System Shock Framework:
Resilient International Supply Chains

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Centre for
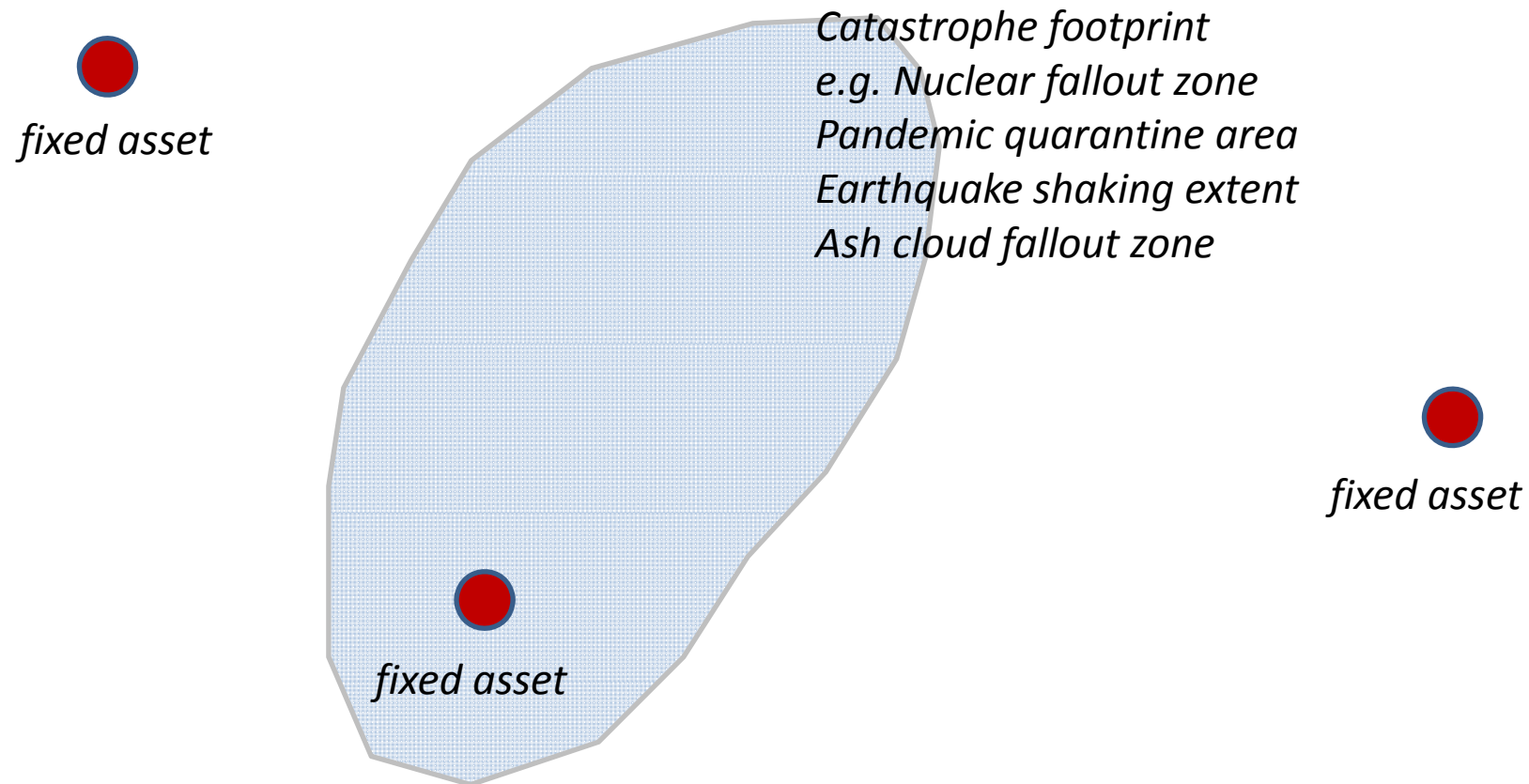**Risk Studies**

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System Shock framework: data structure

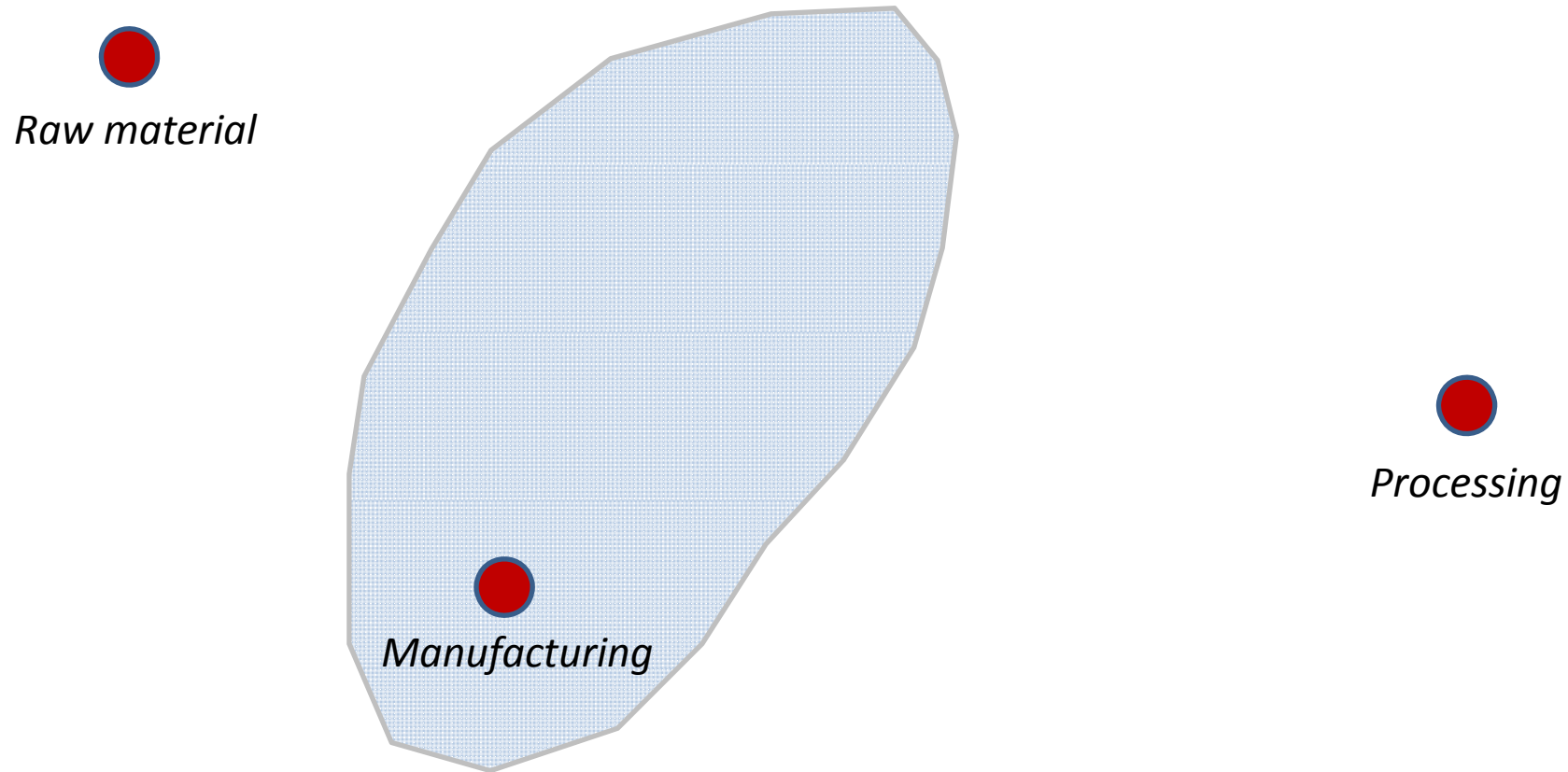*Impact of catastrophic event on network*   *Risk map*

