

The background features a series of vertical panels with rounded ends. The first panel on the left shows a person's hands typing on a laptop. The second panel shows a laptop screen with a play button icon. The third panel shows a target icon. The fourth panel shows an open book icon. The fifth panel shows a magnifying glass icon. The sixth panel shows a person icon. The seventh panel shows a bar chart icon. The eighth panel shows a line graph icon. The ninth panel shows a pie chart icon. The tenth panel shows a scatter plot icon. The eleventh panel shows a bar chart icon. The twelfth panel shows a line graph icon. The thirteenth panel shows a pie chart icon. The fourteenth panel shows a scatter plot icon. The fifteenth panel shows a bar chart icon. The sixteenth panel shows a line graph icon. The seventeenth panel shows a pie chart icon. The eighteenth panel shows a scatter plot icon. The nineteenth panel shows a bar chart icon. The twentieth panel shows a line graph icon. The twenty-first panel shows a pie chart icon. The twenty-second panel shows a scatter plot icon. The twenty-third panel shows a bar chart icon. The twenty-fourth panel shows a line graph icon. The twenty-fifth panel shows a pie chart icon. The twenty-sixth panel shows a scatter plot icon. The twenty-seventh panel shows a bar chart icon. The twenty-eighth panel shows a line graph icon. The twenty-ninth panel shows a pie chart icon. The thirtieth panel shows a scatter plot icon. The thirty-first panel shows a bar chart icon. The thirty-second panel shows a line graph icon. The thirty-third panel shows a pie chart icon. The thirty-fourth panel shows a scatter plot icon. The thirty-fifth panel shows a bar chart icon. The thirty-sixth panel shows a line graph icon. The thirty-seventh panel shows a pie chart icon. The thirty-eighth panel shows a scatter plot icon. The thirty-ninth panel shows a bar chart icon. The fortieth panel shows a line graph icon. The forty-first panel shows a pie chart icon. The forty-second panel shows a scatter plot icon. The forty-third panel shows a bar chart icon. The forty-fourth panel shows a line graph icon. The forty-fifth panel shows a pie chart icon. The forty-sixth panel shows a scatter plot icon. The forty-seventh panel shows a bar chart icon. The forty-eighth panel shows a line graph icon. The forty-ninth panel shows a pie chart icon. The fiftieth panel shows a scatter plot icon.

## PMG 663

# Assessing Supply Chain Resilience upon Critical Infrastructure Disruptions

## Lecture 10

Prepared by  
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**Evolving definitions of agility**

**Review of Relevant SC Risk and CI Disruption Cases**

**Supply chain resilience**

In today's complex, and turbulent market places, organizations and the supply chains in which they operate need to be responsive to the volatilities of demand, supplies and numerous other factors.

While this basic notion of agility continues to dominate, the definitions of agility has also been evolving in recent years.

Today's marketplace is characterized by:

- intense competitive pressures .
- high levels of turbulence and uncertainty.

Organizations require agility in their supply chains to:

- provide superior value
- manage disruption risks
- ensure uninterrupted service to customers.

The cultivation of agility can be approached as a risk management initiative that enables a firm to:

- anticipate marketplace.
- 
- respond rapidly to marketplace changes and disruptions in the supply chain

Agility is thus of value for both risk mitigation and response. an updated perspective of an emerging body of literature devoted to supply chain agility. The authors propose a set of supply chain initiatives as antecedents for cultivation of agility. These include internal integration measures, external integration with suppliers and customers, cultivation of external flexibility, and lean practices

also provide more fundamental, cultural drivers for cultivating agility, which include:

- market orientation
- learning orientation
- organizational culture types that are conducive for agility.

These antecedents were established through empirical research, and we translate them into a set of managerial practices to address the cultivation of agility for both mitigation and response.

provides a summary of evolving definitions of agility amongst representative research studies, covering the breadth and range of concepts that have been included so far as part of supply chain agility

- Using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.

- Ability to offer low-cost, high quality products with short lead times and varying volumes. IVs: Internal initiatives:
- e.g. process re-engineering
- external initiatives like inter-firm cooperation

- Ability to respond rapidly to changes in demand, both in terms of volume and variety
- Ability to efficiently change operating states in response to uncertain and changing market conditions

Chile is the number one copper producer in the world. Supply of copper from Chile was disrupted in April 2014 after the earthquake and ensuing tsunami at an epicentre far from the major copper mines. The disruption was, however, mainly due to the ruined roads, power outages, and closed ports, rather than direct damage to production facilities or capacity.

