9	6.7	7.2	7.0	6.5
Other services	8.0	7.5	7.7	8.0	7.5	8.4	8.5
Public administration	8.6	11.2	3.5	11.3	11.5	8.4	8.1
Other	5.6	6.1	3.5	6.0	7.6	10.1	5.4
Total	7.6	7.2	8.0	7.2	7.1	7.4	8.0

**Table 2.34.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by establishment revenue (in thousands of U.S. dollars) and NAICS 2-digit sector.

[See table 2.20 for the distribution of employment by establishment revenue. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	<\$100	\$101–250	\$251–500	\$501–1,000	\$1,001–2,500	>\$2,501
Agriculture, forestry, fishing, and hunting	2.5	4.3	2.4	2.2	2.3	2.6	1.2
Mining	10.7	10.4	6.8	11.0	6.7	4.6	12.8
Utilities	4.8	4.1	3.3	2.6	3.7	10.7	4.7
Construction	10.1	10.4	9.8	9.5	10.1	10.2	10.3
Manufacturing	9.8	8.9	9.2	8.7	8.5	9.2	10.0
Wholesale trade	8.6	8.4	8.2	7.4	8.5	8.3	9.0
Retail trade	8.2	8.1	8.3	7.6	7.9	7.8	8.5
Transportation and warehouses	7.6	9.8	9.7	7.7	8.5	8.1	6.0
Information	5.6	7.8	7.0	6.8	6.0	6.5	5.0
Finance and insurance	5.3	7.1	6.6	6.2	6.4	5.1	4.5
Real estate, rental, leasing	6.8	7.4	7.2	7.5	5.9	7.6	6.0
Professional, scientific, and technical services	6.0	7.6	6.7	6.7	6.1	6.4	5.0
Management of companies	5.4	4.8	6.4	5.6	5.4	6.8	4.3
Administration, support, and waste	6.9	7.8	6.2	6.2	7.1	7.8	7.5
Education services	10.5	10.8	11.5	11.2	11.0	12.0	9.8
Health care and social assistance	7.5	8.3	7.3	7.4	7.5	8.1	7.4
Arts, entertainment, and recreation	7.1	8.2	7.6	6.2	7.5	5.5	6.9
Accommodation and food services	7.1	8.1	7.9	7.8	7.2	6.1	6.1
Other services	8.0	8.2	7.9	7.9	8.6	7.5	7.6
Public administration	8.6	8.6	5.1				
Other	5.6	5.9	3.8	0.9	1.4	3.3	1.1
Total	7.6	8.2	7.3	7.6	7.6	7.7	7.6

**Table 2.35.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by type of establishment and NAICS 2-digit sector.

[See table 2.22 for the distribution of employment by establishment type. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	Stand alone	Headquarters	Branch
Agriculture, forestry, fishing, and hunting	2.5	2.5	2.8	10.1
Mining	10.7	8.8	13.6	0.3
Utilities	4.8	4.2	4.9	9.4
Construction	10.1	10.0	10.7	13.6
Manufacturing	9.8	11.2	7.9	11.2
Wholesale trade	8.6	8.2	9.6	10.7
Retail trade	8.2	8.2	7.2	9.7
Transportation and warehouses	7.6	7.4	8.3	9.0
Information	5.6	6.4	4.3	5.2
Finance and insurance	5.3	5.8	4.3	5.6
Real estate, rental, leasing	6.8	6.9	6.2	6.3
Professional, scientific, and technical services	6.0	6.1	4.9	9.8
Management of companies	5.4	5.2	5.7	11.0
Administration, support, and waste	6.9	6.8	7.0	12.1
Education services	10.5	10.8	9.7	12.2
Health care and social assistance	7.5	8.0	5.8	5.2
Arts, entertainment, and recreation	7.1	7.4	4.8	4.4
Accommodation and food services	7.1	7.0	8.6	7.1
Other services	8.0	8.0	7.0	7.1
Public administration	8.6	10.7	8.5	7.6
Other	5.6	5.6	5.2	
Total	7.6	7.7	6.9	8.7

**Table 2.36.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by business owner demographics and NAICS 2-digit sector.

