Risk and Resilience: Building Disaster Preparedness in the Bay Area Food System

A Study Conducted for Sustainable Agriculture Education (SAGE)
Berkeley, CA

by
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Disclaimer:
The author conducted this study as part of the program of professional education at the Goldman School of Public Policy, University of California at Berkeley. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author and are not necessarily endorsed by the Goldman School of Public Policy, by the University of California or by any other agency.
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A resilient food system is one able to withstand shock with minimal disruption. Lack of sufficient analysis and prioritization of the Bay Area food system in resilience planning leaves the sector at risk of interruption from natural disaster, threatening regional food security. This analysis uses a mixed-input risk assessment methodology to detail risk variation across 38,000 Bay Area food system businesses in the event of a severe storm. Relative risk for each business is assigned based on a set of contributing vulnerability factors: location, access, and disaster preparedness. Recommendations for further analysis and resilience policy are based on the following results:

- Predicted lack of disaster preparedness among small businesses is the greatest contributor to overall regional food system risk.
- Nine percent of Bay Area food businesses are located in a sea-level rise zone or floodplain and are at high risk of flooding during a severe storm.
- Businesses in Marin County and in agricultural production are at greatest risk of interrupted business operations.
- The average business in San Francisco, Oakland, and San Jose is at lower risk than the average regional business.
- Food businesses in food insecure census tracts are similar in risk to the regional average.

This analysis finds that no intervention targeted to a single vulnerability factor will reduce regional risk more than 12%. To strengthen resilience in the regional food system, a combination of strategies is needed: policy interventions must address food-specific challenges as well as integrate food into whole-community approaches that strengthen the power, water, and communications systems upon which businesses rely. Specifically, regional and local governments should pursue the following strategies to build a resilient Bay Area food system.

- **Conduct a regional supply chain resilience study.** Distribution network tracking can reveal food business assets critical to regional food security. Resilience research beyond the supply chain will advance risk understanding of other food system components, including households and vulnerable populations.
• **Implement a small business disaster preparedness program** to address food business’ specific challenges such as food spoilage and regulation complexity. Include a limited cost-assistance recovery grant program post-disaster to address immediate business needs, while recognizing trade-offs with long-term mitigation.

• **Promote self-sufficient communities.** Interviews with food businesses reveal land pressures and labor shortages as top industry challenges. Housing, zoning, and public transportation policies promoting jobs-housing match will reduce daily economic pressures, promote sector development, and increase overall resilience to economic shock and disaster.

The food system is inherently regional in nature. While many initiatives require local government action, regional agencies are well positioned to coordinate implementation of a food resilience program and facilitate best practices sharing among municipalities. Local action, regional coordination, and better data collection can result in a regional food system resilient to future shocks.
INTRODUCTION

The Bay Area’s seven million residents depend on a fully functioning regional food sector. From corner stores and supermarkets to the farms that supply them, the region’s 38,000 food businesses are responsible for feeding one of the nation’s largest metropolitan areas. In the event of a disaster or external shock, that system is at risk of disruption. Should an extreme storm hit the Bay Area, total economic costs are estimated upward of $10 billion. Damages are only predicted to increase from more frequent and severe natural disasters attributable to climate change and sea level rise. Yet local efforts to strengthen regional resilience fail to account for the food system. Without understanding food system risk to disaster and addressing resilience needs, the $113 billion sector is in danger of interruption, with impacts to both businesses and consumers. This report seeks to spur additional food system resilience analysis by introducing a risk assessment and recommendations for resilience in the Bay Area food sector.

THE BAY AREA FOOD SYSTEM

The Bay Area food and agriculture sector is a key contributor to the region’s economy and cultural identity. The sector comprises 38,000 businesses in all parts of the supply chain, from agricultural production to manufacturing and distribution to retail and food service.

Figure 1. Number Businesses by Sector in the Bay Area Food System

Valued at $113 billion annually, the food economy employs nearly half a million people, roughly 13% of the region’s workforce. The Bay Area is internationally renowned as a progressive food system leader, from the organic and local foods movements to the food-tech startup scene. At the same time, while other regions are analyzing risk and building resilience in supply chains, the
Bay Area has to date lacked sufficient analysis and prioritization of the food system in resilience planning.

CLIMATE CHANGE AND NATURAL HAZARDS

The food system is threatened by extreme weather events linked to climate change. As the atmosphere warms, sea levels rise from glacier melt and expansion due to increased heat absorption.iii While ocean levels are rising more slowly on the west coast of the United States than the east coast, California’s sea level is predicted to rise between 36 and 239 cm by 2100 according to the California 4th Climate Change Assessment.iv

Figure 2. Bay Area 1-Meter Sea Level Rise Scenario

In parallel with rising seas, severe storms and other extreme weather events are increasing in frequency and intensity as a result of climate change. An extreme or severe storm is not formally defined by technical factors such as wind force or precipitation level, but typically refers to infrequent, unusually large storms with the potential to cause significant damage or loss of life.v While the Bay Area is not threatened by hurricanes, it is exposed to combinations of heavy rainfall, high tides, and extreme winds or “atmospheric rivers.”vi During a major storm surge, water levels can rise up to 3 feet above predicted sea levels.vii This combination of sea level rise and extreme storms can cause significant damage from flooding, landslides and associated debris, and interrupted public infrastructure.

