



System Shock Framework: Resilient International Supply Chains

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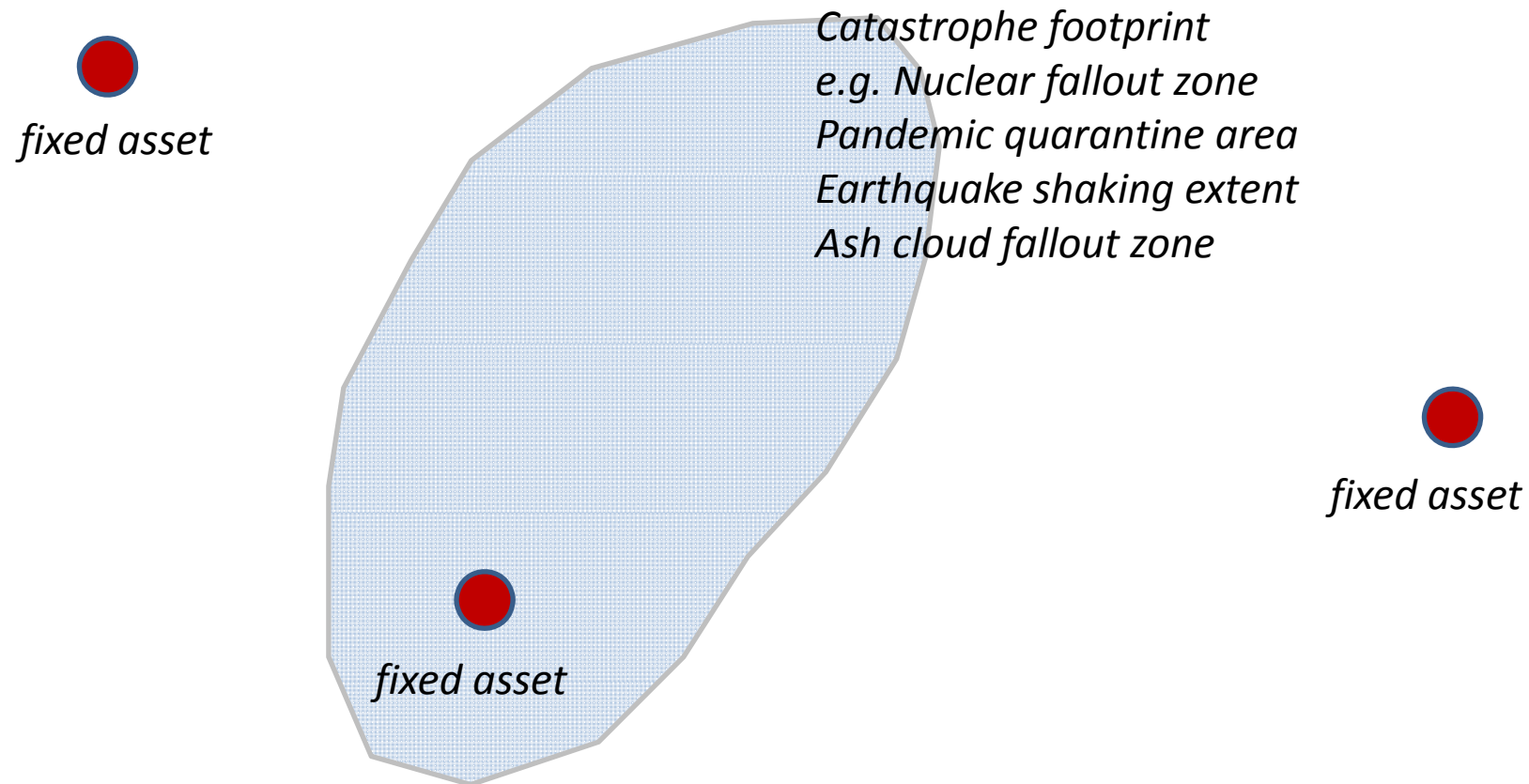


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System Shock framework: data structure

