Resilience in Supply Chain Transportation Networks

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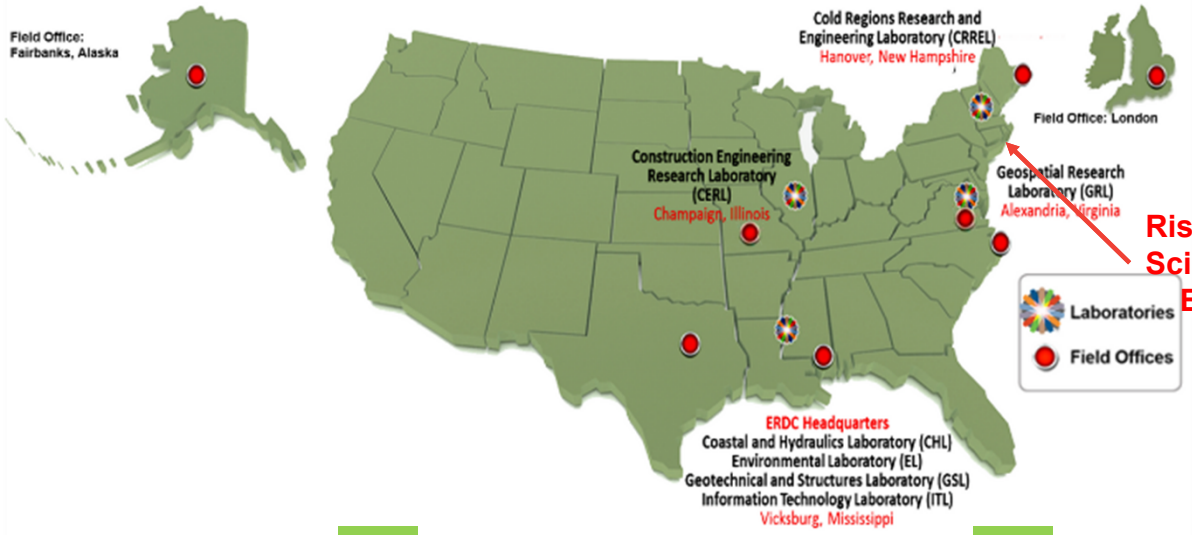
This presentation does not necessarily reflect the views of the United States Government, and is only the view of the author

US Army Corps of Engineers

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

DISCOVER | DEVELOP | DELIVER

About Army Engineer R&D Center



7 Laboratories

Coastal and Hydraulics Laboratory (CHL)
Cold Regions Research and Engineering Laboratory (CRREL)
Construction Engineering Research Laboratory (CERL)
Environmental Laboratory (EL)
Geospatial Research Laboratory (GRL
Geotechnical and Structures Laboratory (GSL)
Information Technology Laboratory (ITL)

Annual Research Program Exceeding $1.3 Billion

People

2100 Strong
61% E&S
71% of E&S with Advanced Degrees
29% of E&S with PhD

Core Competencies

- Blast and Weapons Effects on Structures and Geo-Materials
- 3-D Mapping and Characterization
- Cold Regions Science and Engineering
- Civil and Military Engineering
- Computational Prototyping of Military Platforms
- Coastal, River, and Environmental Engineering
- Military Installations and Infrastructure

Partners

All DoD Services
Army, Navy, Air Force, NASA, DHS, FEMA, DIA, NGA
Academia
68 EPAs with top engineering schools
Industry
172 CRADAs
International
14 international agreements with 7 countries

US Army Corps of Engineers
U.S.ARMY

Supply chain woes caused US auto sales to fall 8% last year

AP | TOM KRISHER
January 5, 2023, 12:01 PM

A Resilient Supply Chain Starts With Full Visibility

Forbes Technology Council

Dan Shey Forbes Councils Member
Forbes Technology Council
COUNCIL POST | Membership (Fee-Based)

Sep 30, 2022, 09:45am EDT

Gartner Predicts 95% of Companies Will Have Failed to Enable E2E Resiliency in their Supply Chains by 2026.

