The Role of Groceries in Response to Catastrophes

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Foreword

This research began with the hypothesis that for the grocery sector to serve as a significant source of nutrition following a catastrophic event[1], the federal government would need to undertake some level of strategic procurement. The purpose of the study was to examine issues of sizing and feasibility for such procurements.

Late in the research process, it became clear that data were actually confirming a sort of null hypothesis. Such procurements are unnecessary because the current shelf-stable stocks held by the grocery industry are much larger than anticipated.

Commercial inventories demonstrate that in case of a catastrophic event in a dense urban area, the grocery sector in the United States has the potential to be a robust partner in feeding survivors. The key impediment to serving this role, at least during the initial two to four weeks, is not a matter of supply, but delivery of extant supply. Evidence gathered during this research suggests that in the immediate aftermath of a catastrophic event, transport of existing supply by the grocery sector is likely to be significantly delayed. Given the current level of preparedness, transport could be disrupted for much of the first two or three weeks—arguably when the grocery sector's preexisting local supply could contribute most to saving lives.

The importance of this finding, especially in contrast with the original hypothesis, is difficult to overstate. Given the emergent nature of this finding, it is certainly appropriate to conduct follow-on studies. But, even if federal procurement were to be needed to access these supplies, such a measure would only be worthwhile if the procured product could be delivered to survivors.

Given the combination of surprising good news and challenging bad news, this report gives considerable attention to the grocery supply chain's context in the United States. Further analysis and any effort to solve the delivery problem must be well-calibrated to this context.

[1] For the purposes of this report, catastrophes are disasters in which recovery of prior conditions is not possible. Derived from the classical Greek *katastrophḗ,* these are extreme events—natural, accidental, or intentional—that reverse social expectations through wide-spread destruction, disease, death, and/or despair.

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Executive Summary

Catastrophic events involving dense urban areas—especially densities exceeding 3,000 people per square mile over a wide area—involve complex collections of socio-technical systems, including demand and supply networks. Any extreme, extended, and wide-area disruption of key supply chains poses an acute threat to dense populations. In effect, supply chain disruption can determine whether an event is "catastrophic" or not. Where supply chains persist, catastrophic consequence is unlikely. Where supply chains experience sustained failure, catastrophe is difficult to avoid.

Current public and private strategies for mitigation, response, and recovery do not adequately reflect supply chain dependencies, interdependencies, vulnerabilities, and potential opportunities for resilience in case of catastrophe. For dense populations under immediate threat, *replacing* broken supply chains is essentially impossible—the capacity required is beyond the capability of those outside the preexisting system; rather, quick recovery and agile redirection is needed. This is especially true for water, food, selected pharmaceuticals, and, often, medical goods. In catastrophic contexts, there is an urgent need for the operational recovery of these supply chains, or a post-disaster death toll will accelerate.

CNA funded this research and analysis out of recognition of the critical role that supply chains play in enabling effective response to and recovery from catastrophic events, and that non-resilience of supply chains has too often been a weakness in preparedness efforts. CNA is a not-for-profit institution with more than 15 years of experience working in homeland security, emergency management, and national preparedness. From this body of experience, CNA recognizes that supply chain resilience is critical to effective response to and recovery from catastrophic events.

Grocery supply chain

This study focuses on food and, more specifically, on groceries. In most urban areas, approximately half of all calories are consumed at home. These calories are mostly supplied by the grocery industry.

The National Research Council has characterized the United States food system as a complex, adaptive system:[2]

> *The food system is composed of a variety of actors, including human actors…institutions…and organisms. The decentralized behavior and interaction of these actors shapes and modifies the food system; at the same time, actors respond and adapt to changes in the system around them… Multiple interacting mechanisms across levels of scale can lead to interdependence among actors, sectors, or factors. Feedback loops can also arise… The presence of feedback, interdependence, and adaptation can produce dynamics in the food system with characteristics such as nonlinearity (a small change yielding a large effect), path dependence (dynamics strongly shaped by early events), and resilience (the ability to bounce back after a shock to the system).*

As an important part of this system, grocery demand and supply reflect significant resilience *and* the potential for catastrophic cascades. So, the question remains: How can resilience be enhanced and catastrophe avoided?

Preparing for catastrophe

The traditional public-sector strategy for disaster logistics has been to fill gaps with replacement supplies. This is helpful in signaling social solidarity and giving preexisting supply networks more time and space to adapt to post-disaster conditions. However, these gap-filling resources are much less than what is needed to meet preexisting capacities.

Recognizing that traditional approaches can be insufficient during response to a catastrophe, some have suggested enhancing capacity through public-sector procurement of Vendor-Managed Inventory (VMI) for disaster response. This approach is designed to integrate the public sector's need to prepare for low-frequency, high-consequence events with private-sector capabilities in sourcing, flow management, and delivery. Products that are appropriate for survival in the aftermath of an extreme event—and for which there is already significant market demand—can be made "surge-ready" through specific public-sector procurements.

[2] National Research Council. (2015). *A Framework for Assessing Effects on the Food System.* National Academies Press: https://www.nap.edu/catalog/18846/a-framework-for-assessing-effects-of-the-food-system

However, to date, VMI has not been a significant aspect of federal preparedness efforts. This study considers the plausibility and feasibility of such an approach for shelf-stable food. If feasible, several benefits could emerge:

- Substantial crisis-contingent resources could be maintained in a way that avoids expiration.
- Because such resources are maintained within the preexisting supply chain, they would (if surviving the event) be immediately present in the impact area and, potentially, accessible to survivors, even in the case of no-notice disasters.
- Planning for and exercising crisis-contingent VMI should enhance the likelihood of effective private-public collaboration in the aftermath of a catastrophic event.
- Implementing VMI could generate fiscal savings in comparison with current practices in disaster logistics.

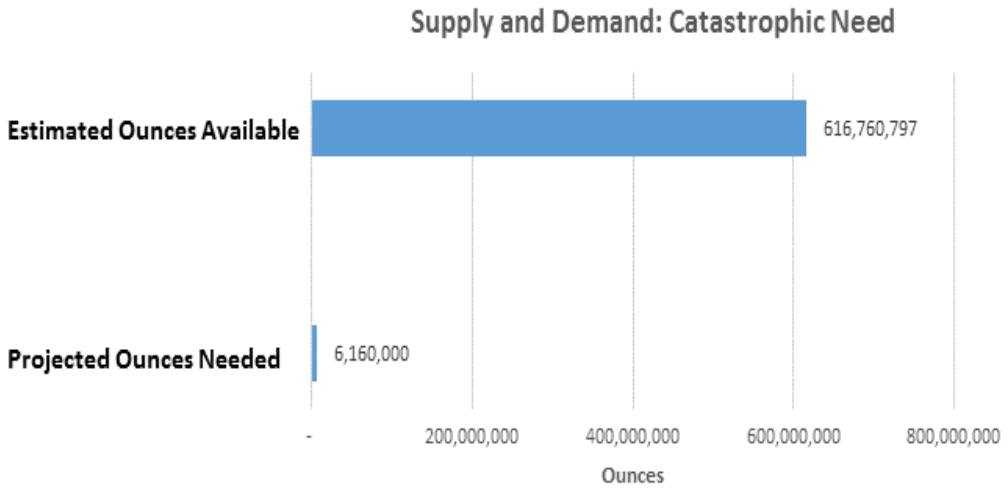
In a surprising discovery, **this study finds that plus-up procurements by the public sector are not needed**. Sufficient supplies of shelf-stable products already exist in the commercial grocery supply chain. **The problem is not a matter of supply, but one of delivery to survivors following a catastrophic event.**

Sufficient Supplies

Grocery inventories at the store level have narrowed over the last 50 years. A much-tighter match exists between near-term demand and available supply at most retail locations, reflecting "Just-In-Time"[3] supply chain disciplines. However, significant inventories (especially of shelf-stable products) exist at the distribution level. The price advantage of volume purchases, among other factors, continues to result in some "warehousing" of products, particularly shelf-stable ones. Of even greater impact is the velocity of demand for many popular shelf-stable products during a crisis, such as peanut butter, canned tuna, and ramen noodles. High demand in dense urban areas requires the staging of significant supplies. Turnover can be quick, but density of flow reflects density of demand. Figure 1 reflects total shelf-stable products on hand in one U.S. Metropolitan Statistical Area (top bar) against what that jurisdiction has projected as being needed to serve 300,000 displaced persons per day in a worst-case natural disaster.

[3] "Just-In-Time" is a measure and signal of current or very recent demand that informs, calibrates and pulls supply.

Figure 1. Supply and demand: Catastrophic need



Difficult to Deliver

Given the ongoing level of consumer demand for over 2,000 shelf-stable products, this study found that in most urban markets, **on-hand supplies of shelf-stable products far exceed the projected needs of displaced populations** in even the most extreme maximum-of-maximum scenarios. However, **it is entirely possible that this supply will be trapped in distribution centers** and remain undelivered to survivors.

Several sources of concern emerge when considering the provision of supplies to survivors, including:

- Survival of specific products following a disaster in the region;
- Survival of the distribution center and its functionality;
- Accessibility to and from a distribution center;
- Capability to support packaging and allocation of products;
- Availability of trucks, drivers, and fuel;
- Accessibility to survivors; and
- Resupply of distribution centers.

In some cases, it could be helpful for the federal government (or state or local governmental entity) to become a buyer of last-resort supplies that are available, but for which grocery distributors no longer have commercial customers and/or the capability to deliver during a disaster.

In any case, the crucial problem to be solved in the initial days following a catastrophic event is not insufficient supply of shelf-stable products, but capability to deliver this supply to survivors. These survivors include both those who remain in their homes and displaced populations.

Given the abundance of supply and impediments to delivery, **further attention should be given to issues of allocation, transportation, and emergency contracting with non-traditional sources of supply for disaster response.**

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Glossary

AWG	Associated Wholesale Grocers
DHS	U.S. Department of Homeland Security
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
JFO	Joint Field Office
JIT	Just-In-Time
LMD	Logistics Management Directorate
MSA	Metropolitan Statistical Area
NGO	Nongovernmental Organization
PKEMRA	Post-Katrina Emergency Management Reform Act
USDA	U.S. Department of Agriculture
VMI	Vendor-Managed Inventory
WHO	World Health Organization

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Context: Understanding Contemporary Supply Chains

The following four sections—FEMA's current disaster logistics strategy, urban concentration, emerging supply and demand networks, and network disruption—provide context for understanding contemporary supply chains, and the role supply chain systems play to enable effective disaster response and recovery.

Current Federal Emergency Management Agency (FEMA) strategy for disaster logistics

In the aftermath of Hurricane Katrina, federal policy and strategy called for an enhanced FEMA logistics capability. The Post-Katrina Emergency Management Reform Act (PKEMRA) states:

> *SEC. 636. LOGISTICS. The Administrator shall develop an efficient, transparent, and flexible logistics system for procurement and delivery of goods and services necessary for an effective and timely response to natural disasters, acts of terrorism, and other man-made disasters and for real-time visibility of items at each point throughout the logistics system.*

To implement this legal requirement, the FEMA logistics function was upgraded to a Directorate and realigned to be part of the Office of Response and Recovery with expanded funding and capabilities. In a 2010 annex to the *National Response Framework*, the Logistics Management Directorate's (LMD's) responsibilities were articulated as follows:

As the primary agency for Logistics Management, U.S. Department of Homeland Security (DHS)/FEMA has the overarching responsibility for execution of the responsibilities of National Logistics Coordinator. In this role, DHS/FEMA:

- Serves as the strategic coordinator and single integrator for logistics support;
- Collaborates and synchronizes resource support efforts with national disaster response partners;

- Leverages efficiencies in vendor networks and maximizes full capacity across all partners;
- Facilitates development and execution of the National Supply Chain Strategy; and
- Serves as the strategic coordinator and manager of the national supply chain.

DHS/FEMA divides its Logistics Management responsibilities along functional lines. These functions include:[4]

- Managing material, including determining requirements; sourcing; ordering; and replenishment, storage, and issuing of supplies and equipment. This includes network, computer, and communications equipment required to support Joint Field Offices (JFO) and other field operations.
- Managing transportation, including equipment and procedures for moving material from storage facilities and vendors to incident victims, particularly with emphasis on the surge and sustainment portions of response. Transportation management also includes providing services to requests from other federal organizations.
- Managing facilities, including the location, selection, and acquisition of storage and distribution facilities. Logistics is responsible for establishing and operating facilities, as well as managing related services to shelter and support incident responders in JFOs and other field-related operations, including Base Camps.
- Managing personal property, as well as policy and procedures guidance for maintaining accountability of material, and identification and reutilization of property acquired to support a federal response operation.
- Managing the Electronic Data Interchange to provide end-to-end visibility of response resources.
- Planning and coordinating with internal and external customers and other supply chain partners in the federal and private sectors, as well as providing for the comprehensive review of best practices and available solutions for improving the delivery of goods and services to the customer.

It is worth highlighting the statutory focus noted in the PKEMRA on "procurement and distribution." The Act also authorizes "additional logistics capabilities" as

[4] Interviews conducted with FEMA logistics officials.

needed to respond to catastrophic incidents. However, the scope and scale needed for catastrophic contexts are not explicit in statute. The annex to the *National Response Framework* can be interpreted as anticipating a role in a national supply chain strategy that would exceed what is procured and in the direct possession of federal agencies. But, since 2010, LMD has given most of its funding and attention to the statutory obligation to procure and distribute.[5]

For these purposes, the FEMA Directorate has significantly expanded its own logistics capabilities and has entered into interagency agreements with the General Services Administration, Defense Logistics Agency, and others. FEMA-LMD gives particular attention to: 1) Water, 2) Meals, 3) Cots, 4F) Tarps, 5) Blue Roofing Sheeting, and 6) Blankets. Stocks of these resources are maintained across the United States and associated territories. Primary Distribution Centers are located in Atlanta, GA; Fort Worth, TX; Cumberland, MD; Frederick, MD; Moffett Field, CA; Puerto Rico, Hawaii, and Guam. Stock levels fluctuate with disaster activity but currently comprise over 13 million items, with a total value of roughly $100 million.[6]

Many states also maintain emergency stocks of keys supplies. In some cases, emergency resources available are significant. Florida, for example, maintains 20,000 pallet positions or over 900 semi-trailer loads of resources.[7] The LMD and FEMA Regional Offices plan and exercise with state, local, and tribal emergency management agencies to coordinate logistical capabilities in case of disaster.[8]

There are also important disaster response resources beyond federal and state governments. In "Humanitarian Logistics in the United States" (2011), Jerrod Goentzel and Karen Spens explain:[9]

> *In addition to the governmental capacity, non-governmental organizations (NGOs) have long been essential partners in responding to incidents. The American Red Cross stands out among these NGOs since it was given a specific*

[5] Ibid.

[6] Ibid.

[7] State of Florida Division of Emergency Management, Unified Logistics Section. (2015). *State of Florida Unified Logistics Plan.* http://www.floridadisaster.org/Response/Logistics/documents/State%20Logistics%20Plan%20-%20Cover,%20Preface%20and%20Exec%20Summary%202015.pdf.

[8] Interviews with FEMA logistics officials.

[9] Goentzel, Jarrod and Spens, Karen (2011.) "Humanitarian Logistics in the United States: Supply Chain Systems for Responding to Domestic Disasters." Chapter in *Humanitarian Logistics: Meeting the Challenge of Preparing for and Responding to Disasters*. Eds. Martin Christopher and Peter Tatham. Kogan Page, London.

> *charter by the US Congress in 1900 as the official US disaster relief organization to "carry on a system of national and international relief in time of peace, and to apply the same in mitigating the sufferings caused by pestilence, famine, fire, floods and other great national calamities." Many of the NGO's are faith-based, such as the Salvation Army and various denominational organizations. During Katrina, significant capacity came from the private sector, which hand not traditionally been associated with disaster response. Several companies effectively made preparations for the impending disaster long before Katrina hit and were will and able to bring resources to the disaster area before government agencies in many cases.*

A private-sector role was prominent again in the response to Superstorm Sandy and in a number of local disasters, including water crises in Charleston, WV and Flint, MI; as well as recovery from tornado strikes in Joplin, MO and Moore, OK (and elsewhere). The private sector has self-organized through not-for-profit organizations such as the American Logistics Aid Network[10] and Healthcare Ready[11]. FEMA and several state emergency management agencies seek to facilitate and, in some cases, coordinate private-sector disaster response. In recent years, there has been a proliferation of state and local Business Emergency Operations Centers or similar mechanisms for such coordination. At FEMA, a National Business Emergency Operations Center has been launched by the Private Sector Division as a "clearinghouse for two-way information sharing between public and private sector stakeholders in preparing for, responding to, and recovering from disasters."

Most often, the private-sector response to disaster is a concentrated effort to get back to business as usual as soon as possible. This is often undertaken in parallel with official disaster-response and -recovery activities, but with little or no communication between the private and public sectors.

In the vast majority of disaster situations, the lack of specific coordination with the private sector does not complicate the ability of public and private systems to serve survivors. The "spontaneous" recovery of supply networks demonstrates the system's resilience. Furthermore, in recent years, FEMA has shown considerable effectiveness in serving disaster survivors who have been unable to depend on commercial supply chains (see Table 1).

[10] http://alanaid.org/

[11] https://www.healthcareready.org/

Table 1. FEMA's logistics system performance -- percentage of orders for required, life-sustaining commodities and key initial response resources delivered by the agreed-upon date, fiscal years 2010–2014

Fiscal year	Target value (percent)	Actual (percent)
2010	80	97.5
2011	85	93.3
2012	95	92.8[a]
2013	95	95.4
2014	95	97.9

Source: United States Government Accountability Office (2015). "*Emergency Management: FEMA Collaborates Effectively with Logistic Partners but Could Strengthen Implementation of Its Capabilities Assessment Tool*." GAO-15-781. 16.

[a] In DHS's *Annual Performance Report, Fiscal Years 2012–2014*, FEMA states that there were several reasons for 2012 performance falling short of the target, including a lack of availability and delayed arrival of shipments for some transportation carriers during weather events in late June 2012, changes in original delivery locations of shipments without an adjustment to the established order-requested delivery date, and a small number of partner-sourced vendors that did not meet planned timelines for sourcing and movement during Hurricane Isaac. FEMA added that none of the delayed orders affected mission support.

There is, however, growing concern among some emergency managers that what has proven effective in larger-scale notice-events (e.g., hurricanes) and smaller-scale, no-notice events (e.g., tornadoes) may not be effective in potentially catastrophic disasters involving multiple events over a multi-state area, such as the New Madrid Seismic Zone or Cascadia.

Conceiving a financially and operationally realistic solution to the catastrophe challenge has been difficult. In 2005–2006, FEMA engaged in a sustained process of strategic planning to increase its stock and transportation of commodities for "no-notice/All Hazard(s) multi-state/multi-events." Planning assumptions focused on supplies necessary to support 500,000 survivors for a period of 10 days delivered in less than 48 hours.

An Acquisition Plan[12] and a promising process of Request-For-Proposals was conducted during this time. Then, in 2007, FEMA judged that the large-scale

[12] FEMA, Acquisition Management Division. (2007). Commodity Storage and Support Services HSFEHQ-060R-0050..

operation anticipated was beyond the then-available competence of FEMA and its partners. Considerable progress has been made in subsequent years.[13]

Core concept of Vendor-Managed Inventory

This study has its origins in a renewed effort to meet needs during a catastrophe. The research question involves how the strategic capacity of private-sector food networks—and especially grocery networks—can become a well-assured strategic asset in responding to catastrophic events. It has been proposed that a well-targeted FEMA procurement of shelf-stable inventory managed by private-sector vendors would significantly improve the national capacity to feed the survivors of a wide-area, extreme event involving a dense urban area.

