

What lurks beneath Deep supply chain risks

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The past decade has seen a growing awareness of the need for systematic enterprise risk management (ERM) practices. In the wake of the 2001 Enron accounting scandal in the US, the Sarbanes-Oxley Act of 2002 pushed companies to adopt more formal risk management procedures by requiring a top-down risk assessment and improved internal risk controls. ERM is becoming more standardized, too, through the efforts of groups such as COSO (Committee of Sponsoring Organizations of the Treadway Commission)¹ and ISO (International organization for Standardization).² ISO, for example, maintains a host of related standards that address specific categories of risks such as ISO 31000 (overall risk management), ISO 28000 (security risk management systems for the supply chain), ISO 27001 (information security), ISO 26000 (social responsibility), ISO 14000 (environmental management), and ISO 9000 (quality management).³ The ERM Initiative at North Carolina State University has traced the rising adoption of ERM with annual surveys beginning in 2009.⁴ In 2009, only 8.8% of companies claimed to have “a complete ERM process.” By 2015, the number had risen to 25%.

Much of the maturing discipline of enterprise risk management focuses on risks to the company’s facilities, personnel, and resources. These include risks in categories that span environmental, health, and safety; site security; business process integrity; regulatory compliance; financial controls; and governance. Companies address supply disruption risks with well-known strategies, such as second-sourcing and stockpiled inventories of crucial materials. Yet a series of examples from the new millennium shows how modern global supply chains create new categories of risks that are far outside the four walls of the company and its direct business partners.

Using examples of natural and man-made disruptions, this chapter enumerates many of the types of risks intrinsic to complex, deep, broad supply chains to provide a case-driven multi-organizational view of enterprise risk. These examples cover deep-tier supply chain risks; indirect risk exposures linked to suppliers, customers, or competitors; and supply chain risks that occur at a broader industry or regional level due to companies’ increasing mutual interdependence within the global economy. The chapter also illustrates how companies map and manage these risks to push sound risk management practices out into their industries or through the tiers of their supply chains. The chapter assumes that the company already has sound internal risk management and crisis management processes but needs to understand and manage these extra-organizational risks.

1 Risks beyond the four walls

Three trends – the increasing globalization of suppliers and customers, the widespread use of lean manufacturing, and the increasing sophistication of materials and technologies in products – give rise to a growing category of business risks that occur outside the four walls of an organization and beyond that organization's direct control.

The leading driver of this growing vulnerability is the explosion of global trade. Global merchandise exports surged from \$7.38 trillion in 2003 to \$18.49 trillion in 2014.⁵ Rapidly declining costs of communications and growing efficiency of logistics are enabling all this trade, with the resulting lengthening of supply chains. Digital communications mean companies can more readily work with facilities, suppliers, and distribution centers on the other side of the world.

Global competition motivated companies to hunt for the best price and performance in global supplier markets. As companies outsourced their manufacturing operations to distant lands and distant suppliers, lead time from order to delivery lengthened, meaning that there were more opportunities for things to go wrong. More actors were involved – from suppliers to service providers to multiple governments and regulatory regimes – thereby further increasing complexity and the probability of failure.

With product complexity comes the need to use more suppliers, who in turn may use more suppliers, leading to more complex supply chains. For example, car seats of the past were like pieces of furniture in that they depended only on suppliers of cloth, leather, stuffing, and some metal or plastic framing. But modern car seats are technological gizmos that also include switches, motors, heating elements, sensors, and the ubiquitous microprocessor to control the seat. Even the seat materials themselves are more advanced, with high-tech foams, more durable, fashionable, and sustainable textiles, and high-strength steel alloys that reduce the weight of the seat to improve fuel economy.⁶ Although all of these changes improve the average performance of the products and companies, they also create increased risks as exemplified by the following examples.

1.1 *Disruption in the deep tiers*

At 2:26 p.m. local time, Friday, March 11, 2011, some 72 kilometers off the coast of the Tohoku region of Japan, the Pacific plate broke its locked fault line and began to shear downward and westward while the Okhotsk plate beneath northern Japan thrust upward and eastward. More than 1,000 years of accumulated tectonic strain broke free, sending a seismic shock wave racing at over 7,000 kilometers per hour through the solid rock of the floor of the Pacific.⁷ In less than a minute, the first earthly shudders reached Japan. And after the shaking came an enormous tsunami that inundated much of the northeast coast of Japan and flooded the nuclear reactor complex at Fukushima.

General Motors' Detroit headquarters lay a comfortable 6,400 miles from Japan. The quake and tsunami struck around 1 a.m. Detroit time. When GM's executives learned of the disaster in the morning, they were somewhat worried about their Japanese Tier 1 suppliers but did not think that they faced a corporation-wide crisis. A scant 2% of GM vehicle parts came from Japan, and only 25 of GM's 18,500 Tier 1 suppliers were in Japan. Yet GM's experience with the 2011 quake shows just how deeply interconnected companies have become, and how unknown risks can vastly outweigh known ones.

GM's purchasing department worked through the weekend, trying to get information from Japanese suppliers. However, like many other companies, GM had a difficult time reaching

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these suppliers. Power and telecommunications were down in the affected area. Japanese roads and railroads were closed pending inspection for damage, so workers could not get to suppliers' work sites. By Monday, GM received some initial reports of the severity of the damage and which suppliers had been impacted.

By Tuesday, March 15, GM estimated that 30 suppliers and 390 parts were affected by the quake and tsunami. Although 390 parts out of a total of about 30,000 parts for an average car seems minor, GM can only ship cars that have all their parts. Initial estimates based on available inventories showed that outages of these parts would halt production at many GM assembly plants in only 8 days. More ominously, the initial estimate was that by the end of March, all of GM's factories worldwide would be down. Worse, initial estimates suggested that production might be disrupted for at least seven months. That's when alarm bells rang throughout GM.

The deeper GM's team dug, the bigger the problems they found. Some of GM's non-Japanese suppliers had Japanese suppliers. And some of GM's non-Japanese suppliers had other non-Japanese suppliers who had Japanese suppliers. Although an anti-lock brake module or dashboard assembly might be made in the US by an American Tier 1 supplier, the electrical components may have come from Japan, which has a long history of making these devices. Like many products, automobiles have become more complex through the addition of dozens of microprocessors, sensors, and actuators that boost fuel efficiency, performance, and driver conveniences.⁸ All of GM's cars had computer chips, sensors, displays, radios, and navigation systems made with electronic parts from Japan.

"The list kept growing. And every day, it went up. It was a moving target for us," said Rob Thom, Manager, Global Vehicle Engineering Operations.⁹ Electronics weren't the only concern. GM soon discovered that almost every type of part on many different vehicles required something from Japan. Xirallic, a sparkly additive in the paint used on the Corvette, came from Japan. Special plastics for the body trim came from Japan. Rubber seals and gaskets came from Japan. High-tech chrome plating on turbochargers came from Japan. Cooling fans, radiator caps, air-conditioner compressors, and many more parts had some tie to Japanese suppliers.

From the known 390 affected parts on March 14, the number grew to 1,551 parts on March 24, 1,889 on March 29, and to a staggering 5,329 by April 13. During the month after the quake, GM discovered an average of 160 disrupted parts each day. Nor was the problem helped by the ongoing crisis with the Fukushima nuclear plant and the persistent power shortages in Japan. In the end, it took more than two months to even know how many parts were impacted. The final figure of 5,830 affected parts was nearly 15 times higher than the initial estimate of 390 parts associated with the Tier 1 suppliers in Japan. And each missing part raised the specter of halting production somewhere in GM's system.

1.2 Dangerous diamonds in the supply chain

Some of the individual supplier disruptions during the 2011 Japan earthquake illustrate a more serious category of deep supply chain risk. Silicon chips may get all the glory as the premiere technology that powers smartphones, tablets, laptops and almost every electronic product, but the less glamorous plastics used in chip substrates and printed circuit boards are just as essential. Current-day microchips can have over 500 connections using a tiny grid of solder balls embedded in a thin substrate.¹⁰ That inscrutable density of connections requires extremely specialized materials such as bismaleimide triazine (BT), an epoxy resin that is strong, thermally conductive, and able to hold extremely tight tolerances over time and temperature variances.