Impact of catastrophic event on network

Risk map

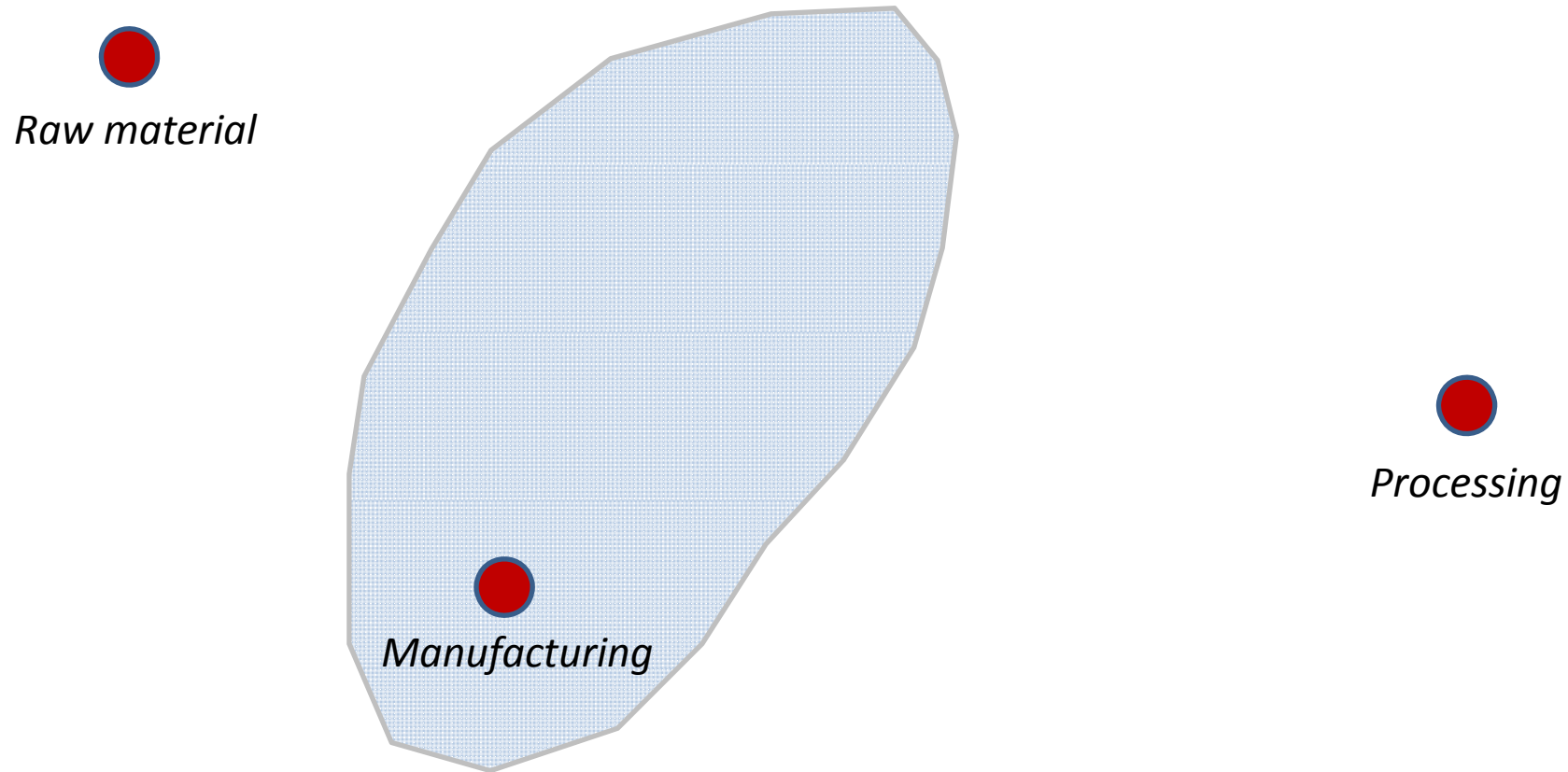


System Shock framework: data structure

Impact of catastrophic event on network

Risk map

Business processes



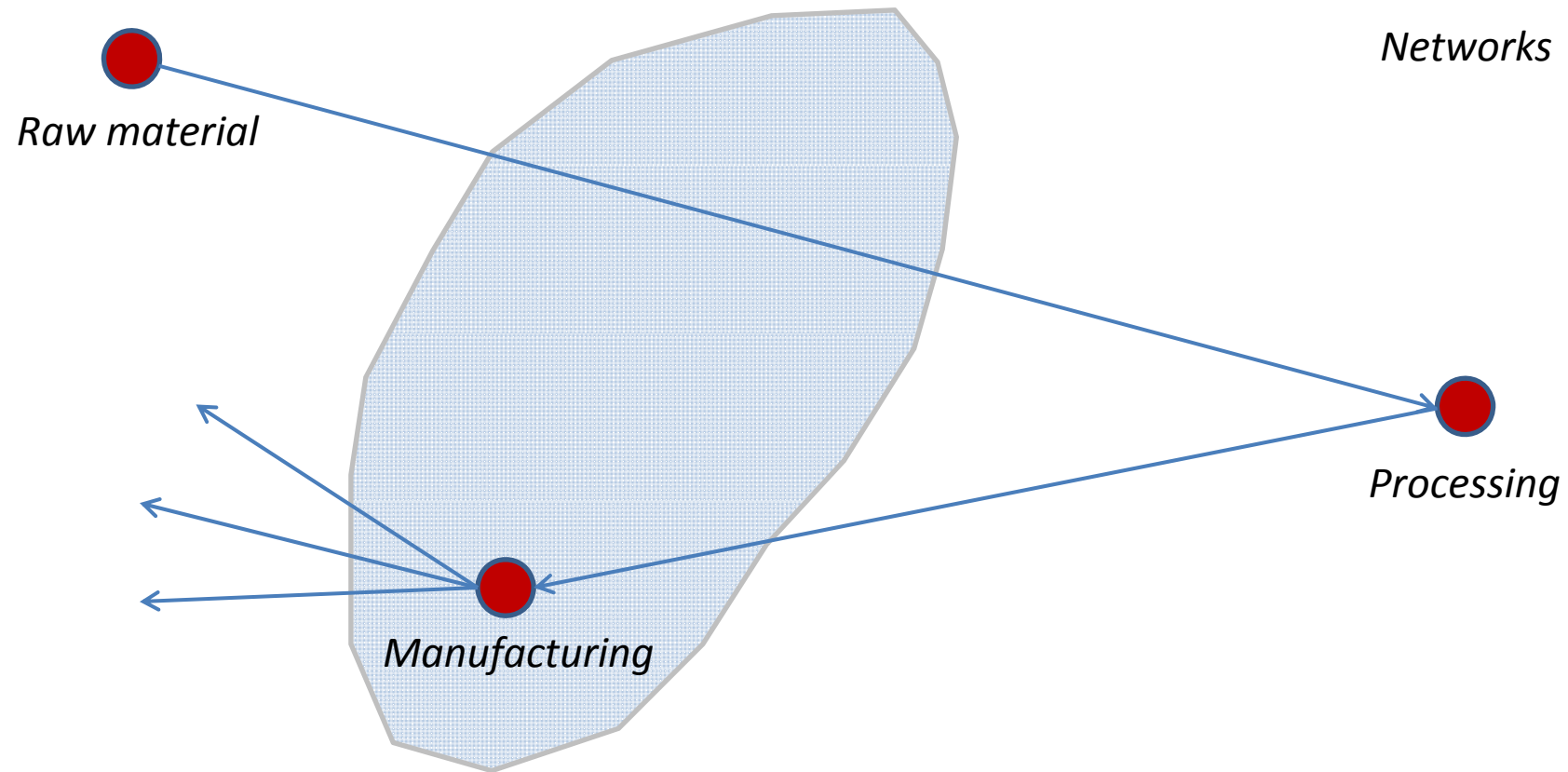
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Networks



System Shock framework: data structure

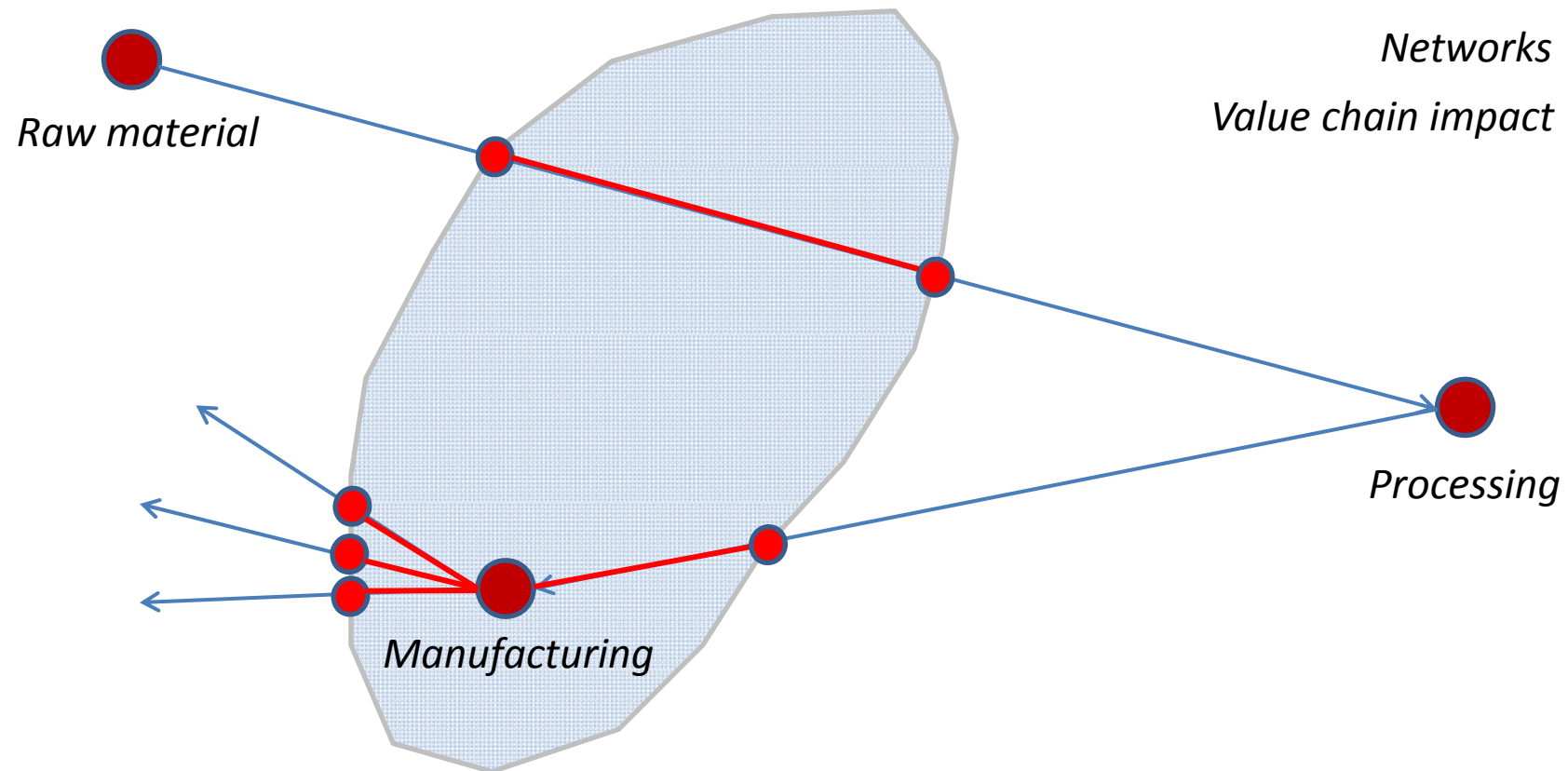
Impact of catastrophic event on network

Risk map

Business processes

Networks

Value chain impact



System Shock framework: data structure

- Scenarios
- Vulnerability regions
- Context geography
- Primary physical networks
- Networked assets at risk

