

Assessing Supply Chain Resilience upon Critical Infrastructure Disruptions

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Lecture 10



Evolving definitions of agility

Review of Relevant SC Risk and CI Disruption Cases

Mutual Dependencies Between SC and CI Systems

- The landscape of risks has broadened: it's no longer just natural disasters or isolated events.
- **Cyber-physical threats, geopolitical instability, regulation shifts, climate-driven infrastructure breakdowns, and supplier-concentration** are all now simultaneously active risk drivers.

Collapse of Key Infrastructure

- Because so many commodities and other supplies are transported globally, any increases in costs or closures of key ports and shipping channels :
- (including the loss of a single bridge in Baltimore) cause wide-ranging effects: shortages, production delays and inflation.

- For example, container ship transit in the Red Sea (a channel for 12 percent of global trade) was slashed by 67 percent due to ongoing conflict in the Middle East.
- forcing shippers to add about 7,000 miles to their routes in some cases, raising fuel use and carbon emissions and sending shipping costs and transit times skyrocketing.³

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.
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- 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

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- The next war will not be fought over oil, it will be fought over silicon. Semiconductors, the invisible engines behind modern technology, are the heart of everything from smartphones and satellites to missiles systems and electrical vehicles.
- Yet the US, a global leader in innovation, finds itself dangerously dependent on foreign manufacturing, particularly in Taiwan and South Korea, for over ninety percent of the world's advanced semiconductor production

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- As geopolitical tensions rise, particularly with China's aggressive posture toward Taiwan, the fragility of this supply chain reveals a glaring vulnerability in American national security and economic resilience.
- Thus the US dependence on foreign semiconductor manufacturing constitutes a critical infrastructure vulnerability with the potential to paralyze defense, economic, and technological sectors.

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Taiwan Dependency and Risk of Disruption

- The most acute vulnerability lies in America's reliance on Taiwan, specifically the Taiwan Semiconductor Manufacturing Company (TSMC), which alone produces over ninety percent of the world's most advanced logic chips.ⁱⁱⁱ
- TSMC's fabrication facilities, clustered around Hsinchu and Tainan, form a geographic chokepoint. If China were to invade, blockade, or destabilize Taiwan, semiconductor production could be disrupted or stopped which would, send global markets into a spiral.

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- The US has no immediate domestic substitute capable of filling this production gap besides a TSMC fabrication facility currently under construction in Phoenix Arizona.
- In this sense, TSMC is not just a business, the microchip company is a strategic asset of similar resemblance to a single oil refinery supplying most of the world's fuel. The US dependence on Taiwan semiconductor production represents a single point of failure in the global digital infrastructure.

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Rise of Foreign Dependency

- Over the past three decades, the US outsourced semiconductor fabrication to Asia in pursuit of lower costs and higher profit margins.
- While US companies like Intel, NVIDIA, and Qualcomm lead in design, they still lack sufficient domestic fabrication capacity to produce advanced nodes below ten nanometers.
- Meanwhile, China is aggressively investing in its own semiconductor ecosystem, aiming to reach self-sufficiency by 2030.

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- Chinese firms, supported by extensive state subsidies, have also acquired, or attempted to acquire foreign semiconductor assets, triggering alarm in Washington and Veldhoven Netherlands which is where Advanced Semiconductor Materials Lithography (ASML) corporation headquarters is located.
- US policymakers increasingly view China's industrial strategy as a form of "chip warfare," where controlling supply chains serves both economic leverage and military deterrence

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Policy Response of The Chips Act and Limitations

- Recognizing the strategic vulnerability, Congress passed the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act in 2022, which allocates \$52 billion to incentivize domestic semiconductor production, research, and workforce development.
- The law offers subsidies and tax credits to companies like Intel, Samsung, and TSMC to build fabrication plants in Arizona, Texas, and Ohio. While the vital first step, the CHIPS Act does not fully close the gap.
- Building leading edge fabrication facilities takes three to five years and costs over \$10 billion per facility which also require a highly trained workforce that the US currently lacks

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- According to the Semiconductor Industry Association, the US will face a shortage of 67,000 semiconductor technicians and engineers by 2030.
- Additionally, the upstream and downstream supply chains, such as, rare earth materials, high purity gases, and ultraviolet lithography machines, remains vulnerable to chokepoints in countries like Japan and the Netherlands.
- For example, ASML in the Netherlands is the only company in the world that currently produces extreme ultraviolet lithography machines, which are essential for five nanometer and below nodes. A single supply disruption at ASML could delay global chip production for months around the world.

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- 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 Power supply Rail transport Manpower 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 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 Power supply Water supply Road transport Ports Manpower 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 Airfreight 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

- 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

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

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:

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- **Supply Chain Risk Management Advanced Tools, Models, and Developments**
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Chapter 10



Thank You