Food and Other Flows in Case of Catastrophe

Philip J. Palin

Editor's note: *This is the first installment of a two-part invited article on food provision to population centers under normal conditions and in the aftermath of a regional catastrophe. Focusing on Washington's Puget Sound region, the present analysis depicts modern grocery supply chain complexity and the dynamics and drivers of food flow. It has a direct bearing on food supply planning during the COVID-19 pandemic. Assessing the impact on food provision of pandemic-related sheltering, workforce and other strategies should rely on the most accurate understanding possible of an area's food supply chain. The article should be helpful to public administrators and planners in marshaling available information to accomplish that.*[1] *The second installment, to be presented in the Winter 2020 issue, will portray the implications on food supply of a "black sky" seismic event in the same region.*

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Populations pull supply. Wealth pulls supply. Demand pulls supply.

Dense urban areas require huge volumes of supply. Pushing huge volumes to dense demand in a timely and affordable way requires a well-calibrated velocity of supply.

Contemporary demand and supply networks increasingly compete on velocity, very quickly fulfilling customized demand within largely commoditized flows. The price of personal preference is amortized across the shared cost of shared flow.

1 The exposition of this article departs from standard journal format in order to facilitate its use in pandemic and broader disaster planning.

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Infrastructure facilitates flow. When infrastructure is effectively engineered and operating, water and power flow; data, transactions, and money flow; and food, fuel, and other goods flow. Flow is fundamental to economies-of-scale (*aka* network effects).

When infrastructure fails, flows are disrupted. The potential for flow can survive infrastructure failure, but reclaiming this potential requires removing the disruption or redirecting flow.

In catastrophes involving dense populations, rapid recovery and redirection of pre-existing networks is crucial to providing survivors with essential supplies. Grocery flows are a meaningful proxy for a range of supply chains. Recovery and/or redirection require an accurate understanding of preexisting capacity, constraints, channels, and interdependencies.

For example, how (and where) infrastructure fails is fundamental. Does the disruption impact volume or velocity or both? Do timely alternatives exist for restoring volume and velocity? Do key players have the ability—and predisposition—to aggressively remove bottlenecks and/or find alternative channels? Or does the response to the disruption create *more* bottlenecks?

In most disasters, demand and supply networks demonstrate considerable flexibility and adaptability. But in catastrophic events—for example, the 2011 Triple Disaster in Japan or Hurricane Maria in Puerto Rico (2017)—pre-existing channels of transportation, communication, financial transactions, and more can be so seriously disrupted that feedback loops fray or break or send inaccurate signals. Fast, accurate feedback is fundamental to velocity. Without velocity, enormous volume can self-create congestion.

When catastrophe strikes a dense population, enormous volume is required. In most places, when the number of dependent survivors begins to edge over a half-million, only pre-existing supply networks have the volume needed to support extended survival. Relief channels can be crucial gap-fillers, but do not have the capacity to replace everyday network flows.[2]

Moreover, volume alone is not enough. In a disaster response, volume repeatedly piles up at staging areas with slow—or no—distribution to survivors.[3] Volume only has value when flowing toward demand in a timely way. Where there is long-term, wide-area power grid loss, telecommunications disruption, and diminished fuel distribution, velocity is constrained. Take out some bridges or major freight routes and bottlenecks multiply or the bottle itself breaks. In a catastrophe

2 Philip J. Palin, The Role of Groceries in Response to Catastrophes (CNA Institute for Public Research, 2017), https://www.cna.org/cna_files/pdf/Final-The-Role-of-Groceries-in-Response-to-Catastrophe.pdf.

3 European Institute for Asian Studies, *The Crisis Response to the Nepal Earthquake: Lessons Learned* (2016), http://www.eias.org/wp-content/uploads/2016/02/The-Crisis-Response-to-the-Nepal-Earthquake-_-Lessons-Learned-colour-1.pdf.

involving dense populations, unless the velocity of preexisting sources of volume can be quickly recovered, the secondary threat of supply chain failure may well endanger more human lives than the originating shock or stress.

Increasing Demand and Density Drives Increasing Velocity

In 1960, the US population was just over 180 million. At the start of 2020, the US population is more than 333 million. Sixty years ago, roughly 64 percent of Americans lived in urban areas. Today, over 80 percent live in urban areas.[4] During the second half of the twentieth century most "core" urban areas in the United States became less densely populated. [5] But there has been increasing densification of proximate suburbs (or edge cities).[6] The spatial concentration of wealth is even more pronounced.[7]

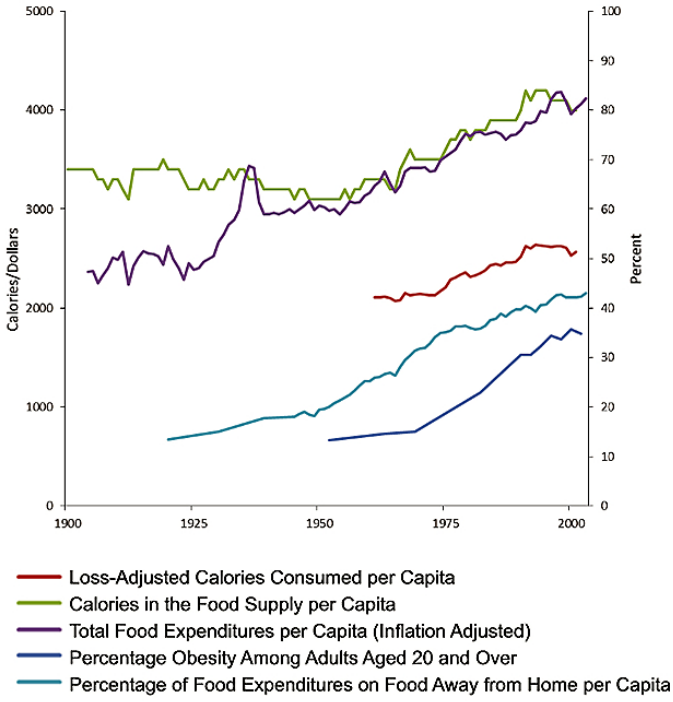

Figure 1. Aspects of the US Food Supply

4 US Census Bureau, *Population Distribution* (2010), https://www.census.gov/population/www/cen2000/censusatlas/pdf/2_Population-Distribution.pdf.