Vendor-Managed Inventory (VMI) varies depending on who owns what products, when and how ownership of a product is transferred, and where products are stored. The Supply Chain Resource Collaborative at North Carolina State University offers this generalized definition:[14]

> *In VMI[,] a manufacturer or distributor assumes the role of inventory planning for the customer. Extensive information sharing is required so that the manufacturer/distributor can maintain a high degree of visibility of its goods at the customer's location. Instead of the customer reordering when its supply has been exhausted, the supplier is responsible for replenishing and stocking the customer at appropriate levels.*

Inventory planning is a persistent challenge for FEMA. This is especially the case for low-likelihood, high-consequence events where the FEMA role is arguably most important. Maintaining sufficient stock levels for a sudden surge in demand at any time and at any place in the territories of the United States is not a common supply chain benchmark. There is a particular concern to ensure access to sufficient supplies in case of a no-notice catastrophic event involving a dense urban area.

Inventory management is also a challenge for FEMA. Even shelf-stable stocks will eventually expire. The larger the stockpile of emergency supplies, the more likely

[13] Interviews with FEMA logistics officials.

[14] Frahm, Scott. (2003). "Vendor Managed Inventory: Three Steps in Making it Work." NC State University Poole College of Management, Supply Chain Resource Cooperative. https://scm.ncsu.edu/scm-articles/article/vendor-managed-inventory-vmi-three-steps-in-making-it-work.

some significant proportion of this inventory will expire before being needed by the survivors of disaster.

To address these challenges, some at FEMA have conceived the possibility of contracting with distributors of groceries to maintain and manage emergency stocks. The core concept informing this research anticipates:

- The identification of an appropriate mix of commercially popular shelf-stable products to serve the survivors of a major disaster;
- The procurement of some quantity of these products from existing grocery distributors as a plus-up to otherwise existing inventory flows;
- The storage of this plus-up procurement in the facilities of the grocery distributors;
- The management of this plus-up procurement into and through ordinary commercial demand streams to avoid expiration; and
- Potential collaboration with grocery distributors to deliver the product in case of a major disaster.

The concept is seen as having three potentially significant benefits for FEMA:

1. VMI would allow FEMA to have access to sources of supply sufficient to meet demand in case of catastrophic events.
2. VMI would, in many instances, essentially pre-position resources in several urban areas in a way that is currently not possible for no-notice events.
3. The VMI relationship with grocery distributors would likely support enhancing supply chain resilience by these key players across the risk continuum.

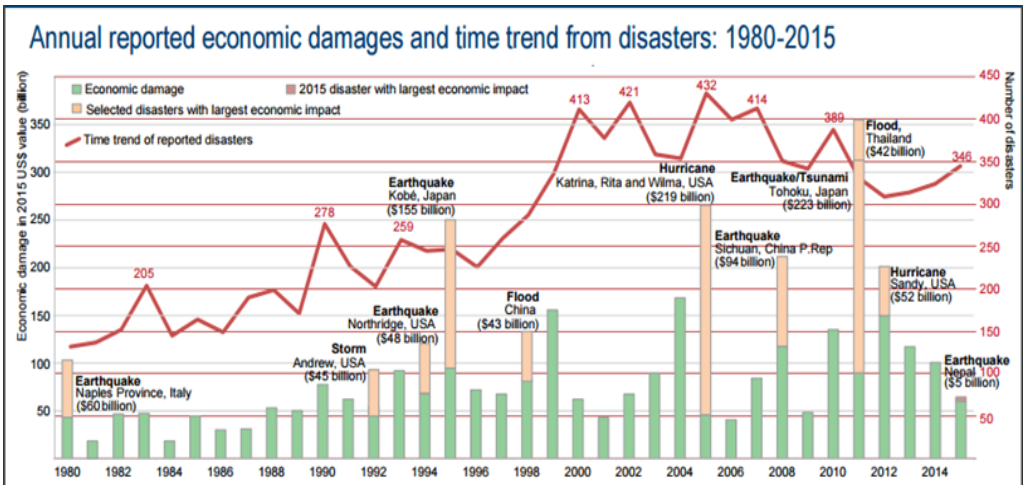
While there are other ways to conceive of VMI for disaster response, this core concept has been the focus of the present study.

Urban concentration

Data suggests that disasters are increasing in both frequency and impact (see Figure 2). Historical data on hazards are often incomplete, especially prior to the last three centuries. But, the demographic context for increased vulnerability and consequence is obvious and accelerating. Regardless of threat, the risk of human harm is growing.

Increasing density of population—and concomitant infrastructures on which large populations depend—is creating much fatter targets for whatever hazards emerge.

Figure 2. Annual reported economic damages and time trend from disasters: 1980–2015



Source: United Nations Office for Disaster Reduction.
http://www.unisdr.org/files/47804_2015disastertrendsinfographic.pdf

Population density

Since some time in 2007–2008, for the first time, most humans are living in cities.[15] Until the last two centuries, dense concentrations of humans were limited by availability of sufficient water, supply of food, and transport/treatment of waste. With the advent of the steam engine and subsequent technologies, it has been increasingly possible to move the massive inputs and outputs required by urban concentrations.

In 1800, Beijing, China, with just over 1 million residents, was the largest city in the world. In 1825, the population of London passed that of Beijing. By 1850, London's population was 2.3 million.[16] In 1950, there were 83 cities in the world with

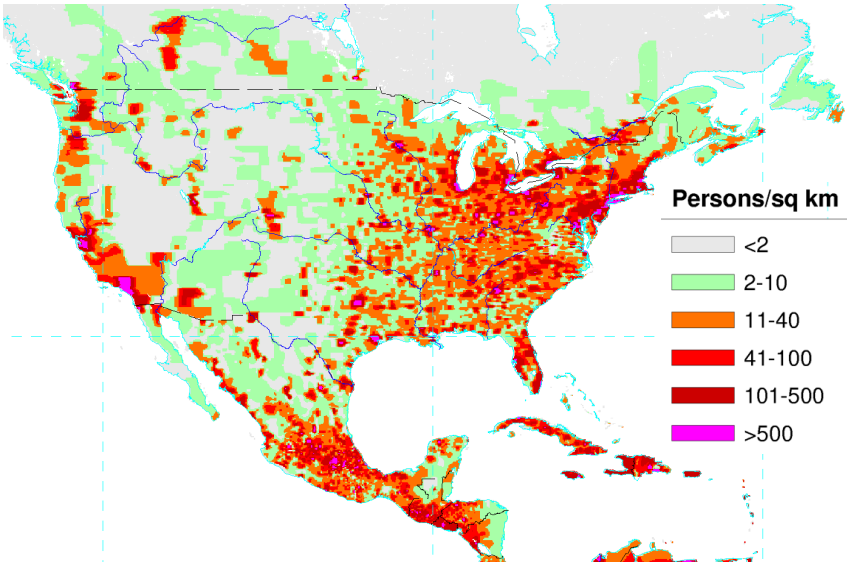
[15] United Nations, Department of Economic and Social Affairs, Population Division. (2009). *Urban and Rural Areas 2009.* http://www.un.org/en/development/desa/population/publications/urbanization/urban-rural.shtml.

[16] Chandler, Tertius. (1987). *Four Thousand Years of Urban Growth.* St. David's University Press http://www.hbs.edu/businesshistory/teaching/resources/Pages/historical-data-visualization-details.aspx?data_id=40

populations of at least one million. Today, there are over 460 cities with more than 1 million people.

Since 1920, the U.S. Census has categorized a majority of the U.S. population as urban. Since 1960, the Census Bureau has used a 1,000-person-per-square-mile definition for "urban."[17] Today, over three-quarters of Americans live in urban areas (see Figure 3).

Figure 3. Urban density in North America



Source: U.S. Department of Agriculture (USDA). (2015).

Technological interdependencies

Such dense concentrations of people cannot persist without moving huge streams of supplies long distances at low cost. Until little more than a century ago, most humans harvested the food that fed them and supplemented their diets, clothing, and household goods by trading with nearby neighbors. Long-range trade certainly existed (e.g., the Silk Road, Sahara caravans, Indian Ocean pepper traders, and more), but this was a high-risk, high-profit luxury exchange. Essential commodities were locally sourced because there was too much risk of long-term disruption.

[17] U.S. Census Bureau. (2015). *Urban and Rural Classification.* https://www.census.gov/geo/reference/urban-rural.html.

Since at least 1846,[18] production of every sort has trended toward specialization and the search for comparative advantage. As steam power reduced the cost and increased the volume of trade—and as Western navies both projected and protected free trade—the prophecies of Adam Smith and David Ricardo have been made manifest in British textiles, German chemicals, Argentine beef, and American cotton.[19] Specialization begets concentration, which begets even greater specialization, which deepens comparative advantage and encourages further specialization, and so the cycle has run for two centuries.

Steam-replacing sails and railways spanning continents made transportation of goods possible where it had previously been nearly impossible. But the cost of transportation remained a significant aspect of the total cost of goods. Writing of the U.S. economy in 1941, Chester W. Wright, explained[20]:

> *Of the $65.6 billion representing the total cost of producing and distributing goods, it is roughly estimated that 59 percent or $38.5 billion represents the total cost of distribution… This means that in general[,] it costs the country about 50 percent more to get goods distributed than it does to get these same goods produced.*

In 2011, the total cost of distribution was 8.5 percent of Gross Domestic Product.[21] The biggest shifts in these 70 years relate to trucks, telecommunications, and computing. More than 5,000 years of supply being *pushed* toward supposed demand has increasingly been replaced by specific demand *pulling* supply (more on this crucial shift in the next section of the report). Pulling supply to specific targets requires an interdependent set of transportation, telecommunications, financial, and other technologies. This density of population and technology is transforming our experience of both time and space. According to the geographer David Harvey, we have, for at least the last 30 years, experienced the "annihilation of space through

[18] Schuyler, Robert Livingston. (1918). "The Abolition of British Imperial Preference, 1846–1860." *Political Science Quarterly*, 33(1): 77-92. https://www.jstor.org/stable/2141881?seq=1#page_scan_tab_contents.

[19] Bhamra, Ran. (2015). Organizational Resilience: Concepts, Integration, and Practice. CRC Press, Taylor & Francis Group. https://www.crcpress.com/Organisational-Resilience-Concepts-Integration-and-Practice/Bhamra/p/book/9781482233568.

[20] Wright, Charles W. (1941). *Economic History of the United States*. McGraw-Hill, 775.

[21] Council of Supply Chain Management Professionals. 2012 *State of Logistics*, http://www.logisticsmgmt.com/images/site/LM1207_CovStateofLogistics.pdf

time."[22] Paul Virilio, an MIT urbanist, describes a widely shared perception in which physical space is replaced with the emotional experience of "speed space."[23]

The industrial revolution tended toward geographic concentration of economic activity around sources of raw material and/or energy. The post-industrial era generates a similar clustering around sources of expertise, ranging from speculation to logistics. In Silicon Valley (CA), a confluence of academic research, venture capital, and advanced manufacturing is supportive of technological innovation. The Memphis, TN and Chicago, IL regions have seen a similar clustering of logistics expertise. In 2014, 40 percent of new drugs approved by the U.S. Food and Drug Administration were formulated by companies located in Central and Northern New Jersey.

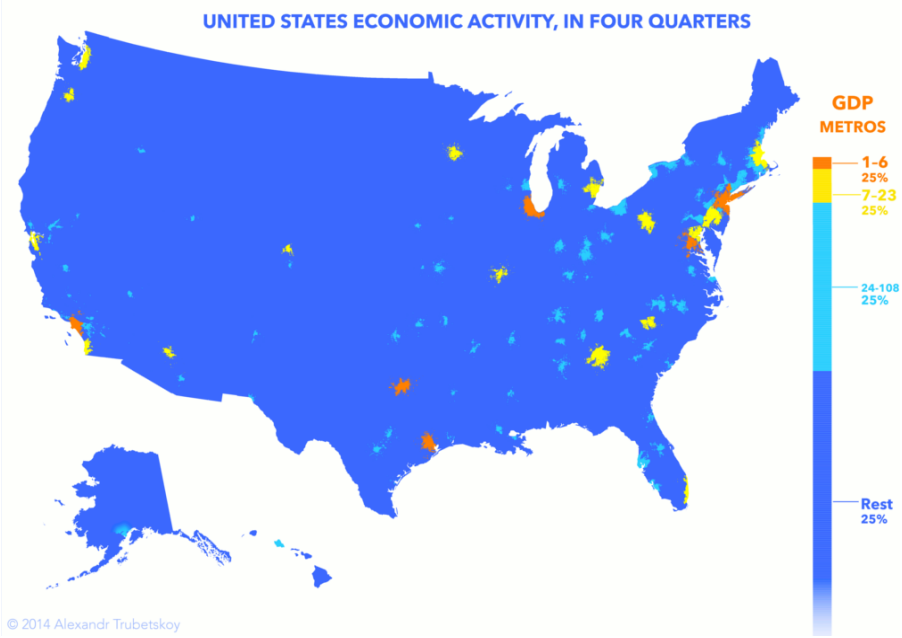
According to IHS Global Insight, six metro areas—New York, NY; Los Angeles, CA; Chicago, IL; Washington, DC; and Dallas and Houston, TX—account for almost a quarter of the United States' $16.8 trillion economy. Add in the next 17 largest cities, and roughly half the national economy is generated within a few thousand square miles of the 3.8 million square miles the United States encompasses.[24] This is not just representative of speed space, but also of dense space, as illustrated in Figure 4 below.

[22] Harvey, David. (1991). *The Condition of Postmodernity: An Inquiry into the Origins of Cultural Change*.Wiley-Blackwell. https://libcom.org/files/David%20Harvey%20%20The%20Condition%20of%20Postmodernity.pdf

[23] Virilio, Paul. (2009). *The Aesthetics of Disappearance, New Edition.* MIT/Semiotext(e, https://www.cambridge.org/core/books/spatial-ecologies/paul-virilio-speed-space/A184963FF8642CA15147F15DAC315C29

[24] IHS Global Insight. (2013). U.S. Metro Economies: Outlook – Gross Metropolitan Product, with Metro Employment Projections. For the U.S. Conference of Mayors and the Council on Metro Economies and the New American City. http://www.usmayors.org/metroeconomies/2013/201311-report.pdf.

Figure 4. U.S. economic activity, in four quarters



Source: Graphical analysis by Alexadr Trubetskoy

Socio-technical density serves to multiply the potential intensity of an extreme event. When disaster strikes less-dense areas, the impact may have horrific local consequences, but the outcome for the whole system will often be quite modest. If an extreme event involves dense yellow or orange areas, human consequences can be enormous, and the economic impact can reverberate well beyond the geographic boundaries of the event.

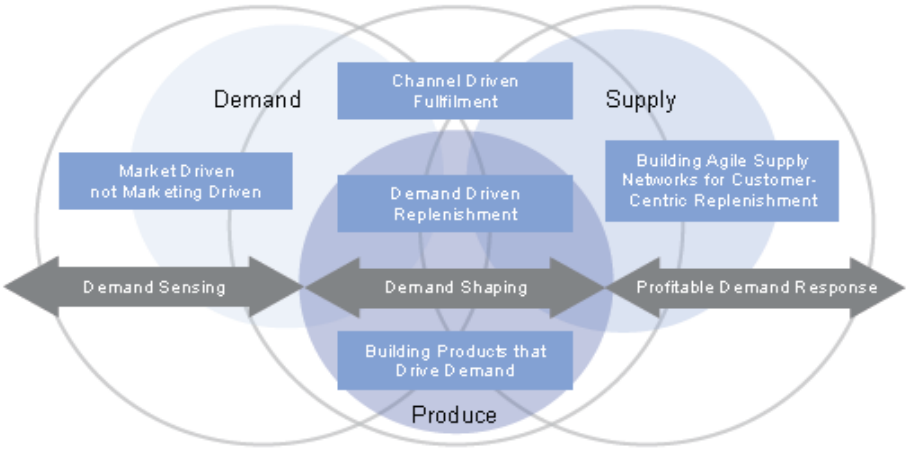
Existing and emerging supply and demand networks

Supply chain is a term that emerged in the early 1980s to describe new decision-making processes from sourcing to production and consumption.[25] By attending to each "link" in the conceived chain of custody, opportunities could be claimed to increase efficiency and/or speed in supplying demand. In recent years, attention has sometimes been given to the network effects that emerge from informational and

[25] Supply Chain Digest. (n.d.). "Origins of the Term 'Supply Chain.'" Supply Chain News Bites: Graphic of the Week. http://www.scdigest.com/assets/newsviews/10-12-16-1.php?cid=4027.

functional linkages between demand nodes and supply nodes.[26] For the purposes of this report, supply chain networks are socio-technical systems by which demand is targeted, anticipated, and fulfilled (see Figure 5).

Figure 5. Contemporary supply and demand networks



Source: Cecere, Lora, et al. (2005). The Handbook for Becoming Demand-Driven, Gartner. https://www.gartner.com/doc/1344630/handbook-demand-driven.

Most supply chain networks are not yet operating on a Just-In-Time (JIT) basis, but moving closer to JIT is a persistent goal for many. JIT is fundamentally a means of measurement. It measures current or very recent reality informing a wide range of choices.

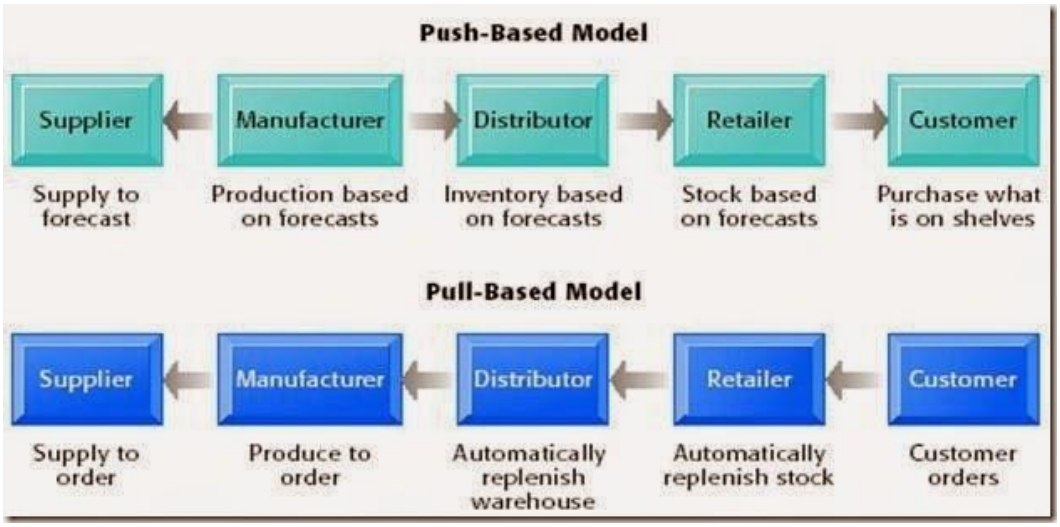
JIT emerged in the early post-World War II years from studies by Japan's Toyota Corporation to improve production efficiency. During a 1956 trip to the United States, a Toyota production engineer, Taiichi Ohno, was especially impressed by his encounter with the American self-service grocer Piggly Wiggly. Unlike most other grocers—and every automobile manufacturer—of the time, Piggly Wiggly placed essentially all of its inventory directly on the shop floor, allowing consumers to pull whatever they needed. Restocking reflected what had been sold, no more and no less. Ohno perceived that as these pull signals travel toward sources of supply, they can facilitate a tight focus on what is being consumed—and, thus, what is really needed.