The Chile copper supply disruption situation mentioned earlier is one demonstration of how supply chain disruptions are caused or worsened by failure in the CI systems (critical infrastructure) that the supply chain depends on. Similar cases that reveal how supply chains are vulnerable to disruptions in CI systems and cascading effects are reported in Table 18.1

**Table 18.1** A few supply chain disruptions and their dependence on CI failures

| Supply chain disruption                                                                         | Related/underlying CI interdependences                                                                                                                     | Disrupted CI                                                          | Consequences of the disruption                                                                                                                                       |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Copper supply shortage in Chile (2014)                                                       | Supplies could not be transported due to damages to roads and power interruptions because of earthquake; employees of mines went to families               | Road transport<br>Power supply<br>Rail transport<br>Manpower<br>Ports | Copper prices showed increases up to as high as 1% on London Metal Exchange and New York Mercantile Exchange in speculation of shortages (Clarke and MacDonald 2014) |
| 2. Delay of essential goods including medical supplies in the EU due to migration crisis (2015) | Border closures and tighter controls to deal with chaos due to stowaways meant that the supplies were severely disrupted, especially those urgently needed | Road transport<br>Rail transport                                      | Great Britain alone lost an estimate of at least 1 billion USD a year due to the crisis (BSI 2015)                                                                   |

| Supply chain disruption                                                              | Related/underlying CI interdependences                                                                                                                                 | Disrupted CI                                                                                             | Consequences of the disruption                                                                                                                                                      |
|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3. Auto and electronics parts shortage following the triple disaster in Japan (2011) | The damaged power and transportation infrastructures had greatly influenced recovery from the disruption                                                               | Airfreight<br>Power supply<br>Water supply<br>Road transport<br>Ports<br>Manpower<br>Gas and fuel supply | The direct economic impact of the disruption is estimated to be more than 22 billion USD excluding damages to damaged buildings and infrastructure (e.g. World Economic Forum 2012) |
| 4. Import items to US stranded at ports (2002)                                       | Workers' strike caused the blockage; airfreights (as alternative routes) became more expensive than they usually are as few fast companies already leased the capacity | Ports<br>Airfreight<br>Manpower                                                                          | Retrospective analysis estimated more than 1 billion USD per day for economic loss to US economy for each day of strike that went for 11 days (Hall 2004)                           |

To start by reciting the Chile earthquake situation, the main cause of copper supply shortage was not damage at the copper mines. The epic Centre of the earthquake was not very close to copper mines, which are mainly located in Northern Chile. In fact, the major mining companies have announced shortly after the quake that the mines and smelting plants were intact. It was, however, difficult to transport the produced copper due to the damaged roads and power interruption

Some of the mines have also stopped production for a while because employees were sent to join and support families affected by the earthquake and the subsequent tsunami. Large amount of mostly perishable items have been stranded at the US West Coast ports during the 2002 dock workers strike. Items supposed to be delivered for Christmas sales season were delayed, and partly spoiled. The US economy as well as large retailers had to bear enormous consequences

During the Great Japan Earthquake in 2011, automotive and electronics manufacturers felt the pain of the natural disaster.

Even those companies with no physically damaged facilities or whose Japanese suppliers could still produce parts had to deal with shortages due to power outages, failed roads, sea ports and airports.

The 2015 migration crisis in Europe, which has exacerbated since late 2015, has caused severe disruptions to logistics and custom services to several European centered supply chains. It has caused enormous disruption to the medical and other essential supplies. Some European countries blocked or tightened security at their borders, which, together with the influx of migrants, caused extremely long traffic jams. The United Kingdom alone incurred 1 billion USD a year due to the supply chain disruption because of the crisis.

The aforementioned cases show how much modern global supply chains are vulnerable to failures or unavailability of CIs, such as road transport, ports, electrical power, water supply, fuel and gas supply.

The vulnerability and the associated consequences becomes much more severe when we consider key resource supply chains, such as food or pharmaceutical products.

This real-life example demonstrates that in any supply chain the flows of materials, information and money can easily be disrupted due not only to supply or demand problems but also due to affected critical infrastructure systems that the supply chains depend on. Similarly, the future prices of copper was threatened by water shortage in a small town due to drought .

Managing supply chain risks involves decision making under uncertainty on multiple parameters. Actors in a supply chain network are often required to consider multiple levels of decision to better address and mitigate supply chain risks as much proactively as possible.

Such a detailed and multilevel consideration of disruption risk interactions is important because it is not sure where the sources of disruption affecting a supply chain might emanate from

As indicated in the aforementioned example, a supply chain could be severely affected by disruption in the critical infrastructure (CI) used by the supply chain.

These effects are magnified due to the (inter)dependencies between CI systems and disruption propagation to Key Resources Supply Chains (KRSC), i.e. supply chains of some industries marked as critical (such as food or pharmaceuticals) which are heavily dependent on other CI

Supply chain risk and disruption of CI are complex phenomena that are difficult to understand in real life circumstances.

