

Improving Supply Chain Resilience to Manage Climate Change Risks

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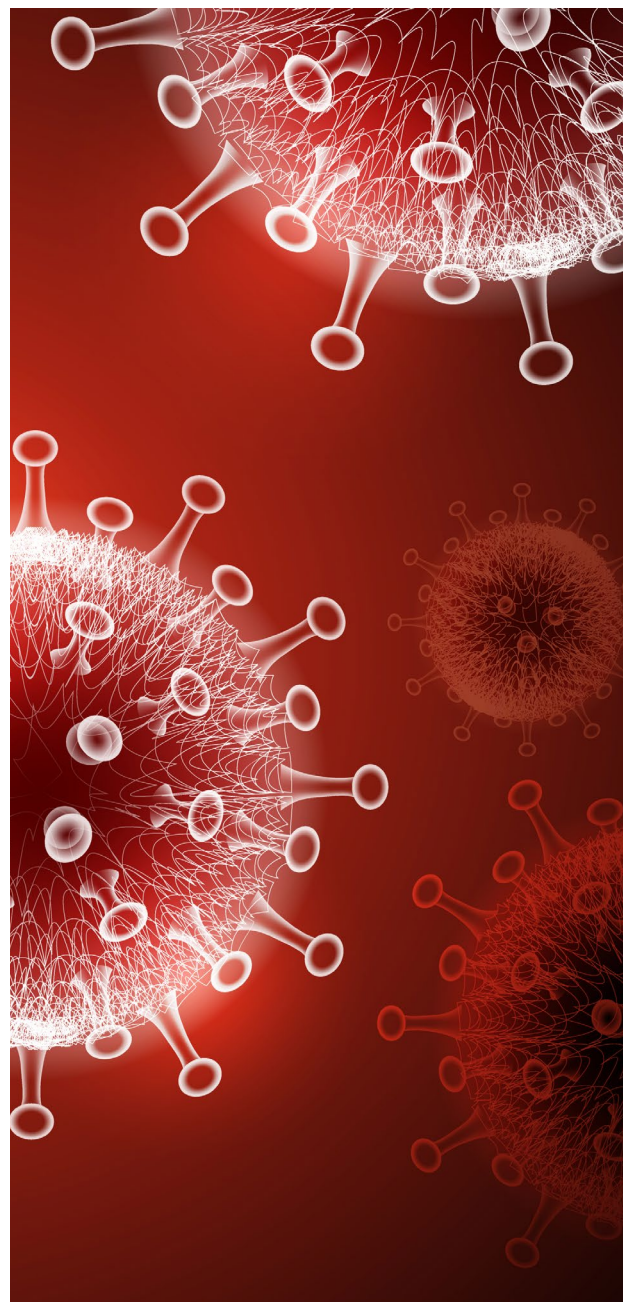
A note during the recent COVID-19 pandemic

When HSBC Bank and The Sustainability Consortium started discussions around this report in mid-2019, no one could have imagined that Improving Supply Chain Resilience to Manage Climate Change Risks would be published amidst the Covid-19 Pandemic and an accompanying global supply chain disaster. Supply chain disruptions have occurred everywhere and impacted every sector, and much can be learned during the pandemic about the supply chain resilience that we need in the light of climate change risks.

Just like the impacts experienced during Covid-19, climate change physical risks can be highly local and can create a lack of available supply, lower the quality of supply, increase the cost of supply or delay the delivery of supply, putting the company's own continuity of operations at risk. Both Covid-19 and climate change can have widespread, long-term, and unprecedented effects on natural, economic, physical and social systems. Almost no company has planned for the extent to which COVID-19 has caused such extensive disruptions to daily life around the world, but companies that were thinking more strategically, in the resilient, long-term framework will be the companies that survive.

There's some evidence that companies with long-term, sustainability focused strategies are weathering the consequences of the disruptions better than those who have not. For example, the Good Governance US equity long/short index outperformed the S&P 500 by 0.66% in April 2020¹. Moving forward, investors will be studying corporate responses to these shocks to better de-risk investments and move away from companies with poor resilience planning.

¹ Tavares, R. (2020), Sustainable finance is performing well in the pandemic—but why?, <https://qz.com/work/1856470/why-sustainable-finance-performs-well-in-the-pandemic/>



Improving Supply Chain Resilience to Manage Climate Change Risks

Executive summary

Supply chain executives and managers contend with supply disruption risks as part of their role. A company's supply chain needs to deliver in a consistent and reliable way in order to meet the demands of the company's customers and manage supply chain costs. Climate change and its consequences, however, are likely to make managing supply disruptions more challenging. Existing acute risks that cause supply disruption, like extreme weather events, will become more severe, frequent, and widespread. Chronic risks like sea-level rise will create new challenges, including risks due to transitions to new supply chain configurations.

In order to better prepare for the future, companies can consider formally incorporating climate change risks as part of the supply chain risk management strategy. A company has two strategies to enhance supply chain resilience: bridging and buffering. Bridging strategies enhance the capability of a supplier to withstand risk events and recover more quickly from a disruption. Bridging strategies include engaging in collaborative planning and control with suppliers, providing suppliers financial support and developing strong supplier relationships.

Buffering strategies protect the company from inevitable supplier failures and supply disruptions. Companies can use inventory buffers, lead time buffers, capacity buffers, liability buffers, and cost buffers to make their supply chain more resilient. A supply chain organization can also intentionally work to develop the culture, processes and discipline of a high reliability organization to provide the foundation for a resilient supply chain.

Attention to climate change risks will not only make the company's supply chain more resilient but may make the company more attractive to its employees, customers and investors. The purpose of this report is to help companies understand why climate change risks should be addressed within a supply chain risk management program and discuss the options that companies have to create greater supply chain resilience.



Introduction: Climate change and supply chain risk

A company's supply chain consists of the suppliers that provide materials, goods and services necessary for the operations of the company. It includes the company's immediate supply base (i.e. those suppliers that the company has direct transactions with) as well as the suppliers of those immediate suppliers, and so on. For example, the supply chain of a canned beverage company includes the metal can manufacturer as well as the metal mining company and all the companies in between them. Companies with superior supply chain management practices experience better operational and financial outcomes.¹

Operating a reliable supply chain requires a company's supply chain organization to manage the risks associated with acute (i.e. one-time) or chronic (i.e. on-going) supply chain disruptions. These risks can create a lack of available supply, lower the quality of supply, increase the cost of supply or delay the delivery of supply, putting the company's own continuity of operations at risk.

