

Resilient Supply and Demand Networks (RSDN)

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CoNBaF '24

June 25, 2024




Ammunition shortage

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The Peril of Ukraine's Ammo Shortage

5 MINUTE READ



Shells for a M109 howitzer lie on the ground in Bakhmut, Ukraine, on Aug. 17, 2023. Viktor Fridshon—Global Images/UKraine via Getty Images

IDEAS

BY JACK WATLING FEBRUARY 19, 2024 10:01 AM EST


Jack Watling is senior research fellow for land warfare at the Royal United Services Institute.

Since Russia's full-scale invasion of Ukraine in February 2022, one type of weapon has loomed large over every other. Artillery has accounted for about 80% of casualties on both sides. Yet political **deadlock** in the U.S. Congress over military assistance to Ukraine, combined with a **lack of production capacity in Europe**, is leading to a **critical shortage in artillery ammunition** that could spell disaster for Ukraine's war effort.

The shortage of ammunition is already being felt across the front, and

Unpredictable supply

ARMY MATERIEL COMMAND WHITE PAPER



The Army's Mission Command Center of Excellence is leading a consortium of stakeholders in addressing this challenge. The current solution, Army Vantage, converts input from over 200 sources into a common data language that provides leaders with a better decision support tool and supports a common operating picture. This solution also integrates sustainment data within mission command systems, enabling a more comprehensive and relevant common operating picture. As this effort matures, we will be able to provide commanders with a clear vision of current conditions and future requirements.

The Army is also investing heavily in predictive logistics capabilities. Based on networked sensors, these will automatically feed data from platforms into a common

11

operating environment, enabling sustainers to monitor, anticipate, and ship necessary commodities, such as replacement parts, ammunition, and energy to the point of need. Faster, better data will enable commanders to make faster, better decisions.

Second, the Army will cut energy demand across the operational force to increase its endurance and agility while reducing the risk, and the cost, of keeping

New tariff impacts

☰
Bloomberg

A Week of Global Trade Tensions Puts Geopolitics on Display

By Bloomberg News
May 16, 2024 at 7:00 AM EDT

The big trade news this week is the [US's move to boost tariffs](#) on a new range of Chinese imports, and it landed just as fresh evidence emerged showing how geopolitical alliances are realigning Asian trade routes.

Nowhere is that clearer than in East Asia, where [Taiwan's booming](#) exports to American shores are one example of how the great-power tensions are reshaping global commerce – and how China appears to be on the losing end.

[Read More: US Reshaping of Global Supply Chains Gathers Pace in Asia](#)

The island's sales to US markets climbed more than 80% in April from a year earlier, hitting a record high, according to data released last Friday. In the first four months of 2024, shipments to the US overtook those sent to China, which continued to shrink. Even when Hong Kong is included, China's share of the island's trade is dropping.

More Tariffs

On Tuesday, the Biden administration [announced tariff increases](#) on a range of Chinese products, from computer chips to electric vehicles and port cranes, as part of US efforts to curtail what it describes as Chinese "cheating."



Our roadmap



Why?

Avoid surprise in supply.

Supply chains are **fragile**. Failures have potential for huge **economic impact** and can **disrupt** capabilities.

Who?

Industry uses: Assess n-tier efficiency and opportunity. Uncover novel scenarios, compare trade-offs for decisions.
DoD uses: n-tier visibility, find weak links, actively consider emergent scenarios, actions for greater resilience.
Gov uses: Know upstream/downstream exposures, assess collateral damage of potential policy, weigh trade-offs.

How?

Model **global supply chains** with big data, find weak links, model resilience, **what-if scenarios**, assess mitigation via **forward and reverse stress testing**.

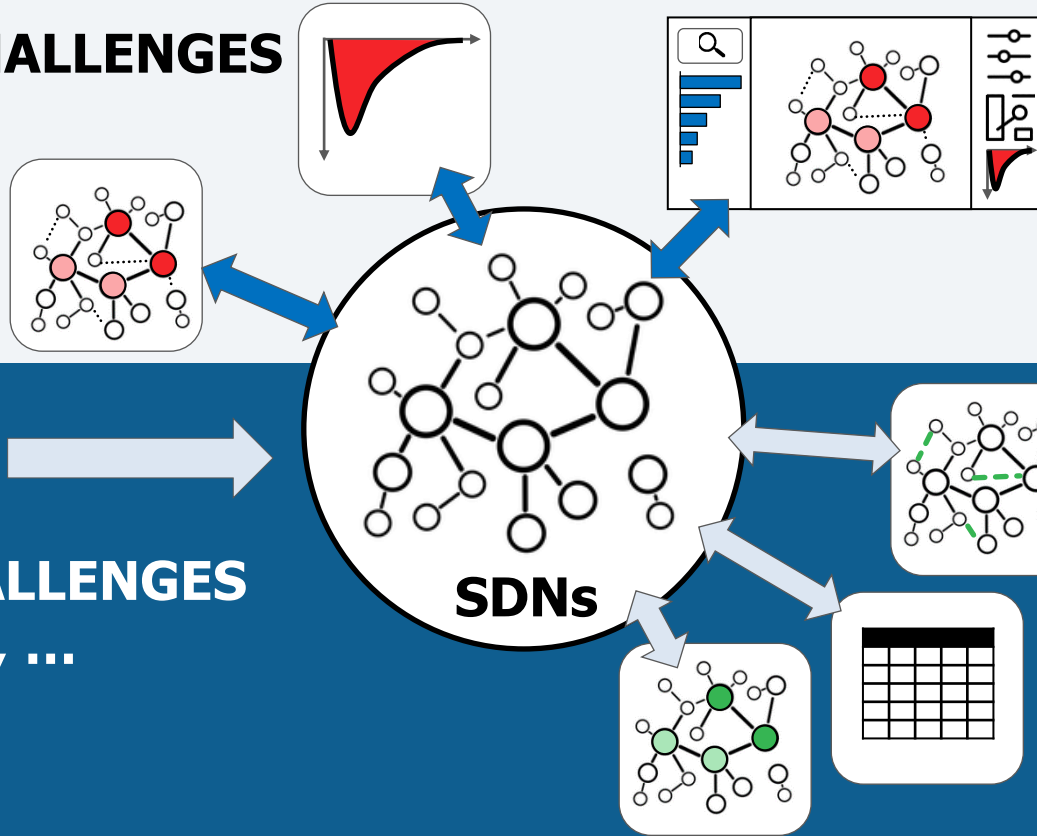
When?

Q2 2024: Integrated system validates **end-to-end approach**
Q4 2024: **Pilot** with early adopters
Q1 2025: **Revise with expert feedback**
2025: Extend to additional data, quantify results
2026: Facilitate external integrations, e.g., data/connectors



How it works: key components

A: SIMULATION CHALLENGES
scenario, shock,
stress-test...



B: UNDERSTAND & ACT
connect, config,
compare, tradeoffs,
playbook...



C: REAL DATA CHALLENGES
tariffs, filings, gov, ...

D: SYSTEMIC RISK
impute, rank,
resilience,
equilibrium,
...