[26] Pearson, Michael. (2006). *Fractals, Complexity, and Chaos in Supply Chain Networks.* Chapter in *Complexus Mundi: Emergent Patters in Nature*, edited by Novak Miroslav. World Scientific Publishing Co., pp.135-145.

If recognized, this can be used to eliminate waste and costs related to Just-in-Case hoarding of resources and overproduction.

Organizing production to reflect consumer "pull" rather than the "push" of historical patterns or guesses about the future was a revolutionary shift. When the signals are treated as measures, and the measures are consistently applied to manage production (and distribution), a different relationship emerges between sources of demand and sources of supply (see Figure 6).

Figure 6. Traditional "push" versus contemporary "pull"



Source: Laudon, Kenneth and Laudon, Jane (2016). *Achieving Operational Excellence and Customer Intimacy* in *Management Information Systems: Managing the Digital Firm*., Pearson Education.

In Ohno's judgment, JIT resupply shifted an organization's mindset from a worried (and wasteful) strategy of risk-avoidance to a confident, empirical strategy of creating abundance. He wrote, "All we are doing is looking at the time line, from the moment the customer gives us an order to the point when we collect the cash. And we are reducing the time line by reducing the non-value adding wastes."[27]

If the Toyota team had visited the same Piggly Wiggly just a few years later, the lean supply chain that inspired them would have been a bit fatter. By the 1960s, U.S. supermarkets were competing on product diversity, proliferation of services, and

[27] Ohno, Taiichi. (1988). *Toyota Production System: Beyond Large-Scale Production*. Productivity Press. Page ix.

volume. The unprecedented affluence of American society in the '60s did not encourage much attention to lean opportunities. The focus was on more, not less.

As a result, JIT supply did not claim a leading role in U.S. supermarkets or any other U.S. sector. Instead, the self-service, lean supply chain "supermarket" format was translated to the Japanese factory floor. Over the 1960s and 1970s, this strategy incrementally, but radically transformed Japanese automobile manufacturing. By the early 1980s, JIT supply and related practices created a comparative advantage for Japanese auto companies that seriously threatened U.S. auto companies and the competitive capacity of other long-time U.S. manufacturing leaders. In 1982, the average Japanese automobile worker was more than twice as productive as his or her U.S. peer and, to many consumers, the quality difference seemed even greater.

This threat re-shored JIT practices to the United States. In the subsequent 3+ decades, JIT and other components of continuous improvement have become common denominators of global competition. Economic value is increasingly generated by eliminating deviation from demand signals, reducing variation in quality, cutting costs, and compressing time from emergence of demand to fulfillment of demand. As Ohno observed, it is more and more about "reducing the time line."

Since 2009, rapid global adoption of smartphones with their real-time, all-the-time capacity for comparison, socialization, communication, and financial transactions has had an enormous impact on whole categories of products. Mobile purchasing, especially among the rising generation, is transforming behavior patterns that have characterized commerce since the rise of mass consumption. Brand loyalty seems to have meaning only as long as the brand is also the source of innovation that satiates or stimulates consumer cravings. New demand patterns are creating new supply requirements.

Mobile online retail payment volume has more than tripled since 2013 and is expected to triple again over the next three years. A 2016 study by UPS found that among the population of online shoppers, "more than 50 percent (51%) of all purchases made by respondents are made online, up from 48 percent in 2015."[28] In late 2015, also for the first time, just over half of all online retail purchases involve bits instead of bytes:[29] persistent physical objects rather than products (like music or games) that could be downloaded. In mid-2016, only 2.5 percent of U.S. groceries are

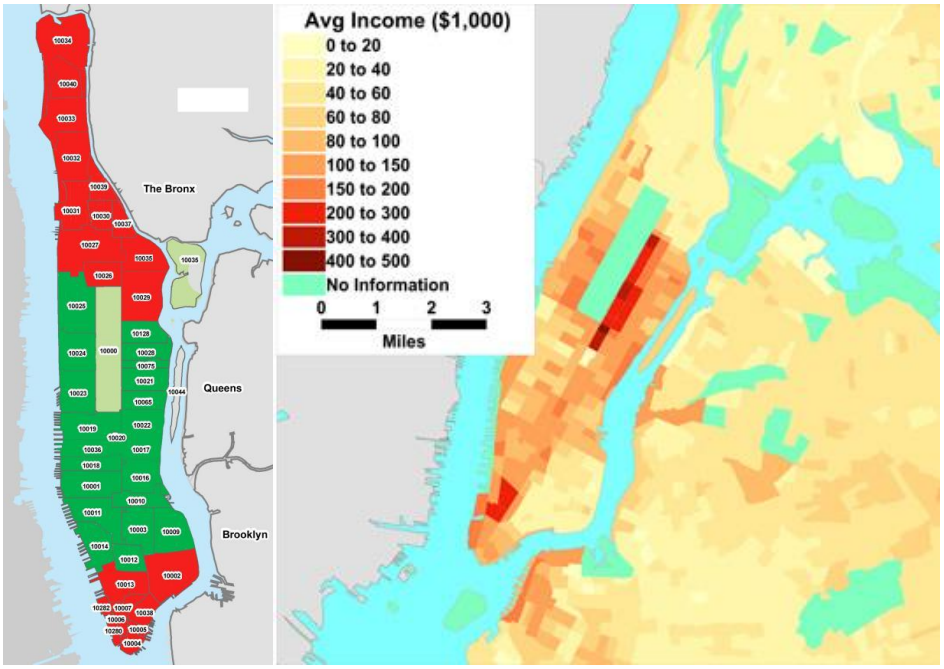
[28] United Parcel Service. (2016). Pulse of the Online Shopper. https://pressroom.ups.com/assets/pdf/2016_UPS_Pulse%20of%20the%20Online%20Shopper_executive%20summary_final.pdf.

[29] Ibid.

purchased online. But this is projected to grow to 8 percent (equal to $100 billion) by 2025.[30] Amazon is—and others are—clearly attempting to deploy JIT to online grocery shopping. Whoever wins is likely to dominate not just grocery but the entire online retail environment.

Amazon does not (indeed, cannot) offer same-day delivery everywhere. It currently offers one-hour delivery to specific postal codes in several dense urban markets. Amazon launched its one-hour *Prime Now* service just before Christmas 2014 to a set of contiguous zip codes in Manhattan. It has since expanded to a much wider pool, including New York, NY; Atlanta, GA; Austin, TX; Baltimore, MD; Chicago, IL; Dallas, TX; Indianapolis, IN; Miami, FL; and London, England. But the initial targeting tells a tale. In Figure 7 below, the green on the map to the left shows the *Prime Now* delivery zone on or about December 23, 2014. The map on the right shows the zip codes with the highest median income.

Figure 7. E-commerce supply and potential demand velocity



Source: Amazon, Inc. and U.S. Census Bureau

[30] Ben-Achour, Sabri. (2016). "Online grocery shopping could add growth to the cart." Marketplace. http://www.marketplace.org/2016/06/15/world/online-grocery-adding-growth-its-cart.

The second map demonstrates another kind of density. Populations follow wealth. A concentration of wealth will almost always generate a proximate concentration of population. *Prime Now* is a premium-priced service. It is especially well-suited for cash-abundant, time-deficient consumers. The Upper East Side enjoys a particular concentration of such consumers. This establishes sufficient volume to sustain the service. Once sunk costs are invested and processes refined to serve the primary target, it makes sense to extend the service to others that happen to be nearby. But at some distance from the locus of wealth, there will no longer be sufficient pull to further reduce the timeline. Space and time unbends. Amazon and others are still exploring where and how these boundaries emerge and morph.

For example, mobile purchasing is pulling entire supply chains to behave with the accessibility, speed, and efficiency that Piggly Wiggly inspired at Toyota, including U.S. grocery stores. In 2013, roughly $6.5 billion was spent online for groceries. This was only one percent of the U.S. grocery market. Three years later, "only" 2.5 percent of groceries are purchased online. But several sources are predicting a compound annual growth rate for online purchases *seven* times that of off-line grocery sales.

The fastest-growing offline grocers are much leaner in terms of product variety and merchandising costs. Trader Joe's, one of the 20-largest U.S. grocery chains, is essentially a 21st-century update of the original Piggy Wiggly: a pure pull-play for high-demand products offered at attractive price points delivered by one of the most efficient supply chains on the planet. Aldi, a close cousin, plans to expand its U.S. store network from 1,400 to 2,000 locations by 2018. Organized to maximize supply chain efficiency, Aldi has been growing at 15–20 percent per year in an otherwise flat (and, arguably, over-saturated) U.S. grocery market.[31] Several traditional supermarkets are experimenting with smaller format stores and much leaner supply chains.

Consumers are now capable of communicating preferences with a speed and clarity never before possible. The pull signals sent are multiplying, as is consumer expectation of the speed by which demand will be supplied. Innovative products often emerge quickly (or not at all), surge sharply, and fade fast. The fundamental structure and behavior of supply networks are in the process of adapting to these shifts.

Sridhar Ramaswamy, a Senior Vice President with Google, writes:

> *Consumer behavior has changed forever. Today's battle for hearts, minds, and dollars is won (or lost) in micro-moments—intent-driven*

[31] Buss, Dale. (2016). "Aldi US Expansion Challenges Walmart and Trader Joe's in CaliforniaAldi Expansion Challenges." Brandchannel. http://brandchannel.com/2016/03/28/aldi-us-032816/.

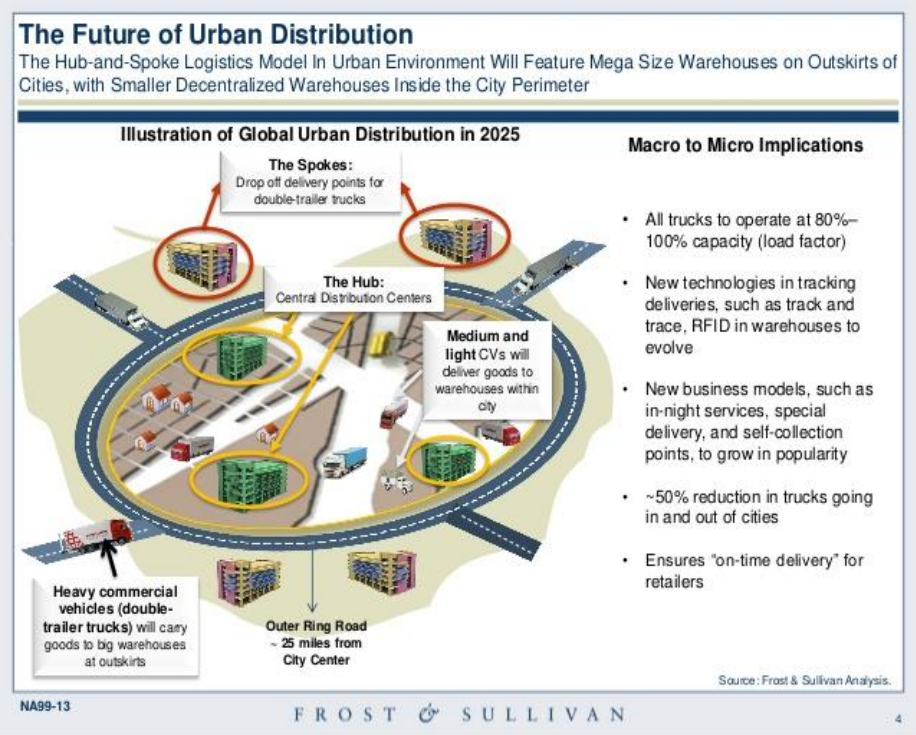
> *moments of decision-making and preference-shaping that occur throughout the entire consumer journey…—the I want-to-know moments, I want-to-go moments, I want-to-do moments, and I want-to-buy moments—that really matter. We call these "micro-moments," and they're game changers for both consumers and brands.*

It took Taiichi Ohno and his colleagues a bit more than three years to triple Toyota's productivity levels (per worker) to equal the productivity of Ford Motor Company. Over the next two decades, Ford's productivity (and other U.S. manufacturers) remained essentially the same, while Toyota's continued to improve. Eventually, four Toyota vehicles were produced by the same number of Ford workers that produced one vehicle. This first JIT revolution required a bit more than a decade to fully unfold. JIT for U.S. grocery purchases in dense urban areas is already starting and is unlikely to take much longer.

Network disruption

As Depression-era customers pulled products at Piggly Wiggly, the opening on the shelf signaled the clerk to restock. The opening in the stockroom signaled the need to reorder. Demand signaled supply. Toyota adapted the JIT concept to build cars. In each case, movement in space determines the moment in time that resupply is signaled. In each case, space is organized to reduce time expended in responding to demand.

Figure 8. The future of urban distribution



Hub-and-spoke supply networks adapt JIT processes from the shop and factory floor to whole regions. The barcode scanned at the checkout (or a sensor on the shelf of a fulfillment center) sends signals upstream toward sources. Supply is pulled toward demand with as few "touches" as possible between source of supply and source of demand.

Networks are expressions of connectedness and compactness. Supply and demand networks consist of nodes that are connected by links, between which signals and supplies are sent. The more compact (i.e., structurally and linguistically similar) the nodes, the smoother the transmission of signals and supplies through the network. Barcodes are a wonderfully adept universal language of contemporary commerce.

In the process of increasing both connectedness and compactness, hub-and-spoke networks tend toward becoming scale-free networks. A frequent advantage of scale-free networks is the potential speed with which new information (bits or bytes) can be *accurately* shared across the network. The fewer hops between supply nodes and demand nodes, the clearer the signal. However, strength is often the public face of hidden weakness. The same innate efficiencies that spread good can also spread bad. Ted Lewis explains:

> *Complex systems are connected, emergent, self-organized networks. The network model is rather flexible – nodes represent anything of interest and links represent any form of coupling or connectivity… Complex systems evolve—they change over time. In most cases, one or more properties of a complex system emerge out of randomness or disorder as the system responds to transformative forces. Efficiency and optimal restructuring is perhaps the most common form of transformative force…*
>
> *In many cases, self-organization increases system risk by reducing resiliency as SOC [Self-Organized Criticality] transforms a system from a non-critical to a critical state. For economic and NIMBY reasons, network systems form hubs, betweeners, and critical nodes and links…*
>
> *Why? Random systems lack organizational structure—the parts of the system are linked together haphazardly. Organized systems exhibit less disorder, meaning there is a distinct pattern in the way the parts are linked together. For example, a scale-free network containing a highly linked hub and many sparsely linked nodes is more organized than a random network. The U.S. telecommunications system has structure because of its telecom hotel hubs. The electric power grid has a few nodes with high betweeness, hence more structure than a random grid. When a highly organized system reaches its critical point, insignificant incidents become significant because they can collapse the entire system…*
>
> *As self-organization increases, typically in the form of larger hubs or nodes with high betweeness properties, the complex system also become more vulnerable to targeted attacks and normal accidents. The extreme case of self-organization is SOC—a state in which small changes are likely to create large effects.*

The grocery market in the United States is huge, hyper-competitive, and dynamic. Before 1988, Walmart did not stock groceries; since then, Walmart has become the single-largest source of groceries in the United States. According to Progressive Grocer, the company currently accounts for over 4,000 retail grocery outlets and roughly one-quarter of all U.S. grocery purchases.[32] Walmart has arguably claimed this role by applying the supply chain expertise it developed with non-groceries to an industry that had not fully embraced the potential of pull instead of push.

[32] Dudlicek, Jim, Goldschmidt, Bridget, Major, Meg, and Chanil, Debra. (2016). "The Super 50 Ripple Effect." Progressive Grocer. http://magazine.progressivegrocer.com/i/673357-may-2016/28.

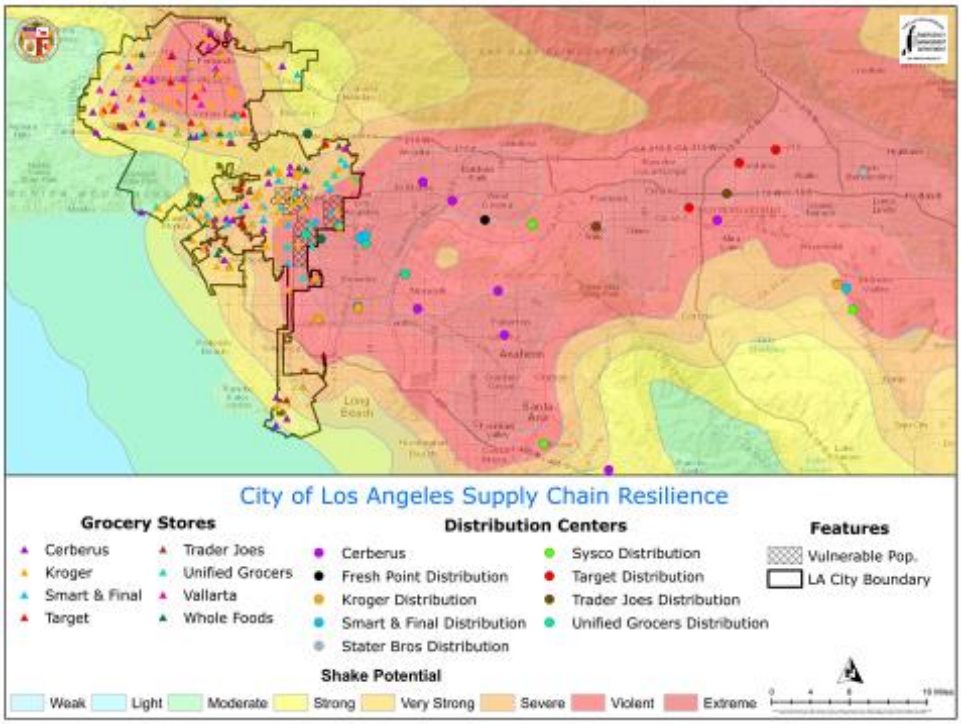
While many long-time grocery leaders faltered and failed as Walmart transformed their commercial ecology, Kroger has survived and even thrived. It remains the largest U.S. "traditional" grocery chain and has added non-traditional products such as pharmacy, dry cleaning, cafes, wine bars, and fuel. JP Morgan-Chase predicts that by 2017, Kroger will surpass Whole Foods as the largest retailer of natural and organic foods.[33] Progressive Grocer reports that in 2014, Kroger's network of 2,600+ stores generated $108 billion in grocery sales. This is about $180 billion less than Walmart; but, as of June 2015, Kroger had achieved 46 consecutive quarters of growing same-store sales.