02/01/2023 | 04:30am EST

BUSINESS

GULF | MENA | WORLD | BUSINESS | OPINION | CLIMATE | HEALTH | LIFESTYLE | ARTS & CULTURE | TRAVEL | SPORT | PODCASTS | WEEKEND

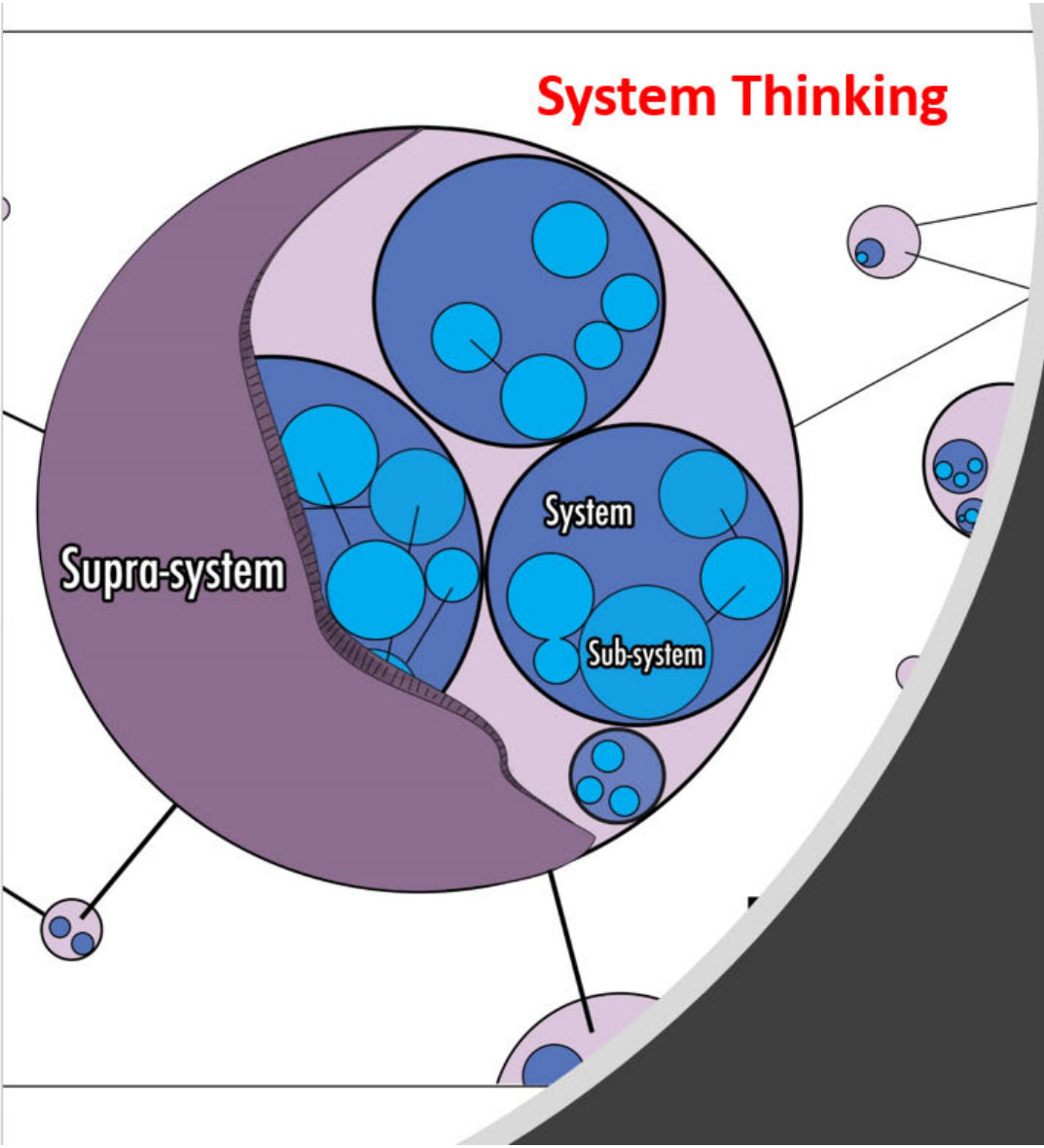
n | Economy | Energy | Money | Cryptocurrencies | Property | Banking | Technology | Markets | Travel and Tourism | Start-Ups | Future | Comment

Rebuild supply chains with greater resilience and open trade, Davos panellists say