5 Gregory Ingram and John Whitehead, *The Distribution and Concentration of Population of the United States: 1900-2000* (2008), https://www.lincolninst.edu/sites/default/files/pubfiles/1346_675_Ingram Final.pdf.

6 Wendell Cox, *Growth Concentrated in Most Suburbanized Core Cities* (New Geography, 2015), http://www.newgeography.com/content/004948-growth-concentrated-most-suburbanized-core-cities.

7 Time Labs, *America's Wealth Map* (2015), http://labs.time.com/story/how-many-rich-people-live-near-you/.

During this same period of rapid population increase, the average per capita consumption of calories has also increased. Many more people are consuming much more food, as shown in Figure 1.[8]

The volume of food required to supply this increasing demand exceeds ordinary experience and, perhaps, even the imagination of many. For example, just considering groceries, every month more than 560,000 tons of processed food (not including raw agricultural products or alcohol)—worth more than $12 trillion per year—flows into Cook County (Chicago), Illinois. Even a much less populated place, say Mahoning County (Youngstown) Ohio, receives more than 35,000 tons of processed food per month, worth more than $240 million per year.[9] (Cook County's population is 5.2 million. Mahoning County has 230,000 residents.)

These are also very diverse flows. The average US supermarket offers over 33,000 different items for sale.[10] It is not unusual for a grocery store to have sixty thousand items. Retail formats receiving these flows have also diversified. Walmart Superstores, Kroger Marketplaces, and Costco Club Stores compete on selection. Aldi, Trader Joe's, and Lidl counter with careful curation. HEB, Publix, Albertsons, Giant, Winn-Dixie, Piggly-Wiggly, and others claim unique regional identities. Almost every grocery banner now competes with Whole Food's pioneering organic and prepared-food offerings. Dollar General has created a niche between full-service and convenience. Independents and boutique grocers differentiate themselves by location, personalized service, and products not otherwise available. Even as the top retailers claim a bigger proportion of the overall market[11], the number and range of retail locations continue to expand.[12] And almost every grocer is investing in curbside-pickup, prepared foods, and/or in-store dining in an effort to preempt Amazon's plan to repeat its bookselling success with home delivery of today's organic eggs, boutique bacon, heirloom tomatoes, and artisan bread.

In the fifteen years prior to 2002, Walmart accelerated from zero to market leader in grocery sales. Less obvious—but as dramatic—were changes in the distribution system supplying this dynamic retail competition. Walmart's phenomenal success was arguably the outcome of efficient supply chain strategies and practices that more experienced grocery competitors failed to match.[13]

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8 National Research Council, Institute of Medicine, *A Framework for Assessing Effects of the Food System* (2015), https://www.nap.edu/read/18846/chapter/5#49.

9 B.L. Ruddell, J. Miller, R.R. Rushforth, R. Salla, E. Soktoeva, and R. Gorantla, "FEW-View 1.0," *FEWSION Project.* April 29, 2019. https://fewsion.dtn.asu.edu/app/public?scenario_id=1.

10 Food Marketing Institute, *Supermarket Facts* (2019), https://www.fmi.org/our-research/supermarket-facts.

11 United States Department of Agriculture, Economic Research Service, *Grocery Retail Trends* (2017), https://www.ers.usda.gov/topics/food-markets-prices/retailing-wholesaling/retail-trends/.