Catastrophe footprint
e.g. Nuclear fallout zone
Pandemic quarantine area
Earthquake shaking extent
Ash cloud fallout zone

fixed asset

fixed asset

fixed asset

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System Shock framework: data structure

Impact of catastrophic event on network

Risk map

Business processes

Raw material

Processing

Manufacturing

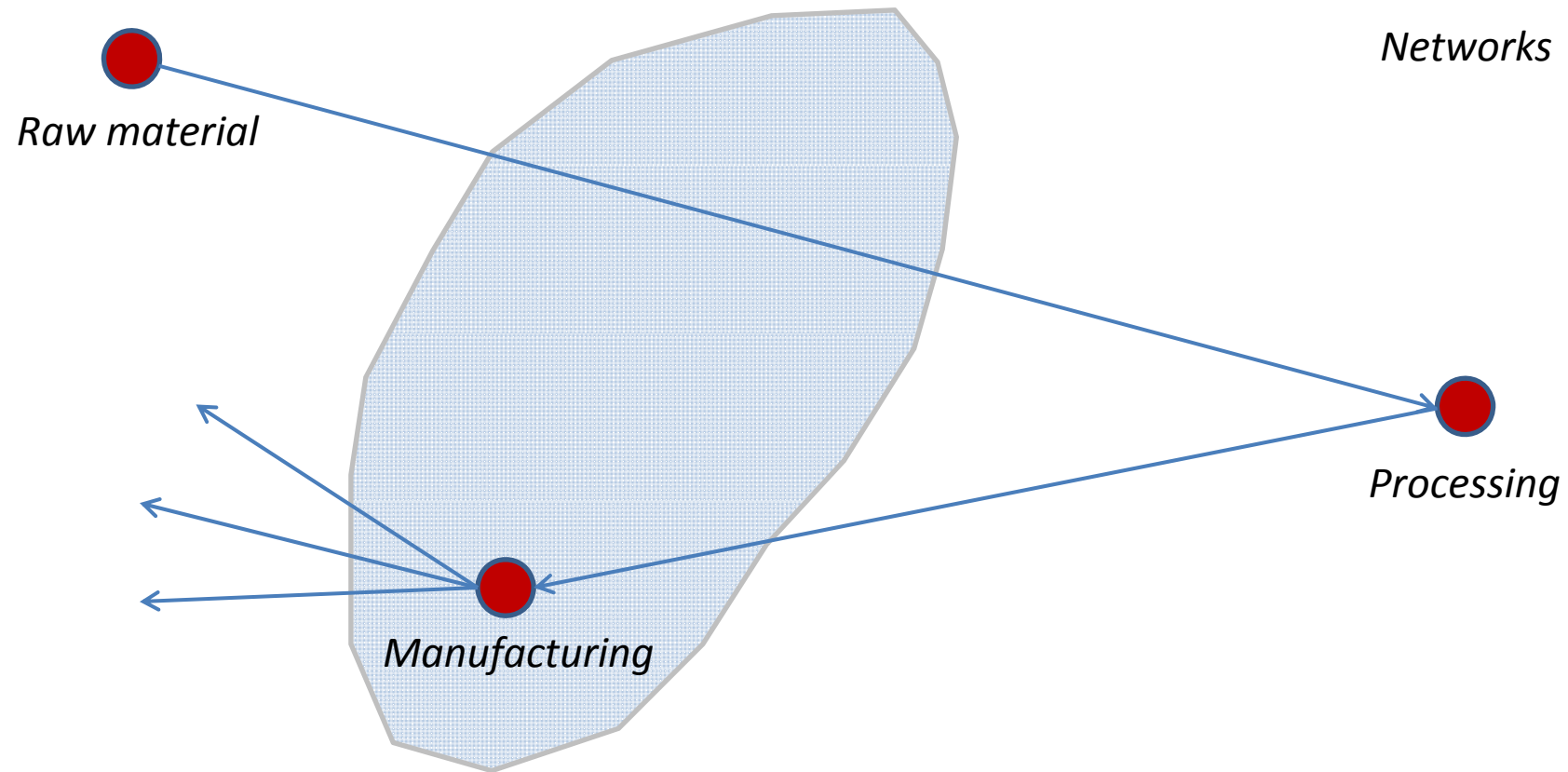UNIVERSITY OF CAMBRIDGE Judge Business School | Centre for **Risk Studies**

