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## Big Lessons from Small Disruptions

On Friday night, March 17, 2000, a line of thunderstorms rolled through the desert city of Albuquerque, New Mexico. When lightning lit up the desert sky, one bolt struck an industrial building that housed a distant outpost of Philips NV, the Dutch electronics conglomerate. The furnace in Fabricator No. 22 caught fire. Immediately, alarms sounded inside the Philips plant and at the local fire station. Sprinklers went off and Philips-trained staffers rushed into action. In less than 10 minutes, the fire was out.

By the time the firefighters from Albuquerque Fire Station 15 arrived, they had nothing to do. “All we did was walk in and check it out,” said firefighter Ray Deloa. “It was fully extinguished by their staff.”<sup>1</sup> After the standard safety check, local firefighters agreed that the situation was under control. So the firefighters filled out their paperwork and left the scene.

A routine investigation showed that the fire had been minor. Nobody was hurt and the damage seemed superficial. The blaze did not make headlines in Europe, did not appear on CNN, and did not even appear in the Albuquerque newspapers. The fire had been extinguished, but the real drama was yet to begin; few would have imagined that it would affect the future of two Scandinavian companies.

### The Spreading Impact of an Extinguished Fire

To the firefighters’ experienced eyes, the damage seemed minor. Compared to the devastation created by a full-scale fire, this small blaze was hardly worth the firefighters’ trip to the plant. What the

firefighters did not realize, however, was that the blaze's location had once been one of the cleanest places on earth.

Philips's plant, a semiconductor fabrication plant, or fab, tolerates no dirt. "Every surface has to be completely clean," said Paul Morrison, spokesman for Philips.<sup>2</sup> The smallest spec of dandruff, lint, hair, or soot can ruin the delicate microscopic circuits that dominate the insides of modern electronics. Specialized air filters, cleanroom coveralls, and painstaking procedures ensure that no particle larger than half a micron<sup>3</sup> gets either inside the cleanroom or into the delicate machinery or silicon wafers.

But on the night of the 17th, the fire resulted in very different cleanrooms. Inside the damaged furnace, eight trays of wafers were immediately ruined. With hundreds of chips per eight-inch diameter wafer, each tray of wafers represented thousands of cell-phones worth of production.

Worse, the effects weren't confined to Fabricator No. 22. Smoke had spread throughout the facility—further than Philips realized. As staffers rushed to deal with the blaze and as firefighters tramped through the facility on their inspection, their shoes tracked in dirt. The smoke, the soot, and the tramping of staffers and firefighters left the cleanroom facilities anything but clean. The contamination ruined wafers in almost every stage of production, destroying millions of cellphones' worth of chips in those few minutes.

Even worse than the loss of valuable chips was the damage to the cleanrooms themselves. "It's as if the devil were playing with us," said one senior Philips manager who was involved in the clean-up. "Between the sprinklers and the smoke, everything that could go wrong did."<sup>4</sup> Two of Philips's four fabricators in Albuquerque were contaminated that night. "Water and smoke creates about as messy an environment as you can imagine. Everything has to be completely sanitized," said Philips spokesperson Paul Morrison.<sup>5</sup>

Returning the cleanrooms to their prior pristine state quickly would be a big job. Nervous executives in Amsterdam joked about showing up in Albuquerque with toothbrushes to help scrub the fabricator themselves. "We thought we would be back up after

a week,” said Ralph Tuckwell, a spokesman for Philips semiconductors.<sup>6</sup>

The first order of business was to communicate with the plant’s 30-some customers, and in particular its two most important ones—the Scandinavian cellphone giants Nokia and LM Ericsson AB—which accounted for 40 percent of the affected orders at the Albuquerque plant.