Until the quake, Mitsubishi Gas Chemical's (MGC) Fukushima facility supplied most of the world's BT.¹¹ A prolonged shutdown of MGC's factories after the earthquake caused bottlenecks in the worldwide integrated-circuit (IC) assembly industry supply chain.¹² "Our contacts in Asia suggest one of the bigger problems may actually be the growing shortage of BT," said Craig Berger, an analyst with investment bank FBR.¹³ Lead times for IC substrates grew to the 75- to 125-day range.¹⁴ A company such as Apple or Samsung might buy chips from more than a dozen different chip makers, including second sources or second fabs for many components. Yet all of those different chip makers and alternative suppliers depend on BT, most of which came from that one MGC facility.

Whereas the typical supply chain diagram shows fans of interconnections by which every company has many suppliers – shaped like a pyramidal hierarchy – the BT/MGC example shows that sometimes those lines converge to a single dominant supplier deep in a lower layer – a diamond-shaped interconnection structure. BT/MGC wasn't the only diamond structure disruption of specialized materials exposed by the Japan quake. Disruptions in the supply of Xirallic, the pigment made in Japan by Merck, affected manufacturing of certain colors of luxury cars at Toyota Motors, Chrysler LLC, GM, Ford Motor, BMW, VW, Audi and other car makers.¹⁵ Lithium ion batteries require PVDF (polyvinylidene fluoride), and 70% of the global supply came from one factory in Fukushima province. Although the plant survived the quake, the tsunami devastated the nearby port that was critical to supplying raw materials to the plant.¹⁶ Other supply chain diamond structures revealed by the Japan quake included high-purity hydrogen peroxide used in chip making, and EPDM (ethylene propylene diene monomer) used by car makers in rubber gaskets and seals.¹⁷ "What we've found is that in Tiers 3 and 4, the convergence of underlying raw material supply starts to become really significant," said Jackie Sturm, Intel's Vice President and General Manager of Global Sourcing and Procurement.¹⁸

Other examples of deep diamond risks occur at the country level. Japan makes 100% of the world's supply of protective polarizer film for LCD displays, 89% of aluminum capacitors, and 72% of silicon wafers.¹⁹ Four companies in Japan have a near monopoly on digital compasses: the tiny magnetic field sensors that sit inside almost every new phone, tablet, laptop, and navigation system device.²⁰ "Many organizations are more or less forced to put all eggs in one basket because of the clusters of suppliers for various goods around the globe," said Damien Pang, Regional Manager, Claims, at Allianz Global Corporate & Specialty Asia/Pacific.²¹

1.3 Lateral disruptions of customers

Moreover, some supply chain risks can have indirect, lateral effects on companies that don't even buy materials from the disrupted suppliers. For example, hard disks would seem to be extremely easy items to procure and to second-source. They adhere to well-known mechanical, electrical, and software standards. Although drives do vary somewhat in performance and reliability, most are generally interchangeable for most applications. Further, in 2011, the hard disk industry had five large competitive suppliers to handle the volume.²² But then the rains came.

Between late June and early October 2011, above-normal monsoons plus five tropical cyclone systems struck Southeast Asia and dumped heavy rains in the highlands of Thailand. Over a period of weeks the waters rose, displacing more than two million people, flooding 7,510 factories, and damaging 1,700 roads, highways, and bridges. Some factories were underwater for more than five weeks.²³

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The floods proved that second sourcing doesn't always mitigate risks. The industrial parks in central Thailand had become an economic cluster for making hard disks and their components. Four of the five top suppliers of drives (Western Digital, Seagate Technologies, Hitachi Global Storage Technologies, and Toshiba) all had facilities or key suppliers in Thailand. And all four suffered substantial capacity disruptions during the Thai floods.²⁴ In aggregate, Thailand provided 45% of worldwide hard-drive production. The flood disrupted much of it,²⁵ creating a 35% shortfall in disk supplies for the PC industry.²⁶

The floods in Thailand did not directly affect Intel nor its suppliers. In fact, Intel stood to gain from the disruption because the company sold SSDs (Solid State Drives), which compete with hard disks for mass storage solutions in PCs, laptops, and servers. "We'll be using this as an opportunity" to increase sales of solid-state drives, Intel's Chief Financial Officer Stacy Smith told analysts.²⁷

But the 35% shortfall in disk supplies hit PC production, which meant that PC makers curtailed purchase of all PC components, including Intel products. "We've seen a drop in orders for microprocessors in the fourth quarter," said Smith.²⁸ Intel lost about \$800 million in revenue for the fourth quarter 2011 relative to expectations.²⁹ "We found with Thailand that for want of a nail a kingdom can be lost. So for us, even though our production might continue, if other critical components to our customers can't ship, like a hard drive, then everybody stops," said Intel's Jackie Sturm.³⁰

Unlike many other classic disruption risks, lateral disruptions impact demand: customers curtail purchasing. Traditional supply chain risk strategies such as second sourcing or added inventory offer no mitigation. In fact, the inventory stockpiling strategy actually increases the risks of obsolete inventory.

1.4 Industry-wide risks from economic clusters

The Intel Thailand example shows how a supplier disruption can disrupt customer companies which, in turn, disrupts other unrelated suppliers. The reverse can occur with a disrupted customer company that disrupts suppliers and, in turn, disrupts other customers. It's not every day that the CEO of one major company pleads for a government bailout of his fiercest competitors. Yet that's exactly what Ford CEO Alan Mulally did in front of the Senate banking committee on November 18, 2008. He said:

If any one of the domestic companies should fail, we believe there is a strong chance that the entire industry would face severe disruption. Ours is in some significant ways an industry that is uniquely interdependent – particularly with respect to our supply base, with more than 90 percent commonality among our suppliers. Should one of the other domestic companies declare bankruptcy, the effect on Ford's production operations would be felt within days, if not hours. Suppliers could not get financing and would stop shipments to customers. Without parts for the just-in-time inventory system, Ford plants would not be able to produce vehicles.³¹

"Our dealer networks also have substantial overlap. Approximately 400 of our dealers also have a GM or Chrysler franchise at their dealership. The failure of one of the companies would clearly have a great impact on our dealers with exposure to that company." Mulally concluded, "In short, a collapse of one of our competitors here would have a ripple effect across all automakers, suppliers, and dealers – a loss of nearly three million jobs in the first year, according to an estimate by the Center for Automotive Research."³²

Yet Mulally may have been wrong in his belief of being “uniquely interdependent.” The contaminated peanut scare and German *Escherichia coli* cases (described in the next section) show the interdependence of food producers in which quality failures at one producer can severely disrupt the sales of all producers. The acetonitrile/acrylonitrile case (described in the following section) shows the interdependence between housing and pharmaceuticals industries. It also demonstrates the fragility of coupled production, in which a manufacturing process creates two or more different commodities simultaneously. If demand for one commodity drops, then supply of the other commodity falls, too. Issues such as rare earths, conflict minerals, and RoHS-obsolete³³ parts create interdependence among many companies, industries, and regions.

Finally, the economic events of 2008 proved that the global financial system was the biggest diamond of them all. Most companies discovered just how dependent they were on their suppliers of capital – the banks – to support themselves, their suppliers, and ensure customer demand. Ultimately, government bailouts did avert a systemic cascading failure in the banking system and major industries.

1.5 Lateral co-supplier disruptions

During a 2-month period beginning in May 2011, some 3,100 German residents and European tourists suffered from bloody diarrhea, 850 developed hemolytic uremic syndrome, and 53 people died.³⁴ The frantic search for the cause depended on very sick people’s fuzzy memories for where they had eaten and what they had eaten. “Our absolute first priority is to clarify the source of the outbreak because, if we can’t do that, we’re not going to win back consumer confidence,” said Roger Waite, a spokesman for Dacian Ciolos, the European agriculture commissioner.³⁵

Based on victims’ reports, salad in Germany topped the menu of suspects. The Robert Koch Institute advised consumers to avoid raw vegetables.³⁶ European supermarkets drastically cut orders for tomatoes, lettuce, and cucumbers, causing European farmers significant losses. On May 26th, the Hamburg Institute for Hygiene and the Environment found three Spanish cucumbers that tested positive for *Escherichia coli*,³⁷ causing eight countries to ban Spanish cucumbers.³⁸

The effects were swift and devastating. Spanish farmers lost €200 million a week as some 150,000 tons of unwanted Spanish fruit and vegetables (not only cucumbers) piled up each week, according to FEPEX, Spain’s fruit and vegetable export body.³⁹ Asked about the scope of the slump in demand, Jorge Brotons, FEPEX president said: “Almost all Europe. There is a domino effect on all vegetables and fruits.”⁴⁰

When further tests showed that Spanish cucumbers did not have the outbreak’s particular strain of *E. coli*,⁴¹ the German agriculture secretary Robert Kloos admitted: “Germany recognizes that the Spanish cucumbers are not the cause.”⁴² Yet German officials continued to advise avoidance of raw tomatoes, lettuce, and cucumbers, causing the slump to hit farmers in other countries, too. Victor Miranda, a grocer in Paris, said, “Even if the cucumbers are from France and not from Spain, nobody wants to eat them.”⁴³ Koos De Vries, a Dutch cucumber grower, said, “From a business point of view, it’s a catastrophe for us.”⁴⁴

Ultimately, neither Spanish produce nor any kind of cucumbers, tomatoes, or lettuce proved to be the cause. Instead, the contamination was traced to Egyptian fenugreek seeds⁴⁵ used by a small German producer of organic sprouts.⁴⁶ Yet vindication was cold comfort for all the cucumber and salad ingredient producers in Spain and across Europe who were brought to the edge of bankruptcy by the scare and erroneous government warnings.