System Shock framework: data structure

Impact of catastrophic event on network
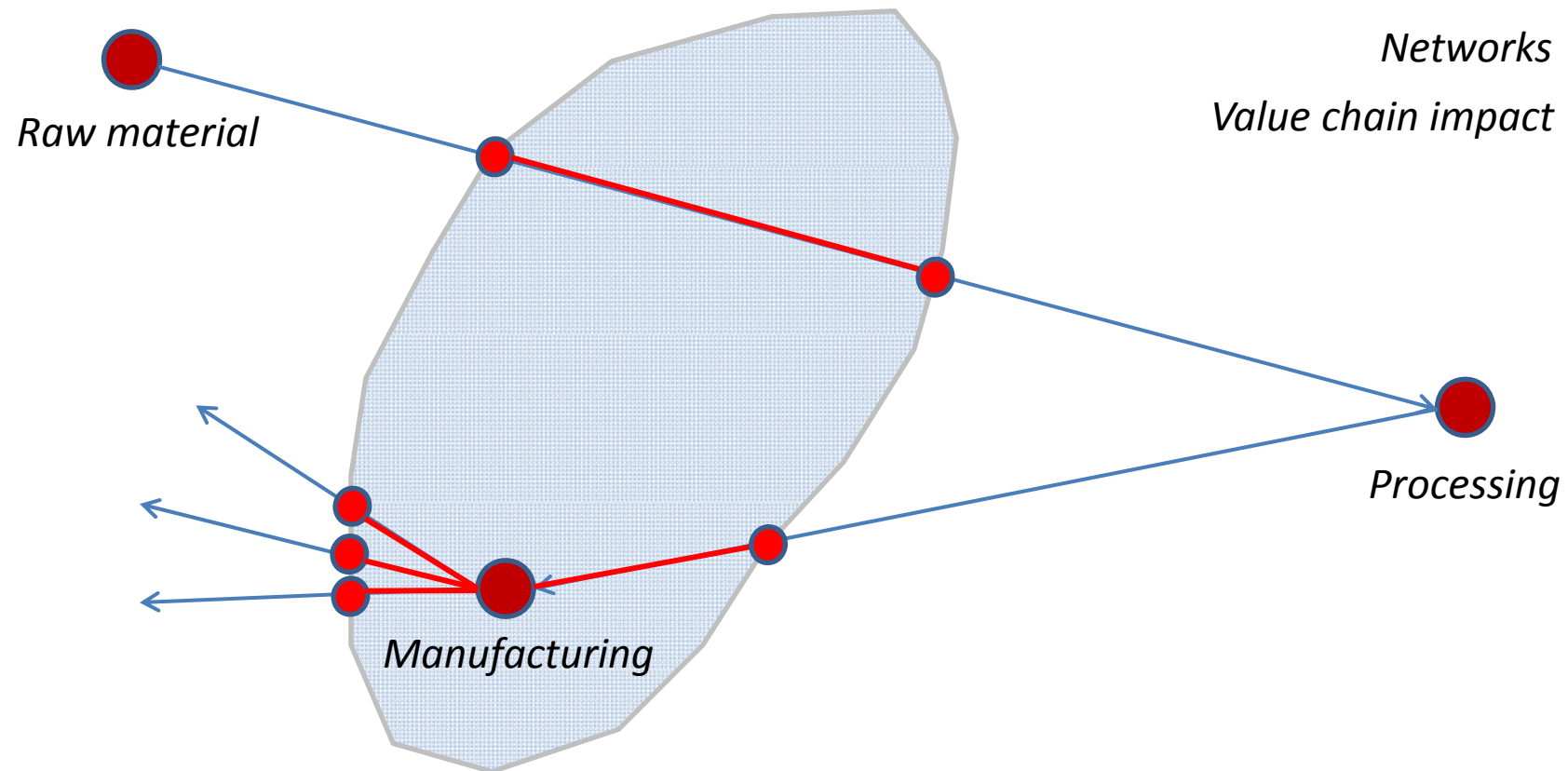
Risk map

Business processes

Networks

Raw material

Processing

Manufacturing

System Shock framework: data structure

Impact of catastrophic event on network

Risk map

Business processes

Networks

Value chain impact

Raw material

Processing

Manufacturing

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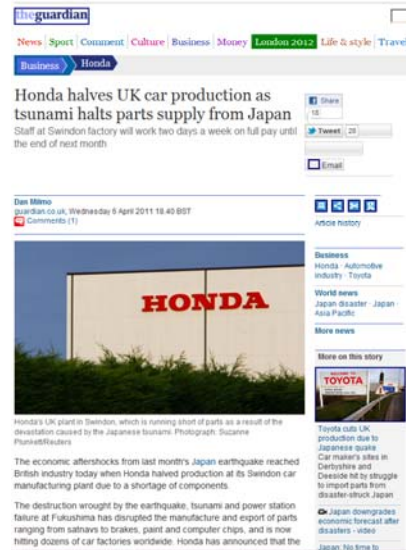
"Sony's production and sales were severely affected by the earthquake and tsunami in Japan in March last year.

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

Pomegranate

- 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	Kazahkstan
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)