Around 355,000 people and $46.2 billion in structures are located in a regional 100-year floodplain,viii an area with a 1% predicted annual chance of flooding. In total, the economic costs of a 100 to 200-year mega storm in the Bay Area are valued at $10.4 billion.ix While precise impacts of an extreme storm on the food system are unknown, all parts of the supply chain could
be threatened, potentially endangering regional food security. To protect food businesses and the food supply, it is necessary to understand the system’s vulnerabilities and strengthen its resilience.

**Hurricane Sandy Impacts in New York City**
Forty-three lives were lost. Two million residents and 70,000 businesses lost power. In 2011, Hurricane Sandy flooded more than 23,000 New York City businesses, with many more impacted by failure of public infrastructure. The 14 ft-high storm surge flooded 51 square miles of New York City, exceeding FEMA 100-year floodplain boundaries by 53%. Some hard-hit areas were without power for weeks. In total, the storm caused an estimated $19 billion in damages.

**RESILIENCE**

A resilient food system is one able to withstand external shocks, natural or otherwise, with minimal interruption. To reduce the time necessary after a shock to return to normal operations, strategies can adopt hazard mitigation or disaster response approaches. Hazard mitigation reduces long-term vulnerability and risk proactively (e.g., building codes, land use planning). Disaster response mitigates severity or duration of damage reactively, after a disaster occurs (e.g., emergency services assistance). After a severe storm, existing disaster response plans will work to deliver emergency food supplies to the region, mobilize community food banks, and ensure residents maintain a basic level of food access. However, the food system is not currently incorporated into hazard mitigation strategies. A mitigation approach would strengthen resilience of the existing regional food system to minimize impact, maintain operations, and reduce the need for retroactive disaster response measures. Adopting a hazard mitigation lens to build a resilient food system will result in a more stable supply chain, reduced disruption costs, and greater regional self-reliance.
Understanding risk is the first step in building a food system resilient to natural hazards and external shocks. This analysis develops a novel risk assessment methodology to detail risk variation across Bay Area food system businesses in the event of an extreme storm. A business is at risk of interrupted operations (partial, temporary, or permanent closure) when a severe storm occurs, though interruption can stem from a variety of sources. Food businesses heavily depend on infrastructure, power, water, and communications systems to function. Power keeps cold storage operating for refrigerated products and lights on for staff. Water is a key ingredient for many manufacturing processes. Roads and highways permit goods movement by truck as well as staff access to their places of employment. At the same time, businesses rely on operational supply chain partners for sourcing and distribution. If any of these systems fail, a business is at risk of interruption.

This risk is exacerbated if a business is particularly susceptible across contributing “vulnerability factors.” Each business’ resilience needs vary according to its unique dependencies on the above systems and functions, though certain characteristics can make one business more vulnerable than another. In an effort to examine interruption risk variation across businesses, this analysis assigns each food business a total risk score based on a set of three contributing vulnerability factors: location, access, and disaster preparedness. While this set is not exhaustive, it comprises three of the most critical influences on risk. For a more comprehensive analysis, this method can be expanded to incorporate additional vulnerability factors, such as dependence on power, water, and communications systems.

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1 For a complete methodology description, see Appendix I.
Location is the primary vulnerability factor. If a business is geographically located in a floodplain and/or a coastal area subject to sea level rise, it is at greater risk of interruption from flooding than businesses located outside these zones. Within these zones, businesses located in a 100-year floodplain (1% annual chance of flooding) are more vulnerable than those in a 500-year floodplain (0.2% annual chance of flooding). This analysis uses a Cal-Adapt one-meter sea level rise scenario combined with FEMA flood zone data\textsuperscript{xii} to determine risk of “exposure,” or vulnerability to direct flooding as a result of a severe storm.

Access is used in this analysis to represent dependence on transportation networks. To operate, a business must be accessible by roads and truck routes for both staffing and sourcing/distribution. If one route is compromised from flooding, landslide, or debris, a business must be accessible by alternate routes to continue operating. For purposes of this analysis, the fewer the major truck routes near a business, the more vulnerable the business.

The third vulnerability factor is disaster preparedness. Businesses are less likely to suffer damage from a severe storm if they have preparedness plans in place. These can include alternative staffing models, backup power systems, additional food storage spaces, food spoilage insurance, and others. Lacking data on businesses with existing preparedness plans, this analysis uses size, or number of employees, as a proxy for preparedness.\textsuperscript{xiii} Small businesses face a wide array of competing pressures and may not have the resources, financial or otherwise, to develop preparedness plans. In this analysis, the smaller the business, the more vulnerable. As additional preparedness data becomes available, more direct measures can be incorporated to further refine the model.

These three factors, each scaled from 0 (lowest vulnerability) to 1 (highest vulnerability), combine to establish an individual business’ total relative risk score. The resulting assessment can be used to study risk variation along numerous demarcations, including individual vulnerability factor, county, sector, city, and food insecure zones.