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A similar case occurred when Sunland Inc., a processor of organic peanuts and other nuts, had a salmonella contamination that sickened 42 people in 20 US states.⁴⁷ Although Sunland Inc. was only a \$55 million company, its nuts and the subsequent recall encompassed over 300 products from 36 brand-name companies. The recall hit a number of “healthy” food and retail brands, such as Trader Joes, Whole Foods, Earth Balance, Newman’s Own Organics, and Cadia All Natural,⁴⁸ as well as more mainstream brands such as Harry and David, Target, and Stop & Shop. And it wasn’t just jars of peanut butter but also cookies, snack crackers, brownies, nut mixes, and even ice cream that were recalled.

The direct costs of the recall were \$78 million, yet the estimated costs to American peanut-containing product makers was \$1 billion, including growers and product makers unaffiliated with Sunland.⁴⁹ Deep-tier diamond structures reside in many industries, and a small problem with a niche supplier can reverberate far and wide. As with the Thailand-Intel example, the food contamination events can operate laterally and disrupt demand for many customers and supplier companies beyond those directly hit.

1.6 Lateral disruption of other customers of suppliers

Disruptions can zigzag through one supply chain to disrupt other supply chains. Acrylic and ABS (acrylonitrile-butadiene-styrene) are very popular plastics used in carpet, cars, electronic housings, and small appliances. When the financial crisis struck in 2008, demand for acrylic and ABS plummeted, affecting plastics makers and suppliers of the ingredient chemicals used to synthesize these plastics. One key ingredient is acrylonitrile, a colorless liquid with a garlic-like odor made by reacting ammonia with propylene gas. As demand for these plastics dropped, global acrylonitrile production dropped by 40%.

Acrylonitrile synthesis also creates a sister chemical, acetonitrile, as a by-product. For every 100 liters of acrylonitrile produced, the chemical maker also typically gets about 2–4 liters of acetonitrile. Some chemical plants simply burn the by-product as fuel for the factory. But a few companies extract the acetonitrile, purify it, and sell it for a host of minor applications, including as a solvent used in research labs and in quality assurance testing in the pharmaceutical industry.

When acrylonitrile production plummeted, the acetonitrile supply went with it. At the same time, the Chinese restricted production in order to reduce air pollution for the Beijing Olympic Games, and Hurricane Ike knocked out a Texas supplier.⁵⁰ “The market is beyond short,” said Jerry Richard of Purification Technologies, a Chester, Connecticut-based firm that buys acetonitrile in bulk, purifies it, and sells it to laboratory chemical suppliers. “You have people scrambling around trying to get material. My phone is ringing off the hook,” Richard said.⁵¹ Risks such as these are a side effect of companies’ quests for efficiency and utilization – to the extent that companies in one industry produce by-products that can be sold to another industry, the risks of supply or demand disruptions become coupled between the two industries.

1.7 The dark underbelly of supply chains

Much farther down in all supply chains for material goods lies one more layer of suppliers of basic commodities such as oil, minerals, and agricultural products. Many of these commodities – such as oil, gasoline, diesel, natural gas, steel, copper, wheat, and cotton – have very broad production and distribution networks around the world. Aside from local distribution disruptions (e.g., the scarcity of gasoline in New York City after hurricane Sandy⁵²), these commodities are available at all times on world markets, although the prices can be volatile.

And because companies can manage price volatility risks of common commodities using hedging or vertical integration, the risks of true disruptions seem minimal. Yet companies face two serious exceptions to this general rule of mitigatable risks for base commodities.

High technology supply chains, especially, depend on a very large number of commodities, many of which either don't come from broad supply bases or lack adequate hedging instruments in the financial markets. This risk has risen with the increasing use of obscure elements in electronic products. "Twenty or thirty years ago electronics were being made with 11 different elements. Today's computers and smartphones use something like 63 different elements," explained Thomas Gradael, a professor of geology and geophysics at the Yale School of Forestry & Environmental Studies.⁵³

Of special importance are 17 metals known as rare earth elements (REE) that go into a wide range of technology products such as iPhones, wind turbines, solar cells, jet engines, fiber optics, hard disk drives, and compact fluorescent bulbs.⁵⁴ The average Ford car, for example, contains about half a kilogram of REE scattered in the vehicle's sensors, electric motors, displays, and catalytic converter. In 2002, those REE cost only about \$10 per car. In 2012, they cost \$100. New electric cars require even larger amounts of rare earth materials in their batteries and electric motors – about \$1,000/car (in 2012 REE prices).⁵⁵ In 2007, the metal europium (an REE) cost \$300/kg.⁵⁶ By 2010, that price had more than doubled to \$625/kg. In 2012, it surged to \$3,800/kg.⁵⁷ Yet unavoidable price volatility is least of the risks.

China produces 95% of the world supply of REE and in July 2010, China restricted exports of REE – cutting off many companies that make products using these materials.⁵⁸ In response, the US lodged a formal protest with the World Trade Organization (WTO). EU Trade Commissioner Karel De Gucht said, "China's restrictions on rare earths and other products violate international trade rules and must be removed. These measures hurt our producers and consumers in the EU and across the world, including manufacturers of pioneering high-tech and 'green' business applications."⁵⁹ Whether China's rationale for this action was environmental⁶⁰ or economic⁶¹ is beside the point. Such actions – dubbed "resource nationalism" – can disrupt raw material supplies on which so many products and global companies depend.

An EU Commission study of 54 materials identified 20 as being of both of global economic importance and having supply risks, including concentration of supply, instability of the producing countries, and difficulty of substitution.⁶² Besides REE, the study found potential supply risks in materials such as silicon, chromium, magnesium, graphite, phosphates, and others. An analysis of risks in the mining industry ranked "resource nationalism" as the #1 risk in both 2011 and 2012.⁶³ Some 33% of companies in a 2011 World Economic Forum survey ranked "export/import restrictions" as "most likely to provoke significant and systemic effects on supply chain or transport networks."⁶⁴

A second category of commodity-related deep supply risks comes from the other end of the supply chain and is actually exacerbated by breadth of supply. For example, to protest the destruction of tropical forests for the farming of palm oil, Greenpeace attacked Nestle with a video parody of the company's KitKat "give me a break" candy bar ads.⁶⁵ The video implied that Nestle was killing orangutans by buying palm oil from suppliers who were destroying Indonesian rain forests.⁶⁶ Greenpeace raided Nestle's annual meeting in 2010. Activists dressed as orangutans stood outside Nestle's headquarters in Frankfurt, Germany, while other activists unfurled a banner inside the meeting itself.⁶⁷

Consumer-facing companies are especially sensitive to brand reputation issues, which is why activists typically attack consumer brand companies rather than the deeper tier suppliers who may be the ones directly guilty of perceived environmental or social responsibility misdeeds. Greenpeace attempted to disrupt demand for Nestle products despite the fact that Nestle

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does not directly buy palm oil from any specific plantation and, in the words of Jose Lopez, who was responsible for Nestle's manufacturing of KitKat, "you would have to 'look through a microscope' to find the palm oil in the snack."⁶⁸

In another example, Forest Ethics has a long-running campaign to force companies to avoid buying diesel fuel derived from Canada's tar sands.⁶⁹ Although many of the targeted manufacturers and retailers buy no diesel fuel directly because they rely on trucking companies to move their wares, consumer-facing companies are more susceptible to public pressure, demonstrations, and boycotts. "The trucking companies care more about what their customers want than what we want," explained Forest Ethics' U.S. campaign director Aaron Sanger.⁷⁰

1.8 Knots in the network

Although most disruptions hit the manufacturing nodes in the supply chain, a crucial category of deep supply chain hazards affect the transportation links that connect all those nodes together. For example, in April 2010, a modest-sized ice-capped volcano named Eyjafjallajökull in southern Iceland roused from a 187-year slumber. When blazing hot lava hit the volcano's ice and water-filled caldera, the mixture flashed into ash-laden steam that blasted high into the atmosphere. The prevailing winds carried the thick gray-brown ash cloud southeast.