The UN Office for Disaster Risk Reduction defines resilience as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management."² Thus, a supply chain is considered resilient to the degree that it provides the buying company operational continuity in lieu of disruption risks.

It is likely that managing supply chain risk will be more challenging in the future because of global

warming and climate change. A company that does not adapt its supply chain risk management strategy to account for climate change may be putting a significant portion of its corporate value at risk.

What is different about supply chain risk due to climate change? After all, companies already have to manage supply disruptions due to events linked to climate change such as extreme weather events, resource depletion, or socio-economic disruption.

First, climate change will increase the frequency, magnitude, and scope of acute supply chain disruptions. This will require companies to invest more time and money in their supply chain risk management programs. Second, it will create chronic changes to supply chains that companies will need to adapt to. Third, it will create new types of risks that have not typically been addressed by supply chain risk management programs. For this reason, it may be beneficial for a company to assess its current state of supply chain resiliency and to consider how to modify or enhance it, relative to climate change risks.

In the next section, we'll discuss what we know in general about the business impact of supply chain disruptions and how supply chain disruptions due to climate change may be different than disruptions that we have historically encountered. We will propose how a company can improve its supply chain resiliency related to climate change via bridging strategies, buffering strategies and creation of a high reliability supply chain management organization. Throughout the report we'll share corporate examples.

The purpose of this report is to help companies understand why climate change risks should be addressed within a supply chain risk management program and discuss the options that companies have to create greater supply chain resilience.

¹ Min, S., and Yu, W. (2013). Supply chain management and financial performance: Literature review and future directions, *Int. J. of Operations & Production Management*, 33(10): 1283-1317.

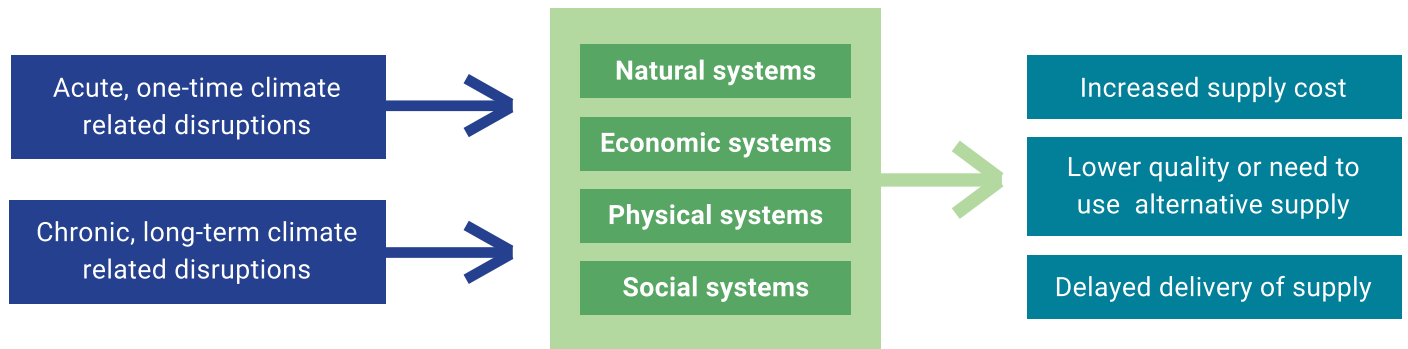
² United Nations (2016). Report of the open-ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction. A/71/644. Downloaded from https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf.

The impact of supply chain risks and disruptions

Sources of supply disruption that are typically cited in the literature include disruptions to:

- Natural systems (including agriculture), due to extreme weather events, climate change, resource depletion or ecosystem collapse.
- Economic systems, due to financial losses, depressed growth or structural changes.
- Physical systems, due to damage, degradation or failure of physical capital, including infrastructure.
- Social systems, due to labor issues, social change, mass migration or political unrest.

Any good or service that is provided by a supplier has cost, quality, quantity and delivery requirements. A supply chain disruption puts these requirements at risk. The typical effects of a supply chain disruption are shown in the table below, with some examples related broadly to climate change impacts.



Impact to supply	Description and examples
Increased cost	<p>Supply chain disruptions almost always incur increased cost which can impact the buyer, supplier or entire supply chain. For example, in 2018 it was reported that manufacturing companies in Germany were experiencing increased inbound shipping costs due to the Rhine River being at low levels. This led transportation barges to be loaded at a lower capacity, increasing the number of barge trips needed to deliver the same amount of goods.³</p> <p>In 2018, retailers and restaurants purchasing South African wine experienced a lack of supply and a 10% price increase due to water shortages from drought, impacting the vineyards around Cape Town, South Africa.⁴</p> <p>As pollinators, bumble bees are critical to the growth of crops like tomatoes, squash and berries. Heat waves have put bumble bee populations at risk, leading to lower yield and increased costs for those food manufacturers or retailers who depend on such crops.⁵</p>

3 Resilience360 Annual Report, accessed at <https://www.resilience360.dhl.com/resilienceinsights/resilience360-annual-risk-report-2018/>.

4 Roelf, W. (2018). Historic drought takes toll on South Africa's vineyards, Reuters, May 8, 2018.

5 Briddle, J., and van Resnburg, A. (2020). Discovering the limits of ecological resilience, Science, 367(6478): 626-627.

Lower quality or alternative supply

Lack of supply availability at the desired level of quality may necessitate the buying company to use a lower quality or alternate supply. For example, in 2018 when the U.S. created quotas on the amount of steel⁶ that manufacturers could import from different countries, it caused those manufacturers to increase their sources for importing steel. Managing inputs from multiple suppliers typically increases quality control and inventory management costs. Increased tariffs and quotas are an expected outcome of climate change consequences.⁷

Food manufacturers, distributors, and retailers who purchase agricultural exports like sugar cane and pineapples from Hawaii depend in part on the ability of Hawaii to generate its own food sources, since it is far-removed from other food channels. A vast majority of the fish caught in the waters surrounding Hawaii are used locally as food for the population. Declines, however, in coral reef and ecosystem quality due to chronic climate changes threaten this food security⁸ and imperil local supplier production capacity. This may lead food manufacturers and others to seek other sources.