Amazon Web
Services

Amazon
Neptune

Elastic

OS Graph
Libraries

Kubernetes

Python

Docker



A: Simulation challenges

FINANCE baseline approach:

Forward stress tests via many models for a long time

- Sensitivity analysis
- Historic testing
- Scenario what-if
- Monte Carlo
- Factor analysis
- and others

Reverse stress tests aren't industry standard

Acronyms:
Computable General Equilibrium (CGE)
Agent-based model (ABM)

SUPPLY CHAIN approach:

Different models needed

- Topologic resilience (Operational Resilience, Ganin et al. 2016)
- Dynamic Mode Decomposition
- Macroeconomic CGE model
- Microeconomic ABM

Reverse stress tests active too

- The space of possible worlds is vast
- Optimizations and approximations required
- Produce probability distributions of things to beware:
 - Initial conditions
 - Shocks and stresses

A trade dispute, a viral pandemic, a product failure, a cyber breach, a tsunami: these are not black swan events but **“gray rhinos”**: highly probably, highly predictable

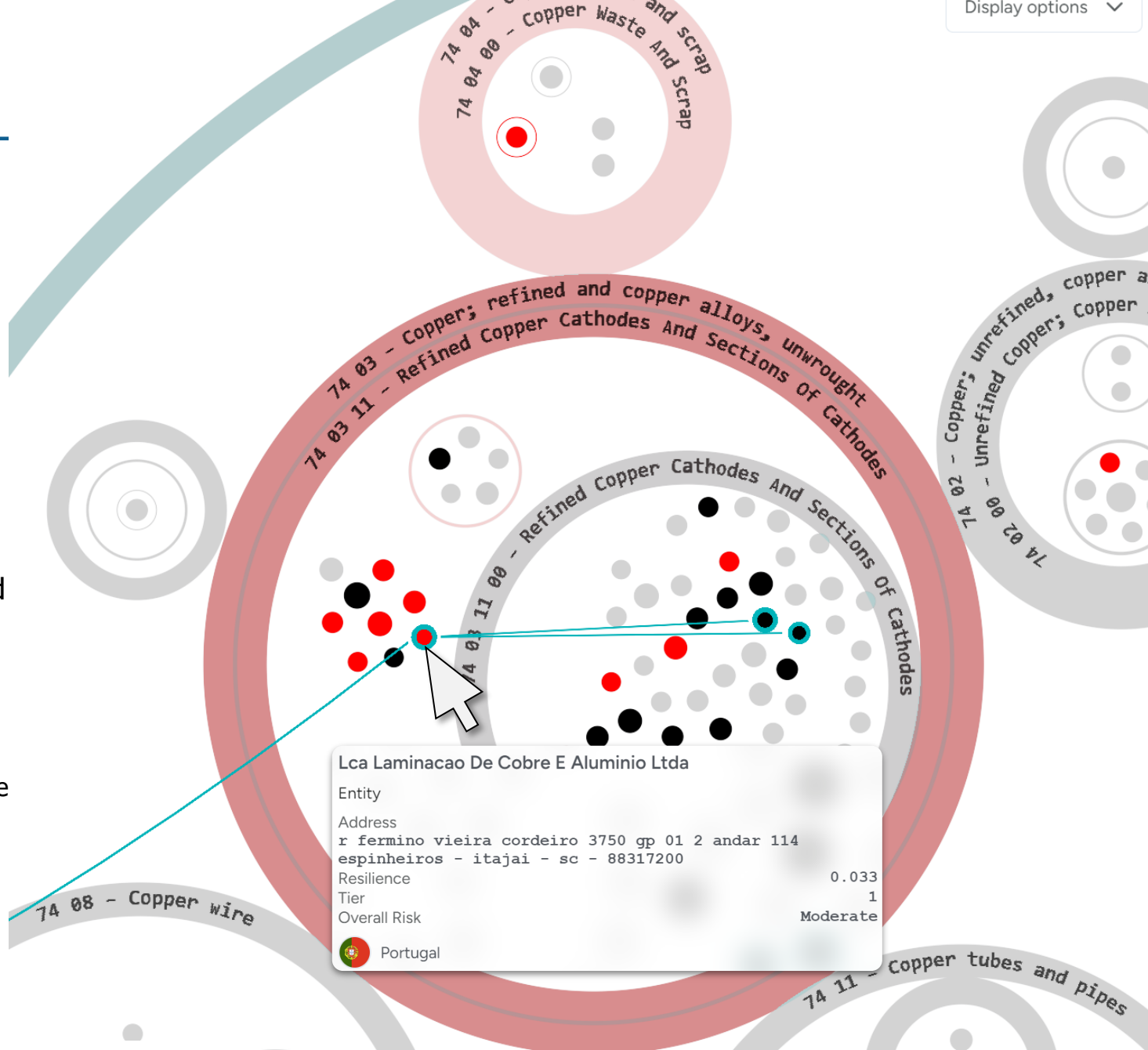
– Michele Wucker, Risk Director, HBR, 2023.



Example resilience with Chile shock

Resilience model can be applied to scenarios, selected and configured per panel to right. Example:

- Entities in black were selected and set to initially damaged, e.g., copper companies in Chile in this example.
- Entities in bright red most heavily impacted (least resilient).
- Click to see the dependencies, e.g. Lca Laminacao De Cobre E Aluminio Ltda in Portugal imports from two Chilean refiners.



Lca Laminacao De Cobre E Aluminio Ltda

Entity

Address
r fermino vieira cordeiro 3750 gp 01 2 andar 114
espinheiros - itajai - sc - 88317200

Resilience 0.033

Tier 1

Overall Risk Moderate

Portugal



Display options

Resilience profile options

Selection initially damaged

Percentage of damaged nodes

Damage severity

Edge switch probability

Recovery days

Run Resilience

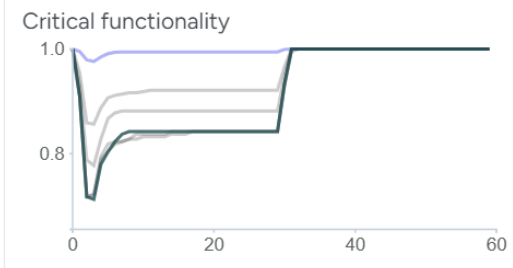
Results

Scenario: Chile no switch

Relative to: Baseline

Resilience 0.84

Robustness 0.71



Worst damaged (0: Full damage, 1: No damage)

Trafigura Chile Ltda	0.000
Cembrass S A	0.000
Codelco Chile	0.000
Sociedad Contractual Minera El Abra	0.000
Corporacion Nacional Del Cobre De Chil...	0.000

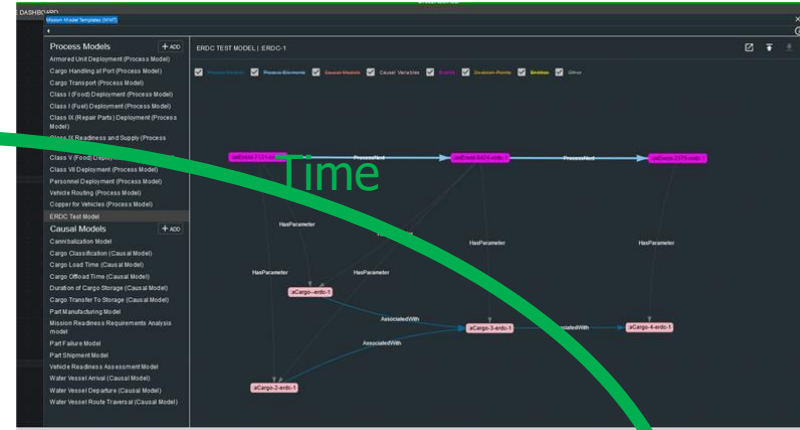
Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)