To evaluate resilience strategies, consequences (losses) of CI disruptions need to be quantified; this requires an adequate understanding of all the possible cascading effects within the CI and to the supply chain network level as well

Supply chain risk management (SCRM) approaches suggest that actors in a supply chain network should consider different risk scenarios to address and mitigate supply chain risks in a better way. Overall performance of a supply chain could be severely affected by disruptions that are triggered by failures or service disruptions in the critical infrastructure (CI) systems that the supply chain relies on. Interdependencies among the CI systems and supply chains, particularly the so-called Key Resources Supply Chains (KRSC) such as food, worsen the effects as disruption and consequences propagate in the network

Critical Infrastructure can be defined as those assets and systems that, if disrupted, would threaten national security, economy, public health and safety, and way of life. Contemporary societies are increasingly dependent on

- availability,
- reliability,
- correctness,
- safety and security of CI (The Council of the European Union 2008).

The vital functions and services of CIs are supplied through networks and assets including:

- electricity grids
- roads
- communication networks

CI systems have interdependence among each other; that is, a bidirectional or unidirectional relationship exists between the states of any given pair of CI systems . These interdependencies can be described in terms of physical, cyber, logical, and geographic types. Physical interdependency exists when an input of one CI is dependent on material/energy output of another (e.g. a rail network depends on power supply)

Cyber interdependency describes the dependence of CI on information infrastructure. When elements of multiple infrastructure are in close spatial proximity, geographical interdependence occurs (e.g. joint exposure to the same natural phenomena). When an interdependence between CIs exists and is not any one of the aforementioned three classes, it is classified as logical (e.g. increased highway usage by commuters due to railway strikes and service interruptions).

A disruption of CI or SC can be described as an unplanned and unanticipated event which prevents or limits flow of material, information or money in a system . argued that disruptions may occur at node (i.e. facility), arc (e.g. transportation), or network (both node and arcs) level of a supply chain. Disruptions that occur at network level are much more important than the other two as they may cause severe consequences on supply chains

By focusing on disruptions at CI, this chapter discusses how resilience strategies minimize the effect of disruptions that can affect multiple actors, i.e. nodes and arcs, in a supply chain–KRSC in our case. Disruptions in a CI include information and communication disruptions, transportation, power, and other infrastructure failures, which is the main concern in this chapter. Disruptions of these CI have a significant impact not only on other interdependent CI but also on supply chains that utilize the CI

In fact, the consequences can ripple along different CI systems and multiple supply chain levels. Societal life can be severely affected by disruptions in CI directly or indirectly as supply chains that provide inputs for human day-to-day activities depend on them.

For example, in the aftermath of Hurricane Katrina, oil pipes and telecommunications systems failed due to power outages.

Folgers coffee plants (back then owned by Procter and Gamble) in the area were hit hard by the hurricane, affecting coffee supply.

Even worse was the lack of access for the recovery effort in the area due to damaged roads, which forced them to use helicopters

describes different robust SC strategies that aim to improve a firm's capability to manage supply and/or demand better under normal circumstances and to enhance the firm's capability to sustain its operations when a major disruption hits.

The majority of these strategies rely on the availability of infrastructure systems that serve the supply chain, either as primary subject of intervention or as subsequent objective associated to other categories of risks

We can say that disruptions of such infrastructure represent one of the most important risk category and their improvements enable to protect SC from either CI disruptions or all the other risk categories closely linked to them

In general, resilience can be understood as the ability of a global supply chain to anticipate, reorganize and deliver its core function continually, despite the impact of external and internal shocks to the system. It describes resilience as the capacity to be better positioned than competitors to deal with and to gain advantage from disruptions. These definitions essentially focus on capabilities that a supply chain has in mitigating disruptions happening somewhere in the network and possibly turn them into an opportunity to gain competitive advantage.

At supply chain network level, resilience can be seen as an attribute to withstand such disruptions triggered at a node (facility) or an arc (transportation) as the consequences of a disruption at one point can ripple along the supply chain identified flexibility and redundancy as two broad strategies for SC resilience. Flexibility entails creating capabilities within the organization to redeploy some existing and previously committed capacities from one area to another (to make up for lost or delayed capacity)

Redundancy, by contrast, is the additional capacity that would be used to replace the capacity loss caused by a disruption. Both approaches require investments in infrastructure and resources prior to the point of need.

When evaluating effectiveness of resilience strategies applied to specific parts of the SC, we also consider different levels of resilience capacity, achievable through either flexibility or redundancy, or most typically a mix of the two.

## Reference

### **Supply Chain Risk Management Advanced Tools, Models, and Developments**

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Chapter 10



# Thank You