12 Paul B. Ellickson, *The Evolution of the Supermarket Industry* (2015), http://paulellickson.com/SMEvolution.pdf.

13 Bobby J. Martens, Frank Dooley, and Sounghun Kim, *The Effect of Entry by Wal-Mart Supercen-*

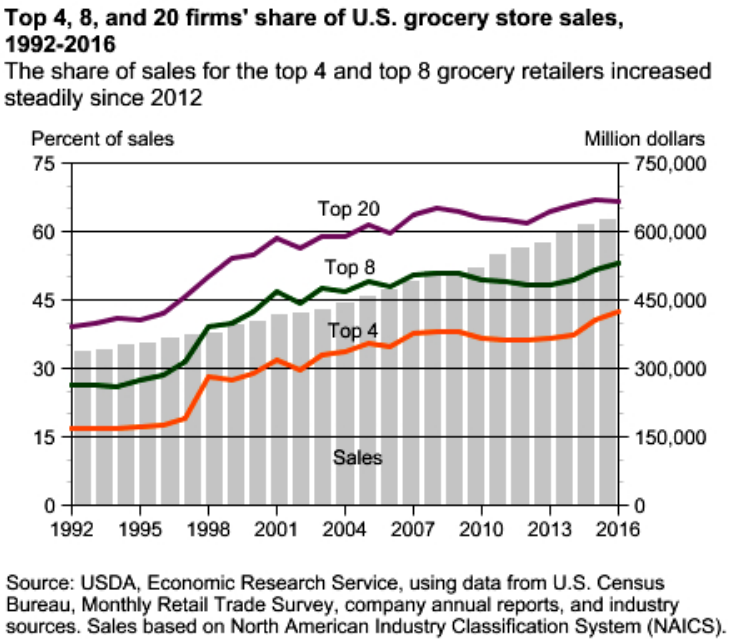

Figure 2. Change in the Grocery Market Share by Category

Year	Gourmet/L.A.	Supermarket	Supercenter	Independent	Chain Store	Total
1996	707	29,742	705	8,691	22,698	31,389
1997	722	28,168	821	7,688	22,260	29,948
1998	866	28,282	899	7,773	22,595	30,368
1999	1,165	27616	1,060	7,370	22,856	30,226
2000	1,807	27,913	1,263	7,696	23,750	31,446
2001	2,041	27,826	1,509	7,780	24,076	31,856
2002	2,169	27,831	1,720	7,939	24,273	32,212
2003	2,881	28,187	1,885	8,664	24,891	33,555
2004	3,285	28,085	2,114	8,662	25,247	33,909
2005	3,356	27,846	2,382	8,509	25,503	34,012
2006	3,527	27,201	2,659	8,468	25,355	33,823

Source: Author's calculation from Trade Dimensions TDLinx data

Figure 3. Change in Top Firms' Share of Grocery Market

The structure of grocery distribution in the United States was still responding to Walmart's sudden surge to dominance when the threat from Amazon began to emerge. By 2012, Amazon Fresh was delivering groceries in several cities, but was a negligible grocery competitor. It was Amazon's 2017 purchase of Whole Foods that has been widely perceived as the starting gun in a serious race for survival.[14] Whether a sprint, marathon, one-legged race, or relay is not yet clear.

ters on Retail Grocery Concentration (2006), https://pdfs.semanticscholar.org/5847/364d073b4a44dd58c4416c5678703827b652.pdf.

14 Business Insider Intelligence, *Online Grocery Report 2020* (December 2019), https://www.business

In October 2019, one financial analyst downgraded Kroger's stock, alleging a "multiyear mistake" as the firm continues to invest in a centralized distribution strategy, rather than more diversified, forward-deployed fulfillment functions.[15] Many other major retailers and distributors are developing alternative network designs, including Micro-Fulfillments Centers or MFCs. According to Grocery Dive: "The premise behind micro-fulfillment is simple enough: Improve the speed and efficiency of online order fulfillment while also relieving pressure on store inventory. The execution, however, is very complex, requiring a high volume of e-commerce orders to become economically viable. Time will tell whether MFCs offer long-term savings and speed of fulfillment that justify their hefty upfront cost."[16]

Demographic trends, shifting consumer preferences, continuing fall-out from the structural upheavals from the turn of the century, new and expensive technologies, and the high cost of experimenting with grocery e-commerce has resulted in increased consolidation in grocery distribution and even lower profit margins. According to the National Research Council:

> The U.S. food system has many features characteristic of a complex adaptive system, both in its structure and in its effects .... It has diverse and adaptive individual actors, with substantial feedback and interdependence among them, and it includes both spatial and temporal heterogeneity as well as an adaptive change dynamic.[17]

The food system is not unique in this regard. According to some scholars, *most* high volume, high velocity demand and supply networks fit the definition of a Complex Adaptive System. As early as 1999, it was argued:

> A SN (Supply Network) is a system. A slight change in one place may cause tremors everywhere else; the whole is more than the mere sum of its parts. Upon more careful examination ... one learns that a SN is more than a mere system. It is a complex adaptive system: it is emerging, self-organizing, dynamic, and evolving.[18]

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insider.com/online-grocery-report. The online portion of the grocery market remains between 5 and 7 percent, but has been growing rapidly. Whether this growth is financially sustainable is not yet clear. Home delivery faces financial challenges that store pick-up does not.

15 Jasmine Wu, "Kroger Made a Multiyear Mistake," CNBC, October 2019, https://www.cnbc.com/2019/10/10/this-fulfillment-method-could-a-multiyear-mistake-for-grocery-chains.html.

16 Jeff Well, "Micro-Fulfillment Companies Adapt to a Changing Industry," GroceryDive, September 2019, https://www.grocerydive.com/news/micro-fulfillment-companies-adapt-to-a-changing-industry/562962/.

17 National Research Council, Institute of Medicine, *A Framework for Assessing Effects of the Food System* (2015), https://www.nap.edu/read/18846/chapter/12.

18 Thomas Y. Choi, Kevin J. Dooley, and Manus Rungtusanatham, "Supply Networks and Complex Adaptive Systems: Control versus Emergence," *Journal of Operations Management* (2001). doi:10.1.1.477.1984.

In case of disaster, grocery is not the only high consequence flow. Access to water is even more time sensitive. Fuel, pharmaceuticals, other food flows and—depending on the context or individual needs—other products can be as essential to the preservation of life. But grocery flows are fundamental in themselves. They are also a meaningful functional proxy for other high-volume, high-velocity flows. Network dynamics for grocery, such as concentration, criticality, vulnerability, feedback, channeling, Just-In-Time, and bottlenecking are strategically similar for other products. A Consensus Study by the National Academies of Sciences, Engineering and Medicine found:

> Resilient supply chains are crucial to maintaining the consistent delivery of goods and services to the American people. The modern economy has made supply chains more interconnected than ever, while also expanding both their range and fragility. Every day, we move and consume a staggering number of pounds of groceries, gallons of freshwater, tons of fuel, kilowatt-hours of electricity, and myriad pharmaceutical products and medical goods. The procurement and distribution of these materials and capabilities depends on supply chains that are effective and straightforward to most consumers. This "effectiveness" is the result of complex and well-ordered networks that, in normal times, are both balanced and fragile. Their fragility, usually invisible, is vulnerable to a network disruption occurring many miles or days distal to the point of consumption that can be both catastrophic and long-lasting.[19]

How can we preserve or quickly recover this effectiveness in the context of catastrophe?