Delayed supply

A disruption can cause a time delay in the delivery of some or all of purchased supplies, which in turn delay the buying company from delivering goods or services to its own customers. For example, during the coronavirus pandemic of 2020, many companies experienced delays in deliveries within their global supply chains, leading to decreased revenues from final product sales.⁹ Microsoft cut sales projections for laptops and tablets because of delayed deliveries of critical supplies it needed to assemble these products. Climate change and global warming are predicted to increase the spread of infectious diseases.¹⁰

Automaker Subaru had to shut down two of its car factories for a period of time in 2019 due to Typhoon Hagibis and the subsequent flooding of its part suppliers' factories.¹¹

Clothing brands who use suppliers in East Asia experience delays in supply during monsoon season, as garment workers utilize sick leave 10% more per month because the flooding keeps them from being able to physically get to the factory.¹²

When supply is delayed because a supplier has gone out of business, the impact of this risk is greatly increased.

6 Nadar, J. (2018). U.S. steel tariffs, quotas disrupt, jumble market. Breakbulk and Heavylift, accessed at joc.com.

7 Gros, D. and Egenhofer, C. (2011). The case for taxing carbon at the border. *Climate Policy*, 11(5): 1262-1268.

8 Kittinger, J., et al. (2015). From reef to table: Social and ecological factors affecting coral reef fisheries, artisanal seafood supply chains, and seafood security. *PLOS ONE*, accessed at <https://doi.org/10.1371/journal.pone.0123856>.

9 Eavis, P. (2020). How bad could it get? Companies gauge the coronavirus impact. *New York Times*, Feb. 28, 2020.

10 Watts, N. et al. (2018). The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come," *Lancet*, 392: 2479-2514.

11 Miyajima, S., and Asayama, R. (2019). Deadly storm flooded Japanese automaker's suppliers. *Nikkei Asian Review*, October 17, 2019.

12 Sebastio, F. (2018). Climate change is threatening the garment industry, *GreenBiz*, March 27, 2018.

Empirical research suggests that supply chain disruptions can lead to significant financial losses. For example, the report “An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm”, which studied more than 800 supply chain disruptions, suggested an average 40% decrease in company stock value after a significant supply chain disruption as well as a 13% increase in equity risk.¹³ A follow-up study explained that companies which had more flexibility in their supply chain, and were more vertically integrated, suffered less loss of market value following the disruption.¹⁴ A similar study in the International Journal of Productivity and Performance Management suggested that supply chain disruptions to the automotive industry in Japan decreased the market value of auto manufacturers by 0.6 percent in an 11-day window, and that the disruptions impacted both the company and its competitors’ stock values.¹⁵

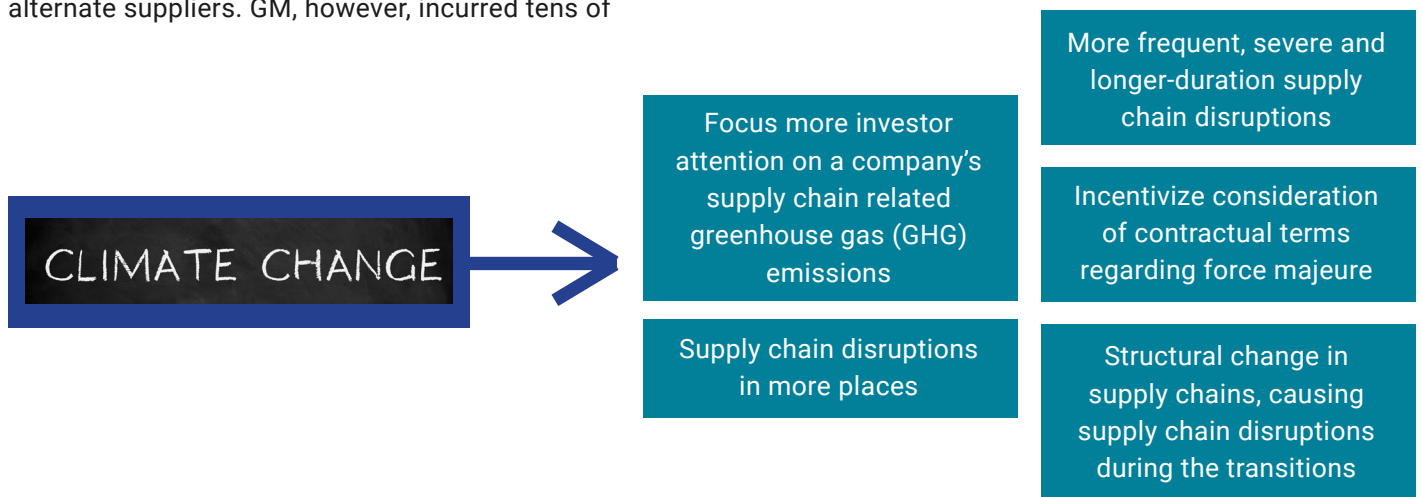
In addition to their impact on corporate financial valuation, supply chain disruptions can cause significant additional costs to the buying organization. For example, when Clark-Cutler-McDermott Co. went bankrupt in 2016, they were automaker General Motor’s sole supplier of certain acoustic damping materials.¹⁶ GM had contractually arranged to take over Clark-Cutler-McDermott Co.’s tooling and equipment in lieu of such an event, and it was able to recover production in a week and subsequently find alternate suppliers. GM, however, incurred tens of

millions of dollars in supplier switching costs in order to remain operational.¹⁷

How are climate change risks different?

In some ways, climate change poses many of the same type of risks to supply chains as have existed in the past. Companies have had to manage supply chains that have been disrupted due to extreme weather events, resource depletion, political unrest, or population migration. So how will climate change create different supply chain risks to companies?

- Create more frequent, severe and longer-duration supply chain disruptions.
- Create supply chain disruptions in more places.
- Force structural changes in supply chains, causing supply chain disruptions during the transitions.
- Incentivize buyers and suppliers to more seriously consider contractual terms regarding force majeure.
- Focus more investor attention on a company’s supply chain related greenhouse gas (GHG) emissions. Future regulation could make a carbon tax or equivalent commonplace, which could be a significant supply chain cost risk for buying companies that have not decarbonized their supply chains.¹⁸



13 Liu, J., Sarkar, S., Kumar, S., & Jin, Z. (2018), “An analysis of stock market impact from supply chain disruptions in Japan,” International Journal of Productivity and Performance Management, 67(1): 192-206.