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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.*
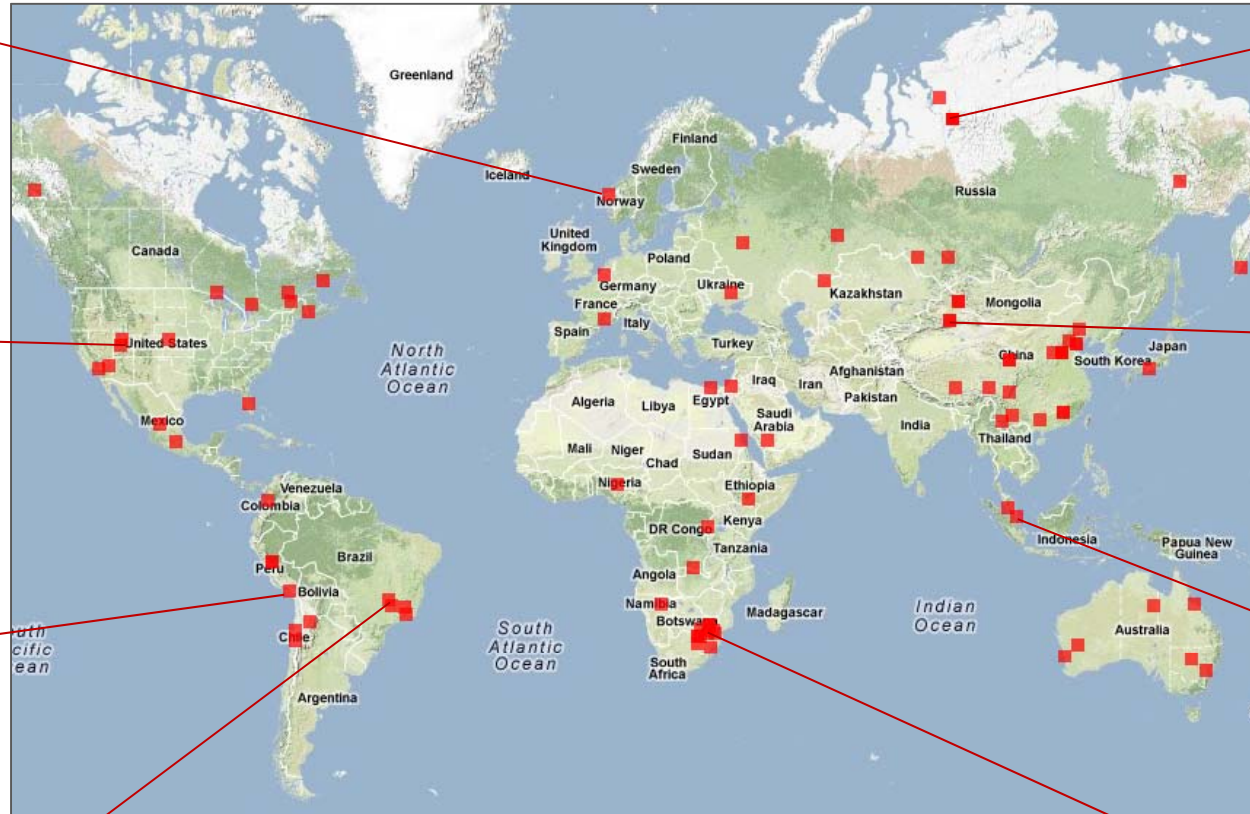
Nickel: *Norilsk Nickel Polar Division*

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
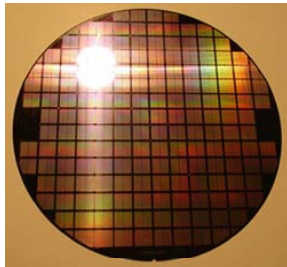
Chip assembly

Module assembly
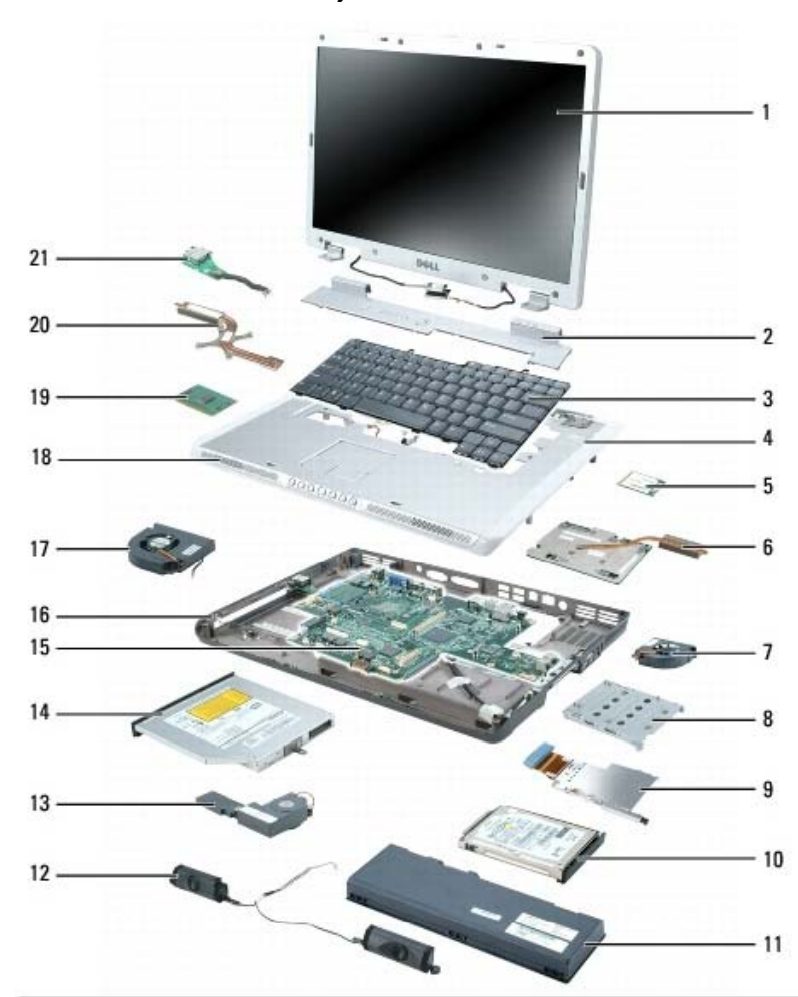
Laptop Supply Chain
Component Manufacture