The ash cloud's potential threat to aircraft caused European aviation authorities to close portions of European airspace, starting with Norway. The closures expanded and shifted over a 6-day period as the eruption continued and capricious winds pushed the ash in different directions. Major air freight hubs such as Heathrow, Amsterdam, Paris, and Frankfurt were closed for up to five days.⁷¹

Although volcanoes, primarily in the Pacific Rim, had in the past caused trouble for individual aircraft and particular air routes, they had been localized incidents easily handled by detouring around the affected area.⁷² Companies, however, weren't prepared for an event that shut down every airport and every carrier over a large, economically vigorous region. For example, FedEx's contingency plan for a closure of Paris was to use Frankfurt, but Frankfurt was closed, too.⁷³

"There's a major disruption of the supply chain," said Paul Tsui, Vice Chairman of the Hong Kong Association of Freight Forwarding and Logistics.⁷⁴ In the UK alone, air freight provides 25% of all imports⁷⁵ and 55% of exports to non-EU countries.⁷⁶ Although some air freight might not be particularly time-sensitive (e.g., jewelry), many categories of freight are (e.g., perishable goods, vaccines, emergency spare parts, surgical instruments, and components for just-in-time manufacturing).⁷⁷ The closures hit supply chains in both upstream and downstream directions.

Migros, the Swiss supermarket chain, noted disruptions in supplies from the U.S. (green asparagus), Iceland (cod), and Southeast Asia (tuna). UK grocery stores ran out of pre-sliced fruit and tropical fruits like pineapple.⁷⁸ Hotels and restaurants in Hong Kong had shortages of French cheese, Belgian chocolates, and Dutch fresh-cut flowers.⁷⁹ In many cases, the declared value of the air freight belied the importance of the shipments to the recipient. Nissan's inability to fly \$30 air pressure sensors from Ireland to Japan kept the car maker from producing \$30,000 Nissan Murano SUVs.⁸⁰ Three BMW plants in Germany couldn't get inbound parts from Asia.⁸¹ And an inability to ship transmissions out of Europe disrupted production at BMW's U.S. factory.⁸²

"It's a terrible nightmare," said Stephen Mbithi, the chief executive officer of the Fresh Produce Exporters Association of Kenya.⁸³ During the 6 days of airport closures, thousands of tons of fresh flowers rotted in storage units and warehouses, representing a loss to the Kenyan

economy of \$3.8 million per day,⁸⁴ which represents about 3% of Kenya's daily gross domestic product (GDP).⁸⁵ "Cow food, that's about all we can do with it now," concluded Kenneth Maundu, general manager for Sunripe produce exporters.⁸⁶ Italian exporters of mozzarella and fresh fruits lost about \$14 million each day during the closures.⁸⁷ For many purveyors of time-sensitive goods, air freight to or from Europe was a diamond in their supply chain structure – a chokepoint in transportation that impacted all of them.

The International Air Transport Association (IATA) estimated that the Icelandic volcano crisis cost airlines more than \$1.7 billion in lost revenue in the 6 days after the initial eruption. At its worst, the ash cloud grounded 29% of the world's scheduled air travel – some 107,000 flight cancellations – over an 8-day period.⁸⁸ The disruption of passenger air travel would seem to mean little to the air freight industry, except for the fact that most air freight actually comes in the bellies of passenger aircraft.⁸⁹ In total, global cargo flights were down over 15% in April, proving that the post-disruption rebound did not make up for the losses.⁹⁰

Air freight isn't the only vulnerable mode, and volcanoes aren't the only hazard that causes disruption to bottlenecks in transportation systems around the world. On the Rhine River, which carries 16% of Germany's trade,⁹¹ recurring droughts,⁹² an overturned barge in 2011,⁹³ and unexploded bombs from WWII⁹⁴ have all created constrictions in freight volume. In the U.S., drought in the Mississippi River basin caused a 2-month disruption in the winter of 2012–2013 and resulted in an estimated \$6 billion in losses.⁹⁵ A quarter of all U.S. rail traffic and half of all intermodal rail traffic passes through Chicago, which was disrupted by a 1999 blizzard. "We basically waited for the spring thaw," said David Grewe, a supervisor for Union Pacific Railroad.⁹⁶ In November of 2012, 400 office clerks walked off their jobs at the ports of Los Angeles and Long Beach, thereby halting the movement of \$760 million a day worth of goods.⁹⁷

These logistical network risks are a paradoxical result of the success of the logistics industry to create high-speed, high-reliability, low-cost movement of goods around the world. As more companies, suppliers, and suppliers' suppliers build manufacturing and distribution strategies around high-performance global logistics, they expose themselves to risks that a disruption in logistical networks can ripple through the supply chain.

2 Managing deep supply chain risks

"I have 14,000 suppliers. I guarantee that with 14,000 suppliers, at least one of them is not performing well today," said Tom Linton, chief procurement and supply chain officer at Flextronics.⁹⁸ As companies realize they are exposed to deep and broad supply chain risks, they seek ways to identify, prevent, and mitigate those risks. And because those risks lie far outside the span of control of the enterprise, these deep supply chain risk management activities sometimes depend on third parties who may have better visibility or better influence over the deeper parts of the supply chain.

2.1 Mapping the supply chain

"We're trying to understand the sub-supply chain wherever it's possible and where our suppliers will share that information," said Intel's Sturm. One major challenge is the natural reticence of suppliers, because the identity of a supplier's suppliers, the materials they procure, and the relationships between the companies are proprietary and are part of the supplier's competitive advantage. A second challenge is the dynamic nature of supply chains, with constant turnover in the supply base as well as the locations used by suppliers for any particular part. Moreover,

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as more companies attempt to map their supply chains, suppliers face administrative costs for responding to multiple requests for information.

Resilinc Inc.⁹⁹ exemplifies a new generation of supply chain software and services companies addressing these mapping issues. Resilinc surveys a client company's suppliers to map them and keeps suppliers' proprietary business data secure. The surveys cover risk management issues such as supplier facility locations, sub-supplier locations, business continuity planning, recovery times, emergency contact data, conflict minerals, and other concerns. Resilinc uses the client's bill-of-material data and value-at-risk estimates (a measure of the potential loss to the company) for each product to cross-reference parts with mapped locations and identify high-risk parts. The software uses data on the supplier locations producing each part, the parts in each product, and the financial contributions of each product to estimate the value-at-risk of each supplier location. Other companies offering similar services include Razient Inc.¹⁰⁰ and MetricStream.¹⁰¹

Some companies, such as IBM, Cisco, and ATMI, created in-house supplier mapping applications. However, third-party services such as Resilinc and its competitors can reduce the costs of supplier mapping and updating because the survey data can be pooled among multiple customer companies, which often have overlapping sets of suppliers. Such a "network effect" reduces the costs of information collection as well as the compliance burden on suppliers. Whichever way it is done, geographic mapping of the supply chain helps find concentrations of risk at the product, supplier, industrial cluster, and commodity level.

2.2 Monitoring the supply chain

"Information and visibility are the backbones of incident response, and these tools have to be in place prior to the crisis," said John O'Connor, Cisco's Senior Director of Supply Chain Transformation.¹⁰² Detecting deep-tier disruptions quickly is essential. It gives the company time to assess the problem and mitigate the disruption – by finding alternative suppliers, qualifying new materials, or helping the deep-tier supplier to recover. It also gives the company a leg up on competitors in securing supplies. Monitoring world events, detecting potentially disruptive ones, and creating alerts can be handled by companies like Resilinc or by the company itself.