Shock integration

Forward stress testing with applied process models

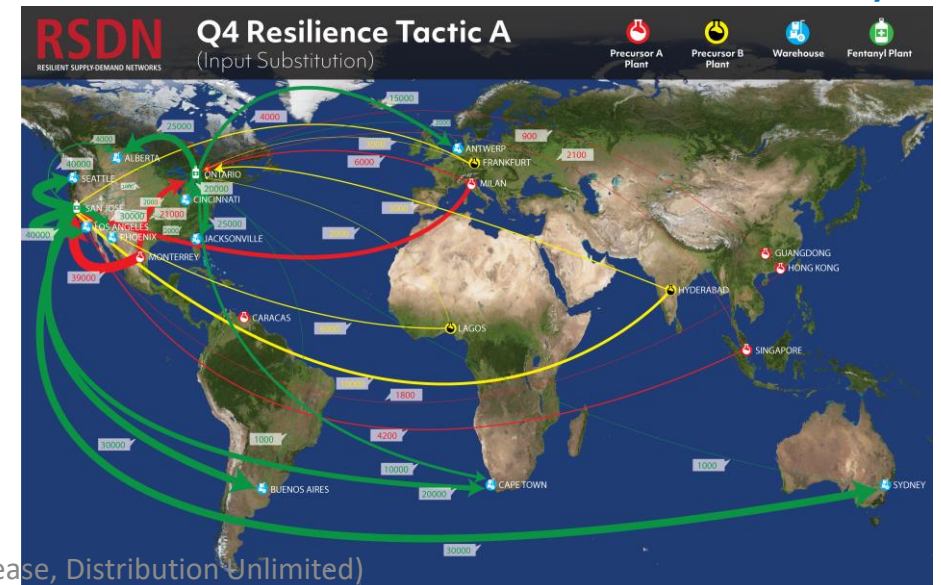
Begin state



Processes carried out over time



End state with history



- Simulations:
 - Move the SDN in time
 - Estimate state values
 - Apply impacts of process models
- Resulting state graphs
 - Are analyzed independently and in groups



B. Understand and act

FINANCE baseline approach:

- Portfolio rebalancing and optimization
 - What-if portfolio compositions
 - Trade-offs: optimal return, level of risk, minimize exposure to unwanted factors, etc.

SUPPLY CHAIN approach:

- Rerun tests in various configurations
- Model counterfactual outcomes and compare them
- Suggestions and mitigation strategies

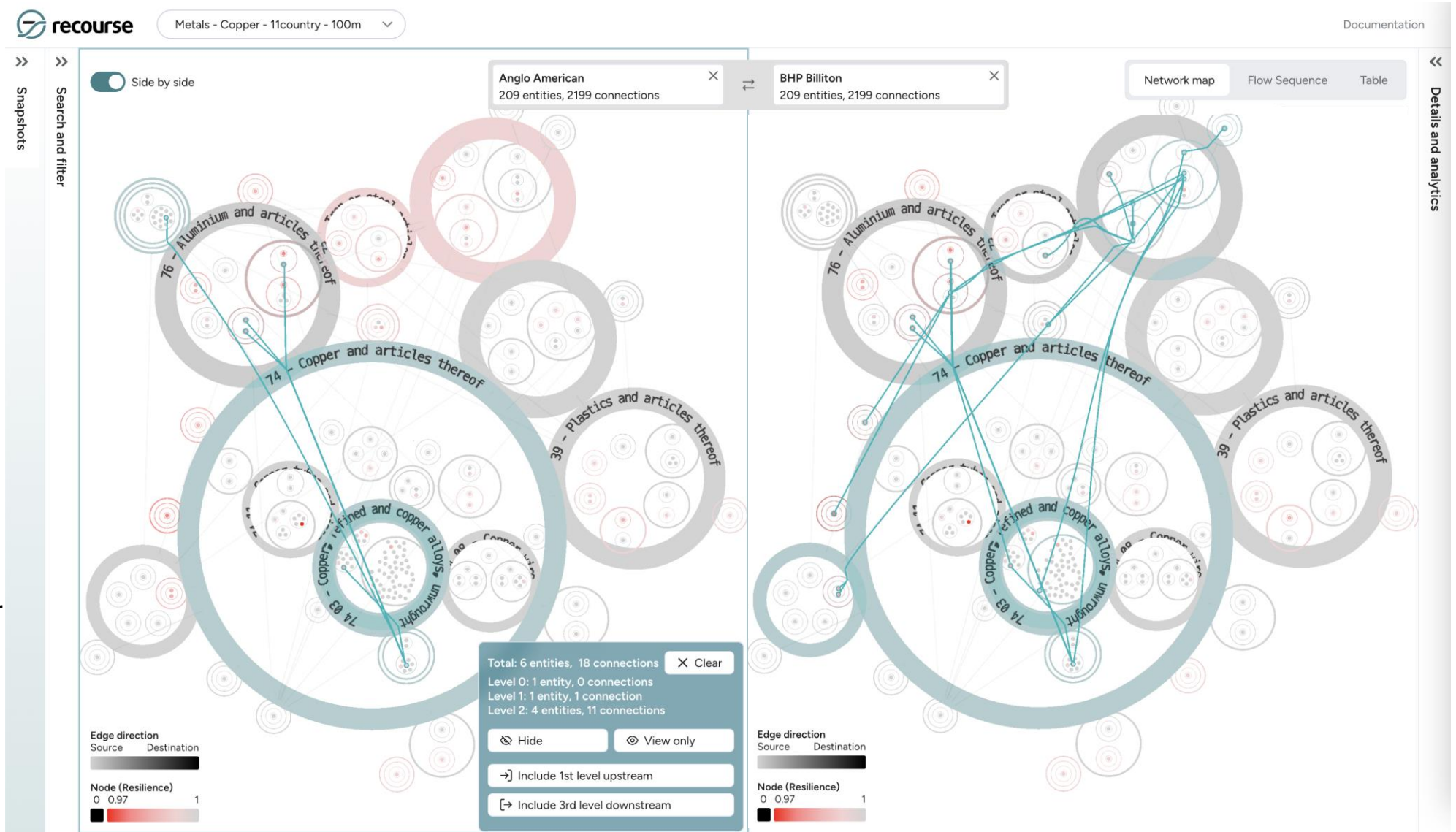


Comparing alternatives

Given multiple possibilities, what's the difference? How can I use this to make a choice between those possibilities?

E.g., choice between 2 suppliers

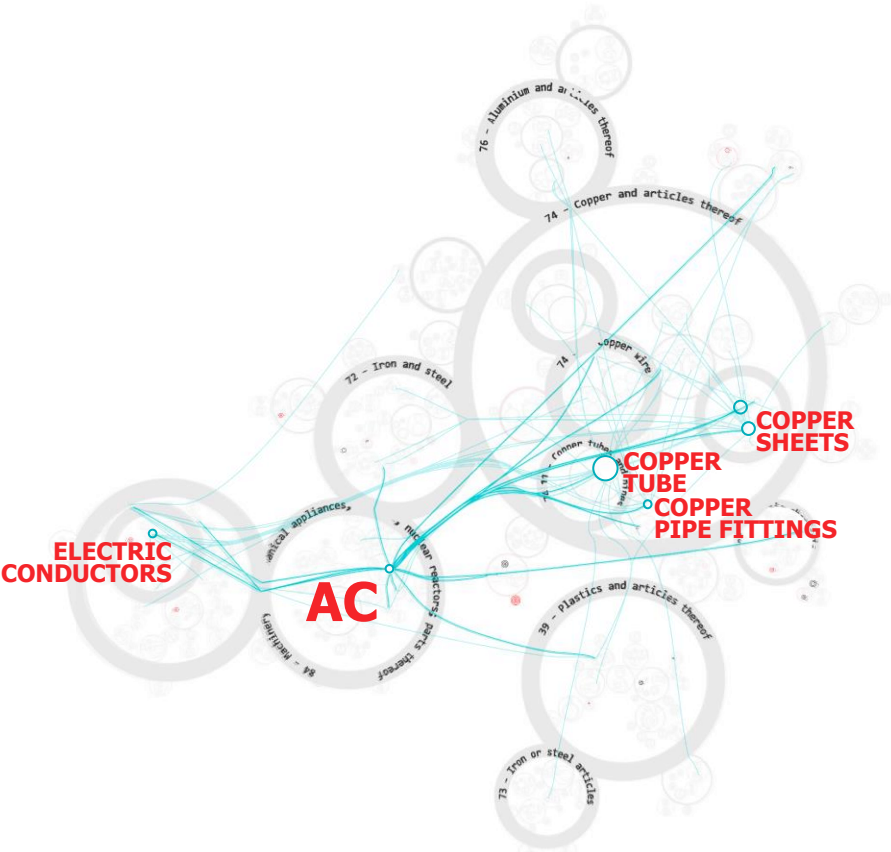
E.g., choice between tariff on companies A or tariff on companies B
Zoom out for other possible suppliers
Zoom out further for possible raw materials (and self process)