VULNERABILITY FACTOR

Regional risk varies by each vulnerability factor: location, access, and preparedness. Twenty-one percent of regional food businesses are located in a flood risk zone, either a sea level rise zone or floodplain. Nine percent are in a 100-year floodplain (1% annual flood risk) and 12% are in a 500-year floodplain (0.2% annual flood risk). Those in a predicted sea level rise zone and/or 100-year floodplain can expect more frequent inundation at greater depths than those in a 500-year floodplain. Marin County and distribution businesses are the county and sector businesses most vulnerable to flooding.
Figure 4. County Level Exposure Vulnerability

Figure 5. Exposure by County and Sector

<table>
<thead>
<tr>
<th>Percent County in Exposure Zones</th>
<th>Percent Sector in Exposure Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda: 3.7%</td>
<td>Production: 1.8%</td>
</tr>
<tr>
<td>Contra Costa: 0.9%</td>
<td>Manufacturing: 4.7%</td>
</tr>
<tr>
<td>Marin: 0.2%</td>
<td>Distribution: 6.6%</td>
</tr>
<tr>
<td>Napa: 22.5%</td>
<td>Retail: 3.9%</td>
</tr>
<tr>
<td>San Francisco: 17.7%</td>
<td>Food Service: 4.3%</td>
</tr>
<tr>
<td>San Mateo: 4.0%</td>
<td></td>
</tr>
<tr>
<td>Santa Clara: 0.6%</td>
<td></td>
</tr>
<tr>
<td>Solano: 0.1%</td>
<td></td>
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<tr>
<td>Sonoma</td>
<td></td>
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</tbody>
</table>
There are far more businesses vulnerable from lack of alternative access routes than from location. 87% of businesses are at high or very high risk based on lack of access compared to 9% from location. Preparedness is even more clustered in high risk categories, with 97% of Bay Area businesses at high or very high predicted risk from lack of preparedness. Figure 6 shows variation in distribution between location, access, and preparedness. With 30,000 businesses registering 10 or fewer employees, it is unsurprising to find preparedness is the greatest contributor to overall risk.

Figure 6. Vulnerability Factor Distribution
Analysis by vulnerability factor demonstrates which characteristics contribute most to total sector risk. While most food system businesses are not located in a floodplain, many are at risk of interrupted operations from dependencies on other systems (power, transportation, etc.) and lacking preparedness plans to continue operating in the event of a system failure.

**TOTAL RISK**

Combining vulnerabilities into a total risk score for each food business allows analysis of overall risk of interruption. This assessment finds risk to be relatively well distributed throughout the region with few high-risk hotspots, which may be a strength. Overall risk is moderate due to opposing risk forces of low location vulnerability and high access and preparedness vulnerabilities.
Figure 7. Regional Risk Variation

Very low
Low
Moderate
High
Very high
Total risk can be analyzed at county and sector levels as well. A county’s total risk score is the sum of its businesses’ scores proportional to the number of businesses within its jurisdiction. At the county level, Marin has the highest overall risk, though there is relatively little variation between counties. At the sector level, agricultural production has the highest overall risk, followed by distribution. Limited access routes in rural areas and few employees contribute to production’s high risk. Alameda County and food service have the lowest total risk scores by county and sector respectively. However, without normalizing by the number of businesses, Santa Clara and Alameda Counties have the highest “raw” risk scores. These heavily populated areas also have the greatest number of businesses.

**Figure 8. Risk Variation by County and Sector**

CITY

This analysis finds the average business in cities (San Francisco, Oakland, and San Jose) to be at lower risk of interruption from a severe storm than the average regional business. This may be due to greater numbers of truck routes running through urban areas. For all three cities, the vulnerability factor contributing most to total risk is preparedness, in line with the region overall.
Operating within the food supply chain risk framework, this analysis briefly surveys the relationship between risk and food insecurity. Food-insecure areas are defined at the census tract level using USDA Economic Research Service data. USDA parameters define food-insecure census tracts based on a combination of low-income (LI) and low-access (LA) data, where LA status is designated if a significant share of individuals is far from a supermarket. This analysis finds that average risk to businesses located in these tracts depends heavily on LA definitions. Using a ½-mile urban and 10-mile rural access standard, the average business in an LI-LA census tract is at slightly lower risk than the regional average business. Expanding food insecure census tracts based on an access limit of 1-mile urban and 20-mile rural results in the average business at slightly higher risk than the regional average.
As a result, this analysis fails to conclude there is a significant difference between risk to businesses in food insecure and non-insecure areas. However, difference in risk to individuals remains out of scope of this analysis. A business may be at equal risk of temporary closure in a food insecure tract as in a non-insecure tract, but there may be a greater population impact from closure in the food-insecure tract. With potentially fewer available alternatives for residents in a low food-access area, existing vulnerable populations may become at greater risk of food insecurity than in non-insecure areas. Therefore, despite the findings of this analysis, food-insecure areas warrant additional attention and prioritization in food system resilience approaches. Further research is required to fully understand the relationship between severe storm risk and food insecure populations.
POLICY INTERVENTIONS

Policy interventions can achieve a regional food sector risk reduction by improving disaster response or hazard mitigation. To build resilience through hazard mitigation, interventions can lower risk by reducing one or more vulnerability factor (location, access, preparedness). The following policy options each target one factor: **regional small business preparedness program, zoning for (re)location, and transportation corridor prioritization.**