Although a company's emergency operations center may be monitoring 24-hour TV news channels, these sources of breaking news only cover the largest of stories of a more general interest. Event monitoring services such as NC4,¹⁰³ Anvil,¹⁰⁴ IJet,¹⁰⁵ OSAC,¹⁰⁶ or CargoNet¹⁰⁷ offer more fine-grained monitoring, sometimes with a specialized purpose such as travelers' security (Anvil), socio-political threats (OSAC),¹⁰⁸ or cargo security (CargoNet). In a representative week, a service such as NC4 might issue 1,700 alert messages covering 650 events around the world.¹⁰⁹ Many events seem quite localized, such as a shooting in a mall in Omaha, student demonstrations in Colombia, or the crash of a small plane in Mexico City.¹¹⁰

The raw event feed is then filtered by the event monitoring service, a company like Resilinc, or by the company's own incident management systems. The filters remove non-supply-chain disruptions (e.g., residential house fires) and then cross-compare the distances of potential disruptions with the locations of mapped facilities. Most alert-software tools offer customization, allowing companies to specify alert thresholds for each type of facility based on event severity and distance from the facility.¹¹¹ If an event potentially affects a supplier and thus affects one or more of their clients' companies, Resilinc determines which parts and products may be affected as well as the potential value-at-risk and sends an alert about the event to each affected company. During the 2011 Thailand floods, Resilinc helped Flextronics gain about a week's warning regarding the threat posed by the rising waters.

2.3 Supplier code of conduct

Supply disruptions are not the only enterprise risks lurking in deep supply chains. On April 24, 2013, horrific images saturated news outlets as over 1,100 bodies were pulled from the collapsed eight-story Rana Plaza garment factory in Bangladesh.¹¹² Rana Plaza wasn't an isolated incident. Six months before, a fire at a different Bangladeshi garment factory, Tazreen Fashions, killed 112.¹¹³ These events put a tragic human face on repugnant conditions deep within some companies' global supply chains.

Paralleling the gruesome search for bodies under the rubble was the search for the Western companies whose garments were made in these death-trap factories. Most companies denied using suppliers operating in the structurally unsafe buildings. In the case of Rana Plaza, name-brand companies such as Benetton, Mango, Bonmarché, Primark, The Children's Place, and others acknowledged their current or past use of the suppliers operating there.¹¹⁴

Many companies simply didn't know which suppliers they were using, given the murky web of brokers, contractors, and subcontractors operating in countries like Bangladesh. For example, in the case of the Tazreen Fashions factory fire, Walmart believed it was not involved because the retailer had banned Tazreen Fashions more than a year prior to the fire after Walmart's hired auditors had declared Tazreen to be "high risk." But one of Walmart's other authorized suppliers subcontracted with another authorized supplier and then that subcontractor shifted the work to Tazreen.¹¹⁵ Nor was worker safety in a few unsafe buildings the only social concern in Bangladesh. When Pope Francis learned that Bangladesh's minimum wage was only \$40 per month, he said, "This is called slave labor."¹¹⁶

Revelations of substandard working conditions or environmental transgressions can disrupt a company's operations in at least three ways: consumer revulsion disrupts demand, local unrest disrupts supply, and regulatory changes impact costs. "Companies feel tremendous pressure now," said Scott Nova, the executive director of the Worker Rights Consortium, a factory-monitoring group based in Washington, DC.¹¹⁷ He added, "The apparel brands and retailers face a greater level of reputation risk of being associated with abusive and dangerous conditions in Bangladesh than ever before."¹¹⁸ The earlier example of Greenpeace's attack on Nestle over palm oil shows that environmental practices of suppliers deep in their supply chains create risks for consumer brand companies.

Companies typically rely on supplier codes of conduct enforced by audits. Such codes define expected or prohibited behavior, with some being prohibitions considered "zero-tolerance" requirements (e.g., child labor, toxic waste dumping). Yet the Walmart-Tazreen example shows that compliance is not always guaranteed, especially in the deeper tiers. Non-compliance incidents per audit are 18% higher at Tier 2 suppliers and 27% higher at Tier 3 suppliers compared to Tier 1 suppliers, according to data from the non-profit supply chain auditing group Sedex.¹¹⁹

Disney may be one of the most reputation-sensitive companies in the world, with a corporate unit devoted to developing and protecting a worldwide brand that is synonymous with happy families, the innocence of childhood, and wholesomeness. "Our goal is to have a supply chain that mirrors Disney's own desire to operate as a responsible business," said John Lund, Disney's senior vice president, integrated supply chain management.¹²⁰ Nearly two months before the Rana Plaza collapse, Disney ordered an end of sourcing from Bangladesh and four other countries (Pakistan, Belarus, Ecuador, and Venezuela) based on audits and personal visits by senior executives.

2.4 Cascading ERM into the supply chain

As large companies implement ERM, they start encouraging or requiring suppliers to do the same. For example, Medtronic expects suppliers to create and maintain Medtronic-specific

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business continuity plans (BCPs) and to show their BCPs to Medtronic on request. The company expects each supplier's planning to include a plan of action, checklist of activities, communication plans, escalation procedures, and the organization of teams, roles, and responsibilities.¹²¹ Similarly, Cisco expects suppliers to use BCP and asks them about specific continuity assets such as backup generators (and fuel), fire protection and sprinkler systems, IT recovery strategies, and overall site recovery plans. Cisco surveys about 700 of its top suppliers and partners twice a year on BCP issues.¹²² If Cisco finds gaps in a supplier's BCP, it works with the supplier via Cisco's supplier commodity managers.¹²³

Rather than try to extract sensitive commercial information about the deeper-tier suppliers, some companies are helping their Tier 1 suppliers to manage their Tier 2 risks with the intent that Tier 2 suppliers will, in turn, manage the Tier 3 risks and so on. For example, Boston Scientific trains Tier 1 suppliers on its supplier risk scorecard system so they can use the system for their own suppliers.¹²⁴ Similarly, Tanya Bolden, Program Manager for the Auto Industry Action Group, said that "auto makers are relying on their large, direct suppliers to 'cascade training on safety and other workplace issues to their subcontractors.'" ¹²⁵ Tim Hendry, Intel's Vice President, Technology and Manufacturing Group and Director of Fab Materials said, "We're trying to get our suppliers to work with their sub-suppliers on their resiliencies, sitting down and discussing their business continuity plans."¹²⁶

2.5 Finding a locus of risk control

In April 2009, John Prendergast, a human rights activist who had worked for the Clinton White House, the US State Department, and UNICEF prior to founding the Enough Project,¹²⁷ sent a letter to leading electronics firms, including Intel, HP, Motorola, and AT&T.¹²⁸ The letter warned that four metals (gold, tantalum, tin, and tungsten) used in electronic products could be akin to blood diamonds. Militants and terrorists in the eastern region of the Democratic Republic of Congo (DRC) were using violence, rape, and other atrocities to force citizens to mine the ore to help finance wars. The Enough Project sought to cut off indirect Western funding of the conflict by convincing companies not to buy so-called conflict minerals. The reputational threat to the companies receiving the letter was clear.

As a first step, Intel attempted to assess if it was using conflict minerals. But no one at the company knew because Intel itself didn't buy these metals or their ores directly. Next, the company asked suppliers about the issue: some didn't know, some didn't respond, and some said they didn't use conflict minerals but lacked supporting evidence.¹²⁹ Intel realized it would need to map these metals' supply chains down to the mine level to understand whether conflict minerals were getting into Intel's products and how Intel might control this risk.

Because the electronics industry consumes 60% of the world's tantalum supplies, Intel picked this metal as its first supply chain to map. The company mapped over 90% of its micro-processor supply chain, with employees visiting 13 countries in person to gain a firsthand understanding of the issues. Company employees toured mines with non-governmental organizations (NGOs) and followed the journey of the minerals as the ore went through a series of intermediaries to the smelters. The employees conducted more than 50 on-the-ground smelter reviews to understand ore sourcing practices. From the smelters, tantalum went to refiners for reprocessing into other forms, such as electronic-grade tantalum powder that is used by makers of electronics components that eventually make their way into Intel's products.

Controlling the risks of conflict minerals would be hard because "putting a de facto ban on materials out of the Congo means that good people might starve," said Gary Niekerk, Director of Global Citizenship at Intel. A ban would impact the 100,000 legitimate artisanal miners in

the country, harm the economy, and fuel further unrest. The mapping effort helped Intel see that the relatively small number of smelters could be the logical focal point for controlling conflict minerals. Smelters were the last stage in the supply chain where the source of the ore could be identified. “Once it’s turned into a bar of something, you can’t trace the source,” Niekerk said. “But as an ore, you can trace it. So we focused on smelters.”¹³⁰

Getting the cooperation of the smelters in managing conflict mineral risks was another challenge. These smelters sat six to seven layers deep in Intel’s supply chain, which is far outside the usual span of influence that buyers have on their suppliers. Why would a Brazilian tantalum smelter care about Congolese ore or about an American chip-maker that’s not the smelter’s customer? As large as Intel might be, it represents a minuscule fraction of the demand for conflict minerals, especially tin, tungsten, and gold. As such, Intel, by itself, couldn’t drive change.