[See table 2.24 for the distribution of employment by business owner demographics. NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Agriculture, forestry, fishing, and hunting	2.5	2.4	4.4	2.4	3.6	1.2	6.8
Mining	10.7	11.6	0.8	11.7	0.2	10.4	3.2
Utilities	4.8	4.8	3.1	4.7	2.3	26.8	6.8
Construction	10.1	10.0	12.6	9.9	11.6	10.8	14.7
Manufacturing	9.8	9.7	10.6	9.6	10.4	12.2	10.9
Wholesale trade	8.6	8.5	9.4	8.3	9.5	13.3	9.1
Retail trade	8.2	8.2	8.3	8.1	7.4	9.3	11.5
Transportation and warehouses	7.6	7.5	8.1	7.3	7.9	12.5	8.4
Information	5.6	5.5	6.8	5.5	6.3	7.4	8.4
Finance and insurance	5.3	5.3	7.3	5.2	7.2	9.7	7.6
Real estate, rental, leasing	6.8	6.8	6.9	6.8	6.3	6.8	9.7
Professional, scientific, and technical services	6.0	6.0	5.5	5.9	4.8	8.1	7.6
Management of companies	5.4	5.4	4.6	5.4	5.1	4.7	2.7
Administration, support, and waste	6.9	6.8	7.4	6.8	7.2	9.1	7.7
Education services	10.5	10.5	10.5	10.5	10.2	13.5	12.6
Health care and social assistance	7.5	7.5	7.8	7.4	7.7	11.5	8.5
Arts, entertainment, and recreation	7.1	7.1	8.0	7.1	8.3	7.2	6.2
Accommodation and food services	7.1	7.1	7.3	7.1	6.5	7.5	9.1
Other services	8.0	8.0	8.0	7.9	7.6	9.5	8.9
Public administration	8.6	8.6	0.0	8.6	0.0		
Other	5.6	5.4	8.6	5.5	10.6	3.2	4.9
Total	7.6	7.6	7.7	7.5	7.1	9.8	9.1



### Appendix 3. Building Damage Risk Results for the HayWired Scenario by Business Owner Demographics and San Francisco Bay County

These tables explain the large disruptive building damage risk for minority business owners found in this study that is caused by larger concentrations of minority business owners in Alameda County—the most heavily impacted county in the region.

**Table 3.1.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by business owner demographics and county.

County	Average risk across employees	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	25.0	24.9	25.7	24.9	25.9	26.1	25.0
Contra Costa	12.2	12.1	12.9	12.1	12.8	14.7	13.2
Marin	0.9	0.9	0.8	0.9	0.8	1.0	1.0
Napa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
San Francisco	1.3	1.3	1.3	1.3	1.3	1.4	1.4
San Mateo	2.1	2.1	2.1	2.1	2.0	2.5	2.5
Santa Clara	2.5	2.5	2.6	2.5	2.4	3.3	3.0
Solano	0.2	0.2	0.3	0.2	0.2	0.4	0.3
Sonoma	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.3	7.2	7.7	7.2	7.3	9.8	8.9

**Table 3.2.** Employment risk (in percent) from earthquake hazards in the HayWired scenario by business owner demographics and county.