Urban Case Studies: Complexity and Catastrophe Preparedness

The National Risk Management Center at the Cybersecurity and Infrastructure Security Agency (CISA) of the Department of Homeland Security wanted answers to the question of catastrophe recovery noted above. Even more, CISA wanted a repeatable, scalable process to answer the question for different supply chains in various locations. In early 2019, CNA, a not-for-profit research institution that has spent several years focused on Supply Chain Resilience, worked with Puget Sound stakeholders to develop an answer.

The Supply Chain—if such an abstraction can have meaning—has emerged from multiple sources, channels, and processes for spurring and satisfying mass

19 National Academies of Sciences, Engineering, and Medicine, *Strengthening Post-Hurricane Supply Chain Resilience: Observations from Hurricanes Harvey, Irma, and Maria* (2020), https://www.nap.edu/catalog/25490/strengthening-post-hurricane-supply-chain-resilience-observations-from-hurricanes-harvey.

consumption for a plethora of products. Similar structures and functions recur across convoluted and sometimes tangled individual chains. Some behaviors can be generalized. But how these structures and functions behave is also shaped by diverse geography, demography, cultural patterns, and human intention, both individual and institutional.

Fundamental to the effectiveness referenced above is the status of bottlenecks: points of concentration—planned or unplanned—in the flow of goods. Planned concentration facilitates volume and velocity. Unplanned concentration—also known as congestion—constrains velocity even when potential volume is available. Mapping pre-existing bottlenecks, perceiving where flows are most likely to experience bottlenecks, and assessing where bottlenecks are—or could be—most consequential, provides a conceptual framework for understanding shifts in network behavior. Knowing who owns, operates, or otherwise can influence these bottlenecks provides a strategic framework for facilitating continued effectiveness.

Working with CISA, emergency management agencies, and stakeholders from the private and civic sectors in the Puget Sound region, CNA developed and tested the Supply Chain Operational Engagement (SCOPE) method.[20] This seven-step process begins with data gathering, network visualization, and assessment. Step 1 often selects a geography coincident with a Metropolitan Statistical Area or Major Trading Area. Step 4 includes validation or correction of data-driven findings by supply chain stakeholders. In Step 5, disaster scenarios probe the vulnerability and criticality of network nodes and links. This is undertaken through private-public workshops and tabletop exercises. Step 6 also requires significant private sector "insider" knowledge of bottlenecks. In Step 7, private and public stakeholders work together to identify pre-disaster priorities for preparedness and/or mitigation.

CNA's SCOPE™ method is, among other things, a practical application of network theory. Networks involve elaborations of nodes (or vertices or junctions) and links (or edges or arcs). Since the 1730s, we have abstracted the real world into paths and circuits between nodes. Since the 1990s, grocery flows have tended to feature larger and larger supply nodes (distribution centers), where flows of individual products are aggregated for allocation to multiple demand nodes (retail stores). Find these nodes of disproportional flow and it is usually possible to trace inbound and outbound links as well.

20 Lars Hanson, Joel Silverman, and Delilah Barton, *A Framework for Characterizing the Supply Chain Ecosystem for Lifeline Commodities* (CNA institute for Public Research, 2019). The SCOPE method is also outlined in *Supply Chain Quarterly, Seven Steps to Counter Catastrophe* (February 2020), https://www.supplychainquarterly.com/topics/Strategy/20200222-seven-steps-to-counter-catastrophe/.

Figure 4. The CNA SCOPE™ Method

Similar network structures are reflected in most high volume, high velocity demand and supply networks. It is not uncommon for a small set of distribution centers to handle a Pareto proportion of flows.[21] It is also not uncommon for these distribution centers to share proximate locations in what might be called "supply clusters," usually with quick access to key transportation routes and intersections. In the current century, Amazon and other e-commerce players have added to these points of concentration. (It is, however, more than rhetorical that Amazon calls their inbound-to-outbound hubs "fulfillment centers" rather than distribution centers. The 1990s were about supply efficiencies. The 2020s will be much more about fulfilling consumer expectations, especially for speed [see again the final paragraph on page 55 and first paragraph on page 56].)

Seventy to 80 percent of groceries consumed in the San Jose-San Francisco-Oakland Combined Statistical Area (population: 8.9 million) originate from five distribution centers. In 2019, the four largest of these five were located along a twenty-mile arc between Tracy and Stockton, California.[22]

21 John Connor, *Concentration and Mergers in US Wholesale Grocery Markets* (1997), https://core.ac.uk/download/pdf/7195545.pdf.

22 Philip J. Palin, *Grocery Supply Chain Resilience in the San Francisco Bay Area* (Filler Security Services/CNA/BAUASI, 2019).