In 1998, Kroger became the owner of Ralphs and Food4Less, two prominent Southern California grocery chains. The company has continued to lead with these local identities. According to The Shelby Report, in May 2015, Kroger operated 368 stores (compared to 130 Walmart SuperCenters) and served roughly 18 percent of this $43.88 billion grocery market extending from Santa Barbara to Las Vegas to San Diego. Walmart is the fourth-largest retailer in this region, with about 10 percent marketshare. In 2007, Ralphs opened the first new full-service grocery store in downtown LA built since the 1960s. It is now the highest-grossing store in the division. Ralphs partners with Instacart for mobile shopping and delivery. Customers can shop Ralphs online and are promised delivery in two hours for $3.99 or in one hour for $4 more. Kroger has matched pull with pull, and is raising the bet with differentiated merchandising and products. This enormous Southern California capacity—generating over $8 billion in 2014 sales—is focused on two distribution centers, two creameries, one bakery, and one meat plant. There are other sources of capacity, other places from which supply is pulled. But the network (as a network) depends on these few dense nodes.

One of the five largest grocery operations in Southern California has its key distribution hub less than 10 miles from the San Andreas Fault and sitting on loamy river bottom (see Figure 9). None of Kroger's capacity is quite so close, but all of its key nodes are located in areas prone to intense earthquake effects. It's hard to find a place between the ocean and mountains that is not. The question remains, then: What happens to the grocery network on which millions depend as the efficiency of hub-and-spoke supply networks encounter the energy of a magnitude 7.0 earthquake or worse?

[33] Lutz, Ashley. (2014). "Kroger is Whole Foods' Biggest Threat." *Business Insider.* http://www.businessinsider.com/kroger-is-whole-foods-biggest-threat-2014-10.

Figure 9. Grocery supply and demand nodes on shake map



On March 11, 2011, a magnitude 9.0 undersea earthquake spawned a tsunami, pulverizing the northeast coast of Japan and doing damage far inland. The ocean-facing Fukushima Nuclear Power Station was especially hard-hit. More than 15,000 died. Over 200,000 were left homeless. In the immediate aftermath of the event, 4.4 million survivors were without electric power, and over 1.5 million lost access to public water systems. The large impact zone—similar to the distance between Los Angeles and San Francisco—is mostly non-urban, but is home to roughly 9 million people.

The usual suppliers of food to the region were sidelined for several days. Initially, roads and bridges required repair. Some delay in regular supply chain operations also resulted from disruptions in fuel supply. The earthquake-related loss of a key refining node reduced Japanese national fuel capacity by roughly 25 percent. The mantra was often heard (in Japanese): "No Roads, No Gasoline, No Delivery."

But even after roads were reopened and fuel was available, the government excluded private parties from the impact zone. A military and police perimeter was established, inside of which the government attempted to create entirely new supply networks.

Outside the immediate impact zone (especially in Tokyo), the food supply chain was hit hard by hoarding. An analysis of retail pull signals and inventory records conducted in the two years after the event found that, "although sufficient supplies of food, fuel, and emergency goods to meet demand in normal time were available, store shelves were left empty due to panic buying and hoarding of certain foods and other basic supplies in the wake of the earthquake. Empty shelves, in turn, gave rise to a vicious cycle of consumers scrambling to stockpile such goods[34]." Even while millions with real need for food could not send their pull signals, those who had no new need amplified their signaling. The supply network responded, but the bullwhip cut deep.

Yet even with the surging demand of real-need and feared-need, supply capacity mostly met or exceeded demand. The source network persisted. Only yogurt and fermented soybeans (natto), among 214 products examined, experienced sustained shortages.

The distribution challenge was enormous. Capacity proved sufficient, but deploying capability was complicated. Dealing with hoarding was tough; dealing with the active suppression of the supply network was even more difficult.

According to the Foreign Agricultural Service[35] at the United States Embassy in Tokyo:

- *As of March 15:* "Major supermarkets such as AEON and Ito-Yokado cannot deliver to their stores in the emergency area at this time. They are sending noodles, water [to the government] for relief supplies and trying to keep up with stocks of water, cup noodles and batteries at their stores in the affected area, but are having difficulty. Kokubu, a major food wholesaler, says that it's hard to tell at this moment when infrastructure will recover. At present, the guesstimate is at least one week from today (March 15) to restart distribution of foods. The wholesaler's 25 storage facilities in the effective region, Tohoku Region, are not operative due to power black-outs… hospitals are not receiving enough food to feed their patient populations."

- *As of March 16:* "7-11 Japan, the biggest convenience store (13,000 outlets), improves its supply ability better day by day. 7-11 Japan is able to shift its

[34] Masahiro Horia and Koichiro Iwamoto, The Run on Daily Foods and Goods after the 2011 Tohoku Earthquake (March 2013) http://icic.org/wp-content/uploads/2017/01/Rockefeller_ResilientFoodSystems_FINAL_post.pdf?x96880

[35] Nawn, Jeffrey, et al. (2011). *Update -Japan Food and Agriculture*. Global Agricultural Information Network, Foreign Agricultural Service, USDA. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/March%2031%20-%20Japan%20Food%20and%20Agriculture_Tokyo_Japan_4-21-2011.pdf

distribution system and is able to adapt the Kanto logistic network to serve the Tohoku region, and then use other plants west of Tokyo to serve Tokyo. As of March 14, both Lawson and 7-11 Japan resumed business in more than a half of shop operations in Tohoku region. Lawson resumed operation of 450 outlets out of a total of 810 in Tohoku region. 7-11 also resumed sales at a 450 outlets out of a total of 920 in the region… Major food wholesalers, Kokubu, Ryoshoku and Nippon Access, have received double the orders from retailers. Wholesalers are maintaining ordinary operations at their warehouses in the Tokyo region. According to the Asahi Shinbum on March 15, sales results of the major retailers jumped dramatically in last two days. Purchases of bottled water vaulted to 10 times, Natto 3 times bigger, Tofu 1.7 times more, milk 1.5 bigger. Sales of chicken rose 9 times more than the sales of same period of last year, canned food 3 times bigger, rice 1.6 times more… Rice, toilet paper and other daily necessities are growing scarce at stores, not only in the quake hit Tohoku region, but also in the Tokyo metropolitan area. But manufacturers across a wide array of industries say they have sufficient capacity to meet the demand. The temporary shortage at retailers is likely caused by such factors as turmoil in logistics networks and anxious consumers stocking up on various goods. Retailers and manufacturers are working to fill store shelves depleted in quake-hit regions and the Tokyo area by using distribution networks and production bases in unscathed in Western parts of the nation."

- *As of March 17:* "Out of 170 outlets of York Benimaru, one of the largest retail grocery chains in Tohoku area, 77 outlets are closed."

- *As of March 18:* "Consumer hoarding behavior, rolling blackouts, and the lack of fuel continue to wreak havoc on Japan's food supply system. In response to nationwide retail level food shortages the Japanese government has made strong overtures to the Japanese people to be judicious in their food purchases. Local retail stores in Tokyo, away from the affected areas, are constantly busy restocking shelves while worried consumers continue to purchase items just in case another disaster occurs. The items that stores can't keep pace of are bottled water, rice, eggs, bread and bread products. Milk purchases are limited to one carton per customer. As already reported, deliveries are slow because truckers can't get sufficient fuel due to high levels of consumer gas purchases and the compromised fuel transportation infrastructure. With regard to gas supplies, prices are going up quickly throughout the nation. Regular gasoline has gone up from about 140 yen ($1.75) per liter to 158 yen ($1.97) per liter, and most stations are limiting customers to 20 liters or 3000 yen per visit."

- *As of March 22:* "Some semblance of normalcy is returning in the Tokyo area. Supermarkets that were having difficulties restocking their shelves are now finding it easier… This differs by region and town, and even sometimes by

store. Rice was almost gone from one store in the Akasaka area, while another store, about a block away had ample stocks."

- *As of March 24:* "NTV reported at 10:13 that there continues to be a serious shortage of food in Ishinomaki, Miyagi, where nearly 80,000 people are dependent on food distribution. The network said that only 110,000 loaves of bread and 60,000 'onigiri' rice balls were delivered to shelters there on Thursday. According to the network, one shelter in the city could only serve one loaf of bread and one onigiri per person for Thursday night and Friday morning." On March 24 transportation restrictions into the Tohoku region were lifted. Despite continuing fuel shortages, this allowed private trucking to freely operate across most of the Tohoku region.

- *As of March 28:* "On Friday we reported that AEON stores have reopened stores in the affected area. Today, Reuters reported that Walmart will reopen 12 of its Seiyu stores in Japan which were affected by the earthquake, and is hoping to open the remaining 12 impacted stores as soon as possible. Walmart has 371 stores and 43 deli outlets in Japan, of which 24 were affected by the March 11 earthquake and tsunami." In several areas, food shortages that had been growing more acute over time were quickly resolved once restrictions on private trucking were lifted. Some suggest this barely averted widespread deaths of infants and elderly from lack of food.

- *As of March 31:* "A growing number of Japanese food makers and retailers are turning to emergency imports to cope with shortages caused by the recent disaster. Aeon Co. has announced plans to import large amounts of food and sundries, purchasing 1,500 tons of onions and 500 tons of carrots from Australia, among other items. Several firms announced to import bottled water from South Korea, Canada, and other countries… Dairy products are still in short supply in eastern Japan as scarce packaging materials such as paper cartons hinder production. Yogurt output, for example, cannot keep up with demand due to rolling blackouts, and supplying products from western Japan is not practical because milk is highly perishable."

In March 2011, the grocery supply chain in Japan demonstrated considerable resilience. It did not collapse under the pressure of extraordinary and extended hoarding in one of the densest urban areas on the planet. Once roads were passable and the perimeter was lifted, the network responded creatively and even courageously to the needs of survivors across Tohoku.

But Tohoku is not Tokyo. As the Foreign Agricultural Service reports indicate, Tohoku benefited from its proximity to the powerful food networks serving Tokyo, all of which had escaped significant physical damage. The hubs continued to hum. The comparatively modest needs of non-urban Tohoku could be absorbed by the gigantic capacity of the Kanto network (Greater Tokyo, population over 42 million)

with help from the nearly as robust Kansai network (Greater Osaka, population over 22 million).

If an earthquake and tsunami devastated Santa Barbara, survivors would benefit by their proximity to Los Angeles. But what if the hardest hit unfolds between the Salton Sea and Hungry Valley as the San Andreas tears open? How many hubs have to fail before the Southern California grocery network is shattered?

Fundamental Aspects of Crisis-Contingent VMI

To deal with potentially catastrophic disruption of demand and supply networks, some at FEMA's Logistics Management Directorate have conceived a "Vendor-Managed Inventory" (VMI) strategy. This concept focuses on developing a surge capacity within the existing commercial grocery supply chain. Products that are appropriate for survival in the aftermath of an extreme event and for which there is already significant market demand would be made "surge ready" through specific FEMA procurements. The VMI concept is based on commercial grocery providers and FEMA collaborating to maintain this crisis contingent reserve over time and to work with local, state, and federal agencies to ensure effective delivery in case of an extreme event.

Nutritional requirements

Nutritional needs differ by individuals and context. A young child or sedentary older person will generally consume up to two-thirds the calories of an active adult. Men generally consume 20–25 percent more calories than women.

The amount of energy needed is mostly a function of how much energy is expended. The more physical an activity, the more calories are needed. Following a potentially catastrophic event, many individuals will be more active than before the event.

Appendix E provides detailed recommendations regarding the intake of calories by age, gender, and activity level. For disaster assistance, the World Health Organization (WHO) recommends a target of 1,700 to 2,000 calories per person per day.[36] A widely

[36] PAHO/WHO Institute of Nutrition of Central America and Panama. (n.d.) "Food and Nutrition in Disasters: Guidelines." World Health Organization. http://www.searo.who.int/entity/emergencies/documents/food_and_nutrition_in_disasters.pdf?ua=1.

accepted international standard is 2,100 calories[37] per person per day. The nutritional information on many products packaged in the United States reference a 2,000 calorie-per-day diet. To calculate population requirements, this analysis will utilize the 2,000 calorie-per-person/day benchmark.

Caloric intake is only one aspect of nutrition, though. There are considerable long-term health benefits when a diverse diet of fresh foods is consumed. The U.S. Department of Agriculture and the U.S. Department of Health and Human Services recommend a diet that is roughly 55 percent carbohydrates, 25 percent fats, and 20 percent protein.[38] Detailed information on the optimal characteristics of dietary intakes is available in Appendix E.

A balanced diet can, however, be difficult to achieve in the aftermath of a major disaster encompassing a wide area and dense population. In such an extreme event, the WHO notes, "As an immediate measure, provide any population group that is or appears to be at high nutritional risk with 3 or 4 kg (6.6 to 8.8 pounds) of food per person per week. The important thing at this stage is to provide a sufficient quantity of energy, even if it is not a balanced diet."[39]

Crisis-contingent VMI is conceived as one of several complementary sources of food energy to assist survivors for an extended period until relocation or substantial recovery can be achieved.

Preparation requirements

In an extreme event impacting a wide area and dense population, housing stock is likely to be lost; electricity and other sources of energy will be disrupted; and potable water is likely to be in short supply, as available water sources may be contaminated. In addition, cooking utensils may be scarce, and significant populations will be displaced.

[37] According to Johns Hopkins University, 2,100 calories is the internationally recognized planning assumption for average per-person needs in a food disaster. The Johns Hopkins and the International Federation of Red Cross and Red Crescent Societies. (n.d.) "Food Security and Nutrition in Emergencies: Public Health Guide in Emergencies." http://www.jhsph.edu/research/centers-and-institutes/center-for-refugee-and-disaster-response/publications_tools/publications/_CRDR_ICRC_Public_Health_Guide_Book/Chapter_9_Food_and_Nutrition.pdf.

[38] U.S. Department of Agriculture and U.S. Department of Health and Human Services. (2010). *Dietary Guidelines for Americans, 2010.* 7th Edition. U.S. Government Printing Office. https://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

[39] Ibid.

In such contexts, dried, canned, vacuum-packed, or other "shelf-stable" products that can be safely consumed with little or no preparation ("ready-to-eat") provide the most assured and most flexible products for general distribution. In a potentially catastrophic situation, it is possible that tens-of-thousands will require ongoing nutritional support for several weeks, until supply chains are restored or relocation can be facilitated.

Individual, meal-sized portions that are easy to open and immediately consumable will usually provide the most flexible solution for feeding large populations during the initial phase of response operations. In addition, many canned products feature "pop-tops." Products developed for camping, hiking, and similar purposes are packaged for extended storage and individual consumption. Dried fruits, meats, seafood, nuts, and other foods are available in tear-open vacuum packs that have long shelf lives. Most of these product lines can be helpful to feeding the surviving population of a major disaster.

Socio-cultural preferences

The more time required for response and recovery from a disaster, the more important the availability of a diet that accommodates socio-cultural preferences. The availability of such preferences is an important signal of a robust response/recovery capacity and reflects a concern for social solidarity that is especially productive in the aftermath of a disaster.[40] Availability of preferences suggests a renormalization of risk. Non-availability will often be perceived as indicating a continued threat. During an extended period of response/recovery, populations are more likely to behave collaboratively when they perceive the worst threats have been contained.[41]

Preferences encompass issues of sourcing, preparation, and variety. Medically motivated preferences are often the most rigorous; religiously oriented preferences are not far behind. Whatever the source, preferences can have a substantive impact on the morale, motivation, and perceived and actual wellbeing of survivors. Among many American subcultures, the perceived availability of choice can be as influential as the exercise of choice. Especially under stress, there is often a default to

[40] Hunt, Andrew R. (2008). *Cultural Competence in Disaster Mental Health*.http://www.tapartnership.org/docs/presentations/20080403_integratingCLCintoDisasterMH.pdf.

[41] Solnit, Rebecca. (2010). *Paradise Built in Hell: The Extraordinary Communities that Arise in Disaster.* Penguin Books. http://rebeccasolnit.net/book/a-paradise-built-in-hell/.

predictable "comfort foods." But even when some semblance of such foods is available in sufficient quantity, the absence of other choices will increase the perception of threat.[42]

Pre-event volume flows

Managing inventory is much more than stocking and storing inventory. VMI generates potential comparative advantage for disaster response when a crisis-contingent reserve can be maintained in an ongoing demand-and-supply stream by vendors that are ongoing participants in the stream.

To avoid product expirations, each vendor involved must serve a sufficiently sized demand-pull for the designated products to be sold and replenished within the product's retail shelf-life, providing significant stock for continued retail distribution, even if wholesale resupply is delayed. For example:

- If a designated crisis-contingent inventory product has a shelf life of two years, and
- If a vendor is projected to maintain a crisis-contingent reserve of 1,000 units, and
- If retail sources of demand expect products to show an expiration date no less than one year in the future…

…then there must be credible evidence that the vendor can move at least 1,000 units of the designated product within one year.

There is evidence that such arrangements are plausible. Peanut butter is shelf-stable and continues to be safe to consume for considerable time after opening. A serving of 34 grams (roughly seven teaspoons) contains 200 calories, including 16 grams of fat, 7 grams of protein, and 6 grams of carbohydrates. A 12-ounce jar contains 340 grams, or just over 10 "servings." One 12-ounce jar can supply the average calories needed per day per person. A jar of peanut butter will usually show a "best-before" date of nine months after production. (If reasonably stored, the product will be safe to eat for at least one year beyond the best-before date.) In one densely populated urban area, one market-leading grocery distributor moves 4,800 cases of peanut butter each week. Given this distributor's market share, at least 12,000 cases of

[42] Hadi, Rhonda and Botti, Simona. (2014). *The Importance of Perceived Control: Choice, Knowledge, and Controllability in Consequential Domains.* Advances in Consumer Research. Vol. 42, pp65.

peanut butter are consumed each week in this urban area. In this single urban market, during a typical six-month timeframe, more than 288,000 cases of peanut butter or 3.4 million jars are moved.

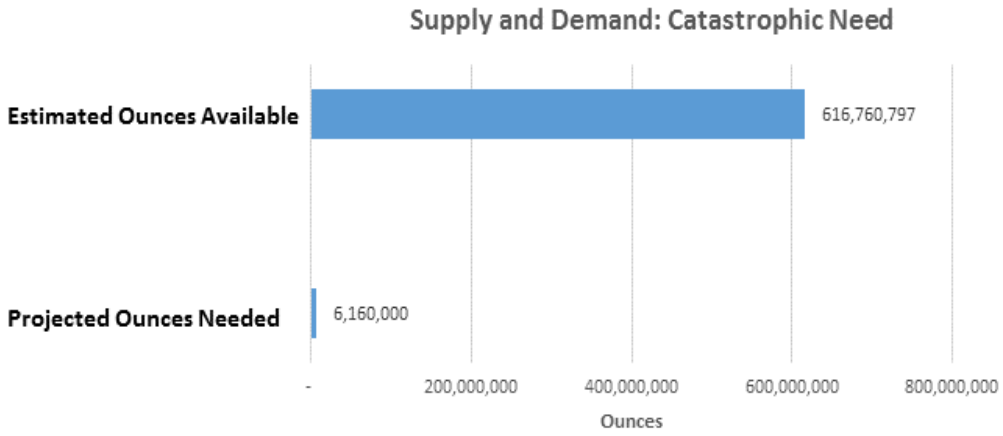
In another large urban market (but with less population than the example immediately prior), a different market-leading grocery distributor in late spring 2016 had over 8,500 cases of peanut butter on hand. Representing almost 50 differently branded and packaged products, this extant reserve totaled more than 3 million ounces of peanut butter, or a sufficient daily ration for more than 266,000 persons. This is without any plus-up procurement and reflects roughly 10–12 percent of the strategic capacity for peanut butter in that particular urban grocery market. If two other market leaders are added, the on-hand supply of peanut butter alone becomes sufficient to provide one day's minimal caloric intake for more than 800,000 people.