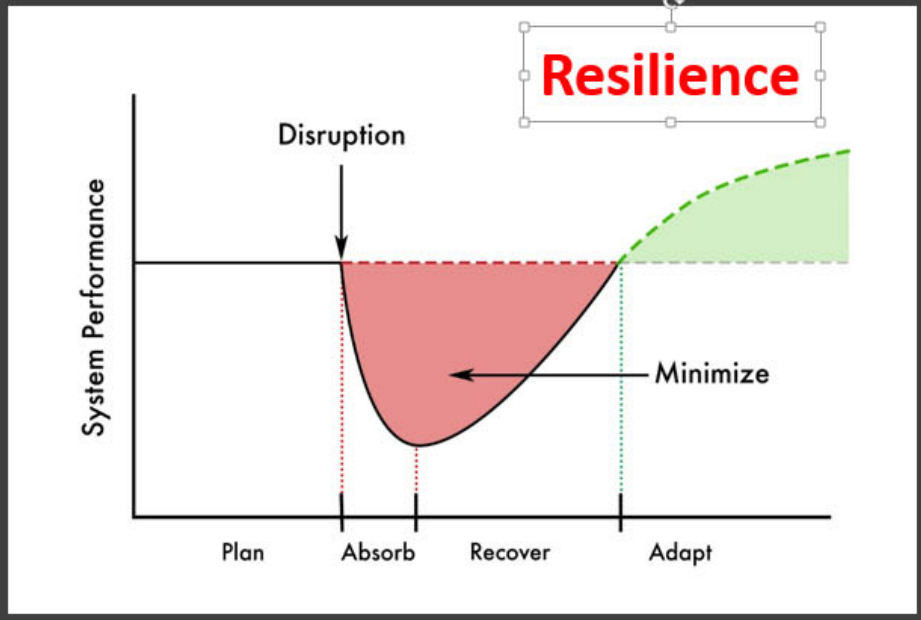
How leveraging connected experiences in logistics can build resilient supply chains

Advances in cloud data storage, artificial intelligence and cellular networks are all collectively driving a more connected experience in transport and logistics