*Small Business Preparedness Program*

A 2015 survey of national businesses found only 18% of businesses with fewer than 50 employees had a disaster recovery plan in place. A regional small business preparedness program would build risk awareness and disaster preparedness among small food businesses through a communications and training campaign. As small businesses are less likely to be prepared for disasters than large businesses, this program targets businesses with fewer than 50 employees to address those most vulnerable. There is an opportunity to pair this initiative with a more inclusive preparedness training incorporating small businesses outside the food sector, or with a broader food-specific resilience campaign encompassing economic development and other subjects beyond disasters. The training would disseminate food-specific business preparedness resources and build resilience capacity among owners and operators. Specifically, it could include some or all of the following: business preparedness plan development, targeted risk assessment training, non-perishable food storage maximization, and resource access training (e.g., business continuity and food spoilage insurance plans, FEMA assistance, SBA recovery loans). Trainings would also provide information about existing temperature and food spoilage regulations, many of which can delay a business’ reopening after a power outage or flood. Such a preparedness campaign would be implemented at the city level, but best facilitated at the regional level to promote knowledge sharing and best practices adoption.

In conjunction with a training and awareness campaign, a cost assistance grant program targeted to small businesses would provide additional risk reduction. This could take the form of backup diesel generator or business continuity insurance plan subsidies. Both are designed to reduce probability of permanent business closure and lost profits, either by continuing power supply and reducing food spoilage and/or reducing length of interrupted operations.

FEMA funds are available through the federal Local Hazard Mitigation Grant Program for backup generator purchase for hospitals and other critical facilities, but not for smaller private businesses. Backup diesel generators range in price, but at over $30,000 for equipment excluding installation, maintenance, and fuel storage infrastructure, they are beyond the reach of most small businesses. With a median annual revenue of $175,000 for Bay Area small food businesses in this sample, any cost assistance would need cover the majority of expenses to facilitate any
generator purchase. In addition, generators occupy a large area and require continued fuel supply. Fuel storage (particularly below-ground) is subject to complex regulation and is unfeasible for most small businesses. Finally, without periodic maintenance, it is not guaranteed a generator will function in an emergency. As a result, backup diesel generators were not pursued further as a feasible option in this analysis.

Business continuity insurance plans can limit damage from power outages or emergencies. Up to 40% of small businesses close after disasters and only 25% reopen.\textsuperscript{xvi} Not only is insurance more affordable than a generator, but it allows businesses that are lessees with limited options to make physical changes to space, such as installing a generator and fuel tank, to improve preparedness. Continuity plans vary greatly in price and do not all cover floods, but are estimated to average nationally at $1,200.\textsuperscript{xvii} A regional continuity insurance plan subsidy grant program for qualifying small businesses (those with a proven preparedness plan in place) would reduce the preparedness burden and with take-up, reduce vulnerability. Notably, this option does not mitigate a hazard’s initial damage, but acts retroactively to reduce impact duration and severity.
**Zoning for (re)location**

Zoning for (re)location would be designed to reduce the number of food businesses in high-risk flooding and sea level rise zones. To lower or limit the number of businesses in high-risk areas, local governments can implement tax incentives in non-risk zones to influence business location decisions. Specifically, overlapping priority zones such as Priority Production Areas can include hazard risk as a decision criterion in designation. Similar to Priority Conservation and Development Areas, Priority Production Areas respond to increasing land pressure with voluntary locally designated zones: PPAs would prioritize manufacturing, warehousing, distribution, and repair services in determining future land use. The precise mechanism and criteria are still under consideration and would need to reflect many competing priorities (e.g., existing industrial clusters, transportation and infrastructure requirements, worker and customer bases). This policy option would include low exposure risk as an additional criterion for PPA designation.

**Transportation Corridor Prioritization**

Transportation corridor prioritization would target the transportation routes most critical to the food sector for protection and repair. There are 14,000 Bay Area food businesses within one mile of Highways 101 and I-80, making these the two major truck routes proximal to the greatest number of food businesses. Total business reliance on 101 and I-80 is likely far greater; food businesses across the region use these throughways. Existing transportation resilience strategies, whether fortification or prioritized clearing, can be applied to these routes for the greatest food system impact.

**POLICY INTERVENTION ANALYSIS**

Each policy is analyzed across regional risk reduction and implementation feasibility criteria. Risk reduction measures the effectiveness of the policy option in lowering the total regional risk score. This is calculated by estimating reduction in vulnerability scores and total businesses impacted. The greater the regional risk reduction, the more effective the intervention. An additional qualitative consideration is contribution to long-term mitigation, or reduction of future hazard vulnerability. Some policies are designed to reduce damage extent post-disaster, while others target impact reduction prior to the disaster and so contribute more to long-term risk reduction.

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2 See Appendix for full policy analysis methodology, including assumptions and sensitivity analysis.
Implementation feasibility measures relative estimated cost, time to implement, and spillover benefits beyond the food sector. A highly feasible project would be relatively low cost, have a short implementation time frame, and include benefits beyond food businesses. Figure 12 shows each policy ranked on risk reduction and feasibility. There is a great amount of uncertainty in risk reduction; numbers provided are not meant to be exact but rather used as indicators for how each option fares relative to one another. This analysis focuses only on impact to existing food businesses. Any policy impacts on businesses newly created or new to the region are out of scope.