County	Average risk across establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	24.4	24.3	25.3	24.4	26.2	22.1	23.8
Contra Costa	12.2	12.2	12.4	12.1	12.6	13.4	11.7
Marin	1.8	1.9	1.6	1.9	1.4	2.4	2.9
Napa	0.0	0.0	0.0	0.0	0.0	0.0	0.1
San Francisco	1.5	1.5	1.8	1.5	1.7	1.9	1.9
San Mateo	2.9	2.9	3.4	2.8	2.5	3.4	4.8
Santa Clara	3.5	3.6	3.2	3.5	2.9	4.0	3.9
Solano	1.2	1.3	0.7	1.3	0.6	0.9	0.9
Sonoma	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.6	7.6	7.7	7.5	7.1	9.8	9.1

**Table 3.3.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by business owner demographics and county.

County	Average risk across establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	26.2	26.2	26.9	26.1	27.1	27.2	26.2
Contra Costa	12.6	12.6	13.3	12.5	13.2	15.1	13.6
Marin	1.5	1.5	1.3	1.5	1.3	1.8	1.7
Napa	0.0	0.0	0.0	0.0	0.0	0.1	0.1
San Francisco	1.4	1.4	1.3	1.3	1.3	1.5	1.4
San Mateo	2.4	2.4	2.3	2.3	2.2	2.7	2.7
Santa Clara	2.9	2.9	2.9	2.8	2.7	3.7	3.4
Solano	0.9	0.9	0.8	0.9	0.8	1.1	0.9
Sonoma	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.7	7.7	8.1	7.6	7.8	10.3	9.4

**Table 3.4.** Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by business owner demographics and county.

County	Average risk across establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	24.4	24.3	25.3	24.4	26.2	22.1	23.8
Contra Costa	12.2	12.2	12.4	12.1	12.6	13.4	11.7
Marin	1.8	1.9	1.6	1.9	1.4	2.4	2.9
Napa	0.0	0.0	0.0	0.0	0.0	0.0	0.1
San Francisco	1.5	1.5	1.8	1.5	1.7	1.9	1.9
San Mateo	2.9	2.9	3.4	2.8	2.5	3.4	4.8
Santa Clara	3.5	3.6	3.2	3.5	2.9	4.0	3.9
Solano	1.2	1.3	0.7	1.3	0.6	0.9	0.9
Sonoma	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.6	7.6	7.7	7.5	7.1	9.8	9.1

**Table 3.5.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by business owner demographics and county.

County	Number of establishments	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	105,186	92.3	7.7	89.8	5.6	2.5	2.1
Contra Costa	73,127	93.1	6.9	91.7	5.5	1.4	1.4
Marin	32,458	91.7	8.3	91.0	7.5	0.7	0.8
Napa	12,334	92.5	7.5	91.8	6.8	0.6	0.8
San Francisco	82,230	92.6	7.4	90.3	5.6	2.2	1.8
San Mateo	60,163	92.9	7.1	91.2	5.6	1.7	1.5
Santa Clara	139,293	93.4	6.6	91.6	4.8	1.8	1.7
Solano	23,870	92.1	7.9	90.7	6.2	1.4	1.7
Sonoma	41,998	92.9	7.1	92.2	6.6	0.6	0.6
Total	570,659	92.8	7.2	91.0	5.6	1.7	1.6

**Table 3.6.** Distribution of employment (in percent) in the San Francisco Bay region, California, by business owner demographics and county.

County	Number of employees	Male	Female	Non-minority		Minority	
				Male	Female	Male	Female
Alameda	615,336	92.9	7.1	88.5	4.5	4.4	2.6
Contra Costa	324,598	93.2	6.8	90.9	5.0	2.3	1.8
Marin	133,599	92.5	7.5	91.8	6.5	0.7	0.9
Napa	63,453	94.3	5.7	93.2	4.9	1.1	0.8
San Francisco	532,713	94.4	5.6	92.1	4.0	2.4	1.6
San Mateo	343,010	93.0	7.0	90.7	4.4	2.4	2.6
Santa Clara	879,667	91.3	8.7	88.4	6.3	2.9	2.4
Solano	104,978	92.8	7.2	90.6	5.2	2.1	2.0
Sonoma	195,549	92.5	7.5	91.3	6.8	1.2	0.7
Total	3,192,903	92.7	7.3	90.0	5.2	2.7	2.0