System Shock Taxonomy

*Countries, cities, currency zones,
economic zones, political geography*

*Transportation, energy,
communications*

*Supply chains, logistical, financial,
social, economic, knowledge &
environmental networks*

System Shock framework: Audience

The primary audience for the System Shock framework

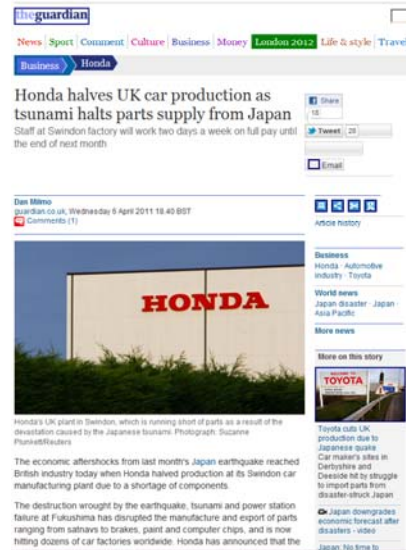
- Banks
- Government
- Corporate

Resilient International Supply Chains

The Centre plans to focus first on Corporate where risk to and resilience of supply chains is of great importance. Sectors to study first include:

- Automotive
- Pharmaceutical
- Consumer electronics

2011 Tōhoku: supply chain disruption and business impact



"Sony's production and sales were severely affected by the earthquake and tsunami in Japan in March last year."

The twin disasters resulted in supply chain disruptions and a shortage in power supply in Japan, forcing Sony to curtail production.

Its fortunes were hurt further by floods in Thailand later in the year, which saw its factories in the country being affected."

Case Study



- Fictional U.S. consumer electronics company
- 9th largest international player in computer hardware
- Sells its products in 75 countries worldwide
- Produces over 10 million laptops a year
- The **Pomegranate Y-Perform** Laptop is their flagship product range

Laptop Supply Chain

Raw Materials Inventory

44 Different Types of Raw Materials

Aluminium	Copper	Mercury	Silicon
Antimony	Europium	Nickel	Silver
Arsenic	Ferrite	Niobium	Stainless steel
Barium	Gallium	Palladium	Steel
Beryllium	Germanium	Petroleum	Tantalum
Bismuth	Gold	Phosphorus	Terbium
Boron	Indium	Platinum	Tin
Bromine	Lead	Refined Gallium	Titanium
Cadmium	Lithium	Rhodium	Vanadium
Chromium	Magnesium	Ruthenium	Yttrium
Cobalt	Manganese	Selenium	Zinc

From 27 Different Countries

Argentina	Japan
Australia	Kazakhstan
Belgium	Malaysia
Brazil	Mexico
Canada	Namibia
Chile	Nigeria
China	Norway
Columbia	Peru
DR Congo	Russia
Egypt	Saudi Arabia
Ethiopia	South Africa
France	Sudan
Israel	Ukraine
	USA
	(27)

Taken from Laptop Supply Chain assembly process documented in Bonanni et al (2010): which focuses on raw materials and High Value Manufacturing (HVM)

Laptop Supply Chain

Raw Materials Source Map



Silicon: Silicon mining by Elkem Bremanger Norway



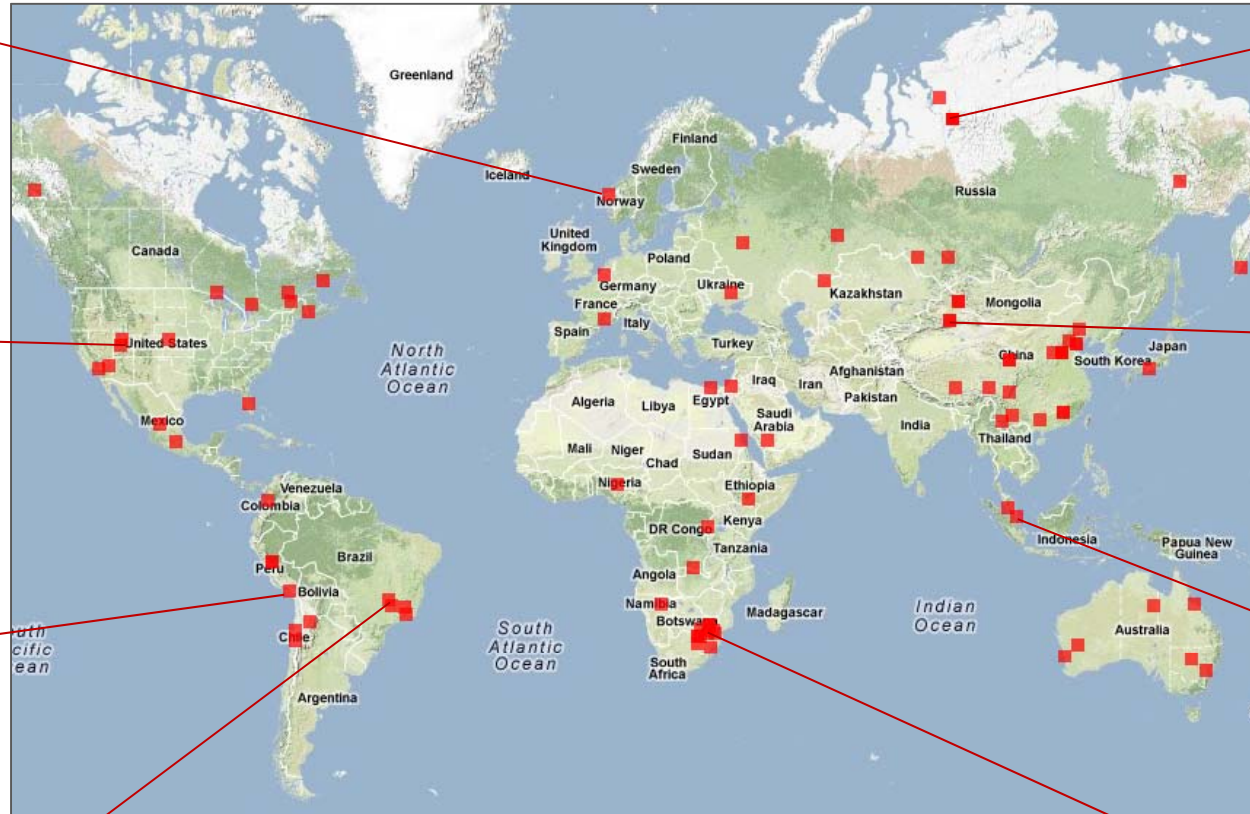
Copper: Bingham Canyon copper mine USA



Lithium: Lithium mining Bolivia



Tantalum: Companhia Industrial Fluminense's Mibra tantalum mine in Brazil.