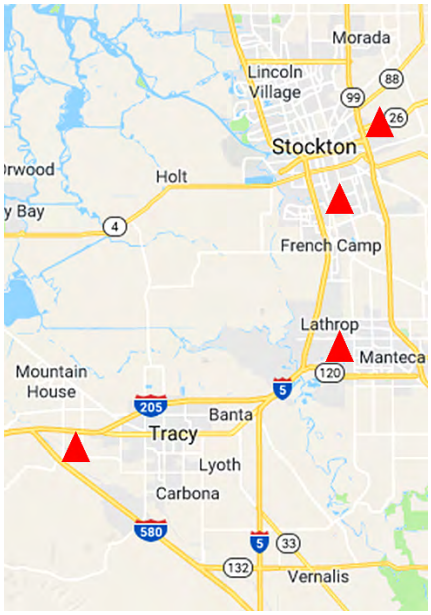

Figure 5. Four Largest Grocery Distribution Centers Serving the Bay Area

In the US grocery sector, this concentration of market share is more common than not. Medical goods and fuel markets demonstrate similar concentrations. The pharmaceutical market is arguably even more concentrated. Physical clustering of competitive supply nodes is less universal but not unusual.

The maps below show the location of the principal grocery (left) and fuel (right) suppliers for the Salt Lake City region. As these examples suggest, nodes and links tend to grow together; rich connections breed more rich connections.[23] The intersection of I-15 and I-80 in Salt Lake City is a "planned bottleneck" for thousands of square miles of the Intermountain West. I-580, crossing the Altamont Pass between Tracy and Dublin, California, carries more truck traffic than any other transportation link in the San Francisco Bay area. The George Washington Bridge is the neck of the hourglass for New York City. The pattern repeats again and again.

Actual delivery of groceries—or any product—depends on the interaction of nodes and links. Both are needed. Without transportation access, supply nodes may have enormous volume, but zero velocity. Less obvious but as vital is the aggregation of myriad smaller flows at distribution centers and the various functions that enable delivery to time-and-place of demand. Even if producers of volume

23 Matjaz Perc, *The Matthew Effect in Empirical Data* (The Royal Society Interface, 2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233686/. Also of interest in terms of market concentration effects, please see: Daqing Li et al., "Network Reliability Analysis based on Percolation Theory," *Reliability Engineering & System Safety* (2015), https://www.sciencedirect.com/science/article/pii/S0951832015001702.

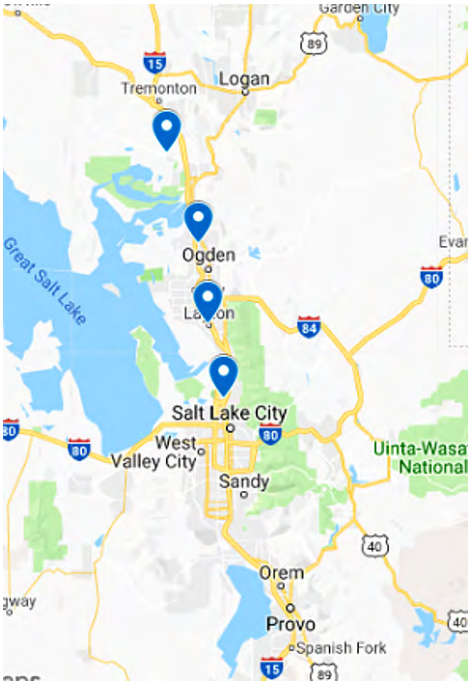

Figure 6. Principal Grocery Distribution Centers

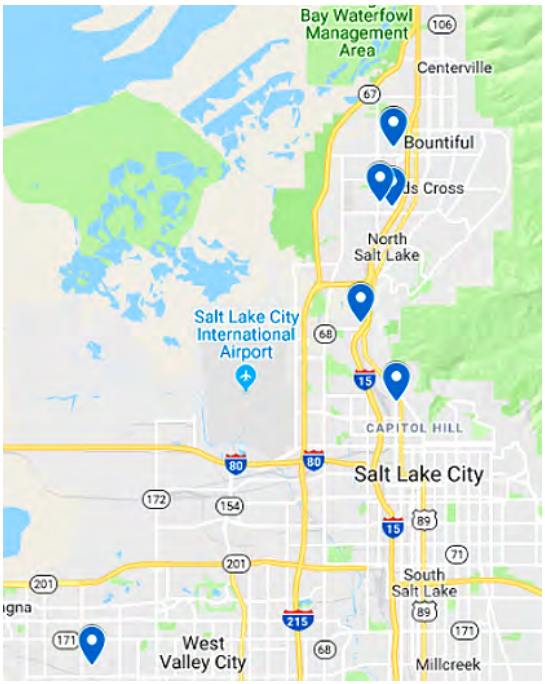

Figure 7. Principal Fuel Racks

continue to operate and transportation links persist, adequate velocity cannot be achieved in a timely and affordable way without the critical functions facilitated by distribution/fulfillment centers. The grocery supply chain is (as most supply chains are) an interdependent system-of-systems.

In many urban areas, a rough rendering of regionally important supply nodes and links can be guessed by a careful look at maps. Figure 8 is a screen capture of the area south of the Seattle-Tacoma airport from the Microsoft Building Footprint[24] database. Many of the large "white top" structures are distribution centers.

The seven-step method developed by CNA went well beyond a good guess. A data-driven, replicable, and scalable analytical process was developed and tested on grocery, water, and fuel flows in the Puget Sound region.[25]

In the case of groceries, the shape of demand—population, wealth, and accessibility—are widely available. Census data unveils concentrations and the opposite. Demand nodes are known. The United States Department of Agriculture maps the location of each certified retailer for the Supplemental Nutrition Assis-

24 Microsoft Building Footprints are available from several sources. The map on this page was constructed with the Arc-GIS interface, https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=f40326b0dea54330ae39584012807126.