## Appendix 4. Building Damage Risk Results for the HayWired Scenario by San Francisco Bay Subarea

This appendix contains four tables of building damage risk to businesses separated by subarea (seven San Francisco Bay region subareas that contain concentrations of extensive and complete damages in the HayWired scenario) with respect to the industry sector to which the businesses belong. The four tables pertain to two different ways of calculating risk: (1) average across

establishments and (2) employment-weighted average; risk is also calculated for two different sets of extensive and completed (disruptive) building damages: (1) from earthquake hazards only (no fire) and (2) from earthquake plus fire hazards. Also included in this appendix are two tables showing the distribution of establishments and employment in each subarea.

**Table 4.1.** Establishment risk (in percent) from earthquake hazards in the HayWired scenario by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments in 9 counties	Central Alameda County	Dublin-Pleasanton	North Alameda County	Novato	South Alameda County	Vallejo	West Contra Costa County
Agriculture, forestry, fishing, and hunting	21.1	32.4	19.4	22.4	0.6	11.2	0.5	35.8
Mining	26.6	45.6	27.3	28.0	1.2	15.4	1.1	52.3
Utilities	20.5	36.2	22.6	22.8	0.7	6.7	0.2	36.7
Construction	32.5	47.7	31.2	28.6	0.7	18.0	0.7	47.8
Manufacturing	27.3	41.4	26.4	26.0	1.2	11.4	1.0	36.8
Wholesale trade	25.6	38.8	22.7	23.3	1.0	10.7	0.8	33.0
Retail trade	24.9	39.3	22.9	19.8	0.7	12.8	1.1	36.1
Transportation and warehouses	26.0	34.9	21.0	21.1	0.8	12.5	0.6	37.9
Information	23.9	39.9	21.4	21.8	0.9	11.5	0.4	42.5
Finance and insurance	23.2	40.2	19.5	22.6	0.8	11.0	0.7	34.9
Real estate, rental, leasing	24.5	38.9	20.3	21.9	0.7	11.9	0.7	36.4
Professional, scientific, and technical services	22.9	38.3	19.9	22.0	0.8	10.9	0.6	38.2
Management of companies	22.4	37.0	18.3	23.2	0.4	9.4	1.1	33.9
Administration, support, and waste	23.7	38.3	19.4	23.2	0.5	12.0	0.4	39.2
Education services	22.7	37.3	21.0	20.3	0.7	11.0	2.0	32.9
Health care and social assistance	23.3	41.4	20.4	19.5	0.7	10.7	0.9	36.3
Arts, entertainment, and recreation	25.2	42.6	24.4	21.3	0.8	11.7	0.6	39.0
Accommodation and food services	24.9	42.7	23.2	18.2	0.7	12.6	1.2	38.4
Other services	24.1	38.6	21.5	18.5	0.7	11.9	1.1	34.2
Public administration	21.9	37.9	20.3	20.0	0.3	10.3	1.4	33.9
Other	19.5	31.5	13.0	18.5	1.1	8.4	0.2	18.6
Total	24.7	39.9	21.6	21.6	0.7	12.0	0.8	37.9