Intel realized it would need to work with other companies in the electronics industry to create a critical mass of buyers who could cascade conflict mineral avoidance practices down through the many layers of the supply chain. To this end, Intel helped found the Electronic Industry Citizenship Coalition (EICC), which grew to encompass dozens of chip-making equipment suppliers, chip-makers, contract manufacturers, and electronics original equipment manufacturers (OEMs).¹³¹ Intel and the EICC worked to create a simple, standardized Conflict-Free Smelter (CFS) certification process and reimbursed some of the costs of certification.

Intel set a 2013 goal to eliminate conflict-sourced tantalum in all its microprocessors. Next, Intel tackled gold, tin, and tungsten. In January 2014, Intel announced that its entire 2014 line of microprocessors would be conflict-free for all four minerals.¹³² In August 2012, the U.S. Securities and Exchange Commission implemented rules outlined in the 2010 Wall Street Reform and Consumer Protection Act (aka “Dodd-Frank”) to require public companies to disclose whether they use conflict minerals.¹³³

2.6 Industry-level incident management

On March 31, 2012, a tank filled with highly flammable butadiene exploded in a chemical factory in Marl, Germany. Intense flames and thick black smoke billowed from Evonik Industries’ cyclododecatriene (CDT) plant at the 7,000-worker chemical complex in the heavily industrialized Ruhr River valley. Roughly 130 firefighters fought the blaze for 15 hours to prevent its spread to the rest of the facility and to ultimately extinguish it. The explosion and fire killed two workers and severely damaged the plant.¹³⁴

Cyclododecatriene sounds like an obscure chemical, but it is a key ingredient in making a high-performance plastic called nylon-12 or PA-12 that is especially prized for its chemical resistance, abrasion resistance, and fatigue resistance. PA-12 is a favorite of the auto industry, which uses it for fuel lines, brake lines, and plastic housings. The average light vehicle in 2011 used over 46 pounds of nylon, up from just 7 pounds in 1990.¹³⁵ PA-12 also goes into solar panels, carpets, athletic shoes, ski boots, optical fibers, cable conduits, and flame-retardant electrical insulation. CDT is a key precursor for making many other chemicals, such as brominated flame retardants, fragrances, hot-melt adhesives, and corrosion inhibitors.¹³⁶

Whereas Japan’s 2011 earthquake, tsunami, and nuclear reactor disaster devastated a region, directly impacted thousands of businesses, and dragged on for weeks, the Evonik fire was tiny and strictly localized by comparison. One part of one factory in one town had a fire. Less than a day later, the fire was out. But the explosion and fire destroyed almost half the world’s production capacity for CDT. Worse, at the time of the explosion, CDT supplies were already tight due to its use in the booming solar panel industry.

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Because Evonik was so deep in the supply chain, automakers weren't initially aware that the fire occurred. Not until a maker of fuel lines and brake lines – TI Automotive – raised the alarm about the dire implications of the Evonik fire did the automotive industry spring into action. The effect of the Evonik fire would prove to be very large – at GM, for example, supplies of 2,000 parts were jeopardized, which was one-third the number of parts that were disrupted by the far larger Japanese disaster. The impact of Evonik was so large because every car made by GM and every other automaker required nylon-12 plastic, which became scarce because of the Evonik fire. Dual- or multi-sourcing couldn't help in the case of the Evonik chemical plant explosion because no second source in the world had the capacity to make up for the loss at Evonik.

The auto industry convened an emergency summit on April 17 because no single automaker or supplier could address the problem. Two hundred people attended the summit, representing eight automakers and 50 suppliers.¹³⁷ All tiers of the affected sectors of the automotive supply chain came, including the big OEMs, their Tier 1 suppliers, component makers, polymer resin makers, and on down to chemical makers such as Evonik and BASF.¹³⁸ The summit was moderated by a neutral third party, the Automotive Industry Action Group (AIAG).¹³⁹ The AIAG is a volunteer-run, non-profit organization that provides shared expertise, knowledge, and standards on quality, corporate responsibility, and supply chain management to a thousand member firms in the automotive industry.¹⁴⁰

The summit participants had three incident management objectives that required the collective expertise of the entire industry. First, they wanted to understand and quantify the current state of global PA-12 inventories and production capacities throughout the automotive supply chain. Second, they wanted to brainstorm options to strategically extend current PA-12 capacities and/or identify alternative materials or designs to offset projected capacity shortfalls. Third, they wanted to identify and recruit the necessary industry resources required to technically test and approve the alternatives.

The group formed six committees to help quickly create action plans to lessen any impact of shortages on component and vehicle production.¹⁴¹ Each committee tackled an assigned task, such as managing remaining inventories, boosting production at existing suppliers, identifying new firms to produce resins, and finding replacement materials.¹⁴² The group hosted multiple technical follow-up meetings during the subsequent weeks on these issues.¹⁴³

This multifaceted collaboration was key to overcoming the challenge. Within a week of the meeting, the top OEMs had jointly drafted a plan to expedite their parts validation processes.¹⁴⁴ Harmonized validation processes ensured that a supplier didn't need a different validation process for each customer OEM. Suppliers from other industries lent their capacity to automotive applications. For example, carpet maker Invista Inc. released capacity for production of CDT.¹⁴⁵ In the end, cars continued to roll off the line even though the Evonik factory was offline for 9 months after the explosion and fire.¹⁴⁶

2.7 Managing broad and deep risks beyond the four walls

This chapter's examples illustrate both the risk exposures and risk management elements of organizations that are operating in a context of global suppliers and global customers. The combined quests for cost reductions, economies of scale, and market share drive consolidation and the development of dominant suppliers and supplier clusters, which then provide large fractions of global demand for a myriad of obscure but essential commodities. Companies' dependence on many different petrochemical, mineral, and agricultural raw materials creates

risks of both supply disruption and demand disruption that arise far outside the normal span of influence of the organization and transcend the ERM capacities of individual companies. These concentrations in suppliers reduce the effectiveness or even the possibility of second sourcing as a risk management strategy. Furthermore, the rise of lean manufacturing, shorter product life cycles, and demand-disrupting risks makes extra inventory an unpalatable risk management strategy.

By taking a broader and deeper view of risk, companies can go beyond enterprise risk management to manage exposures and incidents linked to the deep and broad supply chains upon which virtually all companies depend. A more holistic understanding of the supply base, customer base, and lateral connected industries helps companies understand over-the-horizon risks such as hidden sole sources, lateral risk exposure, geographic chokepoints, and vulnerable commodities that are uncommon (REE) or contentious (palm oil). And because deep risks lie outside the enterprise, the risk management methods often lie outside the enterprise in using third-parties, cascading ERM deep into the supply chain, and collaborating to create industry-level risk management solutions. The economic forces that have driven globalization, innovation, and lean optimization are not likely to abate, which implies that as companies come to control their internal enterprise risks and proximate supply chain risks, they will find that further progress on enterprise risk management will increasingly entail managing broad and deep supply chains.

Notes

- 1 www.coso.org/documents/coso_erm_executivesummary.pdf
- 2 www.iso.org/iso/home/standards/iso31000.htm
- 3 www.iso.org/iso/home/standards.htm
- 4 <https://erm.ncsu.edu/library/article/current-state-erm-2015>
- 5 www.wto.org/english/res_e/statis_e/its2015_e/its2015_e.pdf
- 6 www.automotive-textiles.de/
- 7 www.geonami.com/tohoku-earthquake-geophysical/
- 8 Robert Charette, This Car Runs on Code, *IEEE Spectrum*, February 1, 2009. <http://spectrum.ieee.org/green-tech/advanced-cars/this-car-runs-on-code>
- 9 Interview with Rob Thom, Manager, GM Global Vehicle Engineering Operations, August 2012.
- 10 www.intel.com/content/dam/www/public/us/en/documents/packaging-databooks/packaging-chapter-14-databook.pdf
- 11 www.docstoc.com/docs/88638192/Japan-Earthquake---Related-Industry-News-Update-Compiled-by- “Japan Earthquake Aftermath – Related Industry News Update” Compiled by Advanced MP Technology www.docstoc.com/docs/88638192/Japan-Earthquake---Related-Industry-News-Update-Compiled-by
- 12 “Japan Earthquake Aftermath – Related Industry News Update.”
- 13 Mark LaPedus. “Quake to Cause Prices Hikes, Shortages.” March 15, 2011. www.eetimes.com/document.asp?doc_id=1258944
- 14 www.researchinchina.com/news/NewsInfo.aspx?Id=18292
- 15 www.paintsquare.com/news/?fuseaction=view&id=5329&nl_versionid=859
- 16 Mariko Sanchanta, “Chemical Reaction: iPod Is Short Key Material,” *Wall Street Journal*, March 29, 2011.
- 17 www.advisorperspectives.com/commentaries/gmo_112612.php
- 18 Interview with Jackie Sturm, VP and GM of Global Sourcing & Procurement at Intel, July 31, 2012.
- 19 Peter March, “Industry Left High and Dry,” *Financial Times*, April 12, 2011.
- 20 www.emsnow.com/npps/story.cfm?pg=story&id=45416
- 21 Allianz, *Managing Disruptions*. www.agcs.allianz.com/assets/PDFs/white%20papers/AGCS%20Managing%20disruptions%20Nov2012.pdf
- 22 http://press.ihs.com/sites/ihs.newshq.businesswire.com/files/2011-09-06_HDD_Market_Share_0.jpg