Legend:
- Battery Assembly
- Chip Assembly
- Final Assembly
- LCD Screen Manufacture
- Plastics Processing
- Silicon Processing
- Silicon Purification
- Wafer Fabrication
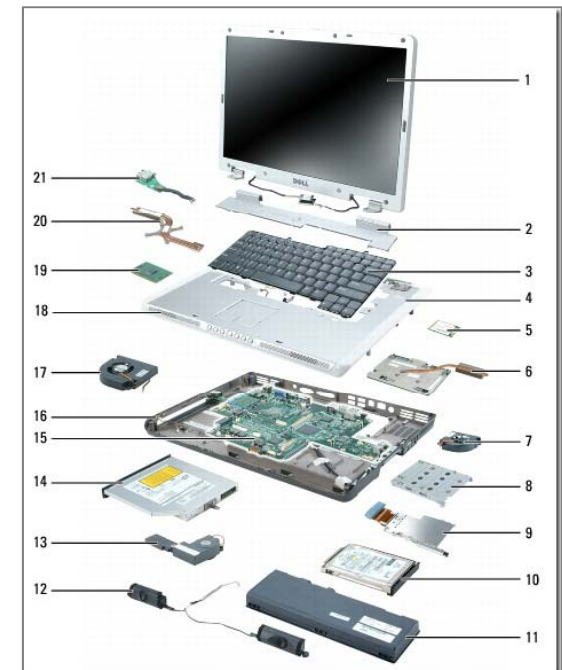
Laptop Supply Chain
Final Assembly

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
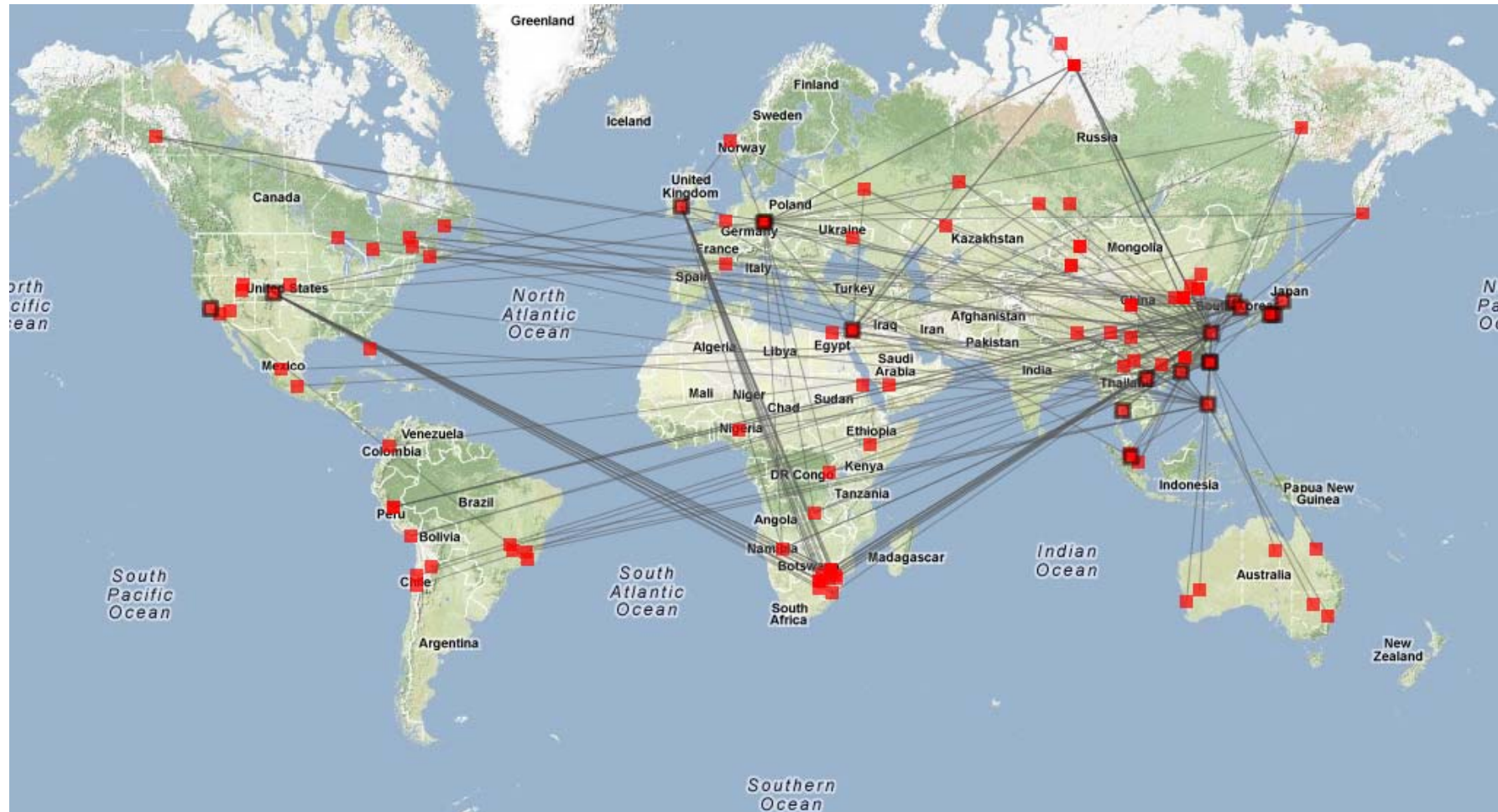
Laptop supply chain: Topological
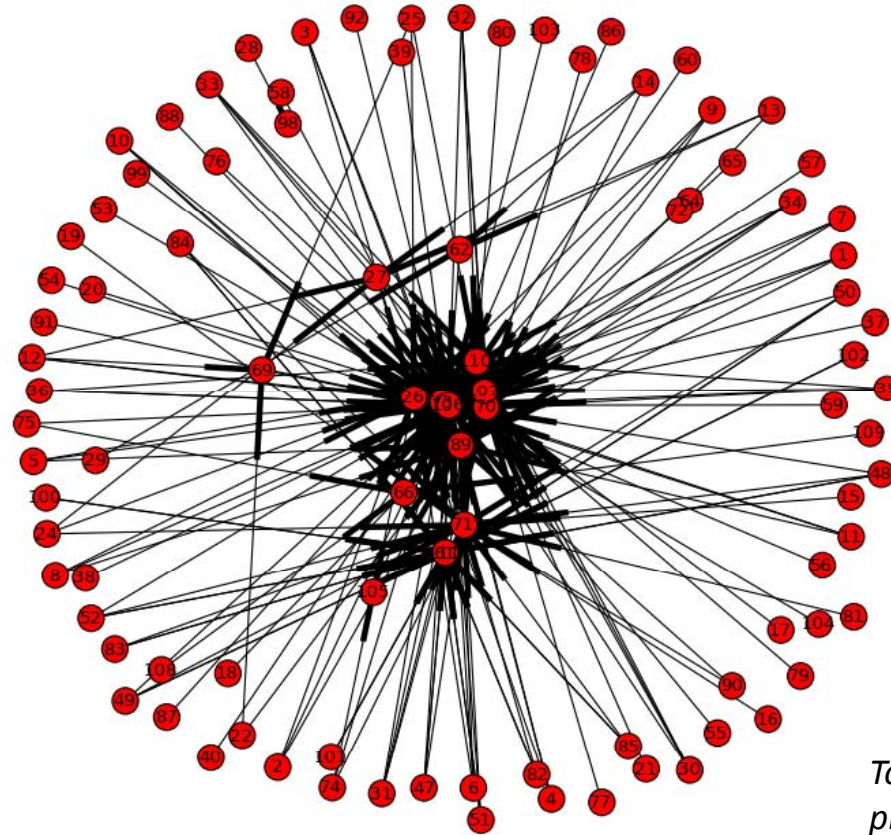
Topological representation produced by NetworkX graph analytic software