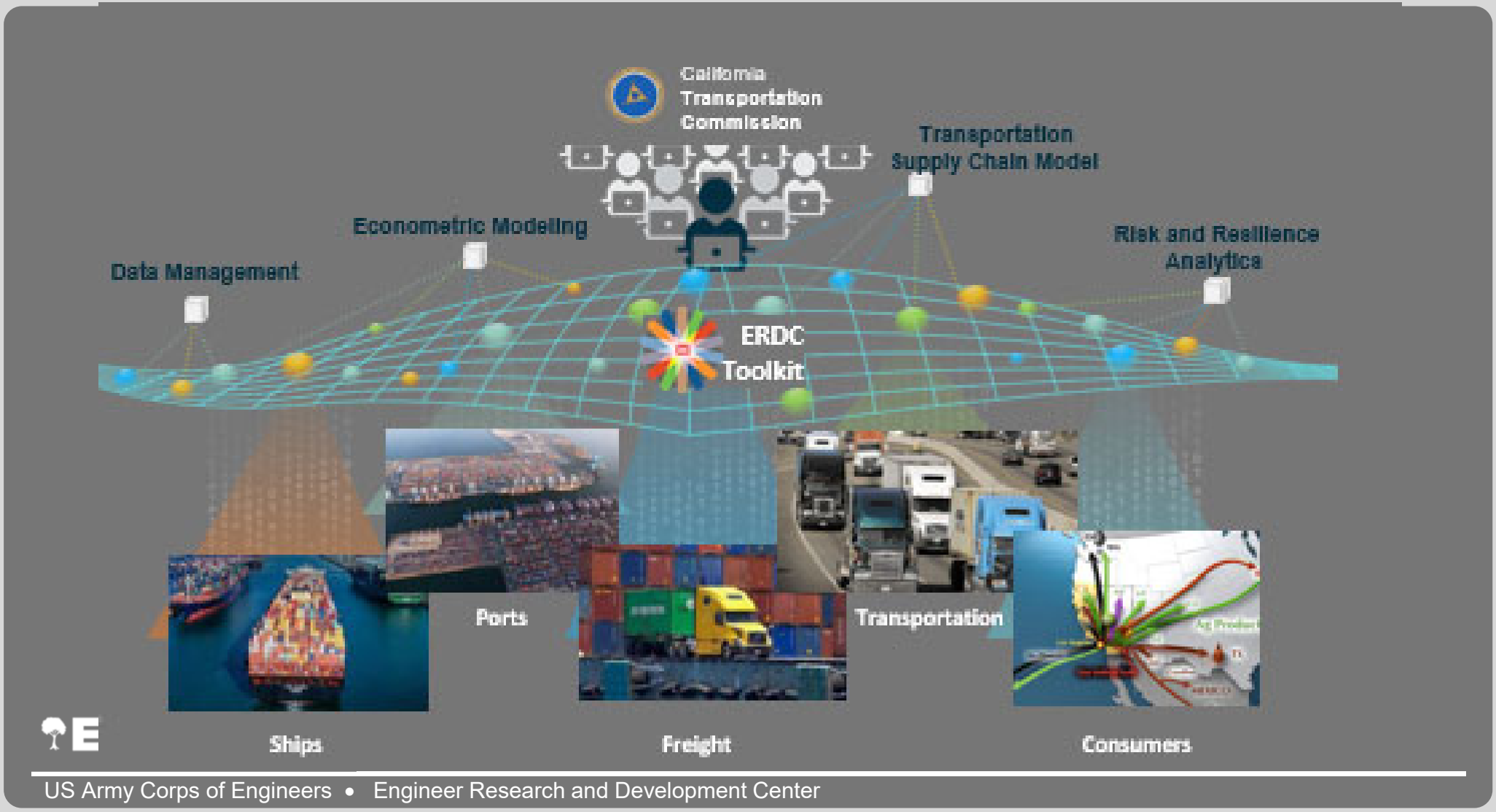
BY BURAK ERTUNA
OCTOBER 1, 2022



What Makes Complex Systems (Communities) Susceptible to Threat?



After Linkov and Trump, 2019


California
Transportation
Commission
Transportation
Supply Chain Model
Econometric Modeling
Risk and Resilience
Analytics
Data Management
ERDC
Toolkit
Ports
Transportation
Ships
Freight
Consumers

Risk -- “a situation involving exposure to danger [threat].”

Security -- “the state of being free from danger or threat.”

Resilience -- “the capacity to recover quickly from difficulties.”

Definitions by Oxford Dictionary

30 | NATURE | VOL 555 | 1 MARCH 2018

Don’t conflate risk and resilience

‘Risk’ and ‘resilience’ are fundamentally different concepts that are often conflated. Yet maintaining the distinction is a policy necessity. Applying a risk-based approach to a problem that requires a resilience-based solution, or vice versa, can lead to investment in systems that do not produce the changes that