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- 23 http://thoughtleadership.aonbenfield.com/Documents/20120314_impact_forecasting_thailand_flood_event_recap.pdf
- 24 www.digitimes.com/news/a20111117PD210.html
- 25 <http://news.techworld.com/personal-tech/3320401/thailand-floods-hard-drive-shortage-makes-small-pc-makers-hike-prices/>
- 26 www.digitimes.com/news/a20111127PD201.html
- 27 Quentin Hardy, "Intel Sees Opportunity in Storage Drives," *New York Times*, December 12, 2011.
- 28 Eric Smally, "Thai Flood Sink Intel Chip Orders," *Wired*, December 12, 2011.
- 29 www.bloomberg.com/news/2011-12-12/intel-reduces-forecast-for-fourth-quarter-sales-on-hard-disk-drive-supply.html; Charles Arthur, "Intel Cuts Revenue Forecast as Thai Floods Hit PC Sales," *The Guardian*, December 12, 2011.
- 30 Interview with Jackie Sturm, VP and GM of Global Sourcing & Procurement at Intel, July 31, 2012.
- 31 www.gpo.gov/fdsys/pkg/CHRG-110shrg50418/html/CHRG-110shrg50418.htm
- 32 www.gpo.gov/fdsys/pkg/CHRG-110shrg50418/html/CHRG-110shrg50418.htm
- 33 http://ec.europa.eu/environment/waste/rohs_eee/events_rohs1_en.htm
- 34 European Food Safety Authority, E. Coli: Rapid Response in a Crisis. www.efsa.europa.eu/en/press/news/120711.htm
- 35 Joshua Chaffin, "Source of E. Coli Eludes Experts," *Financial Times*, May 31, 2011.
- 36 "New epidemiological data corroborate existing recommendation on consumption by BfR." Bundesinstitut für Risikobewertung.
- 37 www.bbc.co.uk/news/world-europe-13605910
- 38 www.thejournal.ie/spanish-cucumbers-not-responsible-for-e-coli-outbreak-146922-Jun2011/
- 39 www.theguardian.com/uk/2011/may/31/e-coli-deaths-16-germany-sweden
- 40 www.bbc.co.uk/news/world-europe-13605910
- 41 <http://metro.co.uk/2011/06/01/1500-now-hit-by-e-coli-bug-as-spain-sues-for-damages-30231/>
- 42 www.thejournal.ie/spanish-cucumbers-not-responsible-for-e-coli-outbreak-146922-Jun2011/
- 43 <http://english.cntv.cn/program/newsupdate/20110601/103130.shtml>
- 44 <http://english.cntv.cn/program/newsupdate/20110601/103130.shtml>
- 45 www.bfr.bund.de/cm/349/chcc-outbreak-2011-updated-analysis-as-a-basis-for-recommended-measures.pdf
- 46 Peter Walker, Abby D'Arcy Hughes and Adam Gabbatt, "E. Coli Outbreak "Trail" Leads to German Bean Sprouts, Authorities Say," *The Guardian*, June 6, 2011.
- 47 www.cdc.gov/salmonella/bredeney-09-12/index.html
- 48 <http://concord-ca.patch.com/groups/politics-and-elections/p/peanut-butter-recall-expands-as-salmonella-outbreak-worsens>
- 49 Associated Press, "Peanut Industry: Recall Price Tag \$1 Billion," March 11, 2009. www.msnbc.msn.com/id/29634279/
- 50 www.zurich.com/internet/main/SiteCollectionDocuments/products-and-services/SCI_Risk_Insight_WSJ_articles.pdf
- 51 www.dailykos.com/story/2008/12/01/668305/-Side-Product-of-the-Economic-Meltdown-160-Important-Research-Chemical-in-Short-Supply
- 52 www.nydailynews.com/new-york/gas-nightmare-drags-new-yorkers-article-1.1198150
- 53 <http://science.time.com/2013/12/20/rare-earths-are-too-rare/>
- 54 <http://blogs.ei.columbia.edu/2012/09/19/rare-earth-metals-will-we-have-enough/>
- 55 Randolph Kirchain, presentation at the MIT CTL conference, "Crossroads 2012: "Supply Chains in Transition," held on June 28, 2012 in Cambridge, Massachusetts.
- 56 Marc Humphries, "Rare Earth Elements: The Global Supply Chain." Congressional Research Services, June 8, 2012. www.fas.org/sgp/crs/natsec/R41347.pdf
- 57 Marc Humphries, "Rare Earth Elements."
- 58 www.forbes.com/sites/larrybell/2012/04/15/chinas-rare-earth-metals-monopoly-neednt-put-an-electronics-stranglehold-on-america/
- 59 Eric Martin and Jennifer Freedman, "Obama Says China Rare-Earth Case Is Warning for WTO Violators," *Bloomberg*, March 13, 2012. www.bloomberg.com/news/2012-03-13/eu-joins-u-s-japan-in-challenging-china-s-rare-earth-export-restrictions.html
- 60 http://www3.weforum.org/docs/WFF_SCT_RRN_NewModelsAddressingSupplyChainTransportRisk_IndustryAgenda_2012.pdf
- 61 www.kitcometals.com/charts/copper_historical.html