Nickel: Norilsk Nickel Polar Division



Aluminium: Chinalco mining base in Lhokha county, Tibet



Petroleum: Jurong Island refinery Singapore



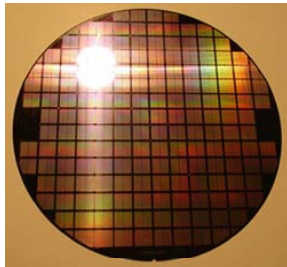
Gold: Gold mining South Africa

Laptop supply chain: Manufacturing

Silicon processing



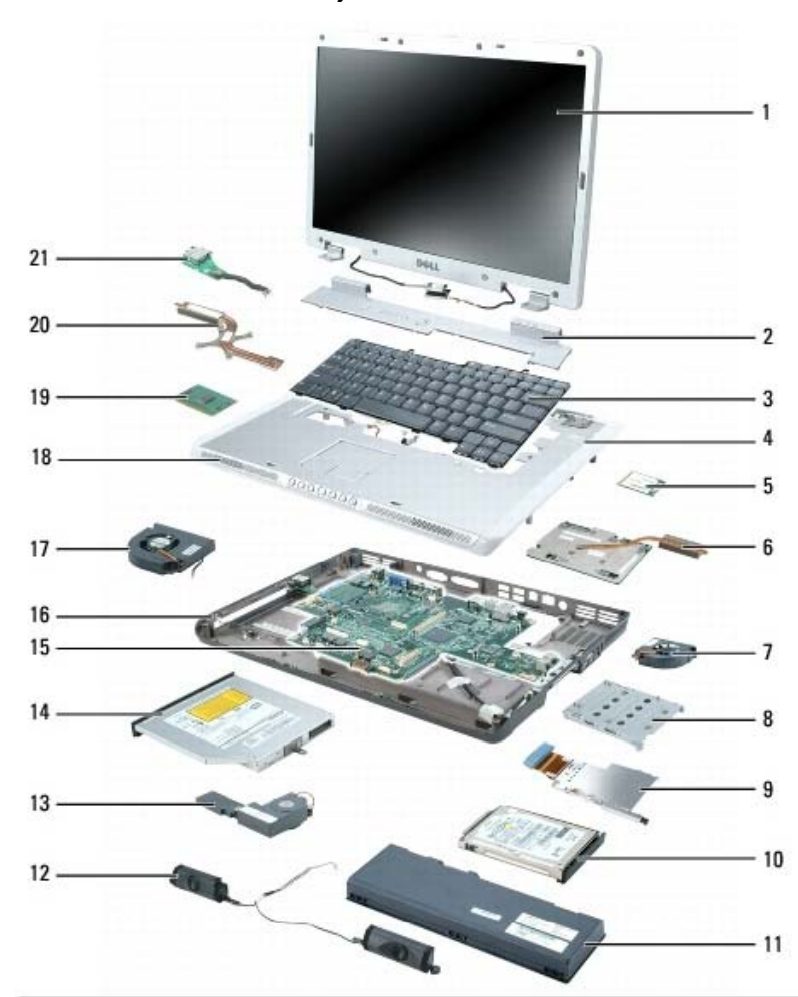
Wafer fabrication



Chip assembly



Module assembly

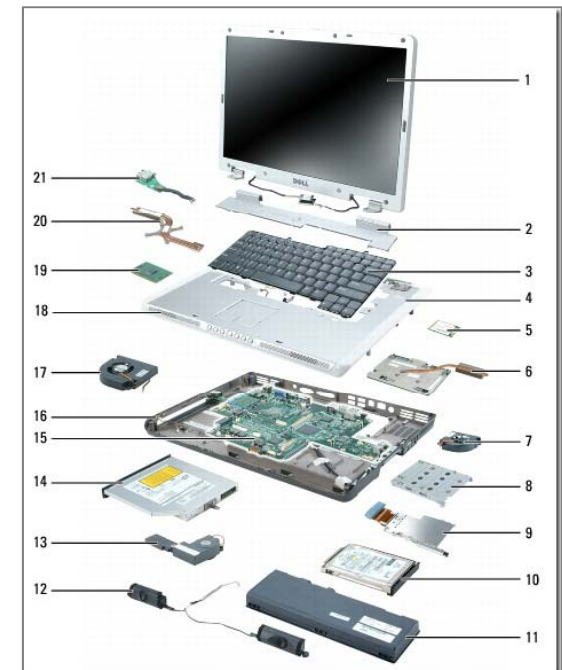


Laptop Supply Chain

Component Manufacture



- ⚡ Battery Assembly
- ◆ Chip Assembly
- ★ Final Assembly
- LCD Screen Manufacture
- ▲ Plastics Processing
- Silicon Processing
- Silicon Purification
- ≡ Wafer Fabrication



Laptop Supply Chain Final Assembly

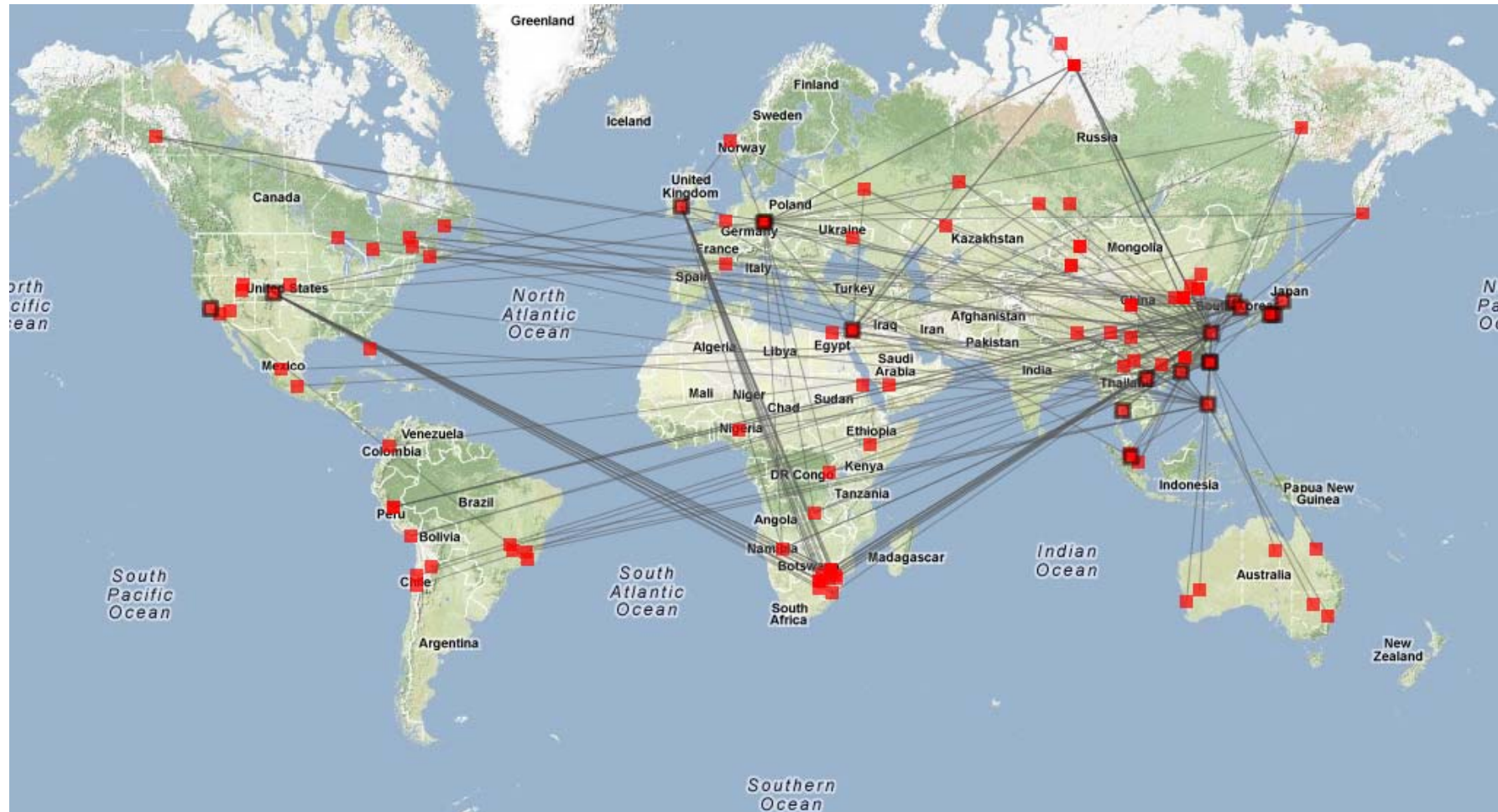


*Quanta Shanghai
Manufacturing City, Songjiang
Export Processing Zone (EPZ),
Shanghai*