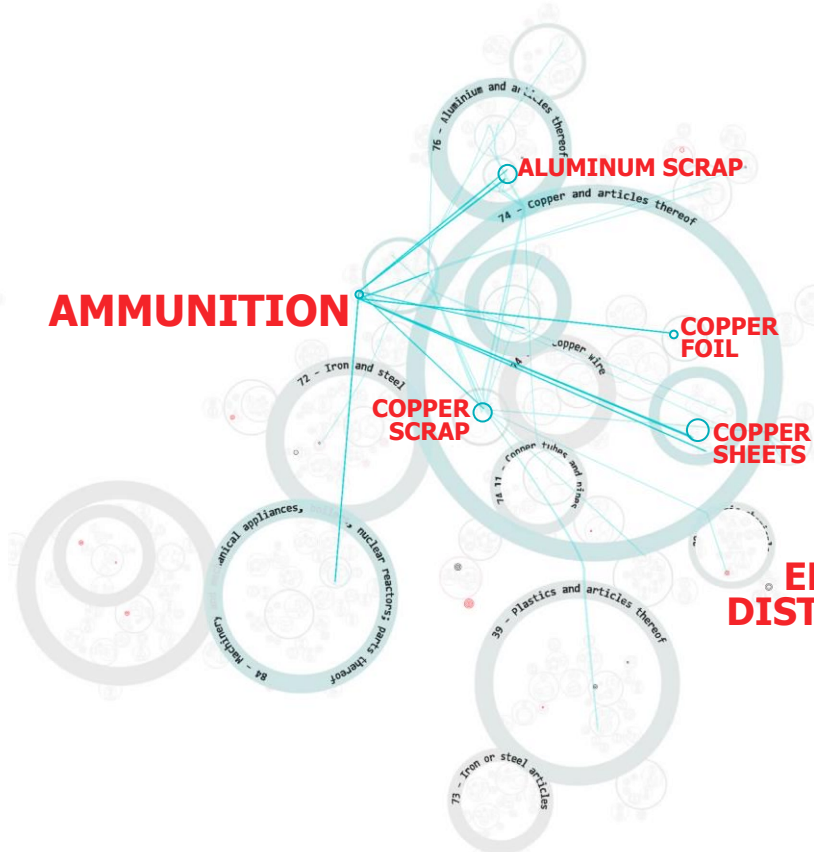
Visualization: Uncharted Software. Data source includes S&P Global Market Intelligence, see [disclaimer](#)



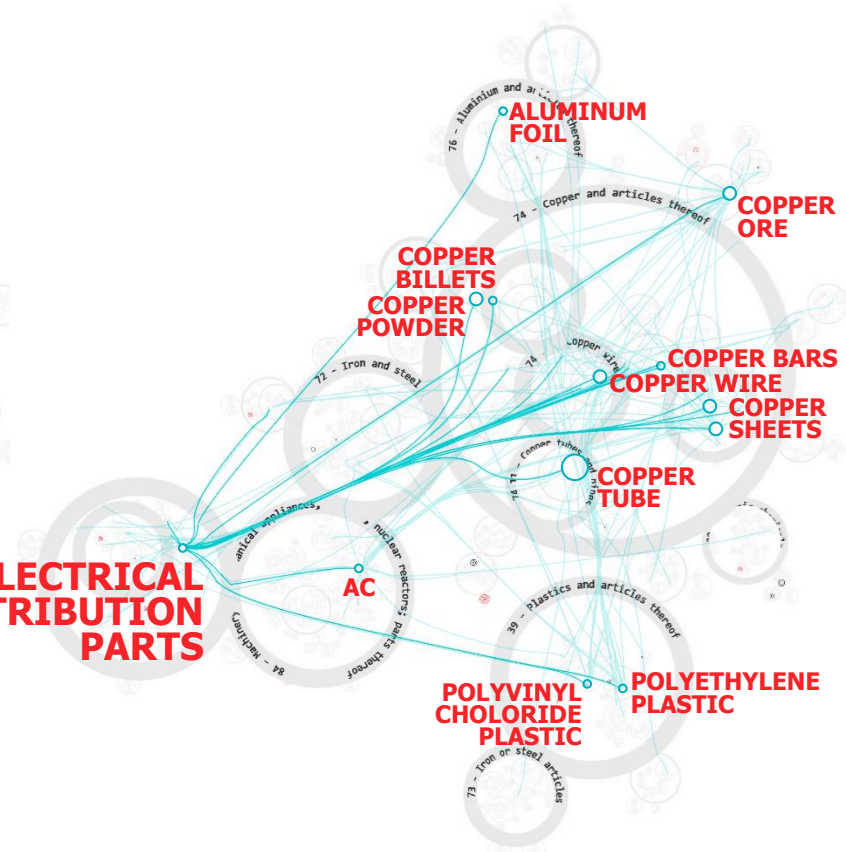
Compare upstream to see shared dependencies



**Air conditioners
+ 2 levels upstream**



**Ammunition
+ 2 levels upstream
*connects to different parts
competes for copper sheets***



**Electrical Distribution Parts
+ 2 levels upstream
*similar to AC but bigger***

→ **Connectivity exploration:** subsets of SDNs, different, similar, overlapping



Resilience Tactics*

Resilience Tactic	Definition (Activities Involved)
Conservation	Maintaining intended production using lower amounts of an input or inputs
Resource Isolation	Modifying a portion of business operations to run without a critical input
Input Substitution	Replacing a production input in short supply with another input
Inventories	Continuing business operations using emergency and ordinary stockpiles
Excess Capacity	Using idle plant or equipment in place of a damaged ones
Relocation	Moving some or all of the business activity to a new location or telework
Mgt Effectiveness	Improving the efficiency of business operations in the aftermath of a disaster
Import Substitution	Importing needed production inputs when not available from local suppliers
Technological Change	Improvising the production process without requiring a major investment
Resource Pooling/	Recontracting, selective exchange of resources, creating new partnerships
Production Recapture	Making up for lost production later by working overtime or extra shifts

*Dormady, N. C., Rose, A., Roa-Henriquez, A., and Morin, C. B., The cost-effectiveness of economic resilience, International Journal of Production Economics, Volume 244, 2022, 108371, ISSN 0925-5273.