14 Kelly-Falls, R. (2016), ‘The ripple effect of supplier bankruptcy: Broad and deep,’ Spend Matters, July 20, 2016, <http://spendmatters.com/2016/07/20/the-ripple-effect-of-supplier-bankruptcy-broad-and-deep/>.

15 Liu, J., Sarkar, S., Kumar, S., & Jin, Z. (2018), An analysis of stock market impact from supply chain disruptions in Japan, International Journal of Productivity and Performance Management, 67(1): 192-206.

16 Walsworth, J. (2016). GM scrambles after supplier bankruptcy. Automotive News, July 18, 2016.

17 Liu, J., Sarkar, S., Kumar, S., & Jin, Z. (2018), “An analysis of stock market impact from supply chain disruptions in Japan,” International Journal of Productivity and Performance Management, 67(1): 192-206.

18 LaPlante, A., and Watson, C. (2017). Managing Carbon Risk: A Look at Environmentally Conscious Indices. Accessed at: <https://globalriskinstitute.org/>

According to a recent study in the International Journal of Production Research, the food, mining and logistics sectors are those likely to be most impacted by climate change.¹⁹ The Task Force on Climate Related Financial Disclosures (TCFD) comes to a similar conclusion, highlighting energy, transportation, materials and buildings, and agriculture, food, and forest product sectors being at greatest risk.²⁰ The impacts to these sectors will cascade to almost every sector of the economy.

Climate change will increase frequency, severity, and duration of supply chain disruptions

The 2018 Intergovernmental Panel on Climate Change (IPCC) report²¹ states that global temperatures are around 1.0 degree C higher since the beginning of the industrial revolution, largely due to human-caused GHG emissions. Without significant changes in the economy, this temperature increase may go to 2.0 degrees C or beyond if emissions continue at current rates.

According to the IPCC, warmer temperatures will increase the impact of climate-related physical events including extreme weather events such as storms, floods, heatwaves and droughts as well as slow on-set events like sea-level rise, water scarcity, loss of agricultural productivity and changes in production regions and land degradation. These climate-related physical events can disrupt business operations by interrupting production, impairing or destroying

production assets and decreasing labor productivity, among other effects.²² As these events threaten a buying company's suppliers, its supply chain continuity is at risk.

Supply chain disruptions will occur in more places

Suppliers who are already located in high-risk regions where extreme or prolonged weather events occur or where local ecosystems are threatened will experience more risk: high risk will grow to higher risk. But suppliers who are located in historically low-risk regions for weather-related events may see their risk level change from insignificant to significant. For example, the U.S. National Oceanic and Atmospheric Administration reported that San Diego, California and Norfolk, Virginia both experienced almost no high tide floods from 1950 to 1980. Since 1980, there has been a linear increase in high tide floods, reaching 13 and 14 floods in the two cities, respectively, in 2017.²³ If a company has suppliers in these regions, these would be emergent risks that the company should become aware of. Thus, the geographic scope that supply chain risk managers will need to consider will be larger than it is now due to climate change risks.

One also needs to consider how disruptions to a supplier's downstream markets (i.e. its customer's customers) might impact their ability to supply an organization. For example, when coronavirus spread in 2020, logistics companies had to decrease shipping capacity due to the drop in demand for transportation services, due to less consumer demand. The impacts of this unanticipated human health issue caused more uncertainty to other downstream companies purchasing these services.

19 Ghadge, A., Wurtmann, H. and Seuring, S. (2019). Managing climate change risks in global supply chains: A review and research agenda. To be published in International Journal of Production Research, available at SSRN: <https://ssrn.com/abstract=3399073>.

20 TCFD (2017), Recommendations of the Task Force on Climate related Financial Disclosures. Downloaded from <https://www.fsb-tcf.org/publications/final-recommendations-report/>.

21 IPCC (2018). Global Warming of 1.5 °C, downloaded from <https://www.ipcc.ch/sr15/>.

22 Watts, N. et al. (2018). The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come," Lancet, 392: 2479-2514.

23 Sweet, W.V., Marcy, D., Dusek, G., Marra, J., and Pendleton, M. (2018)/. 2017 State of U.S. High Tide Flooding with a 2018 Outlook. Supplement to State of the Climate: National Overview for May 2018, accessed from https://www.ncdc.noaa.gov/monitoring-content/sotc/national/2018/may/2017_State_of_US_High_Tide_Flooding.pdf

Structural changes will cause supply chain disruptions

Climate change will force structural changes in supply chains, causing supply chain disruptions during the periods of transition. This is most likely to impact producers, manufacturers, distributors, and retailers who depend on agricultural, fishery or forestry-based products. Climate change will cause long-term changes in temperature and precipitation, leading optimal growing regions to shift from one locale to another. When these growing regions shift, there will be a transition from one locale to another, and potentially from one supplier to another, and these transitions are likely to cause supply disruptions. For example, climate change scenarios predict that suitable land and high yield potentials for staples like corn, rice, potatoes and wheat will shift northward in Canada, U.S., Europe and Asia. While these more northern regions may experience new economic opportunities, downstream customers are likely to experience more uncertainty during the transition period, potentially yielding high prices or price volatility in supplies. Shifting production regions is certain to drive land use changes that may ultimately release more carbon, exacerbating climate change effects.

Contractual terms regarding force majeure will matter more

It is standard for contracts between buying companies and suppliers to have terms related to force majeure, i.e. who bears risk, if any, when an extraordinary circumstance beyond the control of either party occurs. In an example provided by the World Bank,²⁴ a sample contractual clause might be “Neither the Authority nor the Operator shall be considered in breach of this Contract to the extent

²⁴ Accessed at <https://ppp.worldbank.org/public-private-partnership/ppp-overview/practical-tools/checklists-and-risk-matrices/force-majeure-checklist/sample-clauses>

that performance of their respective obligations (excluding payment obligations) is prevented by an Event of Force Majeure that arises after the Effective Date.”