Igor Linkov, Benjamin D. Trump
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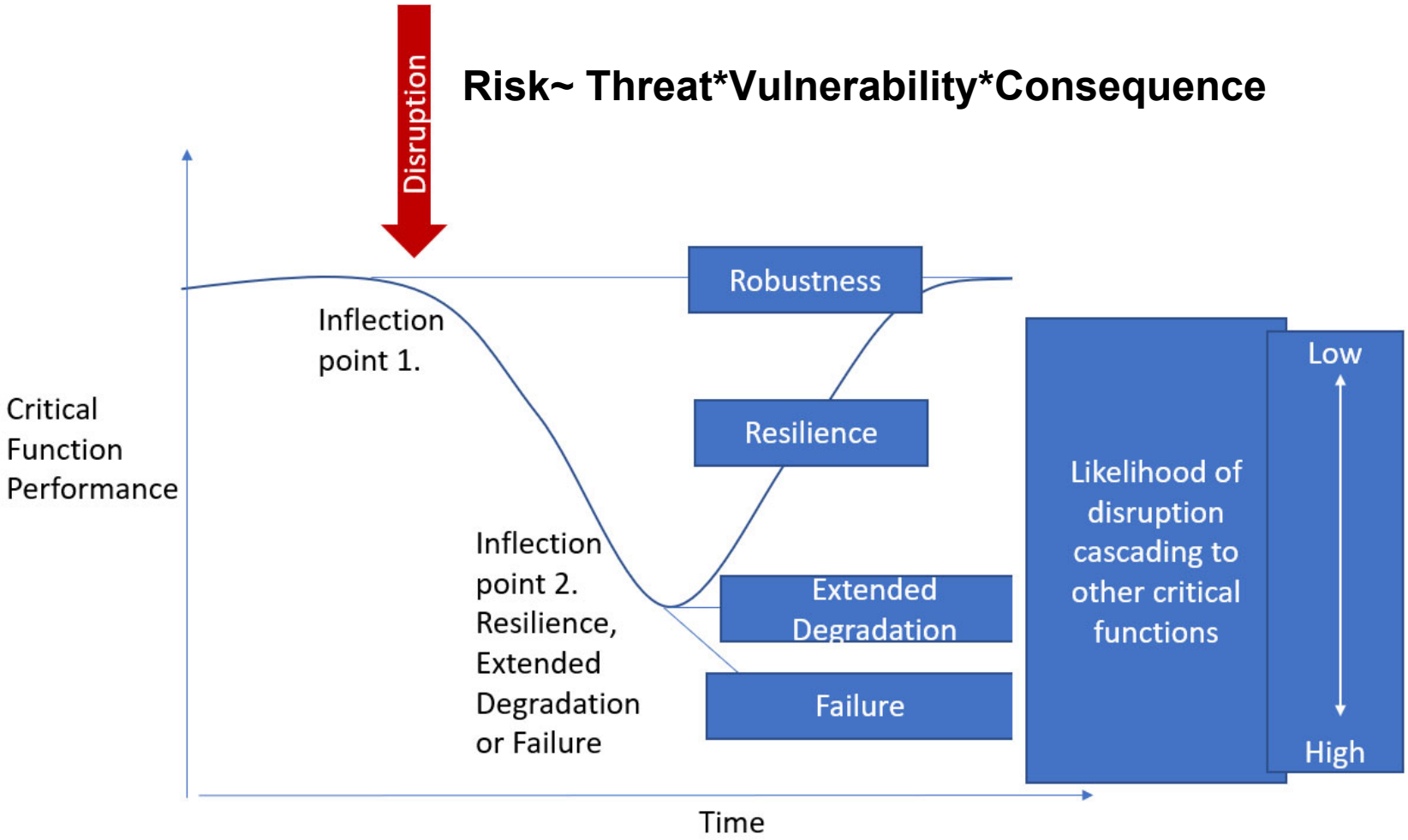