25 Hanson, 6.

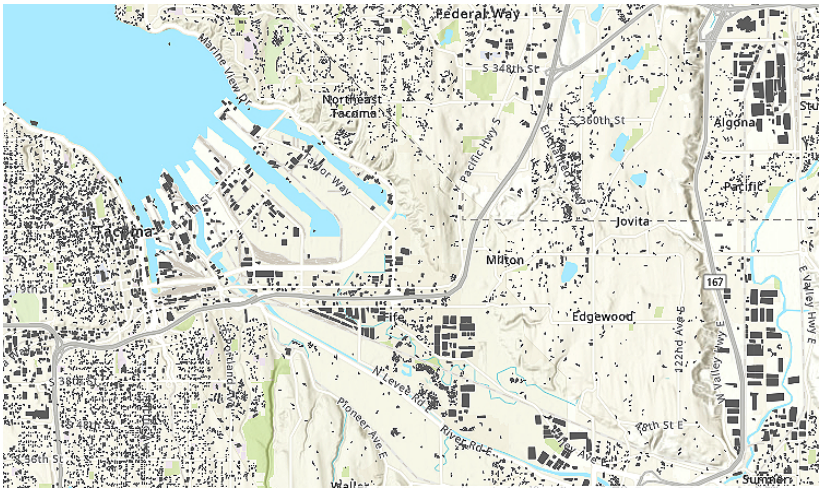

Figure 8. Microsoft Building Footprints in Pierce and King Counties, Washington

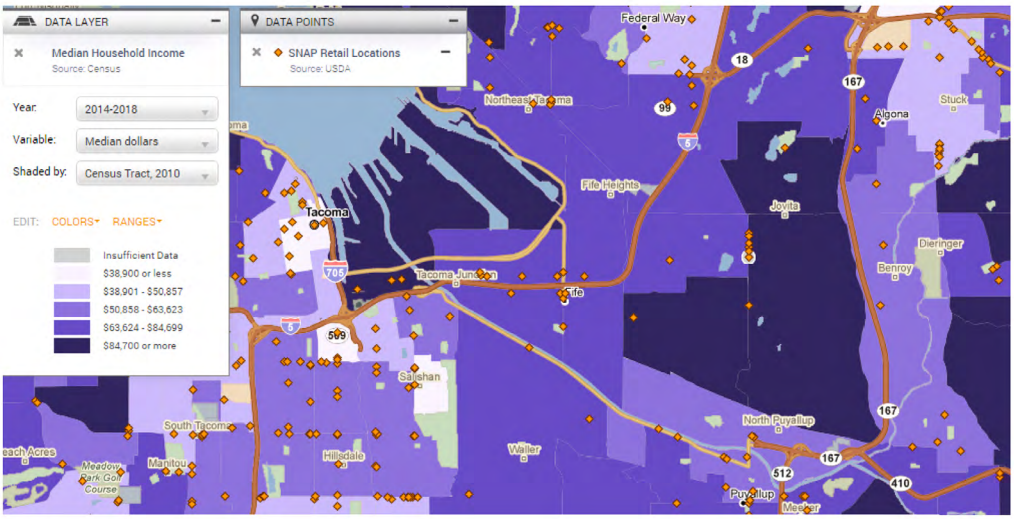

Figure 9. Median Household Income by Census Track with SNAP Retailers, Provided by PolicyMap

tance Program (SNAP).[26] Figure 9 is a mapping of median household income by census track plus the location of SNAP retailers for the same area shown above. The map was developed using the resources of PolicyMap.[27] Many PolicyMap resources are available at no charge, including the results of a multi-year study of market access and grocery "leakage" (mismatches of demand and supply). Deeper resources are available for a monthly subscription fee.

26 United States Department of Agriculture, *SNAP Retailer Locator,* https://usda-fns.maps.arcgis.com/apps/webappviewer/index.html?id=e1f3028b217344d78b324193b10375e4.

27 PolicyMap, OpenMap free resources, https://www.policymap.com/maps, or see details on subscription services, https://www.policymap.com/subscribe/.

SHELBY MARKET SHARES
Washington State

Company	# Stores	% Market	+ or - Change
Albertson's/Safeway	174	34.30%	-3.10
Fred Meyer/QFC	109	26.00%	+1.90
SuperValu/West*	139	10.80%	N/C
Walmart	35	10.20%	-0.50
United Natural*	25	4.40%	N/C
WinCo	13	3.80%	-0.50
U.R.M. Stores	30	3.00%	N/C
Trader Joe's	20	2.50%	-0.70
Grocery Outlet	42	1.80%	+0.10

Figure 10. Shelby Market Shares, Washington Grocery Retailers

Data sources on supply are less readily available than those related to demand, but data sources exist and are accessible. For example, publicly available market research identifies the leading grocery retailers. Figure 10 contains one example.[28] It begins to suggest the current level of competitive churn in the grocery industry. Costco, founded and headquartered in Seattle, is not listed. This is because it is considered a "grocery club" rather than a traditional supermarket. Other market studies place Costco as the number two grocery retailer in the Seattle area. As a result, just three distribution players—Albertsons, Costco, and Kroger (Fred Meyer/QFC)—are likely to be the source for at least 70 percent of grocery flow. Further, since this particular market estimate was completed, Supervalu/West and United Natural have merged and C&S Wholesale Grocers, the nation's largest wholesaler, has announced a major initiative to serve the Pacific Northwest. The top three are likely to remain in place for the next several cycles, but all sources of flow are shifting, sometimes very quickly.

Based on the foregoing, the volume and velocity of grocery flow in the Puget Sound region substantially depend on three providers. Including the top five providers allows tracking well beyond a Pareto proportion.