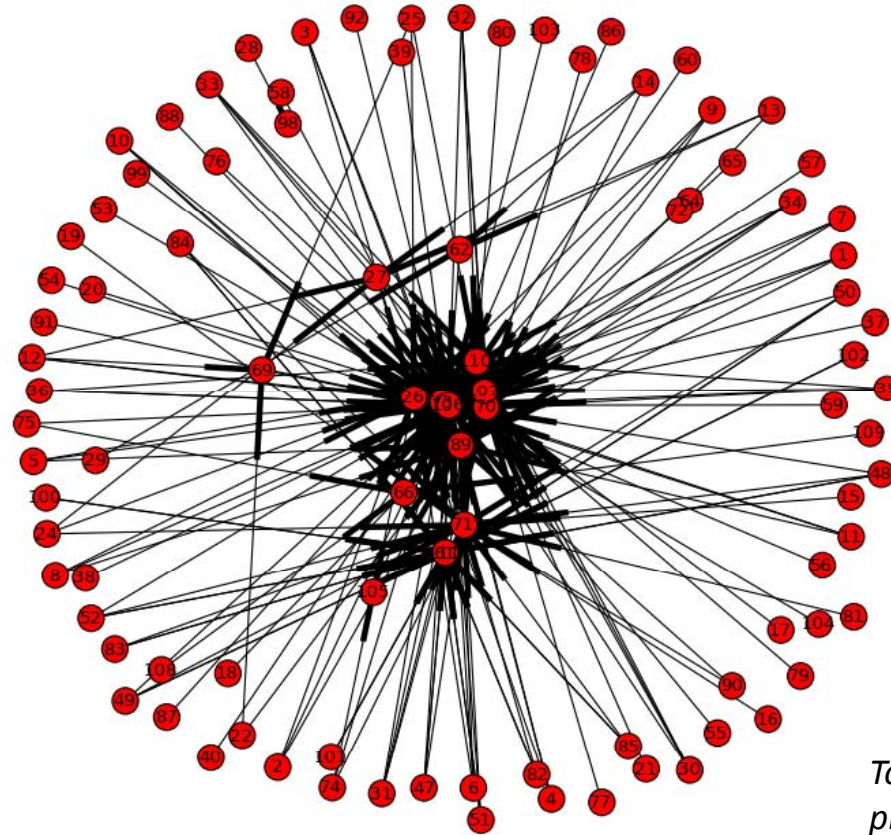
*In 2011, 89.54 million laptops were
produced in Shanghai*
Global and China Laptop and Tablet PC Industry Report, 2011-2012



Laptop supply chain: Geographical



Laptop supply chain: Topological



*Topological representation
produced by NetworkX
graph analytic software*

Laptop Supply Chain Distribution network



Resilient International Supply Chains

Data Structure

1. Location-based
 - Tied to geographical coordinates of a place
2. Graph attributes
 - Nodes and edge relationships captured (topology of the network)
3. Structure
 - A value-adding business function at that location
 - Inputs: 'Upstream' dependencies – where the suppliers are for that function
 - Outputs: Where the production goes to
4. Linkage Type
 - Transport assumptions (air freight, marine cargo)
5. Time Based*
 - Volume of each raw material needed per unit output
 - Outputs: Volumes and capacity of output per unit time
 - Other dependencies such as business information such as orders and control data, operational requisites such as utilities, power, labor force etc.)
 - Stockpile and inventory status