If climate change causes an increase in events including disease outbreaks that might be considered force majeure, then buying companies may wish to consider contractual terms and conditions to better protect (or at least make more explicit) their exposure. A recent article in the *Journal of the American College of Construction Lawyers* states that buying organizations and suppliers both have a vested interest in specifying the details under which “extreme” weather events fall under the conditions of force majeure, and when they do not, in order to reduce uncertainties about liabilities.²⁵ Their conclusion is based on the likelihood that as climate change increases, courts will struggle to create consistent legal interpretations of liability, thus increasing legal uncertainty.

Investors will pay more attention to supply chain GHG emissions

Companies and investors are increasingly using various types of environmental, social, and governance (ESG) assessments to determine investment risk related to climate change and other sustainability issues. More than 85% of S&P 500 companies report ESG data, and signatories to the Principles for Responsible Investment, which incorporates ESG data, comprised more than \$81 trillion in assets.²⁶ The Task Force on Climate-Related Financial Disclosures (TCFD), an organization with more than 30 members selected by the Financial Stability Board, has recommended that all companies report climate-related risks,

²⁵ Knoll, J., and Bjorklund, S. (2014). Force majeure and climate change: What is the new normal? *The American College of Construction Lawyers Journal*, February 2014, 8(1): 1-34.

²⁶ Bizoumi, T., Lazaridis, S., and Stamou, N. (2019), “Innovation in stock exchanges: Driving ESG disclosure and performance, *Journal of Applied Corporate Finance*, Vol.31(2): 72-79.

including governance approach, climate resilience strategy, risk management, and resilience metrics and targets.²⁷ More than 500 companies have signed up to support and disclose according to the TCFD guidelines.

In addition to concern over a company's own GHG emissions, investors are increasingly focusing on a company's supply chain related GHG emissions. In 2018, of the 3,783 companies reporting to CDP more than 70% performed a climate risk assessment.²⁸ Amongst the largest companies, 95% performed a climate risk assessment. The majority of companies who performed a climate risk assessment, and the vast majority of larger companies, did so as part of an integrated supply chain risk management system. Supply chain (i.e. upstream and downstream) risks were considered by about half of the companies performing climate risk assessments. About one-third of the companies performing climate risk assessments only considered risks that were likely to occur within the next six years, while two-thirds also considered impacts that might occur six or more years into the future.

Part of the increase in measuring and reporting supply chain GHG emissions is due to investor concern over future regulation regarding supply chain GHG emissions. If a carbon tax or equivalent became more commonplace, it could significantly impact a buying company's cost of supply and transportation.

Consider two manufacturers, one who has decarbonized its supply chain and another who has not. If a globally scoped carbon tax or cap was enacted, the former would have significantly lower cost of supply than the latter. Given that actions to lower carbon emissions may take many years, first movers on supply chain decarbonization may have competitive supply chain cost advantage. These

impacts would be especially sensitive for supply chains with significant amounts of transportation, as prices from logistics providers that are not low carbon will increase due to their dependence on fossil fuel, which would incur a high tax.

27 TCFD (2017), Recommendations of the Task Force on Climate related Financial Disclosures. Downloaded from <https://www.fsb-tcf.org/publications/final-recommendations-report/>.

28 CDP (2018), Global Climate Change Analysis 2018, <https://www.cdp.net/en/research/global-reports/global-climate-change-report-2018#78ec87e68f-712039dafd856f3bda4a04>.



How to improve supply chain resiliency

There are two main strategies used to manage supply chain risk and disruption and build resiliency: bridging and buffering. Bridging involves the buying organization taking action to help build up the capacity of its suppliers to manage through and recover from disruptions. Buffering involves the buying organization taking action to protect itself from the consequences of supplier failures. In addition to discussing these two strategies, the section will conclude by discussing how to build a high reliability culture that supports and promotes resilience within a supply chain management organization.

The buying company should focus its bridging or buffering actions on supply chains and suppliers that are most critical, from a cost, time, or functionality standpoint. For example, if the company only has a single supplier for a particular item which is critical for the product or service that the company is creating, then disruptions to that supplier would create a disruption to the primary production or service activity. A bridging action might involve helping a supplier get low-interest financing so that it can invest in capital improvements to make its facilities more robust to extreme weather events. A buffering action might involve finding a secondary supplier or keeping safety stock of the supplier's item.

Notice that a company may choose to implement both bridging and buffering strategies. One can think of bridging as the first line of defense, in that it minimizes the chance that a risk event will cause a disruption. Buffering is the second line of defense, in that if a disruption does occur, its impact is minimized.

There are three bridging strategies:



Collaborative planning and control



Financial support



Strengthen relationship with supplier

Five buffering strategies:



Inventory buffer



Capacity buffer



Liability buffer



Lead time buffer



Cost buffer

Bridging strategies

Bridging strategies create a more resilient supply chain by helping a company's suppliers become more capable of continuing operations should a risk event occur and recovering quickly and successfully should there be a supply disruption. There are three common bridging approaches: coordination on risk awareness and planning, providing financing or expertise and strengthening the buyer-supplier relationship.

First, the buying company can engage its critical suppliers in collaborative risk management and inventory planning. This can include developing a joint contingency plan should a disruption occur (i.e. continuity of operations plans). If a small or medium sized supplier lacks resources to become knowledgeable about the climate change risks that they face, then the buying company can share their related knowledge and expertise.

Second, a company can provide financing to help its suppliers either become more resilient or recover from a supply disruption. A company should assess the financial health of their suppliers, as climate change risks can put them into threat of bankruptcy or going out of business. In fact, many large companies subscribe to services that continuously monitor the financial health of their suppliers. A company or a partnering financial institution can provide direct investment in a supplier's operational resiliency through loans, gifts, long-term contracts, price premiums or co-ownership.

Third, a company can strengthen their relationship with a critical supplier. Joint ventures or long-term contracts can increase transparency and trust. This not only improves the outcomes of any collaborative planning but may also yield preferential treatment to the company should the supplier experience a disruption. It is often the case that either supply is only partially disrupted or that during recovery, supply can only be delivered to some customers. Those customers with legal or relational ties to the supplier are more likely to receive the limited supply.

The table on the next page summarizes bridging strategies for supply chain resilience and provides examples. While not all of these are related to weather events, they are illustrative of the resiliency strategy and its effect.