Despite its long shelf life, peanut butter is insufficient—and would quickly become unappetizing—to supply tens-of-thousands of displaced survivors. In the second urban market, the on hand supply of canned tuna and other seafood is triple the ounces available in peanut butter. With just two shelf-stable products, well over 3 million daily rations are available.

As this generalized velocity and quantity of current demand-and-supply demonstrates, for some shelf-stable products, there is clearly sufficient flow to avoid expiration of the product. Successful distribution of these products into a disaster context could complement other emergency feeding measures.

Figure 10 below reflects total shelf-stable products on hand in one U.S. Metropolitan Statistical Area (top bar) against what that jurisdiction has projected as being needed to serve displaced persons in a worst-case natural disaster. As illustrated in the figure, the emergency management plans for this Metropolitan Statistical Area project that just over six million ounces of shelf-stable product will be needed to support 300,000 displaced survivors per day for up to 28 days. When extant supplies of roughly 1,800 shelf-stable products in the grocery supply networks serving that MSA are conservatively estimated, the total available is roughly 100 times what is needed.

Figure 10. Supply and demand: Catastrophic need



Source: Chart developed by Principal Investigator. "Estimated Ounces Available" represents shelf-stable products held by the top three grocery providers in one jurisdiction. "Projected ounces needed" represents daily demand of 300,000 projected survivors each consuming recommended daily ration.

One-use case: Cost of establishing and maintaining crisis-contingent grocery mix for Los Angeles

The cost of procuring a crisis-contingent VMI will vary depending on product, region, and the procuring party. In the peanut butter examples noted above, one urban area's per-person demand was nearly twice that of the other urban areas. If a plus-up procurement is undertaken, production capacity, delivery calendar, and preexisting demand for particular products will all impact contracting costs. The ability to aggregate purchases between regions could have a significant impact on cost-per-unit.

Optimal pricing is most likely to emerge when a crisis-contingent inventory reflects preexisting demand. If a particular urban area prefers canned tuna to peanut butter, then canned tuna is more likely than peanut butter to meet survivor preferences *and* more likely to support volume-based price-discounting and movement through market channels with sufficient speed to support a crisis-contingent inventory that does not expire.

In most regions, both peanut butter and canned tuna (and other products) will be part of a crisis-contingent inventory mix; each region's proportion of products reflecting preexisting flows in that region**.** Almost always: the greater the preference (or demand), the better price-per-unit it is possible to negotiate.

This study has not conducted a comprehensive analysis of comparative demand and pricing across the nation. But it is possible to provide a rough order of magnitude (ROM) example of the sort of costs—prior to detailed negotiations—that will be involved. In the Los Angeles pilot program for supply chain resilience Technical Assistance, a benchmark was established for feeding 700,000 displaced survivors for a period of up to 28 days. Multiplying 700,000 survivors by 2,000 calories equals 1,400,000,000 calories per day. Multiplying these calories by 28 days equals 39,200,000,000 calories. In order to simplify the projections, this ROM will round up to 40 billion calories needed. Is there sufficient existing market demand to support a crisis-contingent inventory of these calories? Almost certainly, yes.

On average, each resident of the United States annually consumes 2.2 pounds of peanut butter. For the 3.9 million residents of Los Angeles, this would equal 11,440,000 jars of peanut butter (953,000 cases). On average, each resident of the United States annually consumes 2.4 pounds of canned tuna. For the 3.9 million residents of Los Angeles, this would equal 29,952,000 cans of tuna (1,248,000 cases). On average, each resident of the United States annually consumes 9.9 pounds of ready-to-eat breakfast cereal. For the 3.9 million residents of Los Angeles, this would equal 29,417,000 boxes of cereal (2,451,000 cases). On average, each resident of the United States annually consumes 7.5 pounds of canned soup. For the 3.9 million residents of Los Angeles, this would equal 24,632,000 cans of soup (2,053,000 cases).[43]

The total calories reflected in the projected annual flow of these four products for the City of Los Angeles is over 90 billion calories. Less than half the annual flow of these products alone would provide the targeted crisis contingent inventory. There are many more shelf-stable products on which to draw. Emphasizing that this is a ROM projection, the cost to procure the 40 billion calories targeted for the City of Los Angeles might be scoped as follows:

- 475,000 cases of peanut butter x $32 per case = $15,200,000 (11.4 billion calories)
- 620,000 cases of canned tuna x $38 per case = $23,560,000 (3.4 billion calories)

43 U.S. Consumption information: The NPD Group National Eating Trends database, for the year ending November 2010. Special Note: Los Angeles projections are population multiples of the national average. Significant differences exist between regions and sub-populations (e.g., canned soup consumption in the region encompassing California, Oregon, and Washington is one-third that of North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Missouri.)

- 925,000 cases of breakfast cereal x $60 per case = $55,500.000 (22.2 billion calories)
- 1 million cases of canned soup x $30 per case = $30,000,000 (3.1 billion calories)

A one-time purchase of roughly $124.3 million would establish a not-to-expire crisis-contingent inventory sufficient for the Los Angeles benchmark. This is almost certainly a high-end projection. Given the volumes identified, the markets to be served, and the possibility of accumulating the reserve gradually, significant volume discounts should be negotiable. There would be additional costs for the multiple distribution center "footprints" required to maintain the crisis-contingent inventory. This cost will vary by region, provider, and product. Given the volume projected above, it is unlikely that any single provider alone will be able to manage the required flow. At least two (and often more) leading distributors will need to be engaged in most dense urban areas.

Costs also reflect the population to be served and the projected duration. One way to generalize costs is to abstract the foregoing ROM cost projections to a per-person-per-month benchmark. In this probably high-end example, to procure the ROM inventory costs $6.35 per-person per day (totaling 2,000 calories). This is a one-time cost. There is a recurring annual cost of 36 to 79 cents per person to maintain the inventory. These projections are based on the Los Angeles benchmark of serving 700,000 displaced survivors for 28 days.

Capability Snapshot: Children in a crisis

Currently, there are more than 220,000 children under five years of age in Los Angeles County[44]; about 380 children are born each day, disaster or not.[45] Children and the elderly are especially vulnerable to dehydration and contamination of their gastrointestinal systems. In the case of a catastrophic earthquake in Southern California, public water networks are likely to be disrupted, and the quality of available water will often be compromised.

[44] Southern California Association of Governments. (2015). "Profile of the City of Los Angeles." Local Profiles Report, 2015. https://www.scag.ca.gov/Documents/LosAngeles.pdf.

[45] Los Angeles County Department of Public Health, Office of Health Assessment and Epidemiology, Epidemiology Unit. (2015). "Recent Birth Trends in Los Angeles County." http://www.publichealth.lacounty.gov/epi/docs/Birth_Trends_Health_Brief_Final.pdf.

In Los Angeles County, there are currently about 156,000 residents over the age of 85. This age cohort is expected to total nearly 200,000 by 2030.[46] According to the Cleveland Clinic, "Worldwide, acute diarrhea constitutes a major cause of morbidity and mortality, especially among the very young, very old, and infirm."

Availability of sanitary nutritional support for infants and elderly is a recurring problem in disaster response in the United States and worldwide. The problem can quickly become acute when large numbers of survivors are displaced from their places of residence. John Hopkins University has found, "Mortality rates of displaced populations can be as high as ten times the death rates for the same populations in non-emergencies."[47]

Whenever possible, infants should be safely breastfed.[48] When this is not possible, or in the case of elderly patients on restricted diets, provision of foods formulated for easy digestion can be lifesaving. It is significant that just one grocery distributor serving Los Angeles recently had on hand 67,000 cases of baby food, or more than 5 million ounces.

According to the U.S. Department of Agriculture,[49] children between the ages of one and three years of age increase their daily dietary intake from about 9 ounces to 15 ounces. One distributor has supplies for over 400,000 daily rations. As a whole, grocery distributors in the LA region are estimated to have about 4.8 million daily rations of baby food on hand.

[46] California Department of Finance, Race/Ethnic Population Projections. (2004). https://www.aging.ca.gov/docs/DataAndStatistics/2000CensusAgingData/T123-2010-2050.pdf.

[47] The Johns Hopkins and the International Federation of Red Cross and Red Crescent Societies. (n.d.). "Food Security and Nutrition in Emergencies: Public Health Guide in Emergencies." http://www.jhsph.edu/research/centers-and-institutes/center-for-refugee-and-disaster-response/publications_tools/publications/_CRDR_ICRC_Public_Health_Guide_Book/Chapter_9_Food_and_Nutrition.pdf.

[48] California Department of Public Health. (2012). "Childbirth and Infant Feeding Emergency Information." http://www.cdph.ca.gov/HealthInfo/healthyliving/childfamily/Documents/MO-BFP-EmergencySupplies-2012-12-11.pdf.

[49] USDA. (2015). "Health and Nutrition Information." ChooseMyPlate. https://www.choosemyplate.gov/health-and-nutrition-information.

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Findings Related to the Structural Resilience of Grocery Supply and Demand Networks

Crisis-contingent VMI is conceived primarily as a means to feed survivors of extreme events involving dense urban populations. When an extreme event impacts non-dense populations, the reach and resilience of proximate supply chains will typically be sufficient to rapidly rebalance supply with demand. Localized supply chain disruptions may create spot shortages or other network permutations, but substantial delivery to survivors in the continental United States can often be resumed within one or two days.

This is demonstrably the case when the impacted locality is embedded within a network of overlapping supply chains. For example, metropolitan New York City, northern New Jersey, and southwestern Connecticut can be characterized as having an intensely connected demand and supply network. This network is also connected to and often overlaps with demand and supply networks serving the Greater Boston and Greater Philadelphia regions. Many major players in the Philadelphia network also serve the Baltimore-Washington metropolitan area.

If an extreme event would hit the Connecticut coast with catastrophic consequences, resilience and recovery would benefit from proximity to both the Boston and New York networks. Similarly (if not quite as significant), networks overlap population concentrations as far west as Kansas City and as far south as Houston and Tampa. The overlaps become attenuated at the edge of this area but, for example, Houston's networks still intersect with those for Dallas/Ft. Worth and Austin/San Antonio (see Figure 11 below).

As this suggests, the grocery supply chain in the United States is especially dense, overlapping, redundant, and robust as far west as Kansas City. In the Eastern one-third to one-half of the North American continent, typically three to five high-capacity providers compete with a large number of other smaller providers procuring and distributing simultaneously into several localized supply chains. These

overlapping sets of differentiated supply networks enhance the resilience of the entire system.[50]

Figure 11. Square footage of grocery distribution space in the United States

Source: MWVPL International. (2014). *The Grocery Distribution Center Network in North America.* http://www.mwpvl.com/html/grocery_distribution_network.html.

In most cases,[51] the grocery supply and demand network is a system of largely local networks with comparatively modest link density and node connectivity. In Los Angeles, for example, five grocery distributors supply between 70 and 80 percent of food consumed at home. Each firm's supply network is highly dependent on one or two (or typically no more than three) nodes/distribution centers. But each set of these nodes (e.g., Albertsons, Ralphs, Unified) is largely independent, not interdependent. The nodes are geographically scattered. Links between the nodes reflect random relationships spawned over time. Some links, such as the 101 Freeway, have become persistent and densely used by all nodes, but alternative linkages are readily available.

[50] In the case of the March 2011 Triple Disaster in Japan, the recovery of the most seriously affected Tohoku region was expedited by its proximity to and ability to draw on the enormous supply networks for the Kanto (Tokyo) region. Please see pages 21-24 above.

[51] There are exceptions; as noted in Appendix C, Hawaii and Alaska have extremely high link density and node connectivity.

In 2016, the grocery supply and demand network in most of the United States is characterized by local clusters of nodes and links that are not predisposed to catastrophic cascades. Increasing competition for online grocery customers is currently spurring development of new nodes and links.[52]

Among 33 Metropolitan Statistical Areas (MSAs) in the United States with populations of more than 2 million, this sort of structural overlapping is *less pronounced* for Miami-Ft. Lauderdale (6 million), Phoenix (4.6 million), San Diego (3.3 million), Los Angeles/San Bernardino (18 million), the San Francisco/San Jose areas (6.5 million), Portland (2.4 million), or Seattle (3.4 million). The supply networks for many commodities serving these dense concentrations are less interconnected, and long distances separate each from other demand and supply networks of similar size.[53] Six of these seven "outlier" regions (see Figure 12) are also arguably among the most susceptible to catastrophic risk.

[52] There is a pronounced tendency for individual grocery supply networks (i.e., retail banners) to feature increasing numbers of links, depending on fewer supply nodes. However, in many markets, recent online competition has reduced the percolation of the grocery network as a whole. In many urban markets, there has also been recent growth in the number of demand nodes (and therefore links), reversing a decades-long trend. As a result, while the spectral radius of the grocery network is increasing in most rural and less-affluent areas, in many affluent urban/suburban areas, spectral radius is declining as new competitors (and their supply capacities) enter these markets. Some scholars argue that lower spectral radius can track greater resilience.

[53] Exceptions exist but, in many cases, reinforce vulnerabilities. For example, Los Angeles is a major source of fuel for Las Vegas (90 percent) and Phoenix (50 percent), which would constrain the ability of supply chains in either location to in case of an extreme event in Los Angeles.

Figure 12. Overview of six high-density/high-risk MSAs

Source: Chart developed by Principal Investigator utilizing base map showing North American population density originally developed by Brandon Martin-Anderson using census data.

Table 2 below presents the current top-three suppliers of groceries in each of these six MSAs:[54]

[54] The U.S. grocery market is highly competitive and often volatile, especially in urban areas. Estimating market share is usually difficult and becomes more difficult as the target area is more narrowly defined. Differences in measuring comparative calendars and geographies further complicate reporting. For these specific MSAs, market share is reported as a range reflecting several diverse sources, including: the Shelby Report, Trade Dimensions, Metro Market Studies, Credit Suisse, and other individual sources as specifically referenced. Grocery sector leaders by revenue in the greater Miami region are according to a 2015 analysis by BMO Capital Markets, DJL Research, and reporting by the *Tampa Bay Times.*

Table 2: Top grocery suppliers in high-density, high-risk urban areas

MSA	Top Grocery Suppliers	Notes
MIAMI, including Ft. Lauderdale	• Publix, 40–44 percent (43 percent for all of Florida) • Bi-Lo/Winn-Dixie, 11–14 percent (also known as Southeastern Grocers) • Walmart, 11–13 percent (29 percent for all of Florida)	C&S Wholesale Grocers supplies Southeastern Grocers and others.
SAN DIEGO	• Albertsons (Vons/Albertsons), 26–35 percent[55] • Costco, 12–17 percent • Ralphs/Food4Less (Kroger), 10–14 percent	Trader Joes, Walmart, and Unified Grocers are also significant in San Diego.
LOS ANGELES, including Long Beach and San Bernardino	• Ralphs/Food4Less (Kroger), 19–21 percent • Albertsons/Vons, 17–20 percent • Unified Grocers, 12–15 percent	Walmart, Trader Joes, and Stater Brothers each serve roughly 10 percent of the LA grocery market.
SAN FRANCISCO, including Oakland and San Jose	• Albertsons, 25–27 percent • Super Store Industries (Save Mart and others), 20–25 percent • Costco, 12–15 percent	C&S Wholesale Grocers has a significant distribution capacity in Stockton and Sacramento.
PORTLAND	• Albertsons, 25–28 percent • Fred Meyer (Kroger), 15–17 percent • WinCo, 9–11 percent	Walmart and Unified Grocers serve over five percent of the grocery market.
SEATTLE, including Tacoma, Everett, and Olympia	• Albertsons, 28 percent • Fred Meyer (Kroger), 23 percent • Quality Food Centers, 13 percent	Walmart and Unified Grocers also serve over five percent of the grocery market in the Seattle MSA.

[55] Large-scale mergers, store sales, and, in some cases, repurchasing of stores occurring since 2015 make it especially difficult to accurately track the Southern California market share for groceries.

Publix is the dominant supplier of groceries in the Miami MSA.

In each of the five Pacific Coast MSAs, **Albertsons** (locally known as Albertsons, Safeway, Vons, and under other banners) is a crucial source of grocery capacity. In every MSA other than San Francisco, a brand associated with **Kroger** is a top-three player. **Unified Grocers** is a significant supplier of groceries in all five of the Pacific Coast MSAs, especially to independents who are often key sources of groceries to vulnerable communities.

In all six MSAs, **Walmart** is a significant secondary or better participant. In four of the six MSAs, **C&S Wholesale Grocers** is a significant source of grocery capacity.

It is not necessary to exclude any source of supply capacity, but these six sources of supply are especially important to the high-density/high-risk and more structurally isolated MSAs identified. Together, these six sources constitute a significant proportion of the strategic capacity needed to address catastrophic risk. These six are also crucial sources of supply in many other areas of the United States. Please see Appendix A for profiles of these six sources of grocery supply.

Is special procurement necessary?

This research has confirmed that crisis-contingent VMI is financially and operationally feasible. The analysis immediately above suggests that VMI could be an especially important element serving survivors of a major disaster in six major urban areas.

The VMI concept at FEMA has assumed that the agency would procure a significant plus-up of ordinary supply levels for specific products. Two perspectives have motivated this predisposition:

1. Given the increasingly JIT supply and demand networks described in the previous section, FEMA personnel have assumed that existing flows of shelf-stable products probably would not be sufficient to make a significant contribution to feeding tens-of-thousands of survivors to a catastrophic event. Current stocks would be exhausted too quickly.

2. To fulfill its obligations in a time of catastrophe, FEMA is predisposed to have a specific legal claim on the supplies it plans to distribute.

However, detailed discussions with some of the key suppliers identified suggests that the first perspective is not accurate, and the second could unnecessarily increase costs and complicate both preparedness and response.

Current stock levels

This research confirmed significant commercial flows of shelf-stable products, much greater than anticipated prior to detailed discussions with major suppliers. The research has potentially uncovered that stock levels in many "more isolated" markets—such as the six highlighted above—may be higher than in other locations as a function of having fewer sourcing options and being at greater distance from these options.

The research on specific flows and stock levels requires access to information from individual firms that can be sensitive. Other suppliers and retail competitors having access to such specific information could complicate pricing negotiations and could be utilized by competitors to the disadvantage of distributors and retailers. To view this information, researchers entered into Non-Disclosure Agreements that allowed firms providing information to preview and approve the information noted below. For all of these reasons, the information below has been aggregated and converted to market-wide projections, rather than reports for any particular grocery distributor or retailer. As such, the analysis provided below should be treated as data-derived estimates rather than specific data reports. Furthermore, the nature of grocery competition in the United States—especially in the market this data reflects—is so dynamic that any single firm's situation at any particular moment in time is not necessarily a good predictor of future demand. However, a large population's demand behavior across a sizeable market is usually more stable, and overall change in demand for food products still tends to be incremental.

Grocery distribution firms that were willing to share detailed data report carrying between 1,800 and 2,000 individual food (non-infant) products that are shelf-stable. Different firms reported on-hand stock of these products for slightly different time periods during the first half of 2016. Each of the grocery distribution firms with data included below serve one of the six MSAs identified in the prior section.

In aggregate, the grocery distribution firms sharing data constitute approximately 50 percent of one MSA's total grocery market. It should, therefore, be possible to reasonably anticipate that actual inventories of these shelf-stable products are at least double what is reported here.