**Table 4.2.** Employment-weighted risk (in percent) from earthquake hazards in the HayWired scenario by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across employees	Central Alameda County	Dublin-Pleasanton	North Alameda County	Novato	South Alameda County	Vallejo	West Contra Costa County
Agriculture, forestry, fishing, and hunting	19.9	28.5	19.0	17.2	0.5	11.2	0.5	33.7
Mining	25.1	37.3	27.4	28.2	3.0	16.1	1.2	48.3
Utilities	19.3	22.2	26.6	21.3	0.6	5.7	0.1	52.7
Construction	29.2	44.8	31.8	27.0	1.1	14.8	0.8	38.4
Manufacturing	23.5	37.5	25.0	22.0	1.7	8.6	1.1	26.5
Wholesale trade	23.4	36.2	21.7	23.5	1.2	8.5	1.0	27.0
Retail trade	24.2	39.2	21.7	19.0	0.7	11.5	1.4	36.0
Transportation and warehouses	23.8	32.6	23.0	20.6	1.3	10.0	1.4	30.0
Information	18.2	44.9	21.8	19.1	0.9	6.6	0.3	44.2
Finance and insurance	18.1	39.7	18.2	20.2	0.5	10.3	0.6	32.9
Real estate, rental, leasing	24.5	40.4	20.5	21.0	0.6	11.1	0.7	37.0
Professional, scientific, and technical services	19.4	35.9	19.1	21.1	1.1	8.4	0.7	34.7
Management of companies	21.9	37.5	19.4	23.6	0.4	9.8	1.5	31.6
Administration, support, and waste	23.3	37.2	18.2	23.3	0.7	10.7	0.4	36.7
Education services	24.8	40.1	22.5	20.7	0.9	9.0	1.9	33.5
Health care and social assistance	22.7	40.4	21.2	17.6	0.7	9.8	1.0	33.6
Arts, entertainment, and recreation	23.7	42.5	22.5	21.2	0.9	11.3	0.5	36.0
Accommodation and food services	23.8	43.1	21.8	17.7	0.7	11.8	0.8	38.7
Other services	23.2	38.2	25.7	17.5	0.9	11.0	1.0	33.7
Public administration	20.8	52.8	24.2	18.8	0.4	9.6	0.7	37.0
Other	19.5	32.7	13.2	18.8	0.3	8.5	0.2	18.5
Total	23.0	39.1	22.2	20.4	0.8	9.6	0.9	34.5

**Table 4.3.** Establishment risk (in percent) from earthquake and fire hazards in the HayWired scenario by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Average risk across establishments	Central Alameda County	Dublin-Pleasanton	North Alameda County	Novato	South Alameda County	Vallejo	West Contra Costa County
Agriculture, forestry, fishing, and hunting	22.1	33.3	20.2	23.8	0.6	11.6	5.0	35.9
Mining	28.5	47.6	29.0	28.6	6.1	16.6	4.6	55.1
Utilities	21.2	37.1	23.7	23.3	0.7	7.8	0.8	37.2
Construction	35.0	50.2	34.1	30.4	4.3	21.1	5.9	48.9
Manufacturing	28.7	43.0	27.5	26.9	4.1	12.7	5.3	37.8
Wholesale trade	26.1	39.4	23.1	23.6	2.0	11.2	1.9	33.4
Retail trade	26.2	40.7	24.1	20.6	2.3	14.2	3.5	37.0
Transportation and warehouses	27.0	36.0	22.0	21.5	1.8	13.5	2.1	38.7
Information	24.9	40.9	22.2	22.6	2.9	12.8	2.5	43.1
Finance and insurance	24.1	41.1	20.4	23.2	2.1	12.1	2.5	35.6
Real estate, rental, leasing	25.3	39.8	21.1	22.5	1.7	12.9	2.3	37.3
Professional, scientific, and technical services	23.7	39.2	20.7	22.6	2.2	11.9	2.3	38.8
Management of companies	23.2	37.9	19.1	23.8	0.7	10.3	1.9	34.6
Administration, support, and waste	24.5	39.2	20.2	23.9	1.2	12.9	1.7	39.7
Education services	33.5	48.6	34.6	29.5	16.5	23.1	18.2	39.9
Health care and social assistance	24.5	42.5	21.6	20.6	1.9	12.6	2.7	37.3
Arts, entertainment, and recreation	26.3	43.6	25.4	22.1	2.8	13.0	3.3	39.7
Accommodation and food services	26.2	44.1	24.4	19.2	2.6	14.1	3.7	39.3
Other services	25.9	40.3	23.3	19.9	3.0	13.8	5.1	35.8
Public administration	26.3	41.6	23.1	22.3	0.3	16.5	26.3	36.3
Other	22.4	35.3	15.6	21.1	6.2	11.0	4.2	19.2
Total	26.1	41.4	23.0	22.7	2.5	13.5	3.5	38.9