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

- 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

After 2 turns
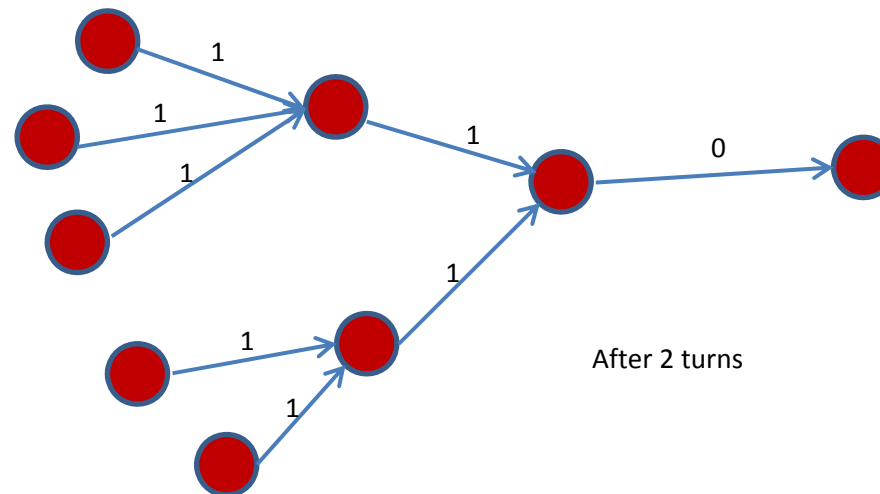
Turn based model

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
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Process finished with exit code 0
```
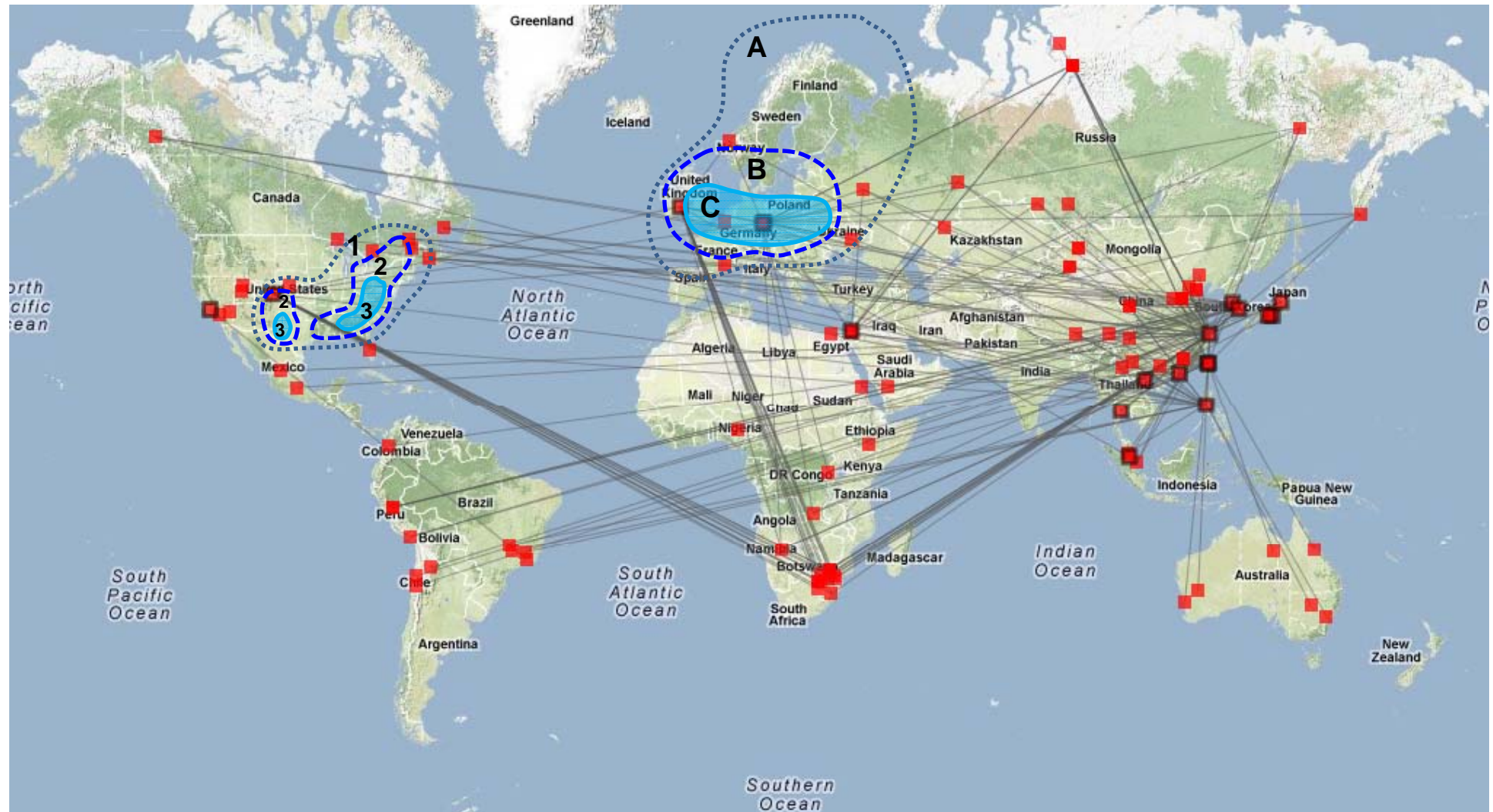