* More quantitative detail needed from subject matter experts

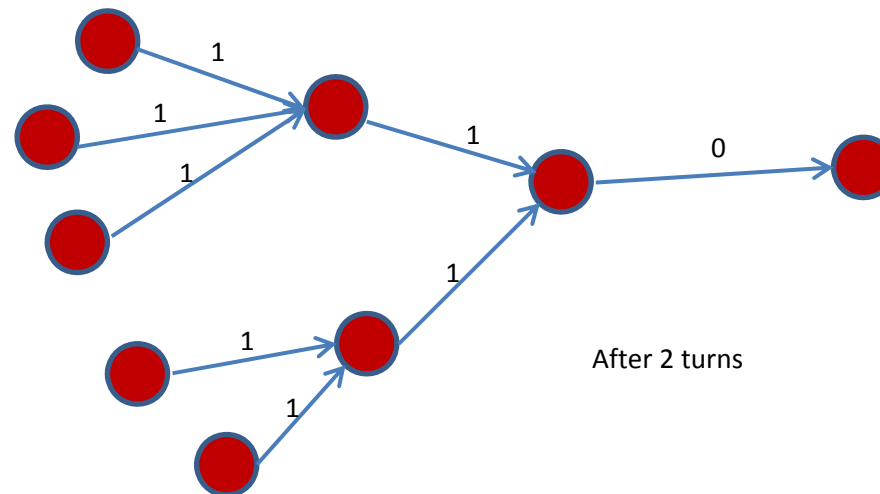
Data Architecture – Example

Edit Data - SQ (www.systemquake.com:5432) - oilnetwork - laptopnode									
File Edit View Tools Help									
No limit									
	id [PK]	location character varying(255)	country character varying	place character varying(255)	organisation character varying(255)	type chara	activity character varying(255)	url character varying(255)	the_geom geometry
10	10	POINT(29.10205 -25.87960)	South Africa	Highveldt	Highveldt Steel & Vandium Mill	R	Vanadium	www.mbendi.com	0101000020E
11	11	POINT(29.45000 -23.90000)	South Africa	Polokwane	Everest North	R	Rhodium	http://en.wikipedia.org/wiki/Rhodium	0101000020E
12	12	POINT(17.866667 -19.25)	Namibia	Tsumeb	Tsumeb	R	Germanium	http://en.wikipedia.org/wiki/Tsumeb	0101000020E
13	13	POINT(25.50819 -10.70919)	DR Congo	Kolwezi		R	Cobalt	www.mbendi.com	0101000020E
14	14	POINT(29.141 -0.987)	DR Congo	Lueshe		R	Niobium	http://en.wikipedia.org/wiki/Coltan	0101000020E
15	15	POINT(-46.940965 -19.594001)	Brazil	Araxá	Companhia Brasileira de Metalurgia	R	Niobium	http://tanb.org/niobium	0101000020E
16	16	POINT(-47.944893 -18.1612)	Brazil	Catalão	Mineração Catalão de Goias	R	Niobium	http://tanb.org/niobium	0101000020E
17	17	POINT(7.2127778 9.0963889)	Nigeria	Zuba		R	Niobium	http://africa.infomine.com/properties/exchange/c157m36/nigeri	0101000020E
18	18	POINT(38.92044 5.76084)	Ethiopia	Kenticha		R	Tantalum	http://www.mbendi.com/indy/ming/af/et/p0005.htm	0101000020E
19	19	POINT(-43.9385747 -19.9190677)	Brazil	Mibra	Companhia Industrial Fluminense	R	Tantalum	http://tanb.org/tantalum	0101000020E
20	20	POINT(29.794921875 31.2034045)	Egypt	Alexandria	Many	R	Tantalum	http://www.mbendi.com/a_sndmsg/facility_srch.asp?gloc=L17&fyt	0101000020E
21	21	POINT(37.19970709125 19.6218)	Sudan	Port Sudan	Al khair Petroleum Terminal	R	Petroleum	http://ports.com/sudan/al-khair-petroleum-terminal/	0101000020E
22	22	POINT(4.160302 44.167109)	France	Salindres	GEO Gallium	R	Refined Gallium	minerals.usgs.gov/minerals/pubs/commodity/gallium/460303.pdf,	0101000020E
23	23	POINT(4.3334197998046875 51.1)	Belgium	Hoboken	Umicore	R	Selenium	www.mmta.co.uk/uploaded_files/SeleniumMJ.pdf	0101000020E
24	24	POINT(5.2955095 61.7685236)	Norway	Bremanger	Elkem	R	Silicon	http://www.silicon.elkem.com/eway/default.aspx?pid=251&strg=Ma	0101000020E
25	25	POINT(34.98046875 48.4874864)	Ukraine	Dnipropetrovska	Nikopol	R	Manganese	http://en.wikipedia.org/wiki/Nikopol_Ferroalloy_Plant	0101000020E
26	26	POINT(-6.524848937988281 53.3)	Eire	Leixlip	Intel Fab 24	F	Wafer fabrication	http://www.intel.com/jobs/ireland/sites/Leixlip.htm	0101000020E
27	27	POINT(13.326416015625 50.9166)	Germany	Freiburg	Wacker Siltronic AG	P	Silicon Purificati	http://www.siltronic.com/int/en/aboutus/sites/freiberg/freibe	0101000020E
28	28	POINT(-43.5528051 -21.457921)	Brazil	Santos Dumont	Dow Corning	R	Silicon		0101000020E
29	29	POINT(-66.68701171875 -23.35)	Argentina	Salar de Olaroz	Orocobre	R	Lithium		0101000020E
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35	35	POINT(79.7701 53.8404)	Russia	Khabarninskiy-Plut		R	Ruthenium	http://mineral-resources.findthebest.com/1/38414/Khabarninski	0101000020E
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39	39	POINT(87.1166667 53.75)	Russia	Novokuznetsk	EVRAZ - Consolidated West Siberian	R	Vanadium	http://www.evraz.com/business/steel/?factory=1092	0101000020E
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42	42	POINT(89.525506 46.994191)	China	Fuyun	Xinjiang Xinxin Mining Industry Co	R	Gold	http://en.wikipedia.org/wiki/Xinjiang_Xinxin_Mining_Industry	0101000020E
43	43	POINT(87.5830078125 43.897892)	China			R	Gallium		0101000020E
44	44	POINT(100.079583 23.877573)	China	Lincang	YUNNAN LINCANG XINYUAN GERMANIUM I	R	Germanium	http://miningcompanydb.com/yunnan-lincang-xinyuan-germanium-i	0101000020E
45	45	POINT(109.415953 24.325502)	China	Liuzhou		R	Cadmium		0101000020E
46	46	POINT(87.5830078125 43.897892)	China	Xinjiang	Xinjiang Fangzheng Chemical & Ligh	R	Barium	http://www.vvchem.com/26496/	0101000020E
47	47	POINT(97.17202 31.140969)	China	Tibet	Chinalco	R	Aluminium		0101000020E
48	48	POINT(102.722202 25.037721)	China	Kunming	Kunming Bismuth Industry Co	R	Bismuth		0101000020E
49	49	POINT(101.964832 30.055309)	China	Kangding	Grupo Villar Mir / Ferroatlantica	R	Silicon	http://minerals-and-metals.blogspot.co.uk/2009/05/ferroatlant	0101000020E

■ Database constructed for System Shock RISC Project

Simplified Representation of Value Flow

- We have demonstrated that this data architecture can be used to model the value-creation flow through the international supply chain
- We have simulated a time-based progression of components through the value chain and are developing a **rule base** to make this representative
- Uses 'Turn-based' modelling e.g. time unit of 1 week
- Requires information flow – 'an order' – from next node
- We have modelled steady-state supply chain system
- We have also simulated the disruption of the chain from shocks disrupting the function of a node



Turn based model

All nodes normal production

```
Starting turn 0
***final assembly node is not producing
Starting turn 1
***final assembly node is not producing
Starting turn 2
***final assembly node producing
Starting turn 3
***final assembly node producing
Starting turn 4
***final assembly node producing
Starting turn 5
***final assembly node producing
Starting turn 6
***final assembly node producing
Starting turn 7
***final assembly node producing
Starting turn 8
***final assembly node producing
Starting turn 9
***final assembly node producing
```