**Figure 12. Policy Risk Reduction and Feasibility**

A small business disaster preparedness training program is feasible to implement and has the potential to reduce risk for a large number of businesses. A small business preparedness training’s effectiveness in risk reduction depends heavily on program participation and take-up rates of risk-reducing practices. There has, however, been little regional data collection of take-up rates in similar programs. Of the options presented, it is the most feasible to implement. It is relatively low-cost, has a short timeline, and can build off existing resilience training programs. The addition of an insurance subsidy grant program increases effectiveness but lowers feasibility with the added program cost and administration needed. While disaster preparedness trainings contribute to hazard mitigation by reducing damage, insurance subsidies do not, focusing instead on reducing duration and severity of impact.

Challenges to implementation include limited resources for program management and low participation rates from small businesses facing competing pressures and priorities. To facilitate business participation, FEMA advises promoting the business case for preparedness and leveraging real world disasters and events.
Zoning for (re)location using the Priority Production Area structure is feasible to implement through voluntary zoning policy but has limited potential for risk reduction. Including flood risk as a criterion for priority use designation zones adds no cost or implementation time to the current process. However, the small share of businesses located in sea level rise and flood zones make this policy limited in its risk reduction potential. There are only 3,000 food businesses located in a 100-year floodplain. PPAs would only impact those businesses in manufacturing and distribution, of which 700 (10%) are in a 100-year floodplain. Depending on the incentives and other criteria used in designation, likely only a fraction of these businesses would take-up the program. If additional businesses were to locate in these areas in future, this policy may have greater effectiveness.

Transportation corridor prioritization has the potential for the greatest risk reduction but ranks low on implementation feasibility. Any measure improving resilience of Highways 101 and 80 would impact 14,000 proximal food businesses and likely many more. However, highway improvements are costly and according to local officials, I-80 is at particularly high risk of flooding and damage from natural hazards. The Bay Bridge/I-80 touchdown area already experiences inundation from annual extreme tides. Should I-80 be compromised by a natural hazard, the impact to food businesses would be marginal compared to the impact on the economy overall. With an aging regional transportation network and limited additional infrastructure building, this issue extends well beyond food and resilience measures are under consideration by local and regional agencies.

No single initiative will reduce overall food system risk significantly. Of the three, a disaster preparedness program for small businesses is most feasible and targets those businesses that are most vulnerable. The greater the participation, the greater the risk reduction. However, to effectively build resilience in the Bay Area food system, a combination of strategies is needed. Policy interventions must address food-specific resilience challenges, such as small business preparedness. At the same time, the food system must be integrated into whole-community resilience approaches that strengthen power, water, and communications systems. The food system, like other sectors, relies on interconnected regional infrastructure. Any intervention that builds resilience into these systems will build food sector resilience as well.

Food specific measures and whole-community approaches, in conjunction with improved data collection, are broken down into preliminary resilience recommendations below.
RECOMMENDATIONS

While all recommendations can be implemented simultaneously, improved data collection should be prioritized to better inform integration of the food system into existing resilience plans and documents. Food-specific strategies such as a preparedness program should be implemented concurrently with whole-community approaches.

Improve data collection to better understand food system risk.

- **Conduct a regional supply chain resilience study.** Distribution network tracking will permit analysis to determine critical nodes and regional assets. Process mapping can reveal the distribution facilities serving the greatest number of retail outlets, routes most trafficked by food goods movement, or supply chains providing the most economic value. Surveys of food business owners will develop a more complete understanding of disaster preparedness perceptions as well as co-dependencies on critical functions.

- **Address risk assessment limitations.** Surveys can more accurately capture disaster preparedness and transportation dependencies to replace proxies. The assessment can be expanded to include additional hazards and vulnerability factors. For example, businesses that have experienced prior disasters are more likely to be prepared for future disasters. This relationship between preparedness and location is unaddressed with this methodology. In addition, impact and scenario studies can be used to determine appropriate weights to apply to each vulnerability factor.

- **Research resilience beyond the supply chain.** To build a resilient food system, it is necessary to understand risk beyond businesses, including households, consumers, and vulnerable populations. Additional research is necessary to understand how food business risk intersects with regional food insecurity.

Address the food system’s specific resilience challenges and opportunities.

- **Implement a small business disaster preparedness program** targeted to address food business’ specific needs such as food spoilage and regulations. Consider including a limited cost-assistance recovery grant program post-disaster to address immediate needs, while recognizing trade-offs with long-term mitigation.

- **Maintain diversified sourcing** and distribution networks to ensure redundancy in the supply chain. Interviews with business owners suggest most already diversify for greater product reliability and financial stability. The greater the diversity in sourcing suppliers and modes of freight transportation, the more resilient the system in the event of a single-component shock. Businesses should maintain diversification, consider alternative transportation modes in preparedness planning, and consider sourcing from multiple geographical areas.

Integrate the food system into whole-community resilience approaches.