Buffering strategies

Buffering strategies involve the buying organization taking action to protect itself from the consequences of a supplier failure. Climate change related risks make it more likely that companies will need to use buffering strategies, because supply disruptions will occur no matter how resilient a supplier is, and the buying company is obligated to protect itself from such failures. There are five types of buffers that can improve a company's supply chain resiliency to climate change risks: inventory, lead time, capacity, liability and cost.

First, a company can order and carry sufficient inventory of supplies so that it could withstand a supply disruption for a certain amount of time. Up until recently, companies have moved in the opposite direction, reducing inventory in order to increase flow and reduce cost. Corporate experience with implementing inventory reduction however shows that without inventory, a company's production system can become fragile to disruption. It is perhaps because of this that companies have swung in the other direction to "right-size" their inventory. In the U.S., the ratio of inventory to sales decreased from about 1.5 in the 1990s to 1.2 in the 2000s, after the introduction of lean practices. It has since increased back up again to 1.4.³⁴

**Bridging strategies
for resilience**

Description and examples

Increased cost

When Hurricane Katrina hit the U.S. in 2005, the electronics manufacturer Cisco was unprepared to manage the impact to its supply chain. When the Japan tsunami occurred in 2011 with similar impacts on its supply chain, Cisco was prepared and suffered almost no financial losses. It had created protocols and processes to work with suppliers to ensure business continuity from a significant disruption, and within one day had a risk assessment of more than 7,000 supplied items and began to talk with downstream customers to temper expectations.²⁹

Financial support

Mars and Coca-Cola have recently joined forces with BSR to provide funding to help enhance resilience and living conditions in vulnerable regions of their supply chain.³⁰

Unilever partnered with WWF and others to increase the number of farmers and hectares of land providing certified palm oil in Malaysia by 60,000 hectares in some of the country's most important regions for wildlife.³¹

HSBC Bank has partnered with Walmart to provide supply chain financing with preferential pricing to Walmart suppliers that are actively engaged in assessing and improving their sustainability performance through The Sustainability Consortium's THESIS index.³² Such financing puts the supplier in a much healthier cash flow position, enhancing their ability to absorb a disruption in operations.

**Strengthen
relationship with
supplier**

While not weather related, the following case exemplifies the resiliency benefits of having stronger supplier relationships. A fire in 2000 closed a critical component supplier of cell phone manufacturer Nokia and its competitor Ericsson. Nokia sent engineers to the supplier's facilities, offered the help that it could and began to tap into social capital they had with other suppliers, requesting to see if they could shift some production to make the unavailable component. Ericsson made no similar efforts and instead depended on its contractual relationship to handle what was needed. Ericsson was less time-sensitive to the disruption and allowed Nokia to get preference for the delivery as the supplier recovered.³³

29 Sáenz, M., and Revilla, E. (2014), "Creating more resilient supply chains," MIT Sloan Management Review, June 17, 2014.

30 BSR (2019), "Major companies join forces to drive climate resilience in supply chains," <https://www.bsr.org/en/our-insights/news/major-companies-join-forces-to-drive-climate-resilience-in-supply-chains>.

31 As accessed at <https://www.worldwildlife.org/blogs/sustainability-works/posts/walmart-and-unilever-push-for-innovative-place-based-partnerships-to-tackle-deforestation>

32 From: <https://www.business.hsbc.com/sustainability/hsbc-and-walmart-partner-to-drive-sustainability-of-businesses>.

33 Paul, S., Sarker, R., and Essam, D. (2018), "A reactive mitigation approach for managing supply disruption in a three-tier supply chain," Journal of Intelligent Manufacturing, 29(7):1581–1597.

Inventory buffers may exist in the form of final products, supplies, equipment or infrastructure. As the cost of inventory can be significant, the safety benefits of the excess inventory have to be balanced with carrying costs. Buffers should be prioritized to the most critical or unique supplies. For example, during the California fires of 2019, many food-based businesses lost perishable inventory because they lacked refrigeration, and suppliers of power generators were low in stock. Those businesses that had back-up power generators before the fire started were able to mitigate that risk.³⁵

Second, a company can create a time buffer that enables it to become aware of supply chain risks and disruptions more quickly, which may lower the impact of the disruption and enable recovery actions to start sooner. A time buffer is primarily created through creating systems that improve the company's situational awareness of chronic and acute risks the supplier may face due to climate change.

While climate change is global, climate change physical risks can be highly local. Companies should have visibility of the suppliers and regions that constitute their supply chain. Some questions that a company can address when mapping its supply chain include: What are our critical supplies and where are they sourced from? What logistics does it depend on to move goods to us?

While most companies know who their immediate (i.e. first tier) suppliers are, awareness of the supply chain beyond this first tier is typically much more limited. For every manufacturer that has very good or excellent visibility into their supply chain and its operations, there are two manufacturers that have little or no visibility, according to The Sustainability Consortium's THESIS Index.³⁶

Once a buying company understands where its suppliers are located, then it can cross reference the climate change risks that pertain to that region.³⁷ For chronic risks, it can use geo-spatial risk maps that indicate future risks associated with temperature rise, sea rise, droughts and water shortages, floods, or deforestation or biodiversity risks. This provides the company a time buffer to start projects that increase resilience relative to those long-term changes. Companies can also monitor weather conditions in the supplier's region to become aware of imminent threats, rather than depending on the supplier to do so. This also gives more of a time buffer to prepare or react to disruption.

Companies should create time buffers with their downstream customers as well. A delay from a supplier may lead to a delay to the company's customer. A customer reaction to a delayed delivery can be mitigated when the supplier communicates the delay as soon as possible to the customer.³⁸ Within the company, this suggests that coordination between the supply chain organization and the marketing and sales organization is needed to create value chain level resiliency (i.e. resiliency both upstream and downstream from the company).

34 As accessed at <https://www.census.gov/mtis/index.html>

35 Eschner, K. (2019), "California power outages hit small businesses—but bolster generator companies," *Fortune*, November 8, 2019. Downloaded from <https://fortune.com/2019/11/08/california-power-outages-small-business-generators/>.

36 The Sustainability Consortium (2018), *Transparent Supply Chains for Better Business*, <https://www.sustainabilityconsortium.org/impact/impact-report/>.

37 Curtis, P., Slay, C., Harris, N., Tyukavina, A., Hansen, M. (2018). Classifying drivers of global forest loss. *Science*, 361(6407):1108-1111.