- 62 <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0297>
- 63 Ernst and Young, Business Risks Facing Mining and Metals 2012–2013. [www.ey.com/GL/en/Industries/Mining---Metals/Business-risks-facing-mining-and-metals-2012–2013](http://www.ey.com/GL/en/Industries/Mining---Metals/Business-risks-facing-mining-and-metals-2012-2013)
- 64 http://www3.weforum.org/docs/WEF_SCT_RRN_NewModelsAddressingSupplyChainTransportRisk_IndustryAgenda_2012.pdf
- 65 www.greenpeace.org/kitkat
- 66 Jeremiah Owyang, “Greenpeace vs. Brands: Social Media Attacks to Continue.” *Forbes*, July 19, 2010. www.forbes.com/2010/07/19/greenpeace-bp-nestle-twitter-facebook-forbes-cmo-network-jeremiah-owyang.html
- 67 Greenpeace, Greenpeace Protests at Nestle Shareholder Meeting, 2010. Retrieved from: www.youtube.com/watch?v=s8kwVU5pujg
- 68 *The Economist*, “The Other Oil Spill,” June 24, 2010. www.economist.com/node/16423833
- 69 <http://forestethics.org/tar-sands>
- 70 www.forbes.com/sites/amywestervelt/2011/08/17/the-big-pr-lesson-companies-still-need-to-learn-about-facebook/
- 71 http://en.wikipedia.org/wiki/Air_travel_disruption_after_the_2010_Eyjafjallajökull_eruption
- 72 <http://pubs.usgs.gov/ds/545/DS545.pdf>
- 73 <http://blog.van.fedex.com/blog/business-unusual-flight-planning-and-iceland-volcano-eruption>
- 74 <http://in.reuters.com/article/2010/04/20/idINIndia-47840520100420>
- 75 Richard Wray and Graeme Wearden, “Flight Ban Could Leave the UK Short of Fruit and Veg.” *The Guardian*, April 16, 2010.
- 76 Bernice Lee and Felix Preston, with Gemma Green, “Preparing for High Impact, Low Probability Events: Lessons from Eyjafjallajökull,” *Chatham House Report*, January 2012. www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r0112_highimpact.pdf
- 77 Bernice Lee and Felix Preston, with Gemma Green, “Preparing for High Impact, Low Probability Events.”
- 78 Richard Wray and Graeme Wearden, “Flight Ban Could Leave the UK Short of Fruit and Veg.” *The Guardian*, April 16, 2010. www.guardian.co.uk/business/2010/apr/16/flight-ban-shortages-uk-supermarkets
- 79 <http://news.bbc.co.uk/2/hi/8631676.stm>
- 80 <http://news.bbc.co.uk/2/hi/8631676.stm>
- 81 <http://news.bbc.co.uk/2/hi/8631676.stm>
- 82 www.thestate.com/2010/04/20/1251405/volcano-disrupts-bmw-supply-chain.html; <http://news.bbc.co.uk/2/hi/8631676.stm>
- 83 Jeffrey Gettleman, “With Flights Grounded, Kenya’s Produce Wilts,” *New York Times*, April 19, 2010.
- 84 Bernice Lee and Felix Preston, with Gemma Green, “Preparing for High Impact, Low Probability Events: Lessons From Eyjafjallajökull,” *Chatham House Report*, January 2012. www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r0112_highimpact.pdf and Airmic Technical, “Supply Chain Failures” www.airmic.com/report/supply-chain-failures
- 85 www.cia.gov/library/publications/the-world-factbook/geos/ke.html
- 86 Jeffrey Gettleman, “With Flights Grounded, Kenya’s Produce Wilts.”
- 87 www.worldtradewt100.com/blogs/14-wt100-blog/post/iceland-s-volcano-does-a-number-on-global-supply-chains
- 88 www.science20.com/planetbye/volcanic_eruptions_science_and_risk_management-79456
- 89 Richard Wray and Graeme Wearden, “Flight Ban Could Leave the UK Short of Fruit and Veg.”
- 90 www.science20.com/planetbye/volcanic_eruptions_science_and_risk_management-79456
- 91 www.toonline.org/books/kits/welcome%20to%20germany/WTGpdf/Handout%204.pdf
- 92 www.handyshippingguide.com/shipping-news/more-misery-for-rhine-shippers-as-drought-continues_626; www.hellenicshippingnews.com/News.aspx?ElementId=1c36a1ec-edf3-4a27-a8c5-d107b0a268c2
- 93 www.csmonitor.com/World/Latest-News-Wires/2011/0113/Acid-tanker-capsizes-on-Rhine-in-Germany
- 94 Mathew Day, “War Bombs Cause Chaos on the Rhine,” *The Telegraph*, November 23, 2011.
- 95 Darryl Fears, “Drought Threatens to Halt Critical Barge Traffic on Mississippi,” *The Washington Post*, January 6, 2013. www.washingtonpost.com/national/health-science/drought-threatens-

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- to-halt-critical-barge-traffic-on-mississippidrought-threatens-to-halt-critical-barge-traffic-on-mississippidrought-threatens-to-halt-critical-barge-traffic-on-mississippi/2013/01/06/92498b88-5694-11e2-bf3e-76c0a789346f_story.html
- 96 www.nytimes.com/2012/05/08/us/chicago-train-congestion-slows-whole-country.html?pagewanted=all
- 97 www.commercialappeal.com/news/2012/dec/04/la-mayor-says-both-sides-in-west-coast-port-have/
- 98 Interview with Tom Linton, chief procurement and supply chain officer at Flextronics, on July 30, 2012
- 99 www.resilinc.com/index.aspx
- 100 www.razient.com/
- 101 www.metricstream.com/solutions/supply_chain_risk_management.htm
- 102 www.usresiliencproject.org/pdfs/USRP_Priorities_Final_020112.pdf
- 103 www.nc4.us
- 104 www.anvilgroup.com
- 105 www.ijet.com
- 106 www.osac.gov/Pages/Home.aspx
- 107 www.cargonet.com/
- 108 www.osac.gov/Pages/Home.aspx
- 109 www.nc4.us/RiskCenterStats.php
- 110 www.nc4.us/FI_Archived.php
- 111 www.nc4.us/riskcenter_security.php
- 112 www.bbc.co.uk/news/world-asia-22476774
- 113 <http://abcnews.go.com/Blotter/fire-kills-112-workers-making-clothes-us-brands/story?id=17807229>
- 114 www.bbc.co.uk/news/world-asia-22474601
- 115 http://online.wsj.com/article/SB10001424127887323401904578159512118148362.html?google_editors_picks=true
- 116 www.nytimes.com/2013/05/02/business/some-retailers-rethink-their-role-in-bangladesh.html?_r=0
- 117 www.nytimes.com/2013/05/02/business/some-retailers-rethink-their-role-in-bangladesh.html?pagewanted=all
- 118 www.nytimes.com/2013/05/02/business/some-retailers-rethink-their-role-in-bangladesh.html?_r=0
- 119 www.sedexglobal.com/wp-content/uploads/2011/06/Sedex-Transparency-Briefing-Nov-2013.pdf
- 120 www.gscreview.com/feb10_john_interview.php
- 121 www.medtronic.com/wcm/groups/mdtcom_sg/@mdt/@corp/documents/documents/019-g034.pdf
- 122 Kevin Harrington and John O'Connor, "How Cisco Succeeds," *Supply Chain Management Review*, July/August 2009. www.imperiallogistics.co.za/documents/06.HowCiscoSucceeds_.pdf
- 123 Kevin Harrington and John O'Connor, "How Cisco Succeeds."
- 124 MIT CTL Crossroads conference: Managing Supply Chains During Turbulent Times. Presentation by Mike Kalfopoulos, Senior Manager, Global Sourcing at Boston Scientific, March 26, 2009, in Cambridge, Massachusetts.
- 125 Colum Murphy, Joseph White and Jake Maxwell Watts, "GM Doesn't Plan to Change Supply-Chain Safety Process," *Wall Street Journal*, August 5, 2014.
- 126 <https://supplier.intel.com/static/bc/considerations.htm>
- 127 See www.enoughproject.org/
- 128 www.enoughproject.org/publications/can-you-hear-congo-now-cell-phones-conflict-minerals-and-worst-sexual-violence-world
- 129 Interview with Gary Niekerk, Director of Global Citizenship at Intel, July 23, 2012.
- 130 Interview with Gary Niekerk, Director of Global Citizenship at Intel, July 23, 2012.
- 131 www.eiccoalition.org/about/members/
- 132 <http://thinkprogress.org/security/2014/01/07/3126271/intel-announces-launch-conflict-free-micro-processors/>
- 133 Jim Low, "Dodd-Frank and the Conflict Minerals Rule," *KPMG Directors and Boards*, 4th Quarter, 2012, pp. 44-45.
- 134 Marc Reisch, "Explosion at German Chemical Plant Kills Two," *Chemical and Engineering News*, April 2, 2012. <http://cen.acs.org/articles/90/web/2012/04/Explosion-German-Chemical-Plant-Kills.html>

- 135 www.plastics-car.com/lightvehiclereport; http://plastics.dupont.com/plastics/pdfit/americas/markets/nylon_under_hood.pdf
- 136 www.daicel-evonik.com/english/products/manufacture/C12,C8/index.html
- 137 Melissa Burden, "Auto Group Looks for Ways to Work Around Resin Shortage," *Detroit News*, April 19, 2012.
- 138 www.aiag.org/staticcontent/press/releases/GENERAL/AIAG%20Post%20Summit%20UPDATE%20-%20FINAL4-18.pdf
- 139 www.bloomberg.com/news/2012-04-13/auto-supplier-warns-of-resin-shortage-disrupting-output.html
- 140 www.aiag.org/staticcontent/about/index.cfm
- 141 Melissa Burden, "Auto Group Looks for Ways to Work Around Resin Shortage."
- 142 Jeff Bennett, "Nylon-12 Haunts Car Makers," *Wall Street Journal*, April 17, 2012. www.crainsdetroit.com/article/20120417/STAFFBLOG12/120419913/auto-industry-tries-to-head-off-resin-shortage-but-what-can-it-do
- 143 www.businessweek.com/news/2012-04-19/dupont-sees-boost-to-polymers-from-automakers-seeking-resins
- 144 Criag Trudell, "Automakers to Speed Part-Validation Process," *BloombergBusinessweek*, April 24, 2012.
- 145 www.plasticsnews.com/headlines2.html?id=25223
- 146 http://ei.wtin.com/article/T4Ellxyt6c/2013/02/26/polyamide_12_production_restarts_without_limitations_at_germ/