- **Develop more resilient power systems** and include food retail. A neighborhood-level microgrid pilot would reduce risk by connecting mixed businesses and services to an
independent grid. In addition to storage, a microgrid functioning as an energy generator paired with electric utilities can amortize high initial costs over more operation. Food businesses with cold storage have unique power needs. This must be accounted for in choosing microgrid generation sources, but is also an advantage: a resilient microgrid is one with diverse load types and generation sources.\textsuperscript{xxvi} The Berkeley Energy Assurance Transformation (BEAT) microgrid is under development at the City of Berkeley and can serve as a model for future regional neighborhood microgrids.

\begin{quote}
**Microgrid Pilot in Hartford, CT**

Hartford, CT installed a microgrid and fuel cell system in its Parkville neighborhood in 2017. Funded through the nation’s first state-level microgrid grant program, the 800-kW fuel cell microgrid uses natural gas to power an elementary school, library, senior center, and health center. During an outage, it will also power a local gas station and grocery store. In non-emergencies, excess power reduces electricity costs at four local schools. The public-private partnership included city and state agencies, local utilities, engineering and construction firms, and the Parkville community.
\end{quote}

- **Promote self-sufficient communities.** Interviews with food business owners reveal land pressures and labor shortages as top industry challenges.\textsuperscript{xxvii} When workers must commute across county lines, food businesses and communities at large become more vulnerable in the event of a disaster. Housing, zoning, and public transportation policies promoting jobs-housing match and allowing businesses to locate near workers and/or customers will reduce daily economic pressures, promote sector development, and increase resilience to economic shock and disaster.

- **Implement regionally.** Regional and local hazard mitigation plans, city resilience strategy documents, and other cross-sector resilience strategies should include food system analysis. The food system is regional in nature and will benefit from regional resilience coordination. While many initiatives require local government action, regional agencies such as the Association of Bay Area Governments or Urban Areas Security Initiative are well positioned to coordinate implementation of a food resilience program and facilitate best practice sharing among municipalities.
CONCLUSION

The Bay Area food system faces increased risk of disruption from more frequent and more severe storms. This analysis uses location, access, and preparedness vulnerabilities to assess relative food business risk across the nine-county Bay Area. Additional research is required to better understand risk, vulnerability, and critical assets in the food sector. To strengthen resilience in the food system, policy intervention at the regional and municipal levels should target food-specific resilience needs while integrating food into whole-community resilience strategies. In the short-term, a disaster preparedness training targeted to small food businesses can mitigate the largest sector vulnerability. Regional agency coordination and partnerships across municipal jurisdictions can facilitate knowledge sharing and best practices adoption. In the long-term, food system resilience will rely on whole-community approaches, from building redundancy in power systems to supporting communities where workers and businesses can co-locate. Policies promoting food sector economic development paired with disaster preparedness strategies will result in a regional supply chain resilient to any future shock.
CONTACT

To follow up, please contact Sibella Kraus at SAGE (sibella@sagecenter.org) and Beth Leuin (eleuin@berkeley.edu).
APPENDICES

1. RISK ASSESSMENT METHODOLOGY

This analysis uses 2016 Dun & Bradstreet data to create a Bay Area food sector dataset. It includes the 37,981 businesses listed in the nine-county Bay Area under the following NAICS code classification system. Each business is grouped into the following sub-sectors: production, manufacturing, distribution (wholesale and warehousing), retail, and food service.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Number Establishments</th>
</tr>
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<tbody>
<tr>
<td>Production</td>
<td></td>
</tr>
<tr>
<td>111 Crop Production</td>
<td>1,924</td>
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<tr>
<td>112 Animal Production and Aquaculture</td>
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<td>3253 Pesticide, Fertilizer, and Other Agricultural Product Manufacturing</td>
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</tr>
<tr>
<td>Wholesale Trade</td>
<td></td>
</tr>
<tr>
<td>42382 Farm and Garden Machinery and Equipment Merchant Wholesalers</td>
<td>88</td>
</tr>
<tr>
<td>4244 Grocery and Related Product Merchant Wholesalers</td>
<td>2,056</td>
</tr>
<tr>
<td>4245 Farm Product Raw Material Merchant Wholesalers</td>
<td>241</td>
</tr>
<tr>
<td>4248 Beer, Wine, and Distilled Alcoholic Beverage Merchant Wholesaler</td>
<td>1,028</td>
</tr>
<tr>
<td>Warehousing and Storage</td>
<td></td>
</tr>
<tr>
<td>49312 Refrigerated Warehousing and Storage</td>
<td>19</td>
</tr>
<tr>
<td>49313 Farm Product Warehousing and Storage</td>
<td>3</td>
</tr>
<tr>
<td>Retail</td>
<td></td>
</tr>
<tr>
<td>445 Food and Beverage Stores</td>
<td>6,845</td>
</tr>
<tr>
<td>446151 Food (Health) Supplement Stores</td>
<td>391</td>
</tr>
<tr>
<td>454210 Vending Machine Operators</td>
<td>242</td>
</tr>
<tr>
<td>Food Service</td>
<td></td>
</tr>
<tr>
<td>624210 Community Food Services</td>
<td>30</td>
</tr>
<tr>
<td>722 All Food Service and Drinking Places</td>
<td>20,006</td>
</tr>
<tr>
<td>Total</td>
<td>37,977</td>
</tr>
</tbody>
</table>

Adapted from The Bay Area Food Economy: Existing Conditions and Strategies for Resilience, SAGE and AFT.