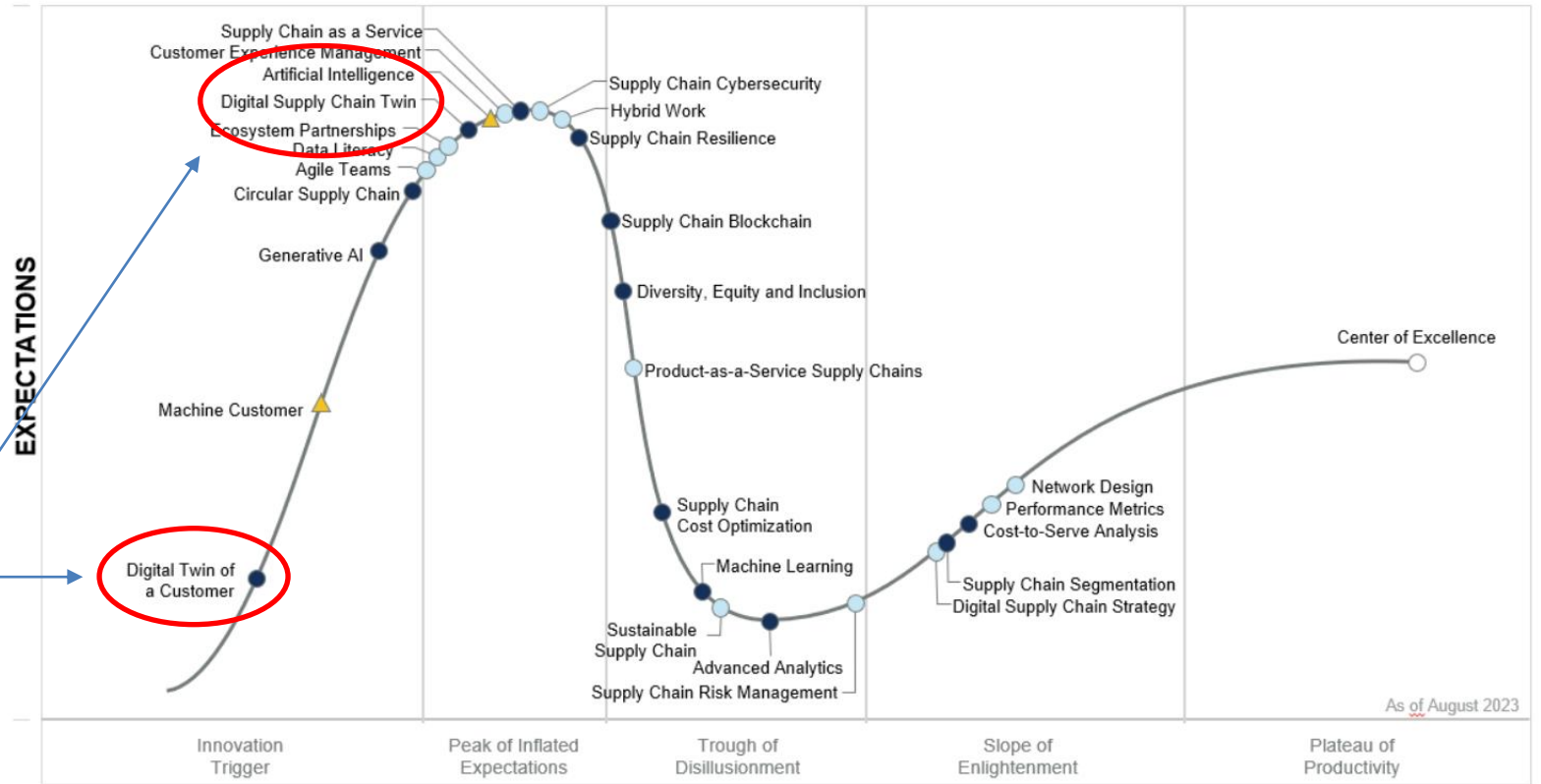


A&B. Prepared for gray rhinos

According to industry analyst Gartner Group:

- digital twin of 1-tier is 5-10 years away
- **we're at early digital twin ±2-3 tiers in 2-3 years**

Hype Cycle for Supply Chain Strategy, 2023



Source: Gartner (August 2023)

793419

<https://www.gartner.com/en/supply-chain/insights/power-of-the-profession-blog/hype-cycle-season-the-most-wonderful-time-of-the-year>



C. Real data challenges

FINANCE baseline:

No complete dataset, but huge banks

- Retail banking: loans, cards, mortgages
- Payment transactions
- Commercial banking
- Capital markets
- Commercial datasets
 - e.g., every mortgage and its performance in a collateralized mortgage-backed security
 - e.g., all the public company holdings by Fidelity as of last month

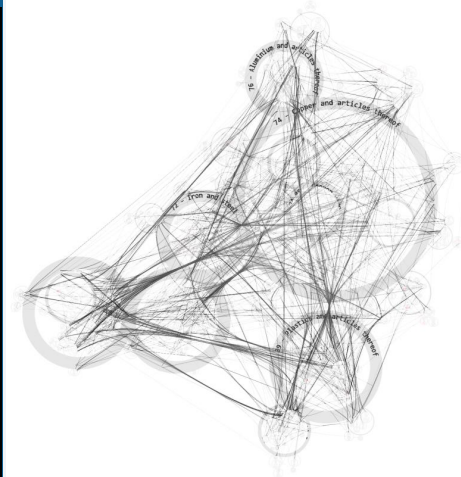
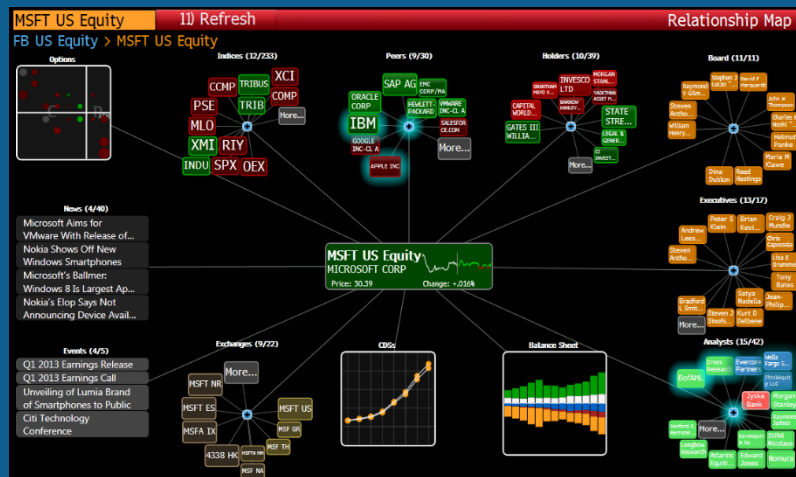
SUPPLY CHAIN:

No complete dataset, and no hubs

- Companies/government only see 1 tier
- Bloomberg SC only 100k (public) companies
- D&B Worldbase 150m businesses (but no connections)
- S&P Bill-of-lading 2bn shipments (but only 11 countries)
- DHL 6% marketshare of logistics, but no licensed data
- MSC Shipping 20% marine marketshare, but no data
- Powerful in imputation, enrichment, and analytics

Where data are missing, **estimate**

Where data are too vast, **aggregate fringe details**



“It is not practical for any single firm to unilaterally take on the mantle of exploring its complete upstream supply chain.”
 – Gaur et al, Harvard Business Review, 2023



Real bill-of-lading data augmentation

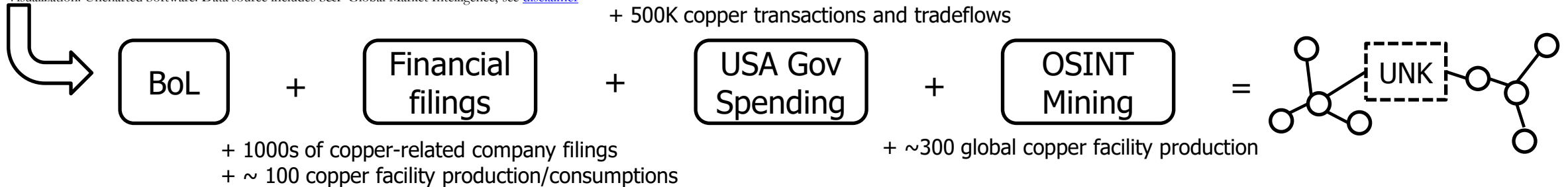
2b customs bill-of-lading (BoL) documents, 2m companies, 11 countries:

Edge Type	Source Node ID	Source Node Country	Source Node Name	Target Node ID	Target Node Country	Target Node Name	Description	HS Code	Timeseries (Year)	Timeseries (Month)
shipment	28429359	germany	festo corporation	44445587	mexico	fluidica sa cv	mangueras de plastico;	39173999		
shipment	28429359	germany	festo corporation	44445587	mexico	fluidica sa cv	regulador de presion;	84101201		
shipment	28429359	germany	festo corporation	44445587	mexico	fluidica sa cv	partes para filtro;	84219999		
shipment	28429359	germany	festo corporation	44445587	mexico	fluidica sa cv	magnetos;	85112003		
shipment	32779969	united states	kksp precision machining llc	45990889	mexico	multi turn precision industries s de rl de cv	desperdicio de rebaba de aluminio	76020002		