### **Nokia Responds to Potential Disruption**

Meanwhile, 5,300 miles away in Espoo, Finland, some puzzling numbers were appearing on the computer screens at Nokia’s headquarters. Shipments of some Philips chips seemed delayed.<sup>7</sup> On Monday, March 20, Philips called Tapio Markki, Nokia’s chief component-purchasing manager, to explain the delay.<sup>8</sup> The Philips account representative explained the evolving situation, the fire, the lost wafers, and the expected one-week delay.

Mr. Markki was not overly concerned after that first call on the Monday after the fire. One-week delays happen in all global supply chains. Downed machinery, material shortages, production schedule errors, quality issues, shipping delays, and minor industrial accidents (like the Philips fire) can all create short delays. Such events require prompt actions, but manufacturers usually keep safety stock—inventory of parts and finished goods—so that production schedules and customer service are not disrupted. Consequently, such routine disruptions create only faint numerical burbles in the smooth global flow of goods, but they don’t usually cause shortages for customers. Nokia could easily cover a short delay with existing parts inventory and shipments from other suppliers.

Although he did not see it as a major issue, Mr. Markki communicated the news to others inside Nokia, including Pertti Korhonen, Nokia’s top troubleshooter. “We encourage bad news to travel fast,” said Mr. Korhonen, who has worked at Nokia for 15 years. “We don’t want to hide problems.”<sup>9</sup> Mr. Korhonen decided that the situation needed closer scrutiny, even though it was not yet perceived to be a crisis. He placed the affected parts on a “special watch” list. Five types of chips from the

Albuquerque plant would receive more intensive scrutiny. Nokia would make daily calls to Philips to check the status of the evolving situation.

Mr. Korhonen also initiated a process of collaborating with Philips on recovery efforts. He suggested that two Nokia engineers in Dallas, Texas, could hop over to Albuquerque to help Philips. Philips feared that the outsiders would only add to the confusion in the disrupted plant and declined Nokia's offer.

Nokia's fears were justified when Philips called Mr. Markki two weeks after the fire to explain the full scope of the disruption. Philips now realized that it would take weeks to restore the clean-rooms and restart production. All told, it might take months to catch up on the production schedule.

At that juncture, Mr. Korhonen realized that the disrupted supplies would prevent the production of some four million handsets. Nokia was about to roll out a new generation of cellphones that depended on the chips from the infirm Philips fab. More than 5 percent of the company's annual production might be disrupted during a time of booming cellphone sales. Messrs. Korhonen and Markki quickly assembled a team of supply chain managers, chip designers, and senior managers from across Nokia to attack the problem. In all, 30 Nokia officials fanned out over Europe, Asia, and the United States to patch together a solution.<sup>10</sup>

The team quickly ascertained the availability of alternative sources for the parts. Three of the five parts could be purchased elsewhere. Japanese and American suppliers each could provide a million chips. Because Nokia was already an important customer of these two suppliers, the suppliers agreed to the additional orders with only five days' lead time. Expedited deliveries would help Nokia maintain production.

But two of the parts came only from Philips or a Philips subcontractor. "This was a big, big problem," Mr. Korhonen remembered realizing.<sup>11</sup> Nokia held meetings at the highest levels with Philips to convey the importance of the issue. When Messrs. Korhonen and Markki went to visit Philips headquarters, Mr. Jorma Ollila, Nokia's chairman and chief executive, diverted his return flight home from the United States to drop in on the meeting.

They spoke directly with Philips's CEO, Cor Boonstra, and the head of the company's semiconductor division, Arthur van der Poel.

Nokia was "incredibly demanding," according to Mr. Korhonen.<sup>12</sup> They demanded to know details about other Philips plants. Mr. Korhonen said that they told Philips "We can't accept the current status. It's absolutely essential we turn over every stone looking for a solution."<sup>13</sup>

The Nokia team dug into the capacity of all Philips factories and insisted on rerouting that capacity. "The goal was simple: For a little period of time, Philips and Nokia would operate as one company regarding these components."<sup>14</sup> The Finns' earnestness got results.

