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ire strikes Toyota's sole supplier of brake pressure valves. An earthquake in Taiwan shuts down chip manufacturers for Dell and Apple. The US Pacific ports are forced to close during the Christmas rush.

What happens when such high impact/low probability (HILP) disruptions strike? How can companies avoid these disruptions? What steps can they take to rebound and even thrive in the face of HILP disruptions? First, it's important to recognize the characteristics that distinguish HILP disruptions from "normal disruptions."

In many cases, HILP disruptions involve public fear (recall 9/11, anthrax, foot and mouth disease, etc.). Fear may lead to hoarding of resources such as fuel during a fuel shortage or antibiotics during an anthrax scare. This fear can also lead to overreaction by governments, further aggravating the disruption because of the need to instill public confidence.

In the fourth quarter of 2001, Ford Motor Company lost 13% of its planned output—not because of the 9/11 attacks, but as a result of the border closing that followed. Similarly, when the United Kingdom closed its countryside to fight foot and mouth disease (FMD) in 2001, it suffered more damage from reduced tourism than from the actual agricultural impact of FMD. Companies should expect these phenomena to be part of any HILP disruption. Furthermore, in this modern, connected world, they should expect that many disruptions simply cannot be foreseen.

The range of potential disruptions to the operations of retailers, manufacturers, transportation carriers, and all others involved in the supply chains of goods and services is infinite. They can be classified as follows:

- random phenomena, such as hurricanes, floods, and earthquakes
- accidents of all kinds, like Exxon Valdes, Chernobyl, and Bhopal
- intentional disruptions, which include not only terrorist attacks, but, on a different scale, sabotage and industrial actions

Each type of disruption should be anticipated and defended against differently. Statistics regarding natural phenomena are available and can be used in deciding

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on facility location and redundancy measures (insurance rates, which are based on these statistics, can be used as a proxy for the risks).

After years of safety research to identify causes and effects, leading companies have dramatically reduced the number of accidents by instituting safety and care processes. Intentional disruptions, however, are adaptive—the threat can change in response to defensive measures. Thus, the probability of a disruption is a function of the security and resilience measures taken.

To reduce the likelihood of successful intentional disruptions, firms have implemented security measures—investing in methods that reduce the vulnerability of an enterprise. Of course, a company is a citizen of its own supply chain, and thus, it is the chain's vulnerability that should be addressed.

While security principles have been practiced for many years in the national defense and intelligence communities, their application to supply chain requires certain adaptation. Principles such as layered and balanced methods should be combined with various collaborative efforts, including public-private partnerships, industry consortia, and employee-based community watch programs, to result in a security culture.

Resilience, a notion borrowed from the materials sciences, represents the ability of a material to recover its original shape following a deformation. For companies, it measures their ability to, and speed at which they can return to their normal performance level (production, services, fill rate, etc.) following an HILP disruption.

Resilience can be achieved either through redundancy or through building in flexibility. The standard use of redundancy includes safety stock of material and

finished goods. Such inventory can give a company time to plan its recovery following a disruption.

Indeed, many companies have increased inventories when preparing for a disruption, such as the extra parts accumulated by New United Motor Manufacturing, Inc. (NUMMI) as the West Coast labor relations deteriorated in the spring and summer of 2002, leading to the East Coast ports lockout.

Extra inventory, however, is expensive to hold. Furthermore, as demonstrated by "lean," "six sigma" processes, it can also lead to sloppy operations resulting in increased costs and reduced quality. By contrast, increasing supply chain flexibility can help a company not only withstand HILP disruptions, but also better respond to the day-to-day vagaries of the marketplace.

To build in flexibility for resilience, companies must involve many facets of supply chain design by:

- developing the ability to move production among plants, use interchangeable and generic parts in many products, and cross train employees
- using concurrent processes of product development, ramp up, and production/distribution
- designing products and processes for maximum postponement of as many operations and decisions as possible in the supply chain
- aligning their procurement strategy with their supplier relationships

These principles create not only resilient supply chains that can recover from disruptions, but also flexible ones that can respond to day-to-day demand changes. One begets the other, because a supply shortage and a demand spike are, at their core, a problem of supply/demand mismatch. Companies that have built

their supply chains to respond to significant demand fluctuations have also built in the ability to respond to supply shortages.

How exactly do these supply chain principles increase resilience? Postponement and built-to-order operations allow for diversions of parts and semi-finished material from surplus areas and products to satisfy shortages. Thus, with only a few days of committed orders, Dell was able to fare much better than Apple during the 1999 Taiwan earthquake, which disrupted the worldwide supply of memory chips.

The use of a small number of commodity parts not only simplifies operations and concentrates the procurement outlays, it also creates flexibility to move the business among suppliers should one falter. When Intel's Systems Group reduced its mix of 2,000 different types of resistors, capacitors, and diodes to only 35 types, it not only simplified procurement and reduced costs, but also increased Intel's ability to respond to demand changes and supply disruptions.

Reducing time to market also means that the time to recover from disruptions is likely to be short. To this end, Lucent created a special Supply Chain Network organization in 2001. Cutting across the company's engineering, procurement, manufacturing, distribution, and even sales divisions, the network increased the company's agility.

The use of multiple suppliers with different characteristics allows HP to not only have redundancy, but also built-in flexibility. HP's choice of supply plants for its printers division means that during ramp up and end of life, it can use its agile (yet more expensive) plant, but during the steady demand period of each printer, HP can use the more efficient one.

Finally, collaborative relationships with trading partners can help companies go to the market faster. Such relationships also allowed Toyota to recover very quickly, with the help of dozens of suppliers, from a fire that gutted the sole plant of its main P-valves supplier in February 1997.

However, the most important factor that clearly distinguishes between companies that bounce back from a disruption and those that don't is the corporate culture. Organizations like Nokia, Toyota, UPS, Schneider National, FedEx, Dell, and the US Navy can be studied to understand the principles that make them flexible and resilient. While on the surface, companies like Dell and the US Navy may not seem to have much in common, but a closer look reveals that these resilient companies share several common traits, especially within their corporate culture.

Unfortunately, culture is difficult to define and even more difficult to change, but it's not an impossible task. The success of the quality movement in the 1980s and the safety campaign in the early part of the last century serve as strong examples of how corporate culture can change dramatically.

Several corporate turn-around cases, like that of Continental Airlines under Gordon Bethune, also show the importance and the plausibility of changing corporate culture. Even the culture of large populations can change as demonstrated by the anti-smoking and anti-drinking and driving campaigns in the US.

These successful cases should serve as blueprints for other companies striving towards resiliency, because the right culture means that the entire organization is deputized to serve as the eyes and ears of the corporate security efforts, and can take the necessary actions to recover from any disruptions when the normal hierarchy is not operational. ■

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