

Complex Multi-vector Disruptions of the Supply Chain



Fred S. Roberts
Director of
CCICADA
Rutgers University

Credit: Wikimedia commons

Remember March 2020?

- When COVID-19 hit, we saw shortages of Personal Protective Equipment (PPE)
 - Masks
 - Gowns
 - Ventilators



Credit: Wikimedia commons, Timely Medical Innovations, LLC



Credit: Wikimedia commons, [James Heilman, MD](#)

Remember March 2020?

- When COVID-19 hit, store shelves were empty.
- We couldn't get important items:
 - Hand sanitizer
 - Disinfectant wipes
 - Toilet paper



Credit: :Laurie Kolano



Hoarding Toilet Paper

Remember March 2020?

- There were shortages of food
- Yet, farmers were burying crops and pouring out milk
- Our supply chains were thrown into chaos



*Despite shortages in grocery stores,
some farmers had to destroy crops.*
Photo Credit: Wikimedia Commons

And in October 2021

- We are seeing a repeat of many of these things.
- Stores shelves are again empty.
- There are long delays in obtaining supplies.
- Chip shortages are affecting manufacture of everything from cars to iPhones.
- There are long lines of ships waiting to dock at ports.
- And large backlogs of containers waiting to be unpacked.
- How did this happen?

Port of Long Beach
Photo credit: Wikimedia commons,
CBP



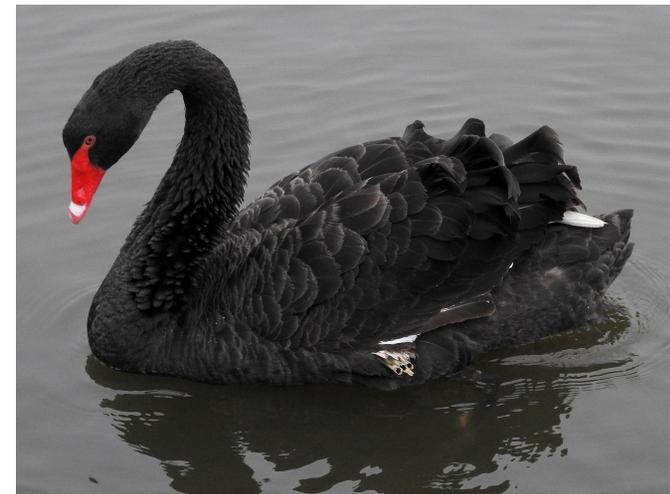
How Did This Happen?

- Combination of disruptions
- Continuing impact of COVID-19 supply chain disruptions
- Labor issues: trucker shortages
- Labor issues: differing rules for workers boarding or leaving vessels at different ports
- Malaysian chip plant shutdown
- Changing spending patterns – after lockdowns and quarantines, people spending more on goods rather than on services



Data-driven Supply Chains

- Supply chains have been dramatically changed in the digital age.
- *Artificial intelligence and machine learning have allowed the private sector and governments to minimize inventories.*
 - Due to extremely accurate knowledge of demand for goods or components.
 - Allowing for *”just-in-time” delivery.*
- COVID has demonstrated the problems with this approach.
- AI/ML-driven supply chains worked great until there was a *“Black Swan” event* – an anomalous event, one that was totally unexpected.
 - Terminology stems from (Western) view that all swans are white.
- Data may be part of the problem, but it is also part of the solution.
- So is systems analysis.



Supply Chains are Not Always Flexible

- Why did farmers plow under food and pour out milk when COVID hit and consumers couldn't get these products in the stores?
- Supply chains are not that flexible.
- There was more demand – people started hoarding. The supply chain didn't foresee this.
- Workers at different stages of the supply chain were out sick or in lockdown.
- It was difficult to change packaging, transportation routes, and contracts.
 - If you are used to delivering 25 Kg bags of potatoes to institutions such as schools or restaurants, you can't suddenly shift to 2 Kg bags.
 - Packaging is different. Transportation is different. New contracts have to be signed.



Supply Chains are Global & the World is Interconnected

- Consider the food supply for example.
- You can't deliver food unless you have the supplies for packaging (e.g., cans and paperboard)
- You can't process food without fuel for the electricity and gas used in producing food
- You can't clean and disinfect food processing plants if you don't have the needed chemicals and cleaning supplies
- You can't deliver food from farm to food processing to warehouses to markets without fuel for the means of transportation



Images from John Hoffman

Moving Supplies by Air

- Moving supplies by sea can be slow.
- Especially when events like the recent blockage of the Suez Canal force some ships to divert around the southern tip of Africa, adding several weeks to transit time.
- Air transport is faster but can be more expensive.
- But to compete, some shippers have introduced special fast-transit shipping options by sea.

Image from Brandin Fried



Moving Supplies by Air

- COVID has really challenged both sea and air transport.
 - Seaports closed causing delays
 - Crews were sickened and vessels couldn't enter a port
 - Shortages of containers at some ports led to innovative solutions, like filling vessels with empty containers to take them where needed. Requires major data handling innovations and modeling as to when and where to take containers.
 - Airlines stopped flying because of lack of passenger demand
 - This resulted in loss of 50% of the world's cargo capacity
 - Innovative solutions led some airlines to carry freight in passenger compartments

Image from Brandin Fried



Suez Canal Incident

- The grounding of the container ship Ever Given in the Suez Canal on March 23, 2021 led to significant short-term supply chain impacts and aggravated other existing supply chain issues.
- When the incident occurred, the global supply chain was already impacted by COVID-19. How did that make impacts of the incident worse?
- The blockage of the Suez Canal illustrates the interconnected-ness and vulnerability of the world's maritime trade system.
- Malicious actors, natural disasters, pandemics, economic and geopolitical events and marine casualties such as the Suez event can disrupt domestic and global supply chains.
- ***These and other disruptions can occur singly or in combination.***
- Examining the Suez incident provides a unique opportunity to identify emerging global supply chain factors, improve preparedness, enhance business continuity, and prioritize future research and policy decisions.