A Philips factory in Eindhoven, the Netherlands, would provide 10 million chips to Nokia. A Philips factory in Shanghai worked to free up more capacity for Nokia's needs. Nokia engineers developed new ways to boost production at the Albuquerque plant, creating an additional two million chips when that plant came back on line.

Through its extraordinary efforts and intensive collaboration with its suppliers, Nokia was able to avoid disrupting *its* customers. Handsets ultimately kept rolling off Nokia's assembly lines, onto store shelves, and into the hands of consumers.

### **Ericsson Waits for Parts**

Across the Baltic Sea, Nokia's arch rival, Ericsson, also bought a sizable number of Philips's chips for its cellphones. The two companies have a long-time rivalry. Not only do Ericsson and Nokia compete in building cellphones and cellular networks, Ericsson and Nokia are each a source of national pride for Sweden and Finland, respectively. Because Sweden controlled Finland from the early sixteenth to the early nineteenth century, the two countries have an intense, ongoing rivalry.

As a major customer of Philips, Ericsson received the same phone call that Nokia did on the Monday after the fire. Yet Ericsson's reaction was very different. It reflected the more consensual and laid-back nature of Swedish culture, while Nokia had the

more individualistic, aggressive culture of the Finns. “Ericsson is more passive. Friendlier, too, but not as fast,” said one official who dealt with both companies in the fire’s aftermath.<sup>15</sup>

Ericsson treated the call from Philips on March 20 as “one technician talking to another,” according to Roland Klein, head of investor relations for the company.<sup>16</sup> Ericsson was content to allow the one-week delay to take its course. The company assumed that Philips would ship the chips after a short delay, that the fire was minor, and that everything would work out. Lower-level staffers at Ericsson neither bothered their bosses with news of this minor glitch nor delved further into the magnitude of the disruption.<sup>17</sup> Even when it was clear that the much-needed chips were significantly delayed, lower-level employees at Ericsson still did not communicate the news to their bosses. The head of the consumer electronics division (which oversaw mobile phone production), Jan Wareby, did not learn of the problem until several weeks after the fire. “It was hard to assess what was going on,” he said. “We found out only slowly.”<sup>18</sup>

By the time Ericsson realized the magnitude of the problem, it was too late. When it finally asked Philips for help, Philips couldn’t provide it because Nokia had already commandeered all of Philips’s spare capacity. Ericsson then turned to other chip makers for parts. But, unlike Nokia, the company didn’t have alternative suppliers available for the chips that had come from the stricken Albuquerque plant.<sup>19</sup> With semiconductor sales running hot in the spring of 2000 and Nokia’s lock on all spare capacity, Ericsson failed to obtain needed parts from other sources. “We did not have a Plan B,” conceded Jan Ahrenbring, Ericsson’s marketing director for consumer goods.<sup>20</sup>

## **End Result**

Philips’s lost sales of the high-margin, high-tech chips resulting from the fire were on the order of US\$40 million.<sup>21</sup> Lost sales amounted to the majority of the financial hit that Philips took from the blaze. Direct damage to the plant was offset by a 39 million Euro insurance settlement.<sup>22</sup>

For that reason, the direct impact to Philips was relatively minor. The lost sales amounted to less than 0.6 percent of the US\$6.8 billion in semiconductors made by Philips in 2000. And, more important, the impact to Philips was minuscule compared to the impact on Philips's customers.

Ericsson bore the brunt of the disruption because it was unable to obtain secondary supplies of the disrupted parts. "These were pretty necessary components," said Kathy Egan of Ericsson.<sup>23</sup> In the end, Ericsson came up millions of chips short of what it needed for a key new generation of cellphone products.<sup>24</sup> That shortage of millions of chips meant a shortage of millions of high-end handsets. Without the high-end handsets, Ericsson had the wrong product mix for the fast-moving cellphone market. At the end of the first disruption-affected quarter, Ericsson reported losses of between three and four billion Swedish Kroner (between US\$430 and US\$570 million) before taxes owing to a lack of parts.<sup>25</sup> This immediate loss, by itself, exceeded Philips's losses by a factor of more than ten.