Each row indicates all the shipments for one type of good between two companies over time

Real-world behavioral characteristics of commodity over time: volume, frequency, trend, anomalies. e.g., Festo corp is shipping to Fluidica SA a lot of *partes para filtro* regularly

Visualization: Uncharted Software. Data source includes S&P Global Market Intelligence, see [disclaimer](#)

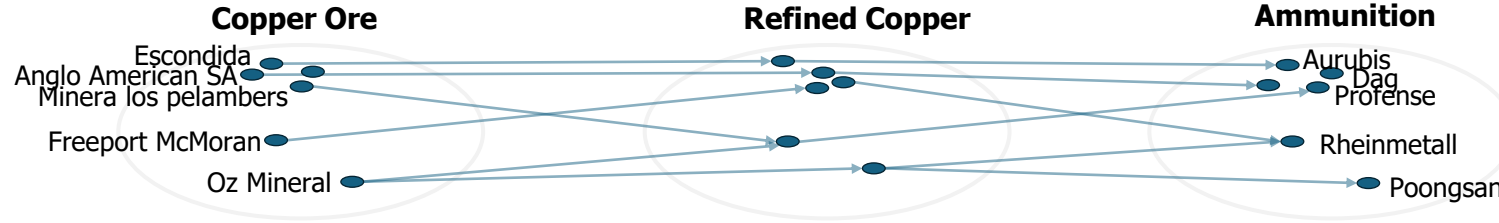


Pure data wrangling is insufficient – capturing only ~20% of inter-national trade, misses entirely intra-company, and intra-national trade...



We are building multi-source multi-tier networks

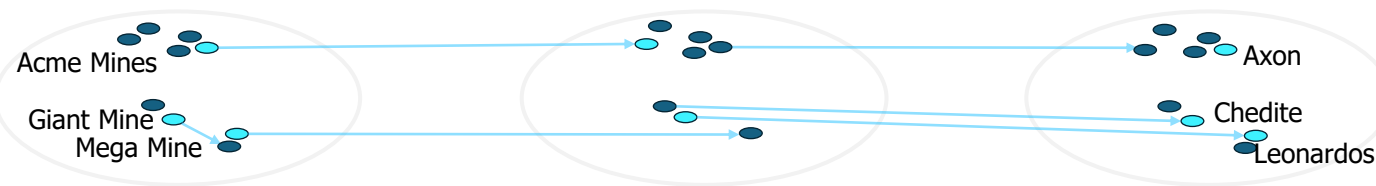
1. Bill-of-lading data for base network



Much progress. Big data challenges.

2. Add data

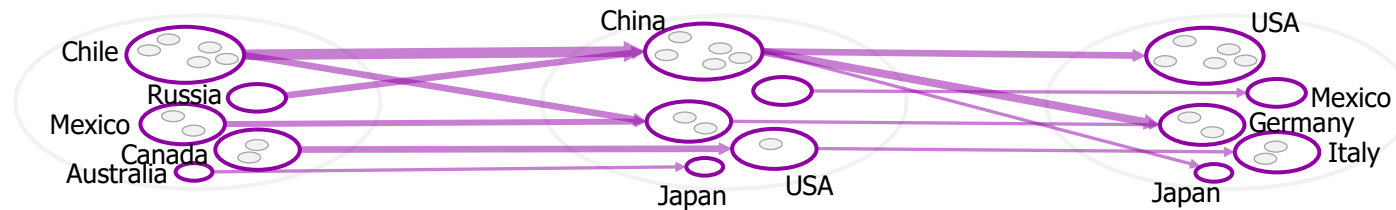
e.g., USAspending.gov, public company filings, OSINT mining & align entities



Much progress. Many possible sources.

3. Add global models

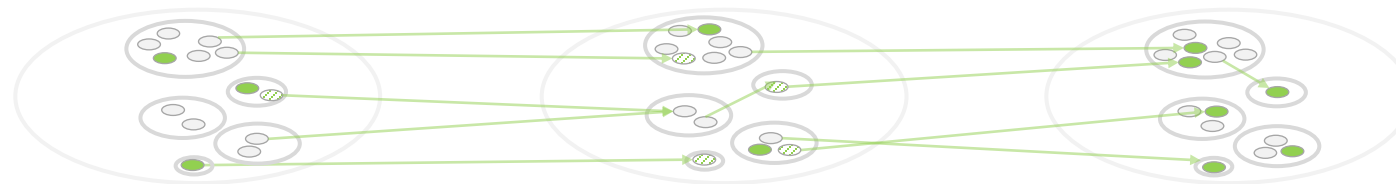
e.g., CGE, global trade



In progress, multi-level integration tbd.

4. Fill in entities and connections

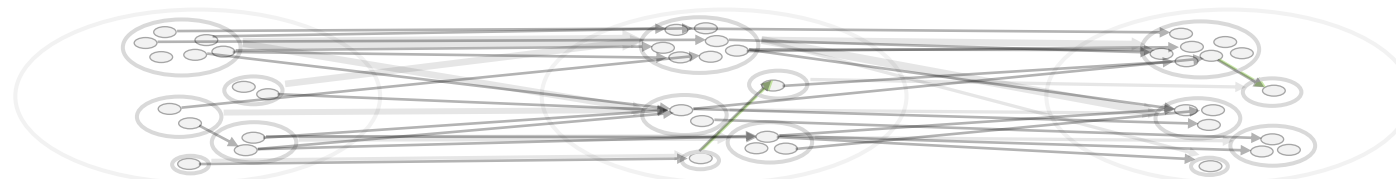
- a. Imputation models (cost flow inference)
- b. Future data sources



Future data opportunities.

5. Result

Detailed, extensible, updatable supply/demand network



Integration in progress.



Multi-tier SDNs are big

A. Example analysis of customs data

"Copper" extraction with at least one tariff code >	Number of companies*	Number of timeseries connections†	Avg connections per company
\$100m	209	2199	21.0
\$10m	1416	35,686	50.4
\$5m	2706	75,884	56.1
\$1m	9522	310,130	65.1
\$500k	16,266	530,613	65.3
\$100k	32,471	1,294,388	79.7
\$0 and >5tx	127,659	7,427,916	58.2

- Tariff-codes: each bill-of-lading has a tariff code, e.g., 2603 copper ore, 7404 copper wire
- Extract: we extract a base-SDN from this data starting with one or more tariff codes (e.g., all tariff codes that include the word "copper" or "ammunition") and extract +/- 3 levels of connections/
- Threshold: A company acquires almost everything (e.g., from big machines down to staples), so we filter the SDN to only include a relationship that matches a value threshold (total within a tariff code).

* Companies:

- Most logistics companies are removed (a logistics company transports every possible good and causes the network to expand to non-related industries)
- Companies are based on IDs in the documents. Duplicates may occur with misspellings, translations, variations in company address, etc.
- Many tasks to do: exports in addition to imports, deduplication of facilities, consolidation of related descriptions, etc.