**Table 4.4.**    Employment risk (in percent) from earthquake and fire hazards in the HayWired scenario by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

<b>NAICS sector</b>	<b>Average risk across employees</b>	<b>Central Alameda County</b>	<b>Dublin-Pleasanton</b>	<b>North Alameda County</b>	<b>Novato</b>	<b>South Alameda County</b>	<b>Vallejo</b>	<b>West Contra Costa County</b>
Agriculture, forestry, fishing, and hunting	21.2	30.1	21.5	18.7	0.5	11.6	3.5	33.8
Mining	28.2	38.7	29.2	28.7	16.0	17.2	5.0	52.5
Utilities	19.9	23.0	28.3	21.7	0.6	6.9	0.5	53.6
Construction	32.5	47.9	35.0	28.7	8.2	17.9	9.8	39.7
Manufacturing	24.9	39.3	25.9	23.1	6.9	9.8	5.7	27.3
Wholesale trade	24.0	36.9	22.1	23.8	2.4	9.0	2.1	27.6
Retail trade	25.3	40.4	22.5	19.9	2.2	12.9	3.3	37.5
Transportation and warehouses	24.7	33.6	24.2	21.1	3.7	11.0	2.7	31.0
Information	19.2	46.0	22.4	19.8	3.5	7.8	3.2	44.8
Finance and insurance	18.9	40.7	19.1	20.8	0.9	11.5	2.6	33.7
Real estate, rental, leasing	25.4	41.3	21.3	21.6	1.6	12.1	2.3	38.3
Professional, scientific, and technical services	20.4	36.8	19.9	21.7	3.3	9.6	2.9	35.7
Management of companies	22.8	38.4	20.1	24.3	0.7	10.8	2.0	32.9
Administration, support, and waste	24.2	38.2	19.0	24.1	1.8	11.7	1.9	37.5
Education services	35.4	50.7	36.9	29.5	22.9	18.2	30.2	45.5
Health care and social assistance	23.9	41.6	22.4	18.7	1.6	12.1	2.7	34.5
Arts, entertainment, and recreation	25.0	43.5	23.3	22.3	3.4	12.7	4.3	36.9
Accommodation and food services	25.1	44.4	23.4	19.0	2.1	13.4	2.6	39.6
Other services	25.1	39.9	27.4	19.0	4.7	13.0	5.7	35.4
Public administration	25.8	57.3	25.9	21.1	0.4	16.3	24.7	38.0
Other	21.6	35.2	15.9	21.0	0.9	10.7	5.9	19.1
<b>Total</b>	<b>24.7</b>	<b>40.9</b>	<b>23.5</b>	<b>21.8</b>	<b>3.4</b>	<b>11.2</b>	<b>5.5</b>	<b>36.0</b>