The after-effects of the disruption lingered for two more quarters beyond March 2000, including the critical (summer production) holiday 2000 quarter, which is ordinarily a time of high production and profitability. "That's definitely some market share that they're missing out on," said Mary Olsson, principal analyst with Dataquest.<sup>26</sup>

The total impact of the shutdown of the Philips plant took more than nine months to resolve. At the end of 2000, Ericsson announced a staggering 16.2 billion kronor (US\$2.34 billion) loss in the company's mobile phone division. The company blamed the loss on a slew of component shortages (including the Philips parts disruption), an incorrect product mix, and marketing problems.<sup>27</sup>

The disruption was more than just a temporary hit to Ericsson's financial growth curves. About a year after the fire, the fallout from the New Mexico fire and other problems (with components, marketing, and design) reached a climax for Ericsson, when the company announced plans to retreat from the phone handset production market. In April 2001, Ericsson signed a deal with Sony to create a joint venture to design, manufacture, and market

handsets. Sony-Ericsson would be owned 50-50 by the two companies.<sup>28</sup>

The fire's impact on Nokia was very different. Ericsson's inability to ship quantities of its high-end models removed one of Nokia's major competitors from the marketplace. Within six months of the fire Nokia's year-over-year share of handset market increased from 27 to 30 percent, while Ericsson's dropped from 12 to 9 percent.<sup>29</sup>

Although both Ericsson and Nokia were hit by the same disruption, one recovered while the other exited significant parts of the business. This example illustrates many of the concepts that are the focus of this book. The fortunes of Nokia and Ericsson were set well before the fire hit the cleanrooms in Albuquerque. Ericsson sat idle while Nokia acted. Nokia's culture encouraged dissemination of bad news; immediate action to monitor the supply of critical parts continuously helped it detect the problem early; deep relationships with its core suppliers helped rally them to fast action; knowledge of supply markets allowed it to procure elsewhere; and modular engineering design enabled the use of chips made by other manufacturers in some of its products.

## **The Challenge Ahead**

Today's supply chains span the globe and involve many suppliers, contract manufacturers, distributors, logistics providers, original equipment manufacturers (OEM), wholesalers, and retailers. This web of participating players creates complexities, making it difficult to realize where vulnerabilities may lie. It also creates interdependencies that exacerbate these difficulties.

Consider, for example, the globe-trotting involved in manufacturing an Intel Pentium processor that powers a Dell computer.

The process starts in Japan, where a single crystal is grown into a large ingot of silicon by Toshiba Ceramics. The silicon ingot is then sliced by suppliers, like Toshiba Ceramics or others, into thin wafers that are flown across the Pacific to one of Intel's semiconductor fabs in either Arizona or Oregon. At the fabs, hundreds of integrated circuits are etched and layered on each wafer, forming

individual dies on the wafers. Finished wafers are packaged and then flown back across the Pacific to Intel's Assembly and Test Operations in Malaysia. The wafers are treated and cut into die, and the dies are finished into sealed ceramic "packages." The packages are then placed in substrate trays that are put into Intel boxes and then packed again in blank boxes (to conceal that they are Intel products) for shipment back across the Pacific to Intel warehouses in Arizona. Having traveled across the Pacific three times already, the chips are then shipped to Dell factories in Texas, Tennessee, Ireland, Brazil, Malaysia, and China, or one of its contract manufacturers in Taiwan, to be used as components in Dell computers. The journey ends when the product ships from Dell to the customer's home or office anywhere in the world, amounting to a fantastic and complex global voyage.