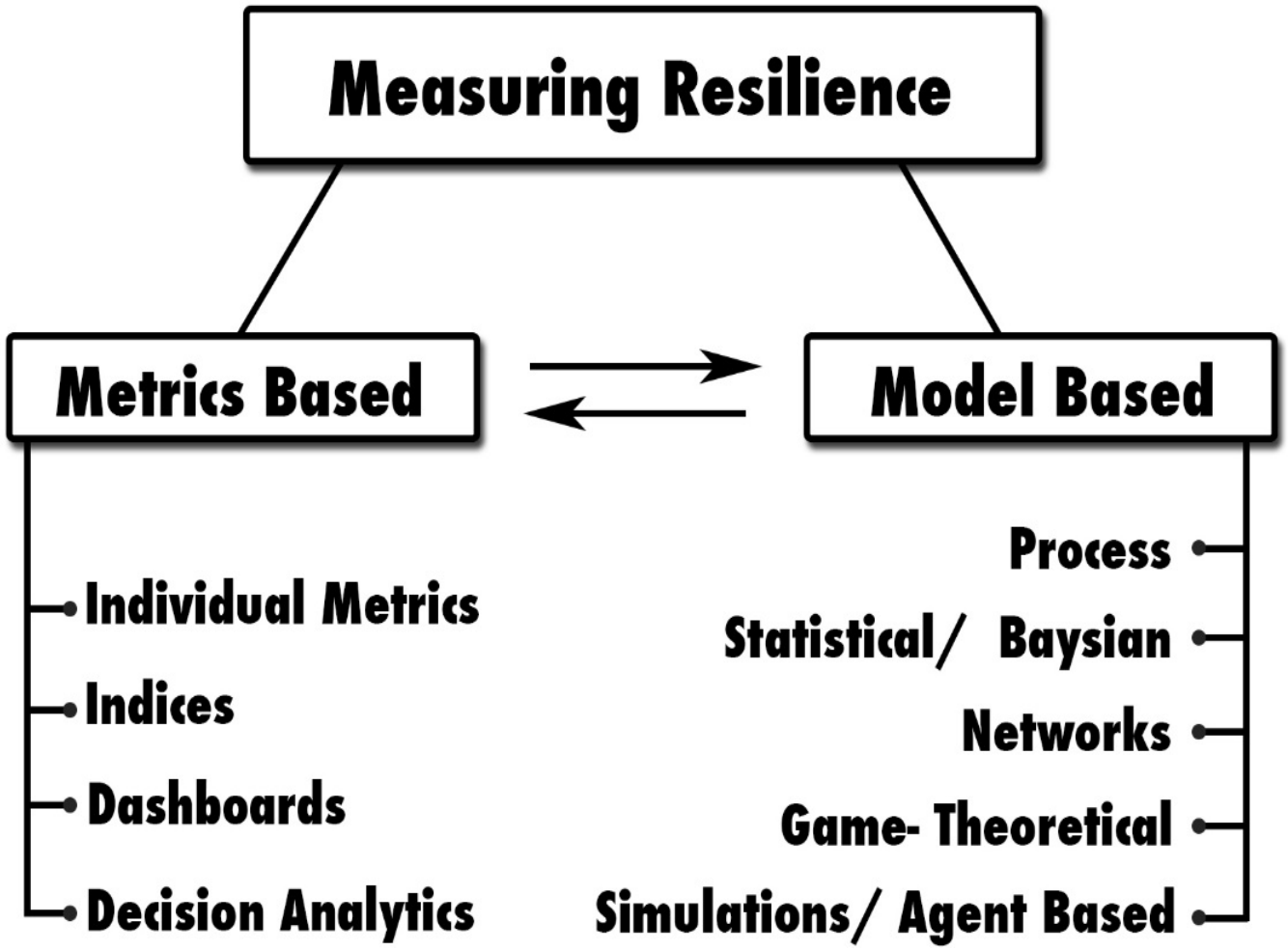
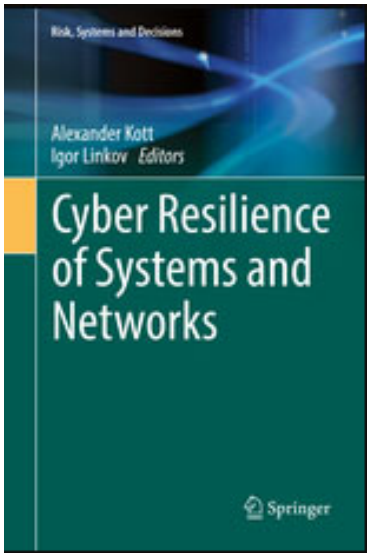
Crisis Management, Risk and Resilience