**Table 4.5.** Distribution of establishments (in percent) in the San Francisco Bay region, California, by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of establishments in 9 counties	Central Alameda County	Dublin-Pleasanton	North Alameda County	Novato	South Alameda County	Vallejo	West Contra Costa County
Agriculture, forestry, fishing, and hunting	412	20.9	12.9	30.1	8.0	12.6	5.3	10.2
Mining	34	17.6	11.8	26.5	8.8	20.6	5.9	8.8
Utilities	73	17.8	9.6	32.9	8.2	19.2	4.1	8.2
Construction	8,917	35.1	7.6	21.3	7.9	12.0	5.5	10.5
Manufacturing	4,640	34.3	6.8	25.0	4.5	19.6	3.0	6.9
Wholesale trade	5,352	35.9	7.2	23.5	4.8	17.9	3.0	7.7
Retail trade	10,168	30.9	6.8	28.5	4.0	13.8	5.7	10.3
Transportation and warehouses	2,891	43.9	5.4	19.7	2.6	13.5	5.3	9.7
Information	3,013	21.4	7.4	40.8	6.3	13.1	3.3	7.7
Finance and insurance	4,242	25.2	12.1	28.6	6.6	15.7	4.7	7.1
Real estate, rental, leasing	5,219	30.4	8.4	29.0	6.0	12.9	5.2	8.2
Professional, scientific, and technical services	18,242	20.8	9.7	38.7	5.8	14.0	3.5	7.5
Management of companies	266	23.7	14.3	31.2	4.1	15.4	4.5	6.8
Administration, support, and waste	22,043	26.5	8.4	26.8	7.1	16.2	5.5	9.4
Education services	2,395	23.0	8.0	38.5	4.5	12.9	3.7	9.3
Health care and social assistance	10,782	23.4	8.1	38.3	4.0	12.8	5.1	8.2
Arts, entertainment, and recreation	2,498	24.1	6.4	39.5	4.6	11.4	4.9	9.1
Accommodation and food services	4,712	26.9	7.2	36.1	3.6	12.1	4.7	9.3
Other services	13,395	31.7	7.2	28.3	3.9	12.3	6.5	10.1
Public administration	127	18.9	7.1	48.0	3.1	5.5	6.3	11.0
Other	83	28.9	8.4	37.3	4.8	8.4	3.6	8.4
Total	119,504	27.9	8.1	30.6	5.4	14.1	4.9	8.9

**Table 4.6.** Distribution of employment (in percent) in the San Francisco Bay region, California, by subarea and NAICS 2-digit sector.

[NAICS, North American Industry Classification System]

NAICS sector	Number of employees	Central Alameda County	Dublin-Pleasanton	North Alameda County	Novato	South Alameda County	Vallejo	West Contra Costa County
Agriculture, forestry, fishing, and hunting	1,426	19.0	9.4	37.3	4.8	11.6	3.1	14.8
Mining	144	20.1	19.4	18.1	12.5	14.6	6.2	9.0
Utilities	1,823	12.5	8.6	56.1	5.3	14.5	0.4	2.7
Construction	42,059	33.5	10.5	20.2	6.4	13.6	7.4	8.4
Manufacturing	99,457	36.1	8.3	19.4	1.2	30.7	0.8	3.5
Wholesale trade	39,038	34.2	10.1	21.1	2.9	24.3	1.0	6.4
Retail trade	48,312	27.3	18.5	25.6	3.1	12.7	4.3	8.5
Transportation and warehouses	13,834	40.9	5.2	27.7	1.9	13.1	4.1	7.1
Information	24,039	11.7	15.2	32.5	5.8	30.5	1.2	3.1
Finance and insurance	21,133	15.6	18.1	25.9	19.6	11.5	3.0	6.3
Real estate, rental, leasing	20,124	28.2	8.5	29.7	5.2	15.6	3.8	9.1
Professional, scientific, and technical services	75,728	14.0	12.8	39.4	5.1	21.6	2.0	5.0
Management of companies	631	21.1	15.1	27.7	4.0	19.8	4.3	8.1
Administration, support, and waste	66,000	25.4	9.4	31.8	6.1	14.3	4.4	8.5
Education services	24,650	28.7	5.3	41.4	2.4	11.9	3.6	6.8
Health care and social assistance	72,692	26.5	5.6	40.9	3.9	11.4	4.6	7.1
Arts, entertainment, and recreation	12,861	19.1	9.8	39.8	5.5	10.6	4.9	10.2
Accommodation and food services	46,070	24.4	9.8	38.3	3.7	11.0	5.1	7.7
Other services	46,061	27.5	11.3	31.8	3.1	11.8	6.2	8.3
Public administration	8,492	15.2	0.9	42.7	3.3	25.3	5.4	7.3
Other	278	32.7	11.5	30.6	10.8	9.4	1.4	3.6
Total	664,852	26.5	10.3	30.9	4.4	17.8	3.5	6.7