Neither Intel nor Dell is alone in its reliance on a global supply chain. Most modern manufacturers are part of global, interwoven networks of companies involved in getting goods to markets. Responding to cost and efficiency pressures, such networks have achieved unprecedented levels of efficiency in moving information, products, and cash around the globe. Even smaller, less-known manufacturers are employing global supply chains. For example, Griffin Manufacturing of Bedford, Massachusetts, buys the fabric for its patented sports bras in Taiwan, moves the fabric to its Massachusetts plant, cuts the fabric to the required sizes on modern computer-controlled machines, ships the cut fabric pieces to Honduras for sewing, and then ships the final products to a Vermont distribution center to be tagged and distributed as Champion jogging bras to retailers across the United States.

Although responsible for high levels of customer service and low costs, modern supply chains also bear the seeds of vulnerability to high-impact/low-probability events.

The very complexity of global supply networks means that, in most cases, it is difficult to assess a priori vulnerabilities. For example, Ericsson's vulnerability to the disruption in the Philips plant was not only the result of relying on a single supplier; it was also the result of having another major industry player rely on the same supplier. When Nokia moved fast to secure all of Philips's

capacity as well as the capacity of other global chip suppliers for the needed chips, Ericsson was stuck.

The vulnerability of the connected world to disruption is not limited to supply chain operations; it affects any business that depends on a reliable global communications network. On March 21, 2000, for example, a contractor laying a fiber-optic cable for McLeod Communications in Iowa mistakenly severed a U.S. West Communications cable carrying Internet traffic for Northwest Airlines. Without use of the lines, the airline was grounded—it lost booking and baggage information, along with systems that calculate the amount of weight and fuel-use of each flight and all its web operations.<sup>30</sup> Because Northwest Airlines also handled traffic for its code-sharing partner, KLM Royal Dutch Airlines, KLM flights in Singapore and elsewhere could not take off. Very few employees of KLM imagined that their airline operations were subject to the care with which a ditch-digging contractor in Iowa ran its business.

Another factor that increases the vulnerability of many firms is the tougher competitive environment they are in. As developing nations join the world of global commerce—and given the speed with which knowledge moves around the world—it is difficult to maintain a competitive edge based on technology or know-how. Consequently, many products are sold like commodities; because these products have many similar characteristics, buyers base their purchase mainly on the lowest prices. This leads to continuously lower prices as sellers try to capture market share by reducing their prices below the competition. For example, from 1999 to 2004 the average prices of sporting goods were down 4 percent, appliances were down 8 percent, and apparel was down 13 percent.<sup>31</sup>

Tough competition means not only that consumers have better choices, and that firms must work harder, but also that when an enterprise fails for any reason, others are waiting to take its place. Thus, firms have to be more resilient than their competitors. They have to invest in the ability to recover quickly from any disruption and make sure that their customers are only minimally affected.

In response to the need to provide high levels of service at low costs, many firms have attacked their idle inventory with a

vengeance. Following the lead of Toyota Motor Corporation in the 1980s, they have introduced just-in-time lean operations that have brought both higher quality of goods and much lower costs.

The resulting tight operational environment, however, carries with it a price tag that is not always apparent. For example, Ford Motor Company had to idle several of its assembly lines intermittently following the 9/11 attack as component-laden trucks were delayed at the Canadian and Mexican borders. This led to a 13 percent reduction in Ford's output in the fourth quarter of 2001 compared to its production plan.<sup>32</sup>

At the same time, Toyota came within hours of halting production at its Sequoia SUV plant in Indiana, because a supplier was waiting for steering sensors shipped by air from Germany that were stalled because air traffic was shut down.<sup>33</sup> Ford, Toyota, Chrysler, and other manufacturers were vulnerable to transportation disruptions because they operated tight supply chains with little safety stock, keeping material on hand for only a few days and sometimes only a few hours of operation.

## Why This Book

As supply chains are becoming more brittle and the world is growing uncertain, concerns are increasing about low-probability/high-impact events that can bring about major earning shortfalls or even unplanned exits from the business. This book is based on a research project at the MIT Center for Transportation and Logistics involving dozens of companies. It presents revealing case studies dissecting disruptive events that have affected the operations of the companies involved.