Each business is assigned three vulnerability scores, one for each contributing factor (location, access, and preparedness). Scores are then combined into a total risk score using the below function. Lacking sufficient data to establish accurate weights, the risk score is unweighted by factor. However, the model is developed to include weights, should they be assigned. This model is additive as opposed to multiplicative under the assumption vulnerability factors do not operate interdependently. For example, a business’ size is not likely correlated with its location in or out of a floodplain.
\[ Risk = \alpha \times VF_1 + \beta \times VF_2 + \gamma \times VF_3 \]

VF = Vulnerability Factor
VF 1 = Location | VF 2 = Access | VF 3 = Disaster Preparedness
\(\alpha = 1\) | \(\beta = 1\) | \(\gamma = 1\)
\(\alpha, \beta,\) and \(\gamma\) may be adjusted to weight vulnerability factors.

To assign location vulnerability scores, the analysis uses a combination of Cal-Adapt 1-meter sea level rise scenario data and FEMA flood zone data obtained from the ABAG open data platform to create a 3-point vulnerability scale. Those businesses located in a sea level rise zone and 100-year (1% annual probability of flooding) FEMA floodplain are assigned a “3” for maximum vulnerability. Businesses located outside a sea level rise zone but within a 100-year floodplain are allocated a “2”. Those in a 500-year floodplain (0.2% annual flood probability) are assigned a “1” and businesses outside these zones a “0”. Additional nuance can be incorporated in future by further breaking down vulnerability into expected depth from sea level rise. Scores are then normalized from 0 to 1, with 1 maximum vulnerability and 0 minimum:

\[ VF_1 = \frac{LocationRisk}{\text{Max}(LocationRisk)} \]

To assign access vulnerability scores, the analysis intersects state truck route data with the nine-county Bay Area. A 1-mile buffer is created around each food business and the count of truck routes within the buffer assigned to each establishment. The vulnerability score is assigned and normalized as follows:

\[ VF_2 = 1 - \frac{RouteCount}{\text{Max}(RouteCount)} \]

To assign disaster preparedness vulnerability scores, the analysis uses size as a proxy, where size is measured by the number of employees. The natural log is used to account for high outliers and clustering of businesses with few employees. These scores again are normalized from 0 to 1 as follows:

\[ VF_3 = 1 - \frac{\ln(\text{EmployeeCount})}{\text{Max}(\ln(\text{EmployeeCount}))} \]
Table 2a. County Raw and Business Normalized Risk Scores

<table>
<thead>
<tr>
<th>County</th>
<th>Raw Risk Score</th>
<th>Number Businesses</th>
<th>Normalized Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>3,946</td>
<td>7,314</td>
<td>0.54</td>
</tr>
<tr>
<td>Contra Costa</td>
<td>2,384</td>
<td>4,103</td>
<td>0.58</td>
</tr>
<tr>
<td>Marin</td>
<td>1,041</td>
<td>1,535</td>
<td>0.68</td>
</tr>
<tr>
<td>Napa</td>
<td>1,314</td>
<td>2213</td>
<td>0.59</td>
</tr>
<tr>
<td>San Francisco</td>
<td>3,433</td>
<td>6,280</td>
<td>0.55</td>
</tr>
<tr>
<td>San Mateo</td>
<td>2,003</td>
<td>3,455</td>
<td>0.58</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>4,368</td>
<td>7,386</td>
<td>0.59</td>
</tr>
<tr>
<td>Solano</td>
<td>1,004</td>
<td>1,698</td>
<td>0.59</td>
</tr>
<tr>
<td>Sonoma</td>
<td>2,342</td>
<td>3,997</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Table 3b. Sector Raw and Business Normalized Risk Scores

<table>
<thead>
<tr>
<th>Sector</th>
<th>Raw Risk Score</th>
<th>Number Businesses</th>
<th>Normalized Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>2,195</td>
<td>3,527</td>
<td>0.62</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,694</td>
<td>2,901</td>
<td>0.58</td>
</tr>
<tr>
<td>Distribution</td>
<td>2,253</td>
<td>3,786</td>
<td>0.60</td>
</tr>
<tr>
<td>Retail</td>
<td>4,331</td>
<td>7,478</td>
<td>0.58</td>
</tr>
<tr>
<td>Food Service</td>
<td>11,209</td>
<td>20,036</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Figure 13. Raw Risk by County
**Food Insecure Census Tract Method**

This analysis uses low-income low-access data from the USDA Economic Research Service (ERS) Food Atlas to analyze risk in food insecure areas. Using 2010 census data, the ERS designates a census tract as low-income (LI) if the tract’s poverty rate is 20% or more or if the tract’s median family income is 80% or less of the metropolitan area’s median family income. Low-access (LA) census tracts are those where 500 or more individuals or 33% of the population or more are greater than ½ (or 1) mile from a supermarket or large grocery store in urban areas and 10 (or 20) miles away in rural areas, depending on how access is defined. To determine the relationship between LI-LA and risk, this analysis averages risk scores for each census tract proportional to the number of businesses per tract. The average tract score is calculated for LI-LA tracts using both measures of LA, then compared to the average regional tract score.

**II. POLICY ANALYSIS METHODOLOGY**

Risk reduction is calculated by estimating the number of businesses impacted by policy adoption as well as a range in reduction of individual vulnerability factor scores. These estimates are highly uncertain and results are not definitive. Instead, the method models how a framework can be applied to estimate total sector risk reduction given a set of inputs. Some uncertainty is accounted for through sensitivity analysis. Using the Monte Carlo method and 1,000 simulations, a mean risk reduction percentage is found for each policy option.