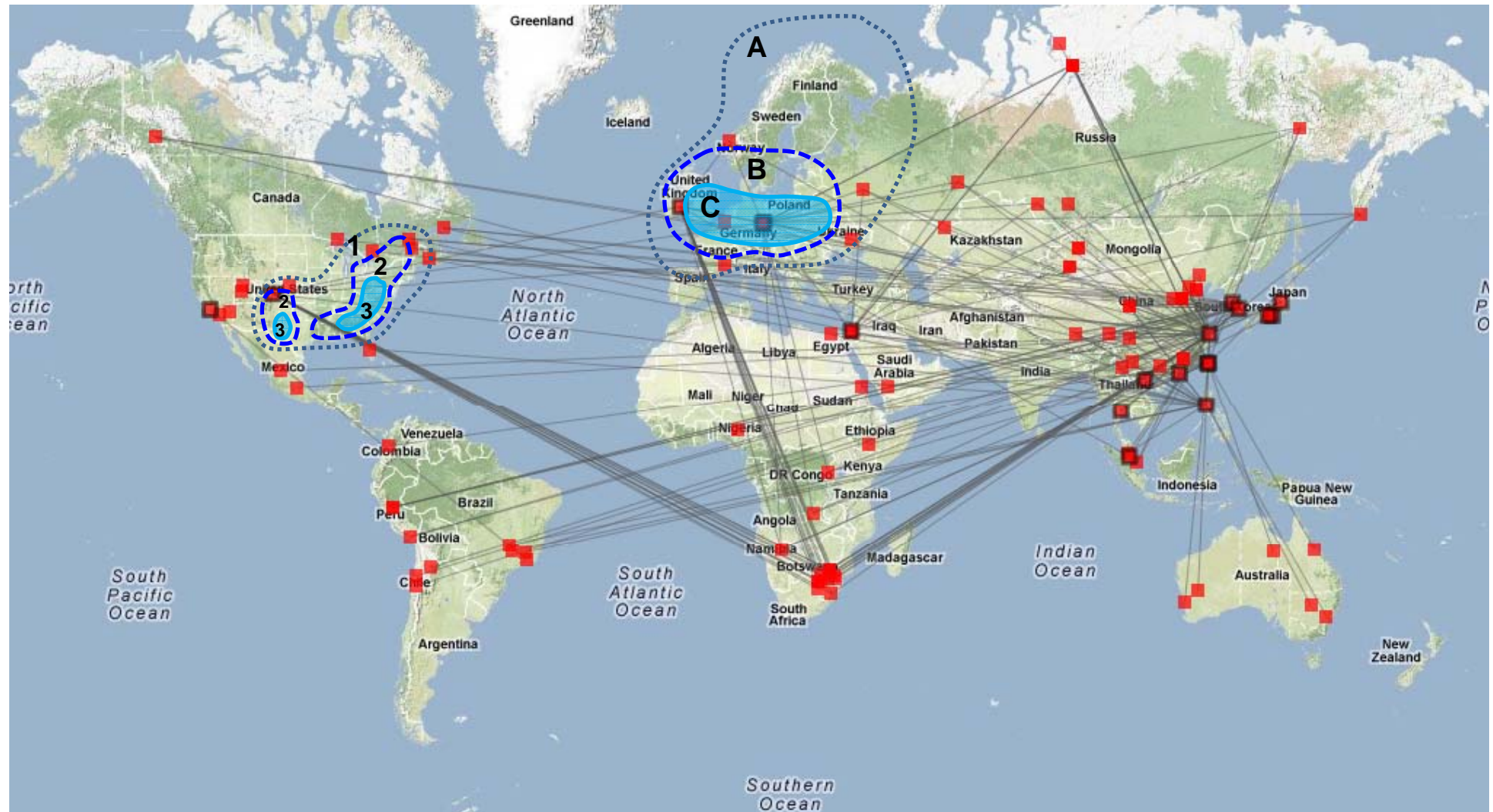
Process finished with exit code 0

Lithium production by Orocobre in Salar de Olaroz, Argentina, halted at turn 5

```
Starting turn 0
***final assembly node is not producing
Starting turn 1
***final assembly node is not producing
Starting turn 2
***final assembly node producing
Starting turn 3
***final assembly node producing
Starting turn 4
***final assembly node producing
Starting turn 5
***final assembly node producing
Starting turn 6
***final assembly node producing
Starting turn 7
***final assembly node is not producing
Starting turn 8
***final assembly node is not producing
Starting turn 9
***final assembly node is not producing
```

Process finished with exit code 0

Freeze event 1-in-100



Freeze event 1-in-100: Node impact

EU Zone C

23 Belgium	Hoboken	Umicore	Selenium ¹
27 Germany	Freiburg	Wacker Siltronic AG	Silicon Purification
110 Germany	Dresden	Global Foundries Fab 1	Wafer fabrication

EU Zone B

26 Eire	Leixlip	Intel Fab 24	Wafer fabrication
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EU Zone A

22 France	Salindres	GEO Gallium	Refined Gallium
24 Norway	Bremanger	Elkem	Silicon
25 Ukraine	Dnipropetrovska	Nikopol	Manganese
36 Russia	Moscow		Petroleum

NA Zone 3

NA Zone 2

89 USA	Colorado Springs	Atmel	Wafer fabrication
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NA Zone 1

83 Canada	Mount Pleasant	Adex	Indium ¹
85 Canada	Lac-Saint-Jean, Quebec	Les Mineraux Crevier (MCI).	Niobium
87 Canada	Quebec		Silver
88 Canada	Sudbury, Ontario		Ruthenium

Freeze event 1-in-100: Wafer fabrication impact

- Intel, Dublin, Eire (EU Zone B)

Due to road conditions many employees unable to get to work and production is at 20% reduced capacity for 8 weeks from mid-December to first week of February.



- Global Foundries, Dresden, Germany (EU Zone C)

Deep snow drifts impact even the resilient German road network resulting in production loss due to employee absence. Road and rail hauled raw material supplies badly affected and Dresden International Airport cargo operations to Philippines are at 50% capacity for 8 weeks from mid December to the first week of February



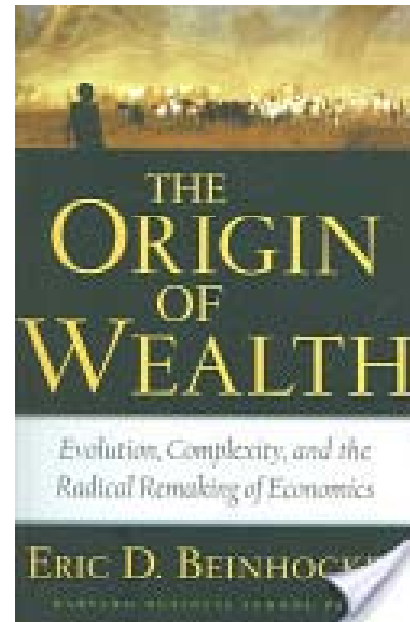
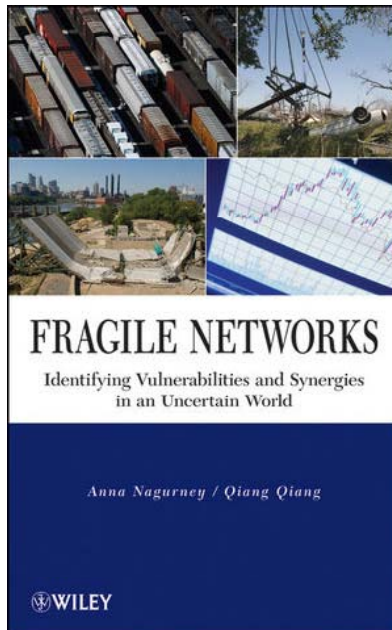
- Atmel, Colorado Springs, USA (NA Zone 2)

Production not affected as most employees are able to use 4X4 vehicles to get to work, and road-hauled raw materials are not affected. However shipments to Philippines via air freight through Denver International Airport reduced by 15% for 4 weeks from mid December to mid January.



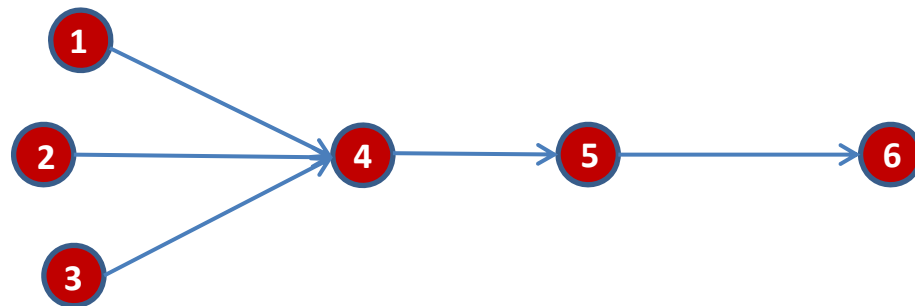
Next: Measuring the impact on value chain

- i % reduction in wafer fabrication – j million laptop units production lost?
- Value functions needed
- Equilibrium or agent based?