† Timeseries:

- A timeseries between a company pair is a tariff-code that has been shipped between those companies 1 or more times.
- 2017-2022

B. TST and others enrich the data

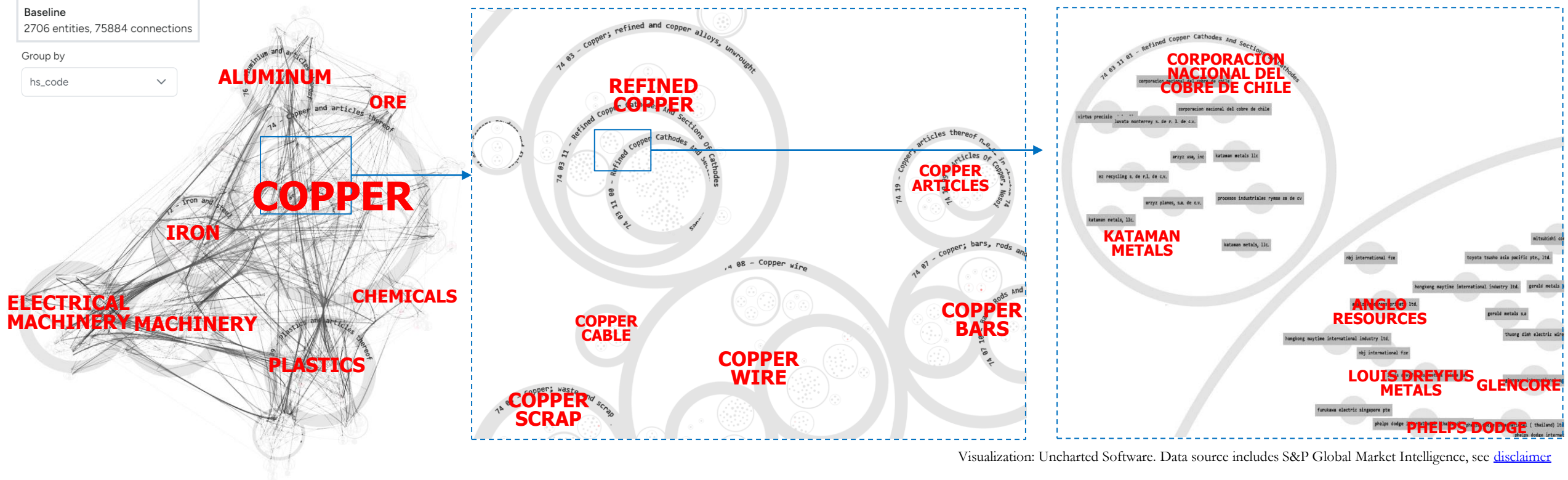
1. USA federal spending for prime and subcontractors
 - 500K transactions and trade flow from 2017-2022
 - NAICS: 212230, 331410, 332992
2. EDGAR SEC filings with various copper commodity keywords and NAICS codes
 - Annual and quarterly filings for 10 years
 - > 10,000 filings for over 100 relevant companies
3. OSINT copper mining database
 - ~100 global entities and ~ 300 facilities
4. Entity alignment data from GLEIF
5. Economic flow inference to infer edge existence and flow



SDN map sectors down to company

Baseline
2706 entities, 75884 connections

Group by
hs_code



Visualization: Uncharted Software. Data source includes S&P Global Market Intelligence, see [disclaimer](#)

rings are industries
connections are flow of goods with grouping
dots are companies sized by value

→ **visual inspection:**
 expected industries, expected companies,
 unexpected companies, data errors



D. Challenges of Systemic Risk

FINANCE baseline:

- Variety of **risks** which could cause a loss
 - Market, credit, settlement, liquidity, operational, cyber, legal, etc.,
- But **systemic** risk is different
 - Company event which has ripple effect and causes collapse of financial industry
 - “Too big to fail”: large with respect to their industry
e.g., Archegos, Credit Suisse
 - “Too connected to fail”: highly interconnected
e.g., Internet DNS

SUPPLY CHAIN:

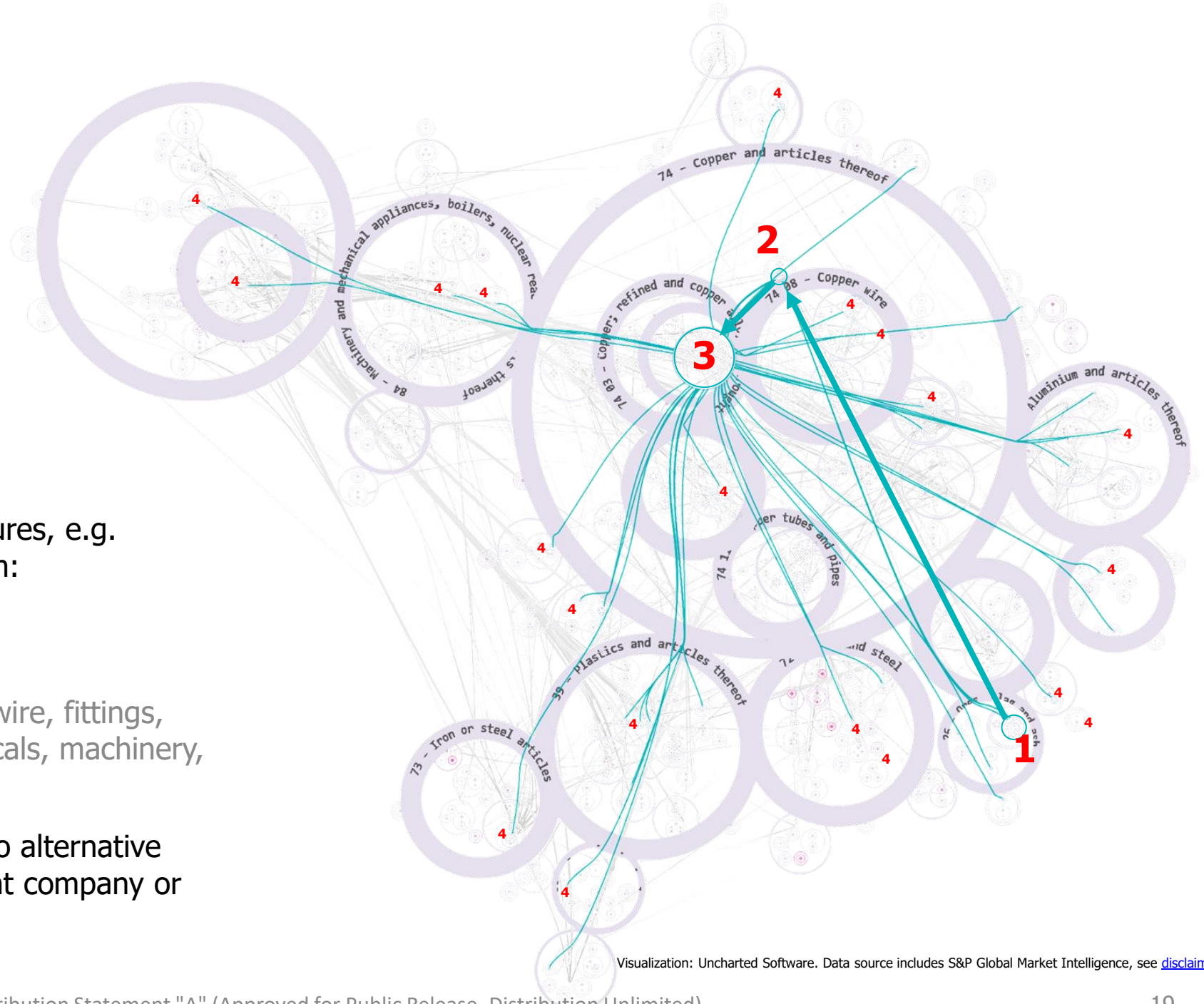
- Variety of **risks** which could cause impact
 - 120 DoD SC risk factors: political, cyber, legal, etc.
 - Like finance risk, but there’s even more
- But **systemic** risk even more complex
 - Same idea of ripple effect, but more exposures:
 - Financial: cashflow, bankruptcy, currency and commodity prices
 - Topology: more connection types, contracts, shipments, litigation
 - Physical: material shortage, etc.
 - Environmental: weather, earthquake, etc.
 - Geopolitical: sanctions, embargo, conflict
 - Labor: strike, unrest
 - Crime: piracy, cyber-theft

Systemic industry risk: narrow chain and big hub

Reveal network connections and structures, e.g. interactive points and click follow a path:

- 1 Copper ore
- 2 Unrefined copper
- 3 Refined copper
- 4 Many things downstream after that: wire, fittings, transformers, alloys, inorganic chemicals, machinery, ammunition