The events of 9/11 have brought home for many U.S. executives the dangers of a terror-based disruption, but accidents and random events such as severe weather or earthquakes can also cause significant disruptions. Intentional attacks are more worrisome, though, since the threat is *adaptive*—that is, increasing defenses or resilience in one part of the system will increase the likelihood of an attack elsewhere. (And intentional attacks are not limited to terrorism; on a different scale, they also include sabotage, computer hacking, and labor actions.)

The number of possible disruptions to a global supply chain is endless. Manufacturing can be disrupted directly because of a problem in a plant, a disruption at a supplier's plant, a glitch in the transportation system, a disruption to the communication and information system, or a snag with a customer. It can also be disrupted indirectly because some other disruption takes capacity out of the supply chain. Several high-technology equipment makers were shut out of chips supply during the time that Philips directed all its manufacturing to Nokia and other suppliers were trying to help Nokia as well.

When thinking about reducing a company's vulnerability to disruption, executives need to look at increasing both security (thus reducing the likelihood of a disruption) and resilience (thus building in capabilities for bouncing back quickly). Increasing security is based on the creation of layered defenses, tracking and responding to "near misses," increasing the participation of all employees in security efforts, and collaborating with government agencies, trading partners, and even competitors.

When thinking about resilience, it may not be productive to think about the underlying reason for the disruption—the kind of random, accidental, or malicious act that may cause a disruption. Instead, the focus should be on the damage to the network and how the network can rebound quickly. When focusing on resilience, then, one can look at existing supply chain designs in industries that are disrupted frequently. Such supply chains exist mostly in the high-technology and fashion industries. These industries are subject to particularly uncertain demand and thus have to develop the capabilities to respond quickly to large changes in the demand pattern. The essence of most disruptions is a reduction in capacity and therefore inability to meet demand. The situation is not dissimilar to large supply/demand imbalances resulting from an unanticipated demand spike.

To respond quickly to supply/demand imbalances companies should build in redundancy without increasing costs; they have to develop supply chains in which products are not customized to the users' requirements until the last possible point, allowing the movement of products from surplus areas to areas where there is

an unmet need; they should develop part and platform commonality and modular product designs, so that the same part can be used in several products; they should increase their use of standard rather than special parts; and they should be tied to their suppliers in flexible contracts allowing for changing quantities and delivery times.

Many of these actions characterize leading supply chains in consumer electronics, computers, or fashion industries. Companies like Dell, the personal computer manufacturer, and Zara, the Spanish retailer and manufacturer of apparel, are faced with demand disruptions continuously. Because these companies and others have developed supply chains that can cope with changes, it is instructive to look at them for relevant lessons.

Robust supply chain designs, however, are not enough. Resilience is also dependent on a set of collaborative relationships with trading partners, since each enterprise is only as resilient as the weakest link in its supply chain. Suppliers whose relationship with a customer is strong, and who identify with that customer, are likely to do more to help in case of a need.

Finally, the right corporate culture—a shared passion to be successful—is a crucial ingredient in creating resilient enterprises. Such different cultures were on display during the 2002 West Coast port lockout; several transportation and logistics companies considered the lockout as a “force majeure” and did not understand that customers like Dell and Procter & Gamble (P&G) did not expect excuses but rather expected their suppliers to find solutions. The result was that Dell, P&G, and others changed several of their transportation and logistics suppliers once they found their suppliers’ attitudes incompatible with their own urgent and passionate mind-set.

Disruptions can take place in numerous ways and affect companies in unanticipated manners, and at any time. To get a handle on the challenge, chapter 2 explores a framework for identifying and prioritizing vulnerabilities. The framework can be applied to determine the relative vulnerability of various firms to a specific type of disruption, or the relative vulnerability of a specific firm to various possible disruptions.