Freeze event 1-in-100

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

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

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.
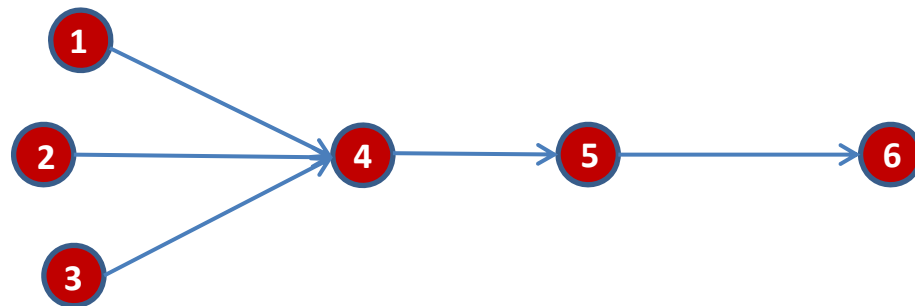
Next: Measuring the impact on value chain

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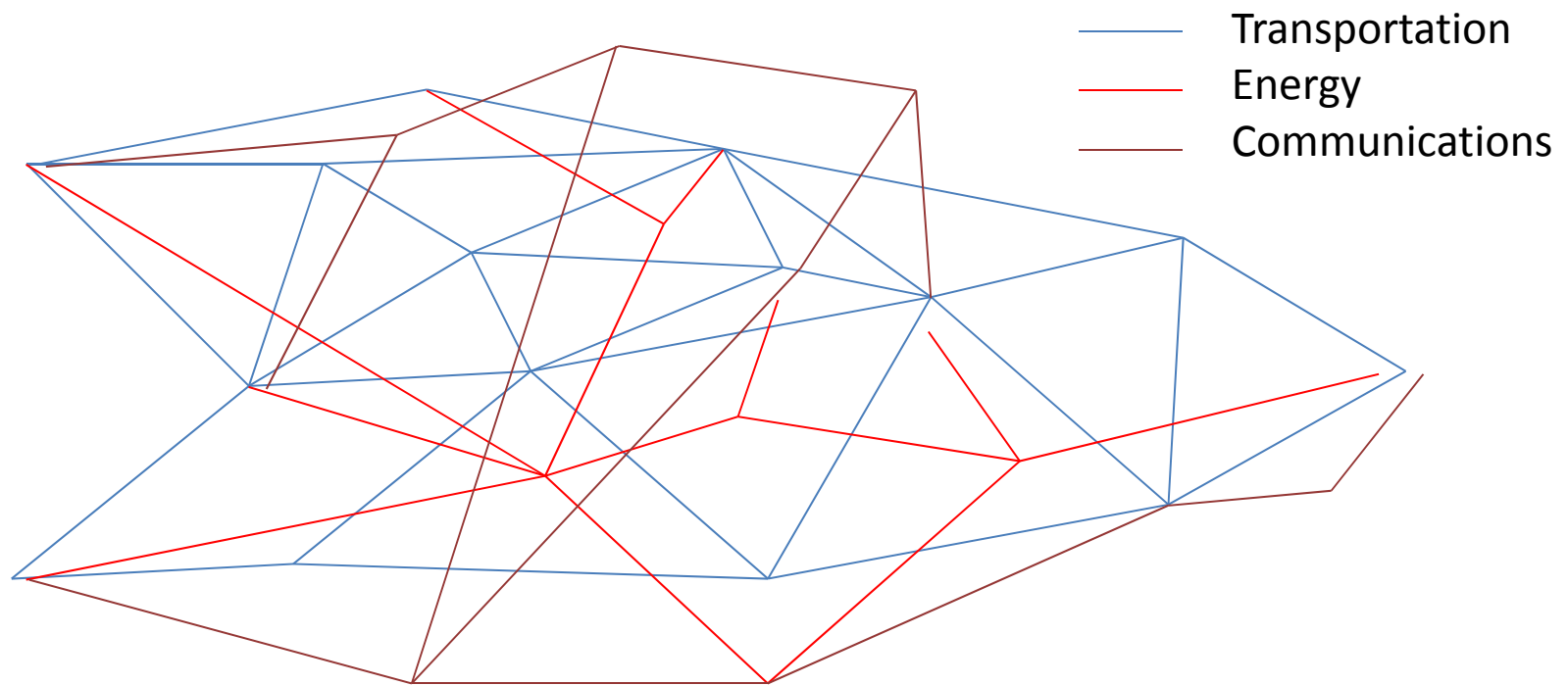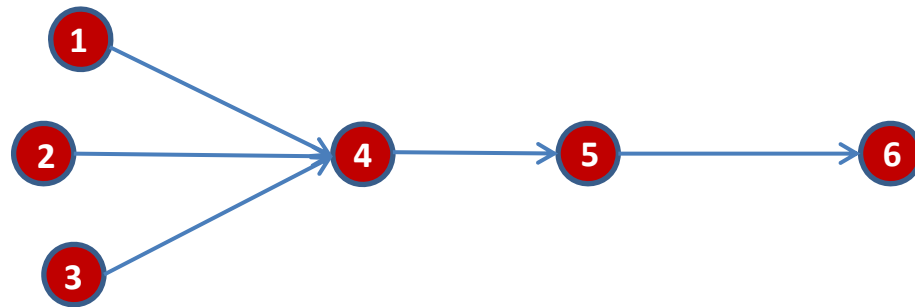- Equilibrium