38 Primo, M., Dooley, K., and Rungtusanatham, M. (2007). "Manufacturing firm reaction to supplier failure and recovery," *Int. J. of Operations & Production Management*, 27(3): 323-341.

Third, a company can develop capacity buffers (i.e. excess or back-up capacity that can be employed that either lowers the impact of a disruption or improves the ability to recover from disruption). Ways to create a capacity buffer include:

- Increasing the number of suppliers, which will spread supply disruption risk across more suppliers, thus decreasing the impact of any single supplier's failure. This is especially true when a supplier is the sole source. Because purchasing from multiple suppliers will increase inventory management complexity, some companies identify and pre-qualify secondary suppliers, and even develop contractual linkages, but they do not order from them except in emergency situations.
- Diversifying the geographic location of suppliers, which will spread supply disruption risk across more regions, thus decreasing the impact of any single region's risks.
- Developing rapid supplier qualification procedures, which allows a buying company to identify and select new suppliers in a quick manner should the need arise.
- Decreasing supply specificity, which provides more options to a company should a disruption occur. For example, a product design may depend on a specialized part from a single supplier, making it risky. Changing product design so that multiple vendors' parts could be easily used improves resilience.
- Selecting a new supplier, which may be necessary when it is deemed that the existing supplier or supply region is too risky and is not a sustainable option into the future.

Fourth, a buying company can create a liability buffer by executing diligence in reviewing its current supplier contracts and creating new contracts in the future regarding issues of force majeure. Because courts may not be consistent initially in how they interpret liability for climate change related events, a company can protect itself by specifying the liability for such risks in its supplier contracts.

Finally, a company can create a potential cost buffer by helping decarbonize its supply chain. If a carbon tax or equivalent is enacted at some point in the future, supply chains which are carbon intensive (e.g. they are energy inefficient or use fossil fuel rather than renewable sources of energy) will be at a cost disadvantage.

The table on the following pages summarizes buffering strategies for supply chain resilience and provides examples. While not all of these are related to weather events, they are illustrative of the resiliency strategy and its effect.



**Buffering strategies
for resilience**

Description and examples

Inventory buffer

In 2011, Chrysler, Toyota, Ford and GM all depended on a sole source for a specialty paint, Xirallic, used for their cars. The factory was disabled by the earthquake and tsunami that struck Japan.³⁹ It took the automakers several months to regain supply. As a longer-term action, automotive suppliers in Japan increased their safety stocks levels over the next several years, leading to increased inventory that is necessary to respond more rapidly to a disruption.⁴⁰

Coffee plants are sensitive to temperature changes. As climate change reduces yield in existing growing regions, growers have to move to higher altitudes, sometimes inducing deforestation.⁴¹ At the same time, increased demand for coffee requires even greater increases in yield. In order to create an inventory buffer for their coffee suppliers, Starbucks proactively has committed that “it will make sure 100 million healthy coffee trees get into the hands of coffee farmers that need them by 2025.”⁴²

Time buffer

The World Resources Institute provides the Aqeduct™ Water Risk Atlas that estimates future water risks by region from quantity, quality, and regulatory perspectives.⁴³ For example, compared to 2019, water supply is expected to decrease 40% by 2030 in the south-central and southwest states in the U.S., but remain relatively the same in the rest of the U.S. So, if a company’s supplies depend on water and are in this region, it would have higher risk of being impacted by climate change risks. Knowing this well-ahead of the risk becoming significant gives companies with suppliers in that region a time buffer to react.

Capacity buffer

The fire in 2000 mentioned earlier in this report that closed a critical component supplier of cell phone manufacturer Nokia and its competitor Ericsson is an example of the benefit of capacity buffers. Nokia, which had superior outcomes compared to Ericsson, developed a rapid supplier certification process to recruit and register a number of secondary suppliers. Ericsson was less time-sensitive to the disruption and allowed Nokia to get preference for deliveries from alternate suppliers.

39 Yoon, J., Narasimhan, R., and Kyo Kim, M. (2018), “Retailer’s sourcing strategy under consumer stockpiling in anticipation of supply disruptions,” *International Journal of Production Research*, 56 (10): 3615-3635.

40 Yoo, et al. (2018), *ibid.*

41 Ovalle-Rivera et al. (2015), *ibid.*

42 Starbucks Corporation (2017), “Starbucks to provide 100 million healthy coffee trees by 2025”. Downloaded from <https://stories.starbucks.com/press/2017/starbucks-100million-coffee-trees/>.

43 World Resources Institute (2019), Aqeduct™, <https://www.wri.org/resources/websites/aqeduct>.

44 Paul, S., Sarker, R., and Essam, D. (2018), “A reactive mitigation approach for managing supply disruption in a three-tier supply chain,” *Journal of Intelligent Manufacturing*, 29(7):1581–1597.

Cost buffer

At Walmart, over 90% of its carbon footprint is embedded within the products it purchases and sells.⁴⁵ This is the case with most companies – their supply chain’s impact is bigger than their own. This supply chain carbon could be a future cost risk if a carbon tax is enacted. Walmart set a goal to reduce absolute GHG emissions by 18% by 2025.⁴⁶ Because such a significant portion of their footprint was in their supply chain, Walmart also created goals to reduce its scope 3, or supply chain, related emissions. Their commitment is to reduce supply chain emissions by a billion tons, or a gigaton, of carbon, by 2030.

Project Gigaton was initiated in 2017 so that Walmart could provide a platform for suppliers to report on the activities they’ve engaged in to help collectively remove a gigaton of carbon emissions. It also helps share their progress on this goal with critical stakeholders. Suppliers can report emissions reductions related to improvements in energy, waste, packaging, agriculture, forests, and product use and design.⁴⁷ As of the end of 2019, over 1000 suppliers had reported to the Project Gigaton platform. In 2018, 380 suppliers reported emissions reductions of over 58 million metric tonnes of carbon.⁴⁸

45 The Sustainability Consortium (2017), Greening Global Supply Chains: From Blind Spots to Hot Spots to Action, link.

46 <https://corporate.walmart.com/global-responsibility/sustainability/sustainability-in-our-operations/reducing-green-house-gas-emissions>

47 <https://www.walmartsustainabilityhub.com/>

48 Walmart 2019 Environmental, Social, and Governance Report, link.



Create a high reliability culture

In addition to the specific strategies of bridging and buffering, supply chain organizations can create a culture that promotes high reliability and resiliency. In their work studying organizations and accidents, Karl Weick and Kathleen Sutcliffe⁴⁹ identified the key traits of what they call a high reliability organization, or HRO: “one that has succeeded in avoiding catastrophes in an environment where normal accidents can be expected due to risk factors and complexity”.