Suez Canal Incident

- The Suez Canal incident was the topic of a CCICADA workshop on June 21, 2021.
- The Workshop addressed the questions: *How do multiple, interconnecting disruptions of global supply chains produce outcomes that are much more complicated and challenging than those of single disruptions? How can we best prevent, prepare for, respond to and recover from these incidents?*
- There has been little analysis of cascading impacts of multiple disruptions, building on each other in complex ways.
- Modeling multiple vector disruptions can help policy makers, business leaders, others anticipate, plan for, mitigate, and recover from them.
- A major challenge for data science and systems analysis.

Some Conclusions from the Suez Canal Incident

- It Could Have Been Much Worse
 - Having to unload the cargo would have led to a much longer delay.
 - Things could be much worse if a chokepoint blockage occurs in the context of a cyberattack or a hurricane, a labor stoppage or another major disruption. ***Complex disruptions need research.***
- Just-in-Case vs. Just-in-Time
 - Before the pandemic, supply chains had become very efficient because of “just-in-time” technology.
 - In the wake of large-scale disruptions during the pandemic, shippers and merchants ramped up shipments “just-in-case” of future shutdowns. ***Research: Will we fully revert to “just-in-time”? Should we?***



Kill van Kull at entrance to NY Harbor – 80-90% of goods pass thru narrow red passage.

Credit: En.Wikipedia.org

Some Conclusions from the Suez Canal Incident

- Predictability Contributes to Resilience
 - Unusual events can be “predictable” but only to the extent that government agencies and others share information on how an incident is being managed, allowing industry to make alternate plans. ***Data sharing is key.***
 - In the Houston Ship Channel, for instance, the US Coast Guard cannot promise to always keep the passage open, but it has been able to limit closures to at most 5 days. ***Modern data systems used to manage today’s supply chains can take such levels of delay into account.***
- Cascading Effects
 - The Suez Canal incident had relatively minimal and short-term impacts on particular U.S. ports, more on European ports. This doesn’t take into account the possibility that cascading impacts might have had large and longer-term economic and supply chain impacts. ***Research on cascading impacts needed. Systems analysis will be a key part of this.***



Houston Ship Channel Oil Spill
Credit: commons.Wikimedia.org

Some Conclusions from the Suez Canal Incident

- Don't Limit the Problem to Individual Ports or Vessels
 - *Research: Consider system interconnections.*
 - Consider chokepoints in connecting rail networks, failures in nearby smart traffic signals and emerging autonomous technology used near a port, and disruptions of emerging communications technologies that could impact trains and vessels.

Credit: Commons.wikimedia.org



Toward Solving Some Supply Chain Challenges: Information Sharing

- Information sharing is a key to enable organizations and individuals to work together while protecting their private information.
- Example: *Blockchain* is a decentralized recordkeeping system that enables disparate parties to transact safely without needing a middleman.
 - *A blockchain is a digital record of transactions.*
 - Individual records (*blocks*) are linked together in single list (*a chain*). Each transaction added to a blockchain is validated by multiple computers.
- Example: You would like to track your supplies at every stage of the supply chain, but not share your private information with other companies.
- Analogy with the vin number of a car. Every time it is sold, that vin number goes with it and so you can trace all transactions.

Toward Solving Some Supply Chain Challenges: Stockpiles

- One way to prepare for an emergency or a shortage is to stockpile goods or components you might need.
- US Federal Emergency Management Agency (FEMA) has an emergency stockpile of goods for emergencies:
 - Water, food, fuel, chainsaws
- There is a US national strategic stockpile for medicines.
- Should companies have stockpiles too?
- There are many challenging research questions about stockpiles.



Credit: Wikimedia commons, [Nick Gray](#),
18



Credit: cdc.gov

Strategic Stockpile for Medicines

Toward Solving Some Supply Chain Challenges: Stockpiles

- Stockpile Questions

- How big should they be?
- What should be in them?
- Where do you locate them?
- Things spoil – how often do you replenish them?

Shipment of PPE
from Strategic
National Stockpile

credit: National Guard, flickr



- Special issues for pharma: API have longer shelf life than the drugs they constitute; once a drug is dosed, the expiration clock starts ticking toward the expiration date

- Distribution strategies

- What triggers distribution?
- How do you prioritize who gets what in case of shortages?

- How best to share information about what is in stockpiles

- Between federal government agencies
- Between federal and local government
- Incentives for information sharing

- 19 – Government incentives for private sector stockpiling?

Toward Solving Some Supply Chain Challenges: Technology

- Technologies such as artificial intelligence and machine learning are partly responsible for the supply chain problems during COVID.
- But they are also part of the solution.
- Other relevant technologies of systems analysis include:
 - Blockchain, trustmarks
 - Optimization
 - Decision trees
 - Time series forecasting
 - Network flow modeling
 - Mathematical modeling and simulation
- Hopefully they can contribute to making supply chains more resilient.