or agent based?
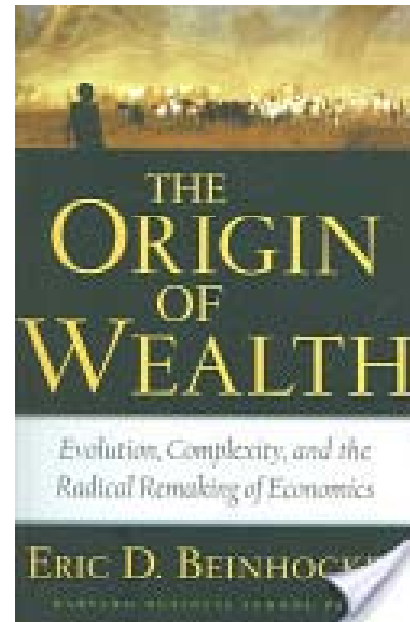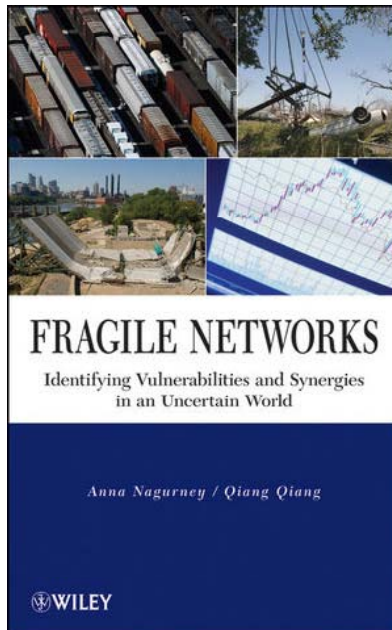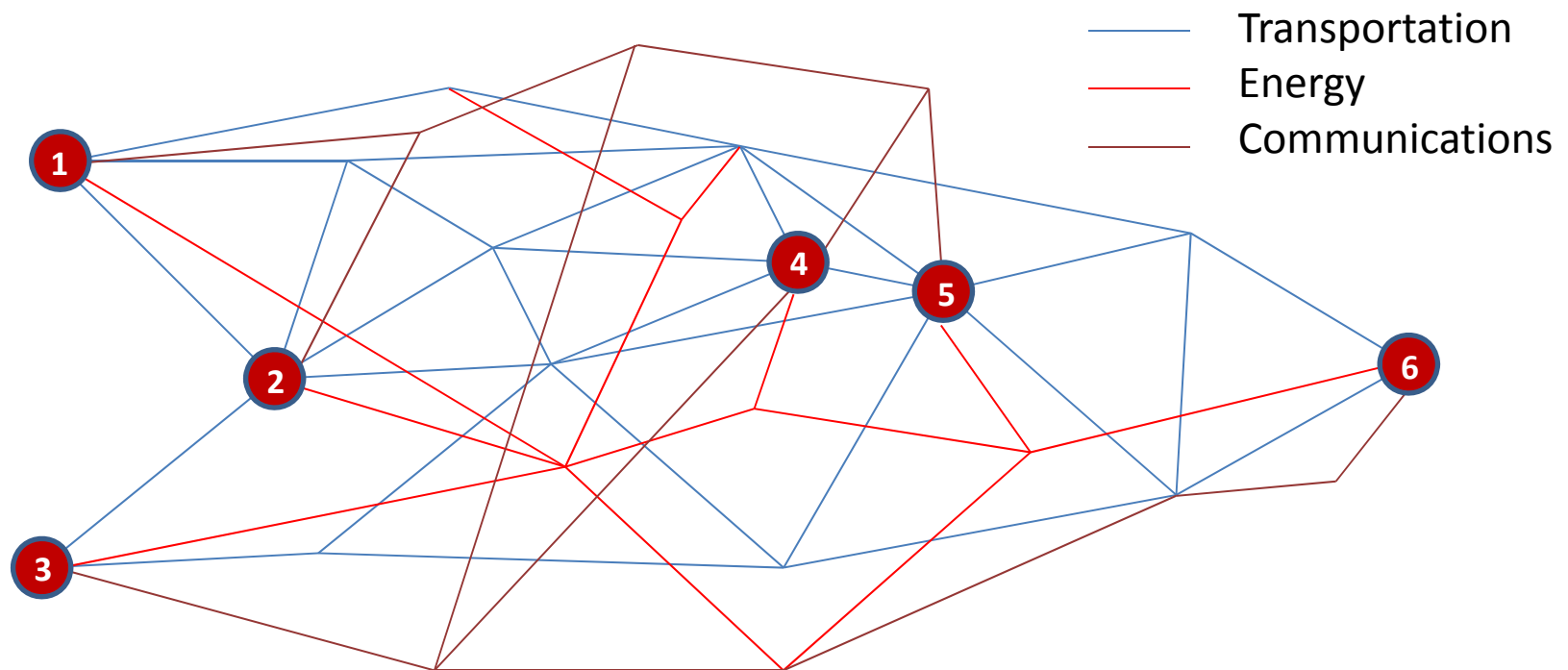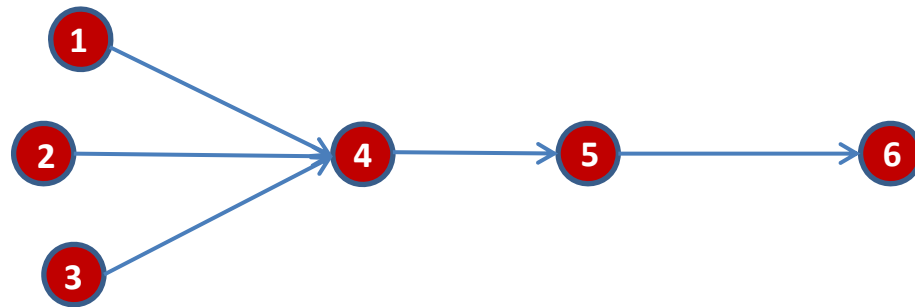

- The New Value Chain

Next: Supernetworks

Next: Supernetworks

Transportation
Energy
Communications

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