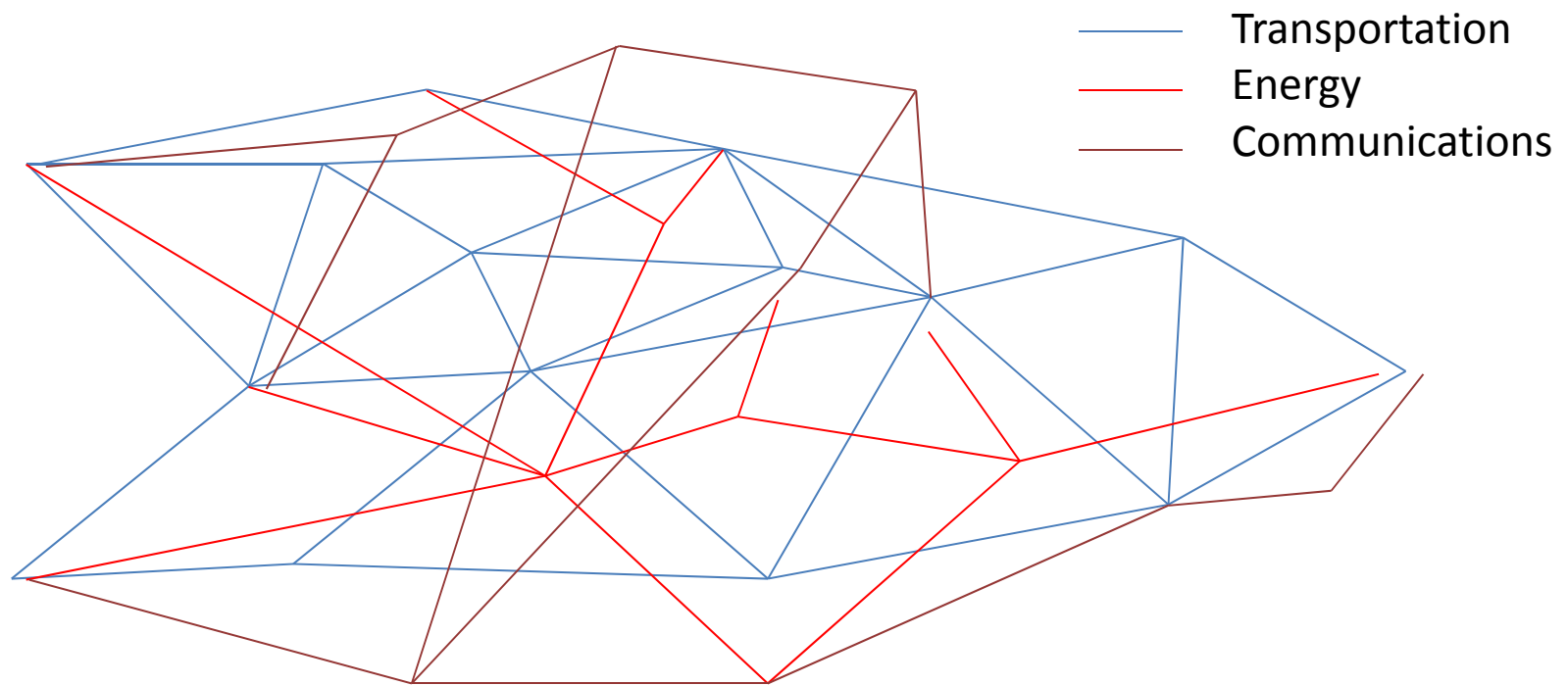
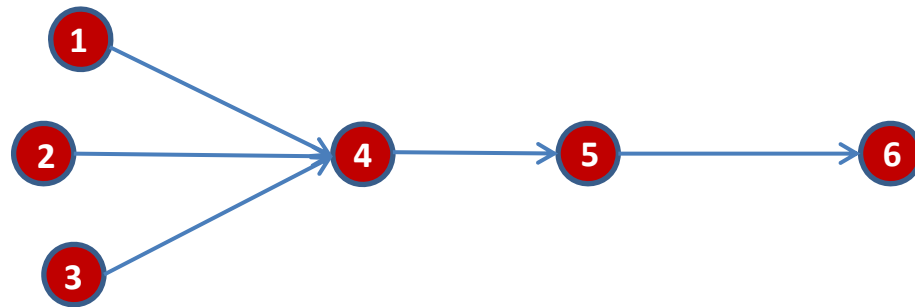


- The New Value Chain

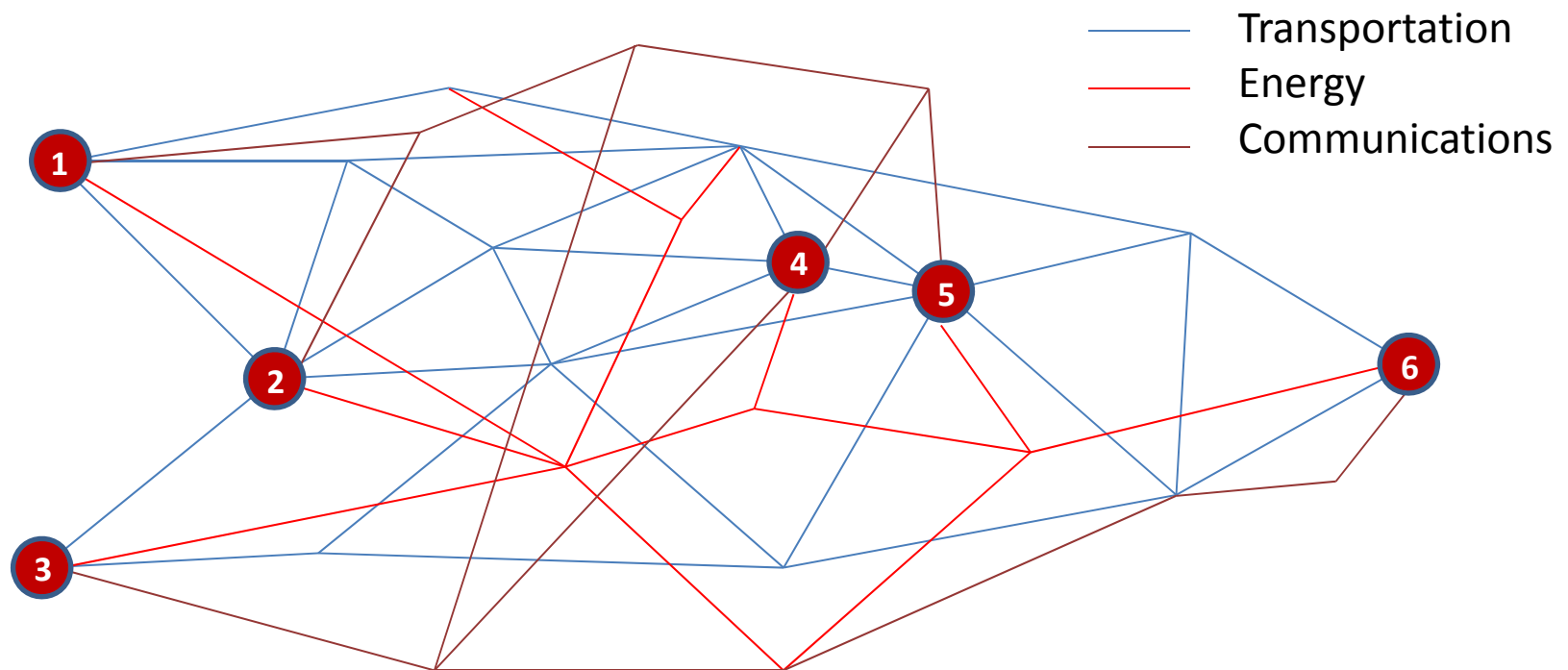
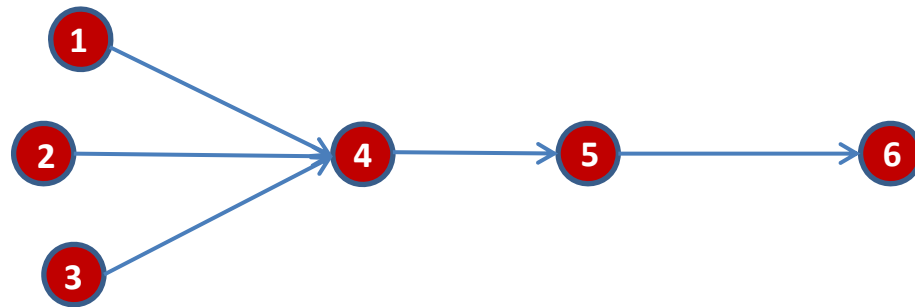
Next: Supernetworks



Next: Supernetworks



Next: Supernetworks



Cambridge Risk Framework: Technology

Open source software, Windows & Linux, cloud computing, web accessible

- Maps: Geoserver/Openlayers
- Relational database: PostGIS
- Programming language: Python
- Network analytics: NetworkX
- Infographics:
- Web, collaboration, social: Drupal/MediaWiki