Narrow chain potential weakness if no alternative
Big hub potential weakness if dominant company or country

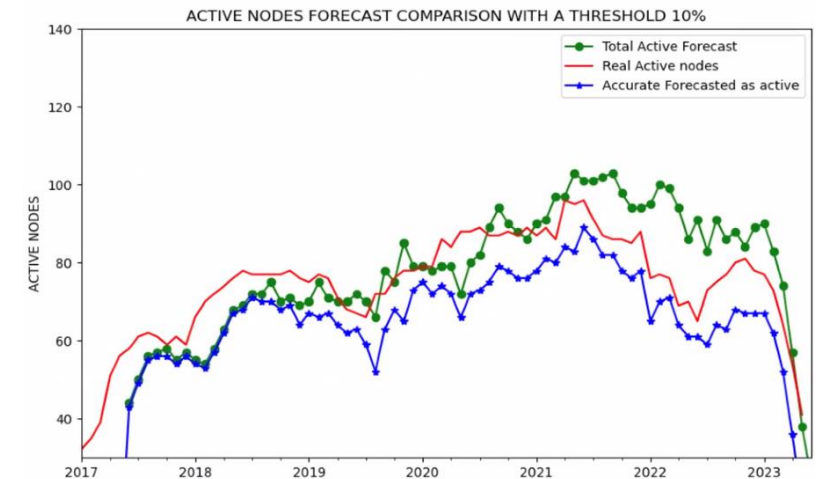
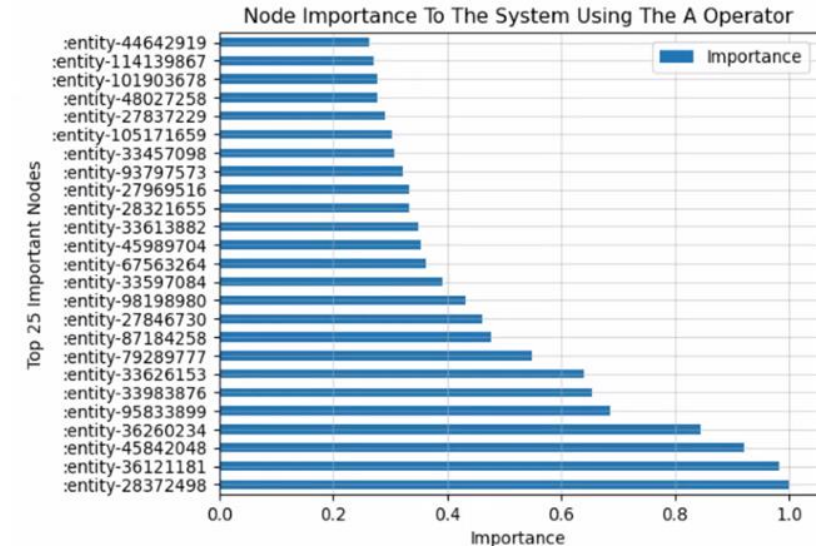
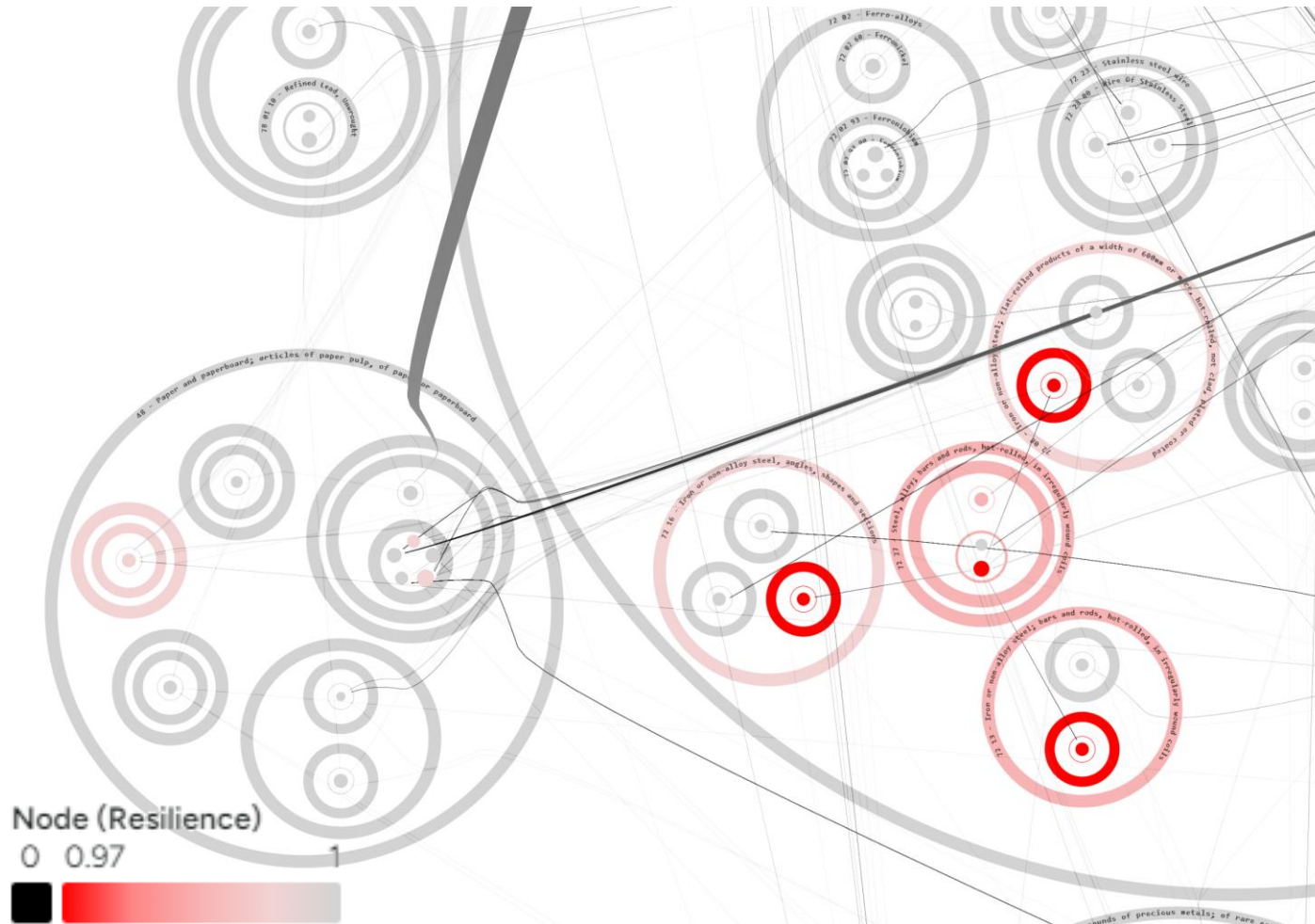


Visualization: Uncharted Software. Data source includes S&P Global Market Intelligence, see [disclaimer](#)



Quantify weak links, show weak pockets

Models traverse the network to find weak links, and aggregate local areas of weakness



Visualization: Uncharted Software. Data source includes S&P Global Market Intelligence, see [disclaimer](#)



So what?

FINANCE baseline:

- Reduced systemic risk
 - Archegos > Credit Suisse failure did not spread
 - Build a better portfolio
- More informed responses
 - 2008 was systemic but was contained
 - Stressed companies can be merger opportunities
- Resource utilization for monitoring and trading
 - Focus on the biggest exposures and connections

SUPPLY CHAIN:

- Reduce my exposure to systemic risk
 - Awareness of weak/susceptible areas in my SDNs
- Informed preparedness, systemic resilience
 - Proactive SDN strengthening
 - Timely answers to global concerns of the day
- Deploy resources for monitoring and purchasing
 - Know whom to monitor
 - Anticipate demand effects



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