The total cases of shelf-stable products identified on-hand by the firms sharing data totaled 1.97 million, yielding a total market approximation of 4 million. This case count equals more than 400 million ounces of product (a total market sum of approximately 800 million), or 25 million pounds of shelf-stable meals.

The World Health Organization recommends that 6.6 to 8.8 pounds of food per person per week be provided to disaster survivors. This indicates that at the highest recommended weekly ration, at least 2.8 million weekly rations of shelf-stable food,

are available from the distribution firms sharing data. It is therefore not unreasonable to project 5.6-million weekly rations for the entire market.

The lower projection is, for example, sufficient to feed 700,000 displaced survivors for four weeks, as benchmarked in the Los Angeles pilot project. This same quantity, alone, would be sufficient to provide all 13 million residents of the Los Angeles MSA with sufficient disaster nutrition for a period of more than three days.

There are complications, however: Some inventory is likely to be destroyed by the disaster. Current retail customers serving many non-displaced survivors will have first claims on the product. Packaging the product for distribution to survivors and delivery to displaced survivors (not to preexisting retail customers) present significant challenges, as well, which are addressed in the final section of this study, Post-Event Delivery of Surviving Inventory. In addition, hoarding is a serious problem in many post-disaster situations.

But, data reviewed for this study suggests that on the day before a potentially catastrophic event—without any plus-up procurement, the grocery distributors in most major U.S. urban areas probably have on-hand stocks of shelf-stable products roughly equal to what is needed by displaced populations for 3–4 weeks following many extreme events. While not a total solution, the existing inventory could be of considerable help feeding survivors, but only if it can be delivered.

Furthermore, grocery distributors note that in worst-case disasters, previously anticipated demand for existing product is likely to decline with the loss of retail facilities and restrictions on transportation. As a result, more will be available for delivery to displaced populations.

Based on these factors, grocery distributors are skeptical that plus-up procurement is needed or would be worth the additional costs. The most serious challenge facing grocery distribution in the aftermath of a major disaster will probably not be lack of supply, but inability to deliver existing supply.

The grocery distributors interviewed for this study would prefer that the government work with distributors to ensure continuity and adaptability of transportation, distribution, and delivery capabilities for regular commercial stocks. Some grocery distributors would also welcome exploring effective modalities for the government to become a “last-resort buyer” for shelf-stable products needed by displaced populations.

At the very least, before plus-up procurements are undertaken, the transportation challenge should be credibly solved.

Post-Event Delivery of Surviving Inventory

Maintaining a crisis-contingent inventory is worthless unless it can be delivered to survivors in the aftermath of an extreme event. Delivery depends on several factors, including:

- Survival of the specific products following a disaster in the region;
- Survival of the distribution center and its functionality;
- Accessibility to and from a distribution center;
- Packaging and allocating products;
- Availability of trucks, drivers, and fuel; and
- Accessibility to survivors.

Survival of products and their distribution centers

Catastrophic events cannot be predicted precisely. Knowing exactly where a hurricane or earthquake will hit hardest is practically impossible. It is, however, possible to consider which facilities have been sited and constructed to most likely survive serious impact, including to threats of:

- Flooding;
- Landslides;
- Liquefaction;
- Fire;
- Contamination; and
- Extreme wind.

Given the potential disruption of transportation networks by an extreme event, one must consider the proximity of the distribution center to pre-event population centers. If plus-up procurements are undertaken, in selecting vendors, it is entirely appropriate to base selection in part on how equally survivable facilities are geographically spread to increase the likelihood of at least one surviving a wide-area event. It is also reasonable (plus-up procurement or not) to give particular attention to those facilities with disproportionally large shares of the market's strategic capacity.

In any surviving distribution center, personnel in the facility at the time of the extreme event may constitute a significant proportion of the workforce during much of the response phase. Planners must also consider whether provisions are in place to support personnel remaining at the distribution center for an extended period of time.

Survival of distribution center functionality

Personnel are one critical element of distribution center functionality. Forklifts must also survive intact, and be able to be powered. Similarly, internal communications capability is essential for picking and packing delivery packages. And even if the distribution center and inventory survived, the racks, roof, and related infrastructure must be sufficiently secure that operations can continue with reasonable safety.

Facility access

If the product and distribution center survives, but bridges and roads to the distribution center collapse or are otherwise impassable, the inventory cannot help survivors. It is entirely appropriate to select vendors and work with non-vendor strategic partners who can demonstrate effective alternate access routes to their facilities. It is valuable to ensure that grocery distributors and local authorities engage in planning and preparation for debris removal, rapid replacement of damaged transportation infrastructure, and other means of ensuring that inventory can be delivered to those in need. Potential accessibility by sea or air increases the potential of an otherwise equally survivable site.

Appendix F provides a draft distribution center survival checklist.

Packaging of products

Procured or not, crisis-contingent VMI will typically consist of a mix of products. In addition to a "core calorie" product (e.g., peanut butter, canned tuna, ready-to-eat cereal, canned soup), other components are likely to include the following:

- Canned or bottled water
- Energy and candy bars
- Roasted nuts
- Raisins and other dried fruit
- Canned milk
- Baby food

Which products are included in the crisis-contingent inventory depends on the potential for flow-management and cost. Local variations will reflect pre-event preferences (demand).

To avoid expiration, even procured product must be stored and distributed into commercial markets as usual. However, following an extreme event, these products will ideally be combined into personal-sized "packages" for delivery to survivors. Such personal-sized packaging cannot occur prior to the extreme event without making market-management impossible. Packaging at the distribution center is typically possible, but following an extreme event, this is unlikely, given the personnel that would be needed to "pick" the packages. Such picking and packaging would also significantly delay delivery. This suggests that breakdown and re-packaging into personal-sized packages for delivery to survivors is most likely to be done once delivery to—or immediate proximity to—survivors is achieved. Plans, resources, and training will be needed for this to be accomplished.

Availability of trucks, fuel, and truckers

Those who lead in procurement and distribution operations are not always involved in trucking. Some distributors maintain their own trucking fleets; others outsource all trucking operations. Many have a mix of trucking solutions.

Because of property prices, zoning, decisions made decades ago, and many other factors, even the most population-proximate distribution centers in the United States are often several miles from dense residential areas. Delivery to survivors will usually require trucks.

As an example, one major grocery provider in metro Los Angeles has its principal distribution center only 6.9 miles from City Hall. Another has two locations less than 20 miles away. But, the single-largest grocery distribution center serving the Los Angeles region is 60 miles from City Hall. Likewise, the nearest full-sized distribution center serving Washington, DC is 19 miles east of the city, but the largest grocery distribution center serving the Capital is 94 miles away. Another metro area studied

for this report sources over 40 percent of groceries consumed from over 200 miles distant. All require transportation assets to move product to survivors.

Some grocery distribution centers include fuel supplies and tractor staging areas. Onsite fuel storage is increasingly uncommon, though, and third-party fuel contracting is most common. Mobile refueling of locally focused fleets is becoming more common. There are often extra trailers onsite at distribution centers, but most tractors may be staged at alternate locations. In the case of one major urban area distributor, most tractors are staged over 50 miles from the facility considered most essential to post-disaster operations. Most grocery delivery in the United States is done using large, two-axle tractors and 28-foot (or bigger) trailers. In the aftermath of an extreme event, which would include delivery to non-traditional locations, other formats may be more flexible and effective.

Furthermore, truckers often commute long distances to begin their routes. In the case of one Southern California grocery distributor, the majority of drivers live on the eastern side of the San Andreas fault and, if at home in case of a major shift, are unlikely to be able to access their trucks. Even those on the west side of the shift will be challenged in navigating to their trucks. Moreover, depending on the situation facing their families, many truckers may be disinclined to leave home until some semblance of social order has been demonstrated. Paradoxically, the movement of food trucks is one of the key indicators of social order.

While the particulars vary dramatically from locality to locality, the range of delivery challenges outlined above will be similar for most prospective vendors of crisis-contingent inventory. The most effective solutions are likely to reflect local conditions and involve a variety of collaborators. It is appropriate to ask potential vendors to describe their current arrangements related to fuel, personnel, and trucking. It is also appropriate to ask about existing relationships with public safety, emergency management, and related public-sector agencies.

Accessing survivors

Wherever retail outlets survive an extreme event and continue to be operational, facilitating re-supply of these outlets should be a priority for both government and private sector supply chain operators. For both functional and psycho-social reasons, continuity of preexisting commercial capabilities will speed overall recovery.

However, in many cases, the preexisting network of demand nodes will be disrupted. Facilities will be destroyed or inaccessible. If still standing, many retail locations will be unable to conduct commercial transactions due to the loss of power and telecommunications. Unable to use credit and debit cards and soon without cash, populations of survivors who can be served out of existing demand nodes should still be served. Alternatives will be needed to typical purchasing practices and places.

The greatest challenge in the most extreme events is almost always delivery of water, food, and medical care to large displaced populations. This can be especially difficult in the first several days following a no-notice event when significant elements of transportation infrastructure have been destroyed or disrupted, power and communications systems are not fully operational, and substantial housing stock is no longer safe to inhabit. In this confused context, even where key resources are available, they often do not reach survivors for several days.

In 2015, this delivery gap was experienced in the otherwise largely successful response to the earthquake in Nepal.[56] In 2013, trucking and other transport was the last gap to be filled in the global response to Hurricane Haiyan (Yolanda) in the Philippines.[57] Perhaps most dramatically, trucks and truckers came to the rescue in the March 2011 Triple Disaster in Japan. Following is a detailed description from a joint Japan–U.S. academic analysis:[58]

> *… with hundreds of thousands of individuals needing critical supplies[,] PD-HL (Post-Disaster Humanitarian Logistics) became a monumental challenge for which cities, prefectures, as well as the national government, were not ready. As a result, for at least the first six days of the crisis[,] hundreds of thousands of survivors did not receive relief supplies (Daily Yumiuri 2011; Sakurai 2011).*
>
> *This prompted heavy criticism of the official response, which was accused of ignoring the plight of the survivors: a member of the Democratic Party of Japan said, …The prime minister and Mr. Edano [Chief Cabinet Secretary] are focusing too much on the accidents at the nuclear reactors, and not caring enough about the evacuees… (Daily Yumiuri 2011). In response to the heavy criticism—in day seven of the crisis—the SDF announced that it will distribute relief supplies to the individuals that survived the disaster (Daily Yumiuri 2011)... At this critical juncture, everything seemed to indicate that—with the SDF strained to the limit—and the normal private sector supply chains severed, that a huge humanitarian crisis was unavoidable.*

[56] *The Guardian*. (2015). "Nepal Government Criticized for Blocking Earthquake Aid to Remote Areas." https://www.theguardian.com/world/2015/may/02/nepal-government-criticised-blocking-earthquake-aid-remote-areas.

[57] Calleja, Niña P. (2013). "Relief Gridlock in Matnog: Lack of ferries ties up traffic to Samar." Inquirer.net. http://newsinfo.inquirer.net/528105/relief-gridlock-in-matnog.

[58] Holguín-Veras, José, et al. (2014). "The Tohoku disasters: Chief lessons concerning the post disaster humanitarian logistics response and policy implications." *Transportation Research Part A: Policy and Practice*. 69: 86-104. http://www.sciencedirect.com/science/article/pii/S0965856414001839.

Fortunately, fate intervened in the form of a handful of trucking/distribution companies (e.g., Yamato, Sagawa, Nittsu, and Akabo) that—because of their role in the food and retail sectors—were in a position to know that the private sector supply chains had been severely disrupted, and that the public sector was not ready to fill the gap. They recognized that a huge humanitarian crisis was underway and that without their intervention things would get much worse.

Independently of each other, they approached local officials during the period March 15th–19th and took the unprecedented step of volunteering to do local deliveries of relief aid (Holguín-Veras, Taniguchi et al. 2011). In the two cases interviewed for this paper (i.e., Yamato and Sagawa), the companies paid for the costs of the local distribution and the supplies that they distributed during the first week, and the costs (except fuel) of the hundreds of trucks and drivers that they volunteered for almost a month of PD-HL operations in entire cities (Holguín-Veras, Taniguchi et al. 2011).

Without their timely intervention—and the assets, expertise, and supplies they brought with them—the situation in Tohoku would have taken the path of Haiti, where the lack of help from the local business class contributed to a crisis of huge proportions (Holguín-Veras, Jaller et al. 2012).

Ironically, many other trucking associations and companies seemed to have volunteered their services, though their offers were rejected because the government could not guarantee the fuel for the return trips (Daily Yumiuri 2011). Although it is not the authors' objective to second guess decisions made in the midst of chaotic field conditions, it is important to highlight that using SDF's assets to transport fuel to the disaster area would have enabled the government to accept the help from the private sector, thus expediting the relief effort. This point was made by an anonymous source that told the Japanese media that "Giving these firms preferential access to fuel would be one way to help us get more aid on the road to Tohoku,"…"There isn't a lack of supplies." (Daily Yomiuri 2011).

These volunteer companies did not have an easy time as they faced numerous challenges, notwithstanding their high level of professionalism, experience, and the fact that at least one of them (Sagawa) stated that they …learned from the 1995 Kobe earthquake experience.... In most cases[,] it took the companies more than a week to start distributing supplies to the RCs, which began in earnest at the end of the period March 19th–25th, 2011. The staff reported being shocked and overwhelmed by the complexity and magnitude of the

> *challenge... In their own words: …transporting to DCs was easy…, while…transporting to RCs was very difficult… (Holguín-Veras, Taniguchi et al. 2011).*
>
> *The experience of these world class companies clearly show that the local distribution of critical supplies cannot be taken for granted; and that the response plans for catastrophic events must seriously take into account, and prepare for, such challenging effort.*

Unless supplies of essential commodities are being delivered within 48 hours of an extreme event, there is an increasing likelihood of civil unrest and foraging behavior that can further complicate effective delivery of resources to survivors.[59]

Even if trucks, fuel, and drivers are available to deliver resources, several issues will continue to complicate delivery to survivors:

- Where are survivors located?
- Which transportation routes are available to these locations?
- Will commercial trucks be allowed to operate on these routes?
- Who and where are parties ready to receive deliveries?
- Will truckers be safe delivering to these locations?

A potentially catastrophic event will make it difficult to quickly and authoritatively answer these questions. Aerial surveillance may be able to identify relocations and available transportation routes, but communicating these findings and coordinating to ensure actual delivery clearly cannot be left pending until the extreme event.

There are many examples when available resources are not delivered because private-sector transportation capabilities are not deployed or are actually suppressed. While a common problem, there is no consensus regarding principles or models of good practice for effectively engaging these private-sector assets for a wide-area, potentially catastrophic event involving a dense urban area. The vast majority of strategies and related planning focus on "official" transportation resources.

[59] Renn, Ortwin, Jovanovic, Alexsandar, and Schröter, Regina. (2011). "Social Unrest." OECD, Future Global Shocks. http://www.oecd.org/gov/risk/46890018.pdf.

How bad is too bad?

In discussions with distributors, truckers, and others, *expectations* of infrastructure failure and civil unrest may actually suppress the development of realistic transportation options. The post-disaster context will be bad. But, as examples from other crises demonstrate, opportunities persist for adapting to even radically altered situations. Greater clarity is needed regarding a range of likely outcomes. Discussions with grocery distributors strongly suggest that a substantial capacity to deliver shelf-stable supplies to survivors will exist following most extreme events. Furthermore, many threats to this capacity can be mitigated in advance of the event. There is much less confidence that the tactical capability to *deliver* supplies is well-established.

Summary of Key Findings and Recommendations

The ability to source and stage post-disaster resources has improved considerably in this century. This progress has been observed in both international and domestic disaster response. In the United States, greater attention to logistics in the Post-Katrina Emergency Management Reform Act of 2006 has resulted in new capabilities and the potential to scale. Similar progress has been made since 2005 as the World Food Program's system of Logistics Clusters has been deployed.[60] Despite this progress, there is a continuing challenge in "last-mile" delivery of resources. Despite the rapid establishment of air hubs and inflow of emergency supplies to affected regions, delays can occur. Again and again, critical supplies—including water, food, pharmaceuticals, medical goods, fuel, and shelter—are staged and available, but distribution is long-delayed and delivery can be tragically uneven.

For example, over the last decade, in anticipation of a major earthquake, extensive logistical plans and preparations were developed for Nepal. This included construction of a model Humanitarian Staging Area that opened just four weeks before the April 25, 2015 7.8-magnitude earthquake. Despite these investments, six weeks after the initial quake, the World Food Program reported that it was still trying, "to provide essential supplies to the most remote locations in Nepal, many of which lie above the altitude of helicopter access, but also to rehabilitate the main artery trails that remain the lifeline of these communities, reopening market access as soon as possible."[61]

As already noted with regard to the Triple Disaster in Japan,[62] **in a wide range of international disaster situations, supply has been unable to fulfill demand until *preexisting* modes of distribution and delivery return to operation**. In some cases,

[60] World Food Programme. (2016). *Logistics Cluster.* http://www.wfp.org/logistics/cluster.

[61] World Food Programme. (2015). *Nepal Situation Repot #12.* http://reliefweb.int/sites/reliefweb.int/files/resources/Nepal%20Earthquake%20Situation%20Report%2012%2012%20June%202015%20.pdf.

[62] See *supra WFP Logistics Cluster,* page 34

this is the black market. In some cases, this is government distribution channels. In most cases, this is a diverse collection of "last-mile" delivery modes and channels.

Last-mile distribution is a significant challenge even in non-disaster contexts. Writing in *Industry Week*, Burton White explains:

> *Even gargantuan[,] high-profile e-tailers—while having succeeded in offering customers inexpensive and same-day delivery options—are still struggling to maintain efficient last-mile solutions in a cost-effective and profitable manner. As retailers strive to offer a near-perfect shopping experience, leveraging the right data and information across multiple channels becomes paramount as reliance on their network's last-mile capabilities and efficiencies is amplified.*[63]

On entirely ordinary days, an estimated 28–53 percent of delivery costs are associated with last-mile operations.[64]

However, **the U.S. grocery industry can procure and manage a non-expiring crisis-contingent inventory** that could substantially assist survivors of a catastrophic event impacting dense urban areas. Evidence even suggests that the regular flow of shelf-stable products is so substantial that plus-up procurement is not needed.

That said, **significant and unresolved challenges remain regarding how this inventory can actually be delivered to survivors.** The problem is usually a matter of how supplies from outside a disaster zone can be inserted into the disaster zone, often from considerable distance. Effective deployment of private-sector transportation assets (especially trucks, truckers, and fuel) is fundamental to responding to and recovering from an extreme event, especially one involving a dense urban area. This is true whether or not the "content" to be delivered is regular commercial inventory, crisis-contingency Vendor-Managed Inventory, or FEMA resources. In the case of local inventory, a principal benefit of the concept is the proximity of content to survivors and the embedding of content in a preexisting supply network.

A potential benefit of crisis-contingent VMI is that supplies are already inside the disaster zone or proximate to it. However, roads still need to be cleared of debris; trucks and truckers must be available; and refueling will soon be required. The "first

[63] White, Burton. (2015**). "Last Mile: The New Frontier in the Retail Supply Chain**." IndustryWeek. http://www.industryweek.com/last-mile.

[64] McCrea, Bridget. (2016). "From DC to Final Distribution: Last Mile Dilemma." *Supply Chain Management Review.* http://www.scmr.com/view/from_dc_to_final_destination_last_mile_dilemma/third_party_logistic.

mile" outside the distribution center may be as difficult as the "last mile" delivering to survivors. If ordinary communications channels are no longer available (as is likely in a catastrophic event), effective adaptation to these new and uncertain conditions will be difficult.