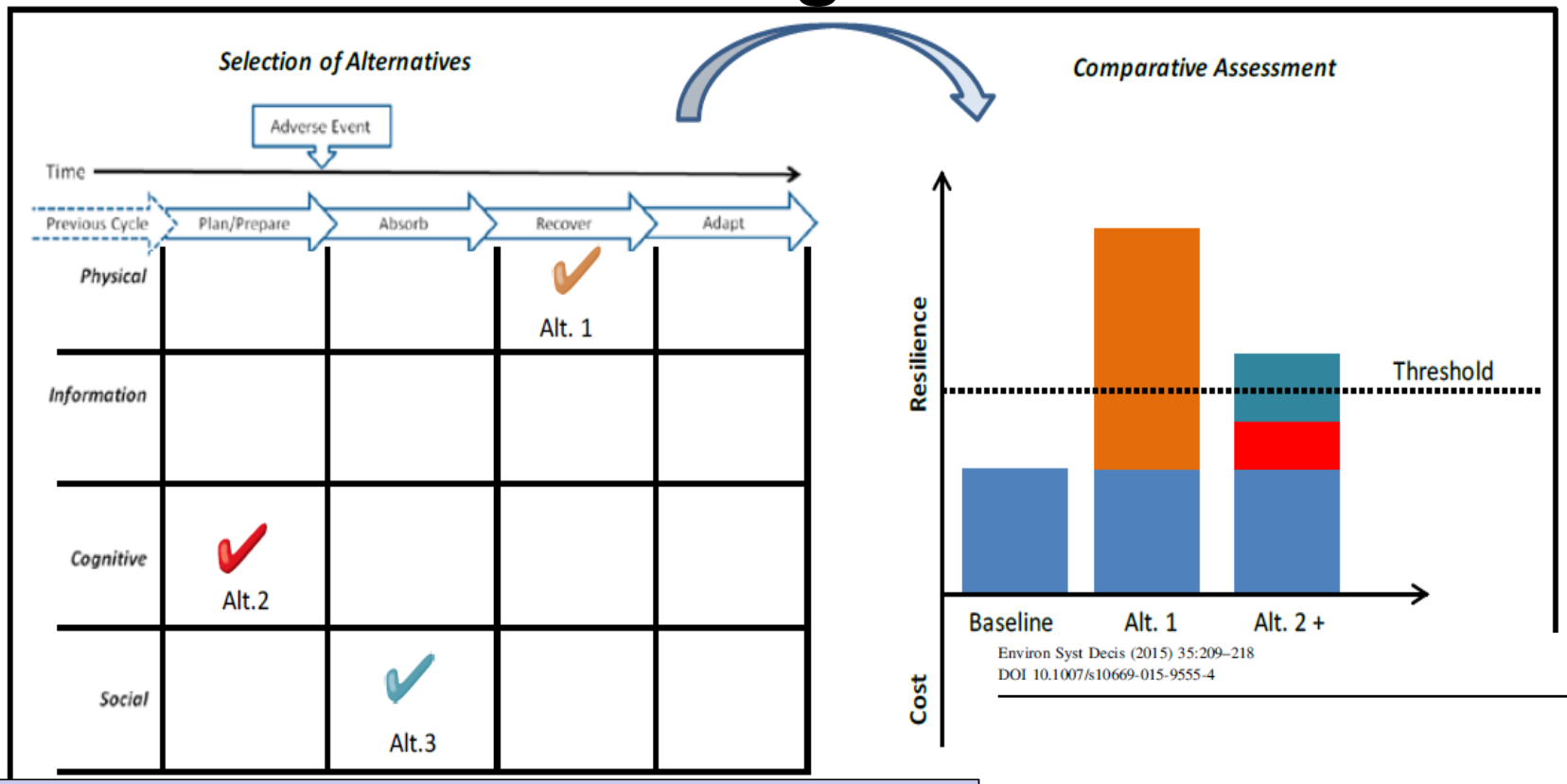
After Galaitsi, Linkov et al, 2022


Measuring Resilience
Metrics Based
Model Based
Individual Metrics
Indices
Dashboards
Decision Analytics
Process
Statistical/ Baysian
Networks
Game- Theoretical
Simulations/ Agent Based

After 2019


Risk, Systems and Decisions
Alexander Kott
Igor Linkov Editors
Cyber Resilience of Systems and Networks
Springer

Assessment using Resilience Matrix



Environ Syst Decis (2015) 35:209–218
DOI 10.1007/s10669-015-9555-4

Use resilience metrics to comparatively assess the costs and benefits of different courses of action

A matrix approach to community resilience assessment: an illustrative case at Rockaway Peninsula

Cate Fox-Lent[1] · Matthew E. Bates[1] · Igor Linkov[1]

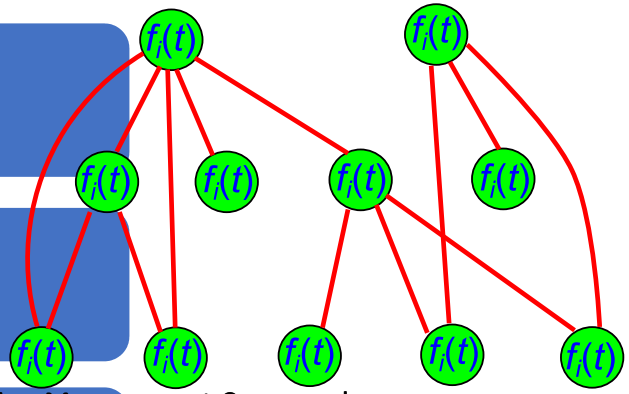
Network-based Resilience Theory?

System's *critical functionality* (*K*)

Network topology: *nodes* ($\mathcal{N}$) and *links* ($\mathcal{L}$)

Network *adaptive algorithms* ($\mathcal{C}$) defining how nodes' (links') properties and parameters change with time

A *set of possible damages* stakeholders want the network to be resilient against ($\boldsymbol{E}$)