The distribution centers for these top suppliers are not difficult to find. In the case of Albertsons, Costco, and Kroger "banners" (such as Safeway or Fred Meyer or QFC), the retail locations are also easy to locate. It can be more of a challenge to map supply-to-demand connections for retail banners that do not self-distribute. UNFI (Supervalu), C&S Wholesale Grocers, and others can support a wide range of stores, from single outlets to well-known regional chains, such as Whole Foods or Giant.

28 *Shelby Report, Shelby Market Shares* (2018), https://www.theshelbyreport.com/about/, another common source of grocery market share estimates is the Nielsen Trade Dimensions-Linx database, https://www.nielsen.com/us/en/.

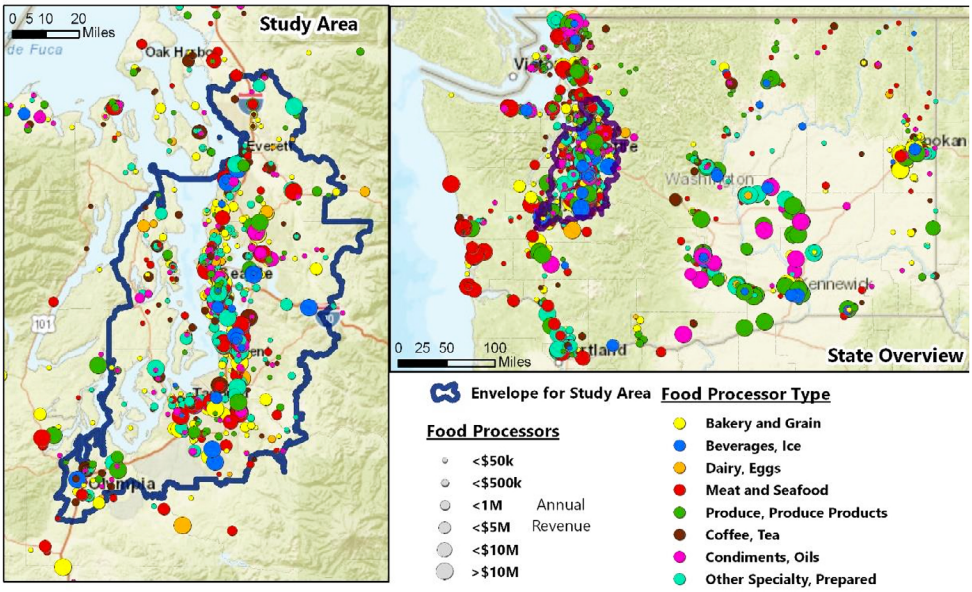

Figure 11. Food Processor Locations by Type, Annual Revenue in the Puget Sound Region

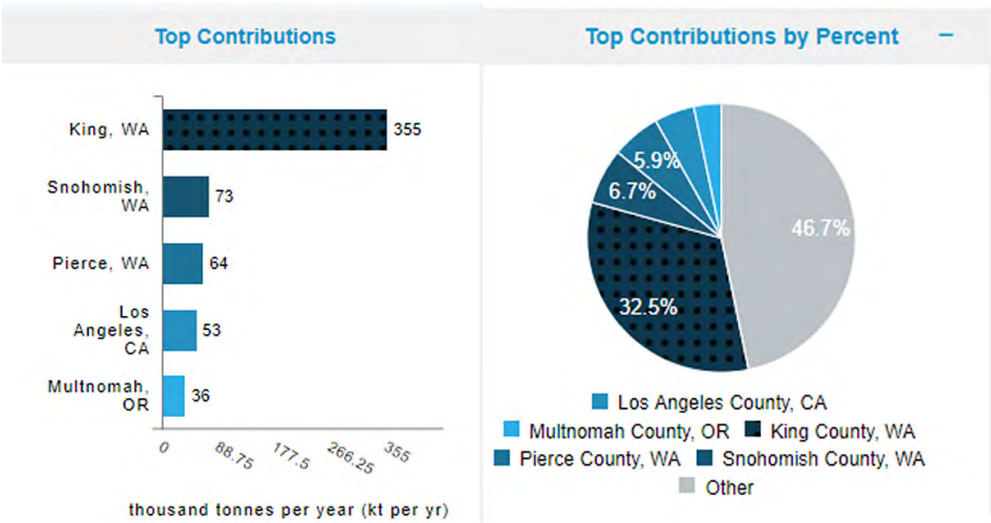

Figure 12. King County, Washington, Processed Food Places of Origin

When CNA began its Puget Sound research in early 2019, four of the five leading grocery distribution centers serving the region were located within roughly three miles of each other in and east of Tacoma (Figure 10). One of these suppliers was building a new distribution center in Centralia (about 55 miles south) that has since opened.

Sources of finished foods upstream from the distribution centers can be complicated for outsiders to identify, but even these more discreet flows can be

data-derived. Most states maintain lists of food processing[29] and food storage facilities[30]. The State of Washington Department of Agriculture cooperated with CNA to differentiate these facilities by recently reported sales revenue.

Various federal agencies track estimates and actual (where possible) measures of commodity flows. Recently, the FEWSION project at Northern Arizona University, with financial support from the National Science Foundation, has aggregated recurring data sources to display flows into and out of each state and county in the United States. As shown in Figure 12, flows of finished food for King County (Seattle) show that up to a third of food products are processed in King County and almost half of King County inflows of finished food products originate in the immediate Puget Sound region.[31] Additional sources are Los Angeles, Portland, Oregon's Willamette Valley, and Salt Lake City. While more analysis is needed, other studies have suggested that especially west of the Mississippi River, raw foods tend to flow to regional processing centers, such as Seattle, Portland, Boise, Denver, Salt Lake City, and Los Angeles. Foods are processed and packaged in these locations to feed urban populations, returning in processed form to feed non-urban populations, and for export.