Developing solutions will require considerable engagement with (and by) the grocery industry and its related transportation partners, as well as by FEMA and its local emergency management and public safety partners. Finding planning solutions that could apply reasonably well to the six high-density/high-risk urban areas featured in this report will be a particular challenge. Moving beyond this small subset will be even more challenging.

The transportation element of the grocery supply chain is sufficiently complicated that these challenges cannot be confidently addressed in the abstract. **There are likely to be different solutions for each urban area and even for each grocery distribution center.**

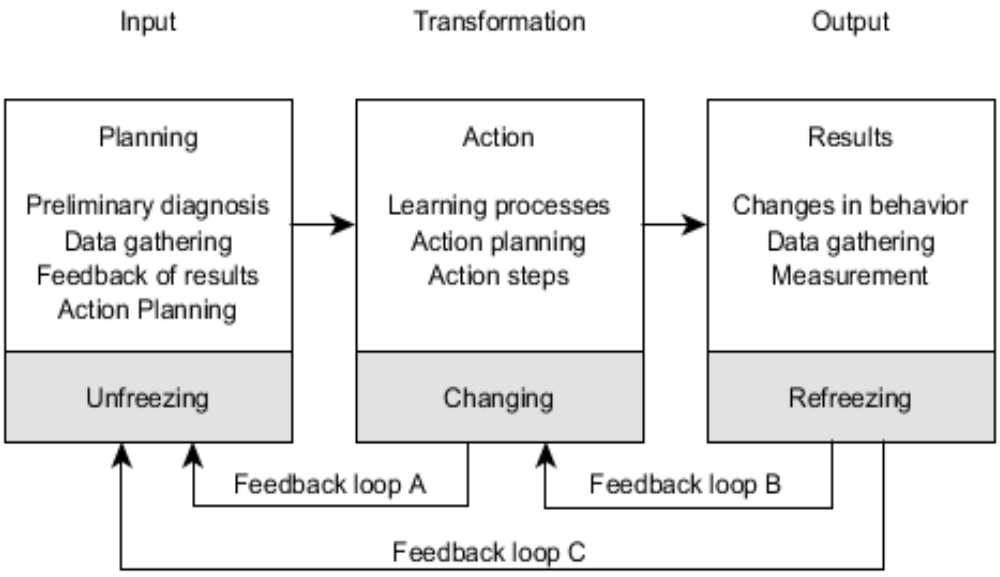
Delivery of the crisis-contingent inventory and resupply of distribution centers will require effective collaboration between key public- and private-sector operators. Public safety and emergency management agencies will often be in a position to provide information on population movements, status of transportation networks, availability of fuel, and other key aspects of situational awareness. **Establishing effective operational relationships between local, state, and federal public-sector agencies and individual grocery distributors will be essential.** In other words, while substantial stocks of shelf-stable nutrition are available from grocery distributors, the potential for effectively applying these in the immediate aftermath of a catastrophic event will require **an unprecedented reorganization of current transportation capacity to create delivery capabilities that do not currently exist**. This is a strategic gap that must be addressed for the potential of crisis-contingent VMI to be achieved.

The question remains: can working with grocery distributors prompt the preexisting supply network to reengage more quickly and adaptably? To answer this question (and because this transportation challenge requires much more careful analysis than is within the scope of this study), **it is recommended that a pilot study—including a functional test of transportation options—be undertaken.**

This follow-on research agenda should focus on reestablishing effective supply chain pull in a crisis through "action research," which David Frost defines as, "a process of systematic reflection, enquiry, and action carried out by individuals about their own

professional practice"[65] (see Figure 13). In this case, **the practitioners should include key stakeholders in local emergency management, disaster logistics, and the grocery supply and demand network.**

Figure 13. Three-step process of action research



Source: Lewin, Kurt, et al.

In the case of grocery supply/demand, our "input," or "preliminary diagnosis" is that there are impediments to transportation and delivery to survivors of available shelf-stable products. The results of the present study could be used to inform the first step in the action research process.

Based on these inputs, the "transformation" step would be explored through a simulation or set of simulations. Based on the findings reported above, the action engaged in the second step ought to be consistent with the following pre-conditions:

- It involves one of the six high-density/high-risk MSAs highlighted in this report.
- It involves at least two leading suppliers of a shelf-stable product.

[65] Costello, Patrick J.M. (2003). *Action Research.* Continuum. https://mthoyibi.files.wordpress.com/2011/04/action-research_patrick-j-m-costello-20031.pdf.

- It involves leading transportation firms supporting these suppliers.
- It involves several potential transportation alternatives (e.g., third-party logistics, Uber, UPS, USPS, FedEx).
- It involves local, county, state, regional, and federal emergency management and public safety agencies.
- It involves U.S. National Guard and U.S. Northern Command transportation functions.
- It involves a wide-area, potentially catastrophic event scenario displacing roughly 20 percent of the population; significant disruption of the electrical grid for at least two weeks; comparable disruption of telecommunications capability; and destruction and damage to substantial portions of the transportation, fuel, and water networks.
- It involves the simulated delivery of grocery supplies already in the impact zone to survivors—both displaced and not.
- It involves resupply of food inventories from outside the impact zone.

The action research would seek to give priority to continuing delivery of grocery products to surviving commercial retailers wherever possible. Private-public collaboration is likely to be needed to facilitate such deliveries. How to organize such operational collaboration would be a principal goal of the action research.

The action research could also explore the FEMA Logistics Management Directorate (or some other appropriate public-sector entity) serving as a "last-resort buyer" for appropriate shelf-stable products that cannot be delivered to commercial retailers or that exceed the commercial demand-pull being experienced by surviving retailers.

The "outputs" of the second step would be assessed to determine how and if it is feasible to deliver commercially available resources in a timely and effective way following a potentially catastrophic event. Results should also confirm or deny the need for plus-up procurement of inventory as originally conceived or determine that existing stocks provide sufficient support for survivors. Additional lessons-learned are likely, which should be documented for response planners across the nation.

This action research is essential if the progress made in the last century in the ability to source and stage post-disaster resources is to keep pace with technological advances and the continued evolution of supply chains in the next century.

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Appendix A: Brief Profiles of Six Crucial Suppliers

C&S Wholesale Grocers, Inc. is the largest wholesale grocery distributor in the United States, based on revenue. Net sales, together the with net sales of affiliated companies, were approximately $30 billion in fiscal year (FY) 2015, making C&S the 10th-largest privately held company in the United States, as ranked by *Forbes*. Founded in 1918, C&S provides grocery wholesaling and distribution services to the retail grocery industry. From distribution centers located in the Northeast, Mid-Atlantic, Southeast, Southwest, West Coast, and Hawaii, the company delivers food and non-food products to approximately 6,500 grocery stores across the United States.

The Kroger Co. was founded in 1883 and incorporated in 1902. It is one of the largest retailers in the United States based on annual sales, holding the #20 ranking on the Fortune 100 list published in June 2015. For FY 2015, the company had net sales of roughly $22.5 billion. At the end of FY 2015, Kroger operated (either directly or through its subsidiaries) 2,778 supermarkets. In addition to supermarkets, Kroger operates (by franchisees or through its subsidiaries) 784 convenience stores, 323 fine jewelry stores, and an online retailer. Kroger also manufactures some of the food for sale in its supermarkets. As of February 1, 2015, it operated 38 food production plants.

New Albertsons is a recent merger of the previously independent Safeway, Inc. and AB Acquisition LLC ("Albertsons"), a privately held enterprise. The merger was completed in January 2015. Safeway Inc., which operated Safeway, Vons, Pavilions, Randalls, Tom Thumb, and Carrs stores, was a Fortune 100 company and one of the largest food and drug retailers in the United States, with sales of $35.1 billion in 2013. Albertsons operated under the retail banners ACME, Albertsons, Jewel-Osco, Lucky, Shaws, Star Market and Super Saver, and stores under the United Family of stores included Amigos, Market Street, and United Supermarkets. The merger created a privately held, diversified network that includes 2,230 stores, 27 distribution facilities, and 19 manufacturing plants, with over 250,000 employees across 34 states and the District of Columbia.

Publix is a privately held and largely employee-owned corporation with 1,128 grocery stores, 8 distribution centers, and 10 manufacturing facilities concentrated

in the southeast United States. In 2015, the company reported sales of $32.4 billion. Publix employs more than 184,500 people.

Unified Grocers ("Unified") is the largest retailer-owned wholesale grocery cooperative in the western United States. Founded in 1922, Unified and its subsidiaries generated approximately $4 billion in sales during FY 2015. Over 500 independent grocers are members of Unified. The cooperative serves over 3,000 stores in Alaska, Arizona, California, Colorado, Hawaii, New Mexico, Nevada, Oregon, Texas, and Washington. Unified has distribution and manufacturing centers in Southern California, the San Francisco Bay area, Portland, and Seattle. While smaller than the other five suppliers listed here, in many Pacific Coast urban areas, Unified is often the principal source of strategic capacity serving the most vulnerable communities.

Walmart is the world's largest private enterprise by revenue and number of employees. Grocery sales account for roughly 55 percent of the company's overall sales. With over 4,000 stores selling groceries, Walmart accounts for roughly one-quarter of all grocery sales in the United States, generating more than $155 billion per year. Walmart has operations in every state of the United States.

Appendix B: Leading Sources of Grocery Capacity, Listed by FEMA Region

In most urban areas, establishing a crisis-contingent VMI would require the involvement of at least two leading grocery suppliers. Given the proportion of overall demand needed to maintain non-expiring flow—those supplying up to 80 percent of pre-crisis flows will typically need to be involved.

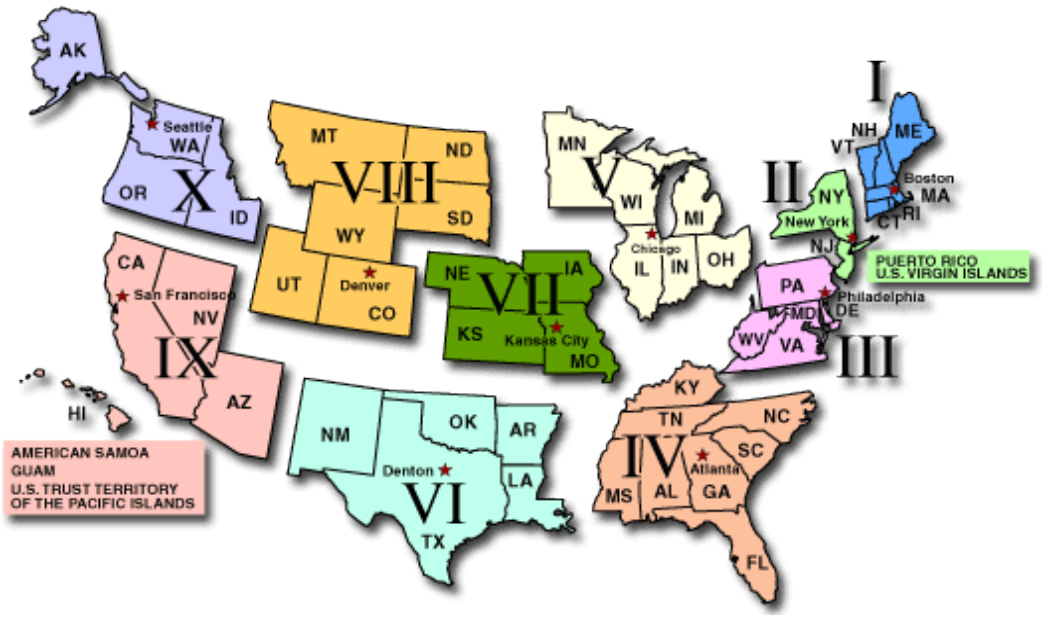
In most dense urban markets, grocery[66] supplies are dominated by as few as two (and seldom more than five) major competitors. While every supplier can make a potential contribution, it is unlikely that a sufficient crisis-contingent reserve can be established without significant involvement by market leaders.

Below is an approach to estimating market leadership by FEMA Region (see Figure 14).[67] Available market analyses typically do not conform to FEMA Regional boundaries and often do not conform with city boundaries or Metropolitan Statistical Areas. Furthermore, the grocery market is currently undergoing significant competitive and structural shifts. Market shares are constantly changing. Accordingly, the information provided should be understood as only identifying promising targets for further investigation.

[66] "Grocery" typically references food purchased to prepare and consume at home. In most markets, this constitutes roughly half of calories consumed. There are other important sources of food, including institutional providers such as Sysco, U.S. Foods, and several large restaurant chains. These sources are not, however, typically significant distributors of large quantities of shelf-stable products that will be especially helpful in the aftermath of a potentially catastrophic event.

[67] Many of the 2015–2016 market estimates were developed by *The Shelby Report*. http://www.theshelbyreport.com/.

Figure 14. FEMA Regions map



FEMA Region I includes Connecticut, Maine, Massachusetts, New Hampshire, Vermont, and Rhode Island. Region-wide, C&S and Walmart are crucial sources of strategic capacity. C&S is currently the principal wholesaler supplying Ahold and Stop & Shop. C&S is headquartered in New Hampshire. All other suppliers hold less than five percent of the regional market.

Western Section of the Region

Supplier	Store Fronts	Market Share
Ahold	108	39.80%
Bozzuto's	130	17.20%
C&S	69	14.30%
Big Y	56	12.80%
Wakefern	43	10.50%
Walmart	21	6.40%
Price Chopper	20	5.10%

Eastern Section of the Region

Supplier	Store Fronts	Market Share
Stop & Shop	139	23.00%
C&S	223	17.30%
Hannaford	144	16.00%
Shaw's	136	14.40%
Market Basket	75	12.70%
Walmart	62	9.20%
Whole Foods	34	5.20%

FEMA Region II includes New York, New Jersey, Puerto Rico, and the U.S. Virgin Islands. Region-wide, C&S, Walmart, and Wakefern are the crucial sources of strategic capacity. Bankruptcy and dissolution of A&P in 2015 will result in some reordering of future market sizing. Wakefern's headquarters is in New Jersey. Wakefern's strength in non-metropolitan New Jersey is probably understated in these market estimates. C&S has been the principal wholesaler for A&P and Stop & Shop. All other suppliers hold less than five percent of the regional market.

Metropolitan New York City

Supplier	Store Fronts	Market Share
C&S	526	35.20%
Wakefern	182	20.90%
A&P	229	16.20%
Stop & Shop	145	15.20%
White Rose	356	10.10%

Upstate New York

Supplier	Store Fronts	Market Share
Price Chopper	87	27.00%
Walmart	46	20.90%
Hannaford	56	16.50%
C&S	107	12.50%
Wegmans	11	8.80%

Supplier	Store Fronts	Market Share
Tops Markets	58	7.70%

FEMA Region III includes Delaware, the District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia. This is a very diverse region, but it is probably reasonable to conclude that on a region-wide basis, the crucial sources of strategic capacity are C&S, Walmart, Kroger, and SUPERVALU. C&S is currently the principal wholesaler supplying Ahold. All other suppliers hold less than five percent of the regional market.

Metropolitan Philadelphia

Supplier	Store Fronts	Market Share
C&S	328	27.10%
Giant Food (Ahold)	149	19.00%
SUPERVALU	228	16.00%
Wakefern	84	14.40%
Walmart	79	14.20%
Acme	95	9.00%
Weis Markets	121	7.20%
Wegmans	17	5.30%

Metropolitan Baltimore-Washington

Supplier	Store Fronts	Market Share
Ahold	181	30.40%
Giant Food	163	28.10%
C&S	142	14.80%
Safeway	126	12.70%
Walmart	62	10.80%
SUPERVALU	189	9.90%
Food Lion	171	7.80%
Harris Teeter	47	5.10%

Commercial market Information on Virginia (outside the DC metro area) and West Virginia tends to be combined with areas outside Region III and is not reliable for the purposes of this report. That said, major suppliers for Virginia and West Virginia

include Kroger, SUPERVALU, Walmart, Food Lion, and Harris Teeter (now a subsidiary of Kroger). Kroger also has significant strategic capacity in Western Pennsylvania.

FEMA Region IV includes Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. This is another diverse region, but Walmart, Publix, and Kroger are probably the crucial sources of strategic capacity. All other suppliers hold less than five percent of the regional market.

Carolinas (plus Southern Virginia and Southern West Virginia)

Supplier	Store Fronts	Market Share
Walmart	270	29.00%
Food Lion	754	23.70%
Harris Teeter	161	10.90%
Kroger	90	7.20%
MDI	253	5.70%

Atlanta Metropolitan and North Georgia

Supplier	Store Fronts	Market Share
Kroger	148	30.10%
Walmart	103	25.50%
Publix	155	22.70%

South Georgia and Northern Florida

Supplier	Store Fronts	Market Share
Walmart	69	29.80%
Publix	106	28.60%
BI-LO/Winn-Dixie	140	24.90%

Central Florida

Supplier	Store Fronts	Market Share
Publix	397	43.00%
Walmart	158	29.20%
Southeastern Grocers	185	12.90%

Tennessee[68]

Supplier	Store Fronts	Market Share
Walmart	119	35.80%
Kroger	86	20.00%
Food City	89	10.70%
Publix	37	5.90%
Associated Wholesale Grocers (AWG)	138	5.10%
Houchens	149	5.00%

Alabama[69] *and Mississippi*

Supplier	Store Fronts	Market Share
Walmart	146	41.10%
Publix	82	14.50%
Southeastern Grocers	82	11.20%
Piggly Wiggly	115	6.00%

FEMA Region V includes Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Kroger's national headquarters is located in Cincinnati, Ohio. Chicago Jewel-Osco and Central Grocers will be key in response to a catastrophe. SUPERVALU is crucial in its Minnesota-Wisconsin heartland. Giant-Eagle is significant in Northern Ohio. In other

[68] These estimates are more accurate for central and eastern Tennessee. In the Memphis metro area, Walmart and Kroger appear to be the leading operators.

[69] This especially includes Birmingham, Montgomery, Huntsville, and Meridian. These market estimates probably do not accurately reflect rural areas of either state where BI-LO/Winn-Dixie and AWG are also leading operators.

parts of the region, Walmart and Kroger are the crucial sources of strategic capacityAll other suppliers hold less than five percent of the regional market.

Chicago Metropolitan and Northern Illinois

Supplier	Store Fronts	Market Share
Jewel-Osco[70]	181	27.40%
Walmart	95	15.70%
Central Grocers[71]	301	15.60%
Strack & Van Til	38	5.00%
Roundy's[72]	33	5.50%

Indianapolis and Northern Indiana

Supplier	Store Fronts	Market Share
Walmart	76	32.00%
Kroger	91	27.00%
Meijer	24	11.70%
Marsh	67	9.60%

Non-Metropolitan Illinois and Southern Indiana

Supplier	Store Fronts	Market Share
Walmart	109	33.30%
SUPERVALU	203	21.50%
Schnuck's	86	18.30%
Kroger	36	6.00%
Dierbergs	24	5.10%

[70] Jewel-Osco is a regional retail brand for Albertsons.

[71] Central Grocers is a wholesale cooperative serving many independent grocery stores, mostly in the Chicago area.

[72] Kroger recently purchased Roundy's.