Assumption Tables

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Estimate</th>
<th>Estimated Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participating Businesses</td>
<td>5,000</td>
<td>---</td>
</tr>
<tr>
<td>Estimated Take-up Rate</td>
<td>Min 15%</td>
<td>Max 80%</td>
</tr>
<tr>
<td></td>
<td>Triangular</td>
<td>Preferred estimate = mean</td>
</tr>
<tr>
<td>Reduction in Individual Vulnerability</td>
<td>Min 50%</td>
<td>Max 80%</td>
</tr>
<tr>
<td></td>
<td>Uniform</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 14. Linear Risk Relationship with Participation Rate**

![Diagram showing the linear relationship between participation rate and risk reduction](image)
Table 5. Assumptions: Disaster Preparedness Cost Assistance

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Estimate</th>
<th>Estimated Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost Assistance Grant Recipients</strong></td>
<td>2,500</td>
<td>----</td>
</tr>
<tr>
<td><strong>Reduction in Individual Vulnerability</strong></td>
<td>Min 50%</td>
<td>Max 90% Uniform</td>
</tr>
</tbody>
</table>

Table 6. Assumptions: Zoning Incentives

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Estimate</th>
<th>Estimated Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eligible Businesses (manuf. &amp; distribution)</strong></td>
<td>6,687</td>
<td>----</td>
</tr>
<tr>
<td><strong>Estimated Take-up Rate</strong></td>
<td>Min 10% Max 40% Triangular Preferred estimate = mean</td>
<td></td>
</tr>
<tr>
<td><strong>Reduction in Individual Vulnerability</strong></td>
<td>Min 95% Max 100% Uniform</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Assumptions: Transportation Corridors

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Estimate</th>
<th>Estimated Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Businesses within 1 mile of Highways 101 and 80</strong></td>
<td>13,855</td>
<td>----</td>
</tr>
<tr>
<td><strong>Reduction in Individual Vulnerability</strong></td>
<td>Min 30% Max 90% Uniform</td>
<td></td>
</tr>
</tbody>
</table>

Monte Carlo Simulation Results

Table 8. Monte Carlo Simulation Results

<table>
<thead>
<tr>
<th>Policy</th>
<th>Risk Reduction</th>
<th>Standard Deviation</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disaster Preparedness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>2%</td>
<td>0.01</td>
<td>(1.9%, 2.1%)</td>
</tr>
<tr>
<td>Training + Insurance Subsidy</td>
<td>5%</td>
<td>0.004</td>
<td>(2.64%, 2.7%)</td>
</tr>
<tr>
<td><strong>Zoning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5%</td>
<td>0.009</td>
<td>(2.43%, 2.53%)</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12.8%</td>
<td>0.037</td>
<td>(12.6%, 13%)</td>
</tr>
</tbody>
</table>
Implementation Feasibility Scoring

Implementation feasibility is a 3-point index comprising cost, time to implement, and spillover benefits beyond the food sector. A highly feasible project would obtain a score of 3 with 1 point each for low relative cost, a short time frame, and benefits beyond food businesses. One limitation of this approach is the assignment of equal weights to each criterion. A transportation policy that has far-reaching benefits beyond the food sector may in fact carry enough weight to overcome other feasibility limitations such as cost and time.

Table 9. Policy Implementation Feasibility Scores

<table>
<thead>
<tr>
<th>Policy</th>
<th>Time to Implement</th>
<th>Estimated Relative Cost</th>
<th>Benefits Beyond Food</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>1</td>
<td>0.75</td>
<td>0.5</td>
<td>2.25</td>
</tr>
<tr>
<td>Training + Insurance</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Zoning</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
REFERENCES


Interview Contacts

Industry

Dan Bassian, CEO
Bassian Farms

Ben Chesler, Co-Founder/Chief Innovation Officer
Imperfect Produce

Michael Janis, General Manager
San Francisco Wholesale Produce Market

Martine Neider, Bay Area Urban Manufacturing Initiative Manager
SFMade

Bu Nygrens, Director of Purchasing
Veritable Vegetable

Albert Straus, Founder/CEO
Straus Family Creamery

Steve Sullivan, Founder/Owner
Acme Bread Company

Caleb Zigas, Executive Director
La Cocina

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Michael Germeraad, Resilience Planner
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Austin Nijhuis, Senior Research Analyst
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Amy Ramirez, Regional Project Manager, Risk Management
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United Food and Commercial Workers Western States Council

Serena Unger, Senior Policy and Planning Master
American Farmland Trust

Heather Wooten, Senior V.P. of Program Strategy
ChangeLab Solutions

Baltimore (Baltimore Food System Resilience Advisory Report), Boston (Resilient Food Systems, Resilient Cities: Recommendations for the City of Boston), Los Angeles, Madison, New Orleans, New York City, Portland, (The Resilience of America’s Urban Food Systems: Evidence from Five Cities.)


Ibid.


Personal communication, University of California, Berkeley.

Personal communication, City of Berkeley.

Personal communication, City of Berkeley and UASI.


Personal communication, City of Berkeley.


Personal communication, business owners.

Personal communication, University of California, Berkeley.

Personal communication, business owners.