These food flows principally depend on trucks, fuel and maintenance for trucks, truck drivers, and roads. In Washington State, the north/south I-5 corridor typically moves more than 14,000 trucks per day.[32] Nationwide, after construction materials, prepared foods and fuel are the largest freight commodities moved by truck.[33]

To serve a densely populated urban area, significant grocery volumes must move at well-calibrated velocities. Grocery volume and velocity depend on trucks and the dependencies that facilitate truck movement. A recent analysis of freight transportation resilience found:

> The resiliency of the freight network during times of disruption typically defaults to the private sector with some localized support from federal, state, and local governments in times of need .... Business continuity dictates that companies strategically manage freight movements along their supply chains and make investments to protect their businesses from risks. It is thus important to understand each supply chain stakeholder's priorities before, during, and after

29 Washington State Department of Agriculture, *Food Processor Licenses* (2018).

30 Washington State Department of Agriculture, *Food Storage Warehouse Permits* (2018).

31 Ruddell et al.

32 Washington State Department of Transportation, *Freight System Plan* (2017), https://www.wsdot.wa.gov/publications/fulltext/freight/Freight-Plan-2017SystemPlan.pdf.

33 US Department of Transportation, Bureau Transportation Statistics, *Moving Goods in the United States* (2017), https://data.transportation.gov/stories/s/Moving-Goods-in-the-United-States/bcyt-rqmu.

> a disruption. Primary objectives of private companies in incident response efforts are (1) ensuring safety, (2) getting traffic flowing again, (3) maintaining customer relations, and (4) ultimately ensuring that incident effects do not significantly affect the financial status of the firm.
>
> Primary objectives of public agencies (depending on their mandate) include (1) administering to the injured, (2) ensuring public safety (including community evacuations, if warranted), (3) managing disrupted traffic on public rights-of-way, (4) investigating the causes of the incident, and (5) cleaning up and recovering the public facilities that were affected by the incident.
>
> The competitive market environment makes it a challenge for public agencies to coordinate and support disaster preparation a priori—they cannot be viewed as favoring one firm over another. In the past, shippers and carriers have been reticent about sharing corporate logistics information, including recovery and service-resumption strategies. While the increasing number of natural disasters and other disruptive events has led, in some cases, to enhanced collaboration with private firms and industry groups, there are still few examples where this has occurred outside the context of emergency response.[34]

CNA's SCOPE™ method explicitly involves private firms and industry groups well before an actual emergency response. The outcomes of the first three steps of the process are vetted—and corrected—with chain owners and operators in step 4. In steps 5, 6 and 7, private sector stakeholders continue as active participants.

In the Puget Sound test case, several data-driven flow maps and other outcomes—in much more detail than reported here—were reviewed by the three top grocery providers, leading trucking firms, and others. These vetting discussions provided important context and further detail, but largely confirmed the places, routes, and proportion of grocery flows in the Puget Sound Region as generated from publicly available data-streams.

As a result, for the first time, major elements of both private and public sectors in the Puget Sound region share a common operating picture for "blue-sky" flows of grocery, water, and fuel. Key sources of volume, facilitators of velocity, routes of supply, and concentrations of demand are now known. Collaborative relationships among key players have been cultivated. This enhanced human net-

34 Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, *Freight Transportation Resilience in Response to Supply Chain Disruptions* (2019), http://www.trb.org/FreightTransportation/Blurbs/179096.aspx.

work is now considering how to better prepare to recover volume and velocity following a major black-sky event.

Infrastructure will fail. Cyclones, major seismic events, and cyber strikes will happen. Pandemics, wildfires, and floods can overwhelm. Many nodes and links will be destroyed. Flows will be seriously disrupted. Hundreds of thousands will be at risk. But what we have also seen—as in Japan on 3/11 and Puerto Rico in 2017—is that human networks can be very creative when other sorts of networks break, especially when humans have prepared themselves for broken possibilities.

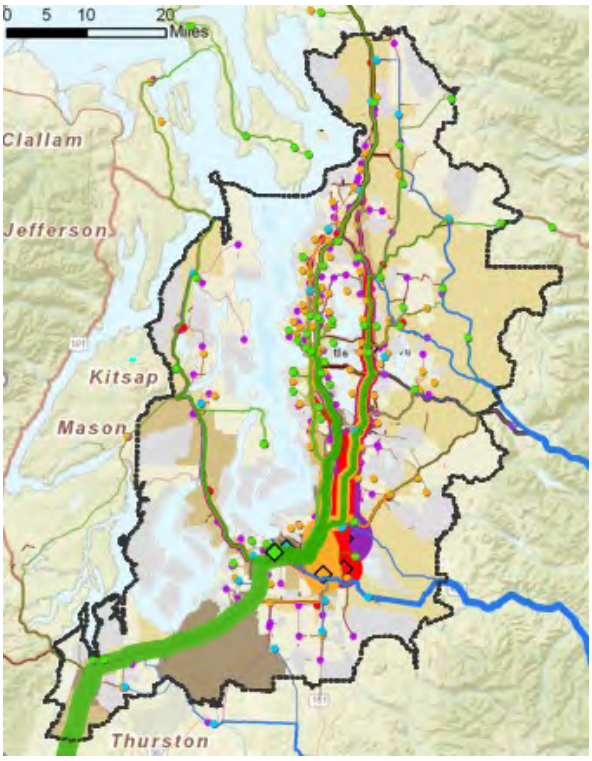

Figure 13. Principal Puget Sound Grocery Flows, Supply Node to Demand Nodes