Minneapolis-St. Paul, Minnesota and Northwest Wisconsin

Supplier	Store Fronts	Market Share
SUPERVALU	244	46.50%
Walmart	63	21.30%
SuperTarget	26	10.20%
Jerry's Enterprises	24	7.30%
Coborn's	31	5.50%

Wisconsin and the Upper Peninsula of Michigan

Supplier	Store Fronts	Market Share
Walmart	84	26.70%
Roundy's	121	24.20%
SUPERVALU	151	16.60%
Certco	33	8.40%
Piggly Wiggly	95	7.80%
Woodman's	12	7.30%
Festival Foods	21	5.70%

Detroit Metropolitan and Eastern Michigan

Supplier	Store Fronts	Market Share
Kroger	113	28.40%
Meijer	53	24.80%
SpartanNash	195	16.40%
Walmart	42	13.40%

Western Michigan

Supplier	Store Fronts	Market Share
Meijer	53	37.50%
SpartanNash	189	27.70%
Walmart	41	18.00%

Northern Ohio

Supplier	Store Fronts	Market Share
Giant Eagle	129	40.90%

Supplier	Store Fronts	Market Share
Walmart	36	17.30%
Marc's	55	12.40%
SpartanNash	44	6.20%

Southern Ohio

Supplier	Store Fronts	Market Share
Kroger	243	41.70%
Walmart	121	23.80%
Meijer	42	8.50%
Giant Eagle	27	5.20%

FEMA Region VI includes Arkansas, Louisiana, Oklahoma, New Mexico, and Texas. Walmart is a consistent source of strategic capacity. Other grocery suppliers are as important, but the players that are the most important depends on the sub-region. All other suppliers hold less than five percent of the regional market.

Dallas/Ft. Worth Metropolitan, North Texas, non-urban Oklahoma, Louisiana, and Arkansas

Supplier	Store Fronts	Market Share
Walmart	209	38.00%
Kroger	104	14.30%
Albertsons/Safeway	113	12.70%
Brookshire Grocery	108	7.70%

Houston Metropolitan, East Texas, and Louisiana

Supplier	Store Fronts	Market Share
H-E-B	93	26.80%
Walmart	99	24.90%
Kroger	110	22.90%
Grocers Supply	175	12.60%

South Texas

Supplier	Store Fronts	Market Share
H-E-B	202	61.20%
Walmart	128	26.70%

West Texas and New Mexico

Supplier	Store Fronts	Market Share
Walmart	103	40.40%
Albertsons/Safeway	54	14.00%
Affiliated Amarillo	176	13.20%
United Family	45	10.70%
Fry's (Kroger)	29	7.00%
Lowe's Pay-N-Save	84	6.90%

Oklahoma City and Tulsa

Supplier	Store Fronts	Market Share
Walmart	105	53.10%
AWG	217	33.80%
Homeland	59	8.00%
Reasors	19	6.20%
Crest Discount	9	5.70%

FEMA Region VII includes Iowa, Kansas, Missouri, and Nebraska. Walmart is a crucial source of strategic capacity. AWG and SUPERVALU are important in sub-regions. All other suppliers hold less than five percent of the regional market.

Iowa

Supplier	Store Fronts	Market Share
Hy-Vee	116	40.00%
Walmart	60	29.60%
Fareway	97	12.10%

Kansas and Missouri (non-metro St. Louis)

Supplier	Store Fronts	Market Share
Walmart	108	33.30%
AWG	226	26.80%
Dillon	62	15.60%
Hy-Vee	34	10.30%
Ball's	27	6.40%
Cosentino's	25	6.30%

St. Louis Metropolitan (includes Southern Illinois)

Supplier	Store Fronts	Market Share
Walmart	109	33.30%
SUPERVALU	203	21.50%
Schnuck's	86	18.30%
Kroger	36	6.00%
Dierbergs	24	5.10%

Nebraska (includes Northeast Colorado, South Dakota, Western Iowa)

Supplier	Store Fronts	Market Share
Walmart	52	33.90%
Hy-Vee	39	22.40%
SpartanNash	56	10.10%
Affiliated Midwest	123	10.00%
Dillon	17	6.90%
AWG	32	6.40%
B&R Stores	17	5.20%
No Frills	17	5.10%

FEMA Region VIII includes Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. Walmart has significant strategic capacity across the region. Other important sources depend on the sub-region. All other suppliers hold less than five percent of the sub-regional markets indicated.

Denver Metropolitan, Eastern Colorado (including Cheyenne, WY)

Supplier	Store Fronts	Market Share
King Soopers (Kroger)	146	35.40%
Walmart	97	24.90%
Albertsons/Safeway	130	19.70%

Utah and the Great Basin (including Boise, ID)

Supplier	Store Fronts	Market Share
Walmart	70	31.50%
Associated Food Stores	201	25.30%
Smith's (Kroger)	87	17.10%
Albertsons	36	8.10%
Harmons	17	7.50%
WinCo	14	6.40%

Montana and Wyoming

Supplier	Store Fronts	Market Share
Albertsons/Safeway	30	36.00%
Walmart	11	32.00%
Associated Food Stores	36	10.80%
SUPERVALU	30	10.60%

North and South Dakota

Supplier	Store Fronts	Market Share
Walmart	23	38.60%
SUPERVALU	85	35.90%
SpartanNash	45	17.10%
Coborn's	11	8.90%
Hugo's	10	5.20%

FEMA Region IX includes Arizona, California, Guam, Hawaii, Nevada, and the United States Trust Territories of the Pacific. No single player has significant strategic capacity across the entire region. Albertsons/Safeway/Vons is probably the most

important single player. Vons and Albertsons are now part of the same company. All other suppliers hold less than five percent of the regional market.

Southern California (including Los Angeles and San Diego) and Las Vegas, NV

Supplier	Store Fronts	Market Share
Ralphs (Kroger)	368	18.50%
Vons	267	15.00%
Unified Grocers	553	12.70%
Walmart	130	10.60%
Albertsons	215	9.80%
Stater Bros	168	8.90%
Trader Joe's	113	5.90%

San Francisco Metropolitan (including Sacramento and Fresno, CA and Reno, NV)

Supplier	Store Fronts	Market Share
Albertsons/Safeway	244	26.70%
Super Store Industries	166	13.40%
Save Mart	202	12.70%
C&S	329	11.90%
Walmart	89	9.80%
Raley's	121	9.70%
United Natural	60	6.10%
Trader Joe's	66	5.90%
Unified Grocers	240	5.70%

Arizona

Supplier	Store Fronts	Market Share
Walmart	105	26.50%
Fry's	123	22.90%
Albertsons/Safeway	142	22.10%
Bashas	127	12.30%

Hawaii

The information sources utilized for other areas of the United States do not estimate the market share of grocery outlets operating in Hawaii. But, the current number of stores operated by retail leaders can be identified (see below). Both Foodland and Safeway are supplied by C&S Wholesale Grocers. There is some evidence that C&S is also a significant supplier for others on this list.

- Foodland (Sullivan Family of Companies), 32+ stores
- Times Supermarkets (PAQ), 25 stores
- Safeway (New Albertsons), 21 stores
- Walmart, 11 stores
- Costco, 7 stores
- Whole Foods, 4 stores

FEMA Region X includes Alaska, Idaho, Oregon, and Washington. Albertsons/Safeway, Kroger, and Walmart have region-wide strategic capacity. Safeway and Albertsons are now part of the same company. All other suppliers hold less than five percent of the regional market.

Seattle Metropolitan (including Bellingham, Olympia, Tacoma, and Yakima)

Supplier	Store Fronts	Market Share
Safeway	132	31.20%
Quality Food Centers	65	14.10%
Walmart	33	10.10%
Fred Meyer (Kroger)	44	9.30%
Unified Grocers	90	7.10%
Albertsons	47	6.50%

Western Washington (not including Seattle Metro), Western Oregon, and Far Northern California

Supplier	Store Fronts	Market Share
Safeway	114	27.60%
Fred Meyer (Kroger)	65	20.10%
Walmart	48	14.50%

Supplier	Store Fronts	Market Share
WinCo	21	9.50%
Albertsons	42	6.70%
Unified Grocers	98	7.00%

Northern Idaho, Eastern Washington, and Eastern Oregon[73]

Supplier	Store Fronts	Market Share
Albertsons/Safeway	48	27.00%
Walmart	23	26.20%
U.R.M. Stores*	102	23.00%
WinCo	5	6.30%

Alaska

Roughly half of Alaska's population of 700,000 is located in metropolitan Anchorage. This is also the center of gravity for grocery strategic capacity in the state. Those with strategic capacity for Anchorage are not, however, necessarily those with strategic capacity in other geographic areas. The information sources utilized for other areas do not estimate the market share of grocery outlets operating in Alaska. But, the current number of stores operated by retail leaders can be identified:

- Carrs-Safeway (Albertsons), 28 stores
- Fred Meyer (Kroger), 11 stores
- Alaska Commercial Company, 26 stores
- Three Bears, 9 stores
- Walmart, 6 stores
- Costco, 3 stores

[73] Boise is not included. The grocery supply chain for Boise is reported in market share estimates for Salt Lake City (Region VIII).

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Appendix C: Special Note on Honolulu and Anchorage

The Honolulu, Hawaii Metropolitan Statistical Area (MSA) has a population of nearly 1 million and a density of nearly 6,500 persons per square mile.

The Anchorage, Alaska MSA has a population of nearly 400,000 and a density of roughly 171 persons per square mile.

Both MSAs are largely isolated nodes in the grocery supply and demand network. Anchorage receives a majority of its groceries from the Port of Seattle (1,200 nautical miles, or typically four days at sea). Hawaii receives most of its groceries from the Port of Oakland (2,000 nautical miles, or typically five days at sea).

Each urban area is susceptible to a range of catastrophic risks. Any disruption of weekly transport by events on either end of shipping could quickly reduce supplies to far less than demand. Hoarding behavior would likely leave significant portions of the population with less than adequate nutrition.

This study was focused on MSAs with populations greater than 2 million. But the special circumstances noted strongly suggest follow-on research related to Honolulu and Anchorage.

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Appendix D: Special Note on the New Madrid Seismic Zone

A repeat of the 1811–1812 New Madrid event would be catastrophic for the middle Mississippi River Valley and for populations dependent on supplies from (or traversing) the impact zone.

The Memphis Metropolitan Statistical Area (MSA) is, perhaps, most vulnerable to such an eventuality. The Memphis MSA has a population of 1.3 million and a density of roughly 2,000 people per square mile. While well-positioned in a typically abundant grocery network, this metro area could be physically isolated for a considerable period by a high-end seismic event.

As with Honolulu and Anchorage (see Appendix C), the combination of significant density and potential long-term isolation could produce supply chain consequences worth more attention than possible in this particular research effort.

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Appendix E: Nutritional Recommendations

This appendix and Figure 15 present nutritional recommendations by the U.S. Departments of Agriculture and Health and Human Services for persons in different age groups.

Figure 15. Nutritional recommendations

Nutrient (units)	Source of goal[a]	Child 1–3	Female 4–8	Male 4–8	Female 9–13	Male 9–13	Female 14–18	Male 14–18	Female 19–30	Male 19–30	Female 31–50	Male 31–50	Female 51+	Male 51+
Macronutrients														
Protein (g)	RDA[b]	13	19	19	34	34	46	52	46	56	46	56	46	56
(% of calories)	AMDR[c]	5–20	10–30	10–30	10–30	10–30	10–30	10–30	10–35	10–35	10–35	10–35	10–35	10–35
Carbohydrate (g)	RDA	130	130	130	130	130	130	130	130	130	130	130	130	130
(% of calories)	AMDR	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65	45–65
Total fiber (g)	IOM[d]	14	17	20	22	25	25	31	28	34	25	31	22	28
Total fat (% of calories)	AMDR	30–40	25–35	25–35	25–35	25–35	25–35	25–35	20–35	20–35	20–35	20–35	20–35	20–35
Saturated fat (% of calories)	DG[e]	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%	<10%
Linoleic acid (g)	AI[f]	7	10	10	10	12	11	16	12	17	12	17	11	14
(% of calories)	AMDR	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10	5–10
alpha-Linolenic acid (g)	AI	0.7	0.9	0.9	1.0	1.2	1.1	1.6	1.1	1.6	1.1	1.6	1.1	1.6
(% of calories)	AMDR	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2	0.6–1.2
Cholesterol (mg)	DG	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300	<300
Minerals														
Calcium (mg)	RDA	700	1,000	1,000	1,300	1,300	1,300	1,300	1,000	1,000	1,000	1,000	1,200	1,200
Iron (mg)	RDA	7	10	10	8	8	15	11	18	8	18	8	8	8
Magnesium (mg)	RDA	80	130	130	240	240	360	410	310	400	320	420	320	420
Phosphorus (mg)	RDA	460	500	500	1,250	1,250	1,250	1,250	700	700	700	700	700	700
Potassium (mg)	AI	3,000	3,800	3,800	4,500	4,500	4,700	4,700	4,700	4,700	4,700	4,700	4,700	4,700
Sodium (mg)	UL[g]	<1,500	<1,900	<1,900	<2,200	<2,200	<2,300	<2,300	<2,300	<2,300	<2,300	<2,300	<2,300	<2,300
Zinc (mg)	RDA	3	5	5	8	8	9	11	8	11	8	11	8	11
Copper (mcg)	RDA	340	440	440	700	700	890	890	900	900	900	900	900	900
Selenium (mcg)	RDA	20	30	30	40	40	55	55	55	55	55	55	55	55

Vitamins														
Vitamin A (mcg RAE)	RDA	300	400	400	600	600	700	900	700	900	700	900	700	900
Vitamin D[a] (mcg)	RDA	15	15	15	15	15	15	15	15	15	15	15	15	15
Vitamin E (mg AT)	RDA	6	7	7	11	11	15	15	15	15	15	15	15	15
Vitamin C (mg)	RDA	15	25	25	45	45	65	75	75	90	75	90	75	90
Thiamin (mg)	RDA	0.5	0.6	0.6	0.9	0.9	1.0	1.2	1.1	1.2	1.1	1.2	1.1	1.2
Riboflavin (mg)	RDA	0.5	0.6	0.6	0.9	0.9	1.0	1.3	1.1	1.3	1.1	1.3	1.1	1.3
Niacin (mg)	RDA	6	8	8	12	12	14	16	14	16	14	16	14	16
Folate (mcg)	RDA	150	200	200	300	300	400	400	400	400	400	400	400	400
Vitamin B_6 (mg)	RDA	0.5	0.6	0.6	1.0	1.0	1.2	1.3	1.3	1.3	1.3	1.3	1.5	1.7
Vitamin B_{12} (mcg)	RDA	0.9	1.2	1.2	1.8	1.8	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Choline (mg)	AI	200	250	250	375	375	400	550	425	550	425	550	425	550
Vitamin K (mcg)	AI	30	55	55	60	60	75	75	90	120	90	120	90	120

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services. (2010). *Dietary Guidelines for Americans, 2010.* 7th Edition. U.S. Government Printing Office. https://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

Appendix F: Draft Distribution Center Survival Checklist

This appendix presents a draft distribution center survival checklist. Answering these questions is meant to inform preparedness planning efforts and assist distribution center operators with better understanding the likely survivability of the center and its operational capacity in a disaster.

- Is the distribution center in a floodplain?
- Is the distribution center in an urban wildfire interface?
- Is the distribution center's foundation liable to liquefaction?
- Is the distribution center adjacent to a formation presenting risk of landslide?
- Is the distribution center built or retrofitted to *current* construction standards:
  - Related to fire risk?
  - Related to tornadic/hurricane risk?
  - Related to seismic risk?
- Does the distribution center have emergency electrical power generation sufficient to maintain "core operations" for three days before refueling?
- Does the distribution center have on-property refueling capabilities for power generation:
  - Sufficient for 1–3 days?
  - Sufficient for 4–7 days?
  - Sufficient for 8+ days?
- Is the distribution center within seven miles of the population center for the principal urban core?

- Does the distribution center have bedding and related supplies to support workers who are on-site at the time of the extreme event?
- Does the distribution center have at least three routes of reasonable entry and egress to the nearest principal arterial highway?
- Is at least one of the routes of entry and egress to the nearest principal arterial highway bridge-free?
- Is at least one of the routes of entry and egress to the nearest principal arterial highway outside a floodplain?
- What percentage of the trucking fleet necessary to deliver a typical day's inventory is staged at the distribution center?
    - <20 percent?
    - 20–39 percent?
    - 40–59 percent?
    - 60–79 percent?
    - 80–100 percent?
- What percentage of truckers live within a 10-mile radius of the distribution center?
    - <20 percent?
    - 20–39 percent?
    - 40–59 percent?
    - 60–79 percent?
    - 80–100 percent?
- What percentage of truckers live within a 20-mile radius of the distribution center?
    - <20 percent?
    - 20–39 percent?
    - 40–59 percent?
    - 60–79 percent?

- 80–100 percent?

- Does the distribution center have on-property refueling capabilities for trucks:
  - Sufficient for 1–3 days?
  - Sufficient for 4–7 days?
  - Sufficient for 8+ days?
- Have distribution center personnel met with:
  - Local and/or county emergency management officials?
  - State emergency management officials?
  - Federal emergency management officials?
- Have distribution center personnel participated in a:
  - Disaster-preparedness planning workshop?
  - Disaster-preparedness tabletop exercise?
  - Disaster-preparedness functional exercise?
- Have distribution center personnel participated in:
  - A local emergency response within the last 10 years?
  - An emergency response anywhere in the world within the last 10 years?

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Appendix H: Review Panel

This report has been reviewed in draft form by individuals known for their experience and expertise in related issues. The purpose of these individual reviews has been to provide candid and critical comments to assist the author in crafting the final report as accurately and constructively as possible. While reviewer inputs have been very helpful, the author remains solely responsible for the content and conclusions set out in the final report. Participation as a reviewer does not indicate agreement with the findings or recommendations of the report. CNA and the author wish to thank the following individuals for their important contributions:

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Appendix I: Acknowledgements

When a major hurricane, earthquake, pandemic, or other worst-case threat shreds the systems on which a major city depends, it will require an authentic, whole-of-nation response to save lives and start toward any sort of recovery. This is a capacity that must be cultivated. Spontaneous emergence from the crisis is possible but likely to be profoundly sub-optimal.

This study had its origin in conversations with FEMA disaster logistics professionals. These are practical people who know how tough it can be to operate on the cusp of chaos. Over the last decade, they have developed a significantly enhanced federal capacity to serve survivors of extreme events. But they realize FEMA does not have the capacity to respond effectively to catastrophic events.

While strategic and operational collaboration between the grocery sector and public sector to serve survivors of catastrophic events will not be easy to design and sustain, during this research effort, the need for such readiness has been recognized on every side. This study would not have been possible without the intelligence and candid vulnerability of key grocery professionals. Individuals and organizations contributed detailed information and valuable insider judgment to the research and analysis.

Finally, I could not have committed the time and focus for this research without the financial and moral support of my colleagues at CNA. As the grocery research demonstrates, relational networks matter. Supply and demand is one sort of pull. But at CNA, among federal, state, and local emergency managers, as well as among grocers, we are also pulled by compelling problems and the opportunity to conceive meaningful solutions.

Many thanks to all for your crucial contributions.

Philip J. Palin
Principal Investigator

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SAS's work helps improve decision-making during crisis operations and fosters innovative answers to challenges in the areas of first response; emergency management; public health and agriculture; homeland security; risk-management policy development and operations; and response and recovery capabilities at a national level.

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