A high reliability supply chain organization is:

- Pre-occupied by failure – The only way to manage supply chain risk is to be aware that it exists and be motivated to manage it. A high reliability supply chain organization weaves risk management into its culture and operations, and in the context of this report, integrates climate change risks into their overall supply chain risk management system. It uses continuous monitoring to note early warning signs of risk or supply disruption and invests in proactive prevention of climate disruptions and divests from climate change inducing supply chains such as those linked to deforestation and fossil fuels, but they do not order from them except in emergency situations.
- Reluctant to simplify interpretations – Supply chains are highly complex systems, so simple rules of interpretation may be inadequate. For example, the resilience to the same amount of sea-level rise in two different coastal regions may be very different because of the local governments' capacity to build protective infrastructure. Context matters.
- Sensitivity to operations – Supply chain organizations that are detail-oriented are more likely to pick up early warning signs of a disruption and create more effective solutions when adapting to a disruption. A high reliability supply chain organization will create formal recovery processes. For example, contracts and quality assurance procedures should be in place prior to any disruption in order to recover as quickly as possible.
- Commitment to resilience – A supply chain organization itself must be resilient to the stress caused by supply disruptions. Disruptions will occur no matter how effective their efforts at prevention are. Efforts must also go beyond the company to support government enforcement of climate related policies and pre-competitive engagement and investment in resilient supply chains.
- Deference to expertise – A high reliability supply chain organization will defer to expertise rather than hierarchical authority when judging risk and determining appropriate recovery actions during a disruption.

⁴⁹ Weick, K., and Sutcliffe, K. (2011). *Managing the unexpected: Resilient performance in an age of uncertainty*. John Wiley & Sons

Supply chain climate resiliency questions

The following questions are offered as a way to do a quick assessment of your own company's supply chain resiliency. You might consider using some or all of these as discussion items amongst the managers within the supply chain organization.

Question	Intent
<p>1. Do you have a formal supply chain risk management program?</p>	<p>Supply chain climate change risks should be managed as part of a broader program of supply chain risk management.</p>
<p>2. What have been your successes and failures in supply chain risk management, and how can you learn from those regarding planning for climate change risks?</p>	<p>Your previous supply chain management risk performance should be informative of which practices and processes are likely to be more effective under the conditions of being more stressed in future.</p>
<p>3. To what extent have you incorporated climate change risks into your supply chain risk management program?</p>	<p>If you have not considered them before, then relying on external experts to provide initial guidance may help. If your supply chain organization has already begun incorporating these considerations, then consider how technology or process improvements can make these efforts more effective.</p>
<p>4. Does your company have a general climate change strategy?</p>	<p>Support for the supply chain organization to address these risks is more likely if it is aligned with the overall corporate strategy towards climate change.</p>
<p>5. To what extent have you employed bridging strategies for supply chain resilience, and what have been the barriers and benefits?</p> <ul style="list-style-type: none"> a. Engage in collaborative planning and control with suppliers b. Provide financial support for suppliers c. Develop strong supplier relationships 	<p>Discussion about how effective particular strategies have been in the past can provide learning to improve future decision making.</p>

Question	Intent
<p>6. To what extent have you employed buffering strategies for supply chain resilience, and what have been the barriers and benefits?</p> <ul style="list-style-type: none"> a. Increase inventory buffers b. Create lead time buffers through weather and climate monitoring c. Create capacity buffers through dual sourcing, increasing geographic diversity of suppliers, or decrease supply specificity d. Creating liability buffers through contract terms and conditions, including force majeure 	<p>Discussion about how effective particular strategies have been in the past can provide learning to improve future decision making.</p>
<p>7. How quickly could you identify and contact any one of your particular suppliers?</p>	<p>The first step in reacting to a supply disruption is to communicate with the supplier. This requires managing contact information, so it is reliable and be accessed quickly.</p>
<p>8. Have you identified your most critical supplies?</p>	<p>Your organization does not have the ability to address all climate change related risks with all suppliers. Suppliers and supplies should be prioritized in terms of their criticality and risk.</p>
<p>9. Do you know what regions you source raw materials from? Do you know which specific suppliers you source raw materials from?</p>	<p>Disruptions can happen at any point of the supply chain. Understanding where you're sourcing from enables you to infer the specific climate change and weather risks the supplier will face.</p>
<p>10. Do you measure and report your supply chain related (e.g. Scope 3) GHG emissions? Do you have scope 3 goals? Have you planned how your supply chain organization would respond to a carbon tax?</p>	<p>If a carbon tax is enacted in the future due to attention to climate change, and you have decarbonized your supply chain, this may provide competitive advantage.</p>
<p>10. To what extent have you led or been a part of broader, more radical efforts to make supply chains more resilient? This could include divesting in known climate change inducing supply chains, supporting policy enforcement, creating peer pressure pre-competitively to have more sustainable supply chains, or investing to prevent/protect against predicted impacts.</p>	<p>Climate leadership requires a company to step beyond its own supply chain and take actions to reduce and mitigate risk within the broader system.</p>

Conclusion

Supply chain executives and managers manage supply disruption risks as part of their role. Climate change and its consequences, however, are going to make this job more challenging. Existing risks that cause supply disruption, like extreme weather events, will become more severe, frequent, and widespread. Chronic risks like sea-level rise will create new challenges, including risks due to transitions to new supply chain configurations.

In order to better plan for the future, companies can consider formally incorporating climate change risks as part of the supply chain risk management strategy. Companies can use bridging strategies to enhance the capability of a supplier to withstand risk events and recover more quickly from a disruption; and use buffering strategies to protect themselves from inevitable supplier failures and supply disruptions. A supply chain organization can intentionally work to develop the culture, processes, and discipline of a high reliability organization to link its intentions to positive outcomes. Attending to these issues will not only make the company's supply chain more resilient but may make the company more attractive to its own employees, customers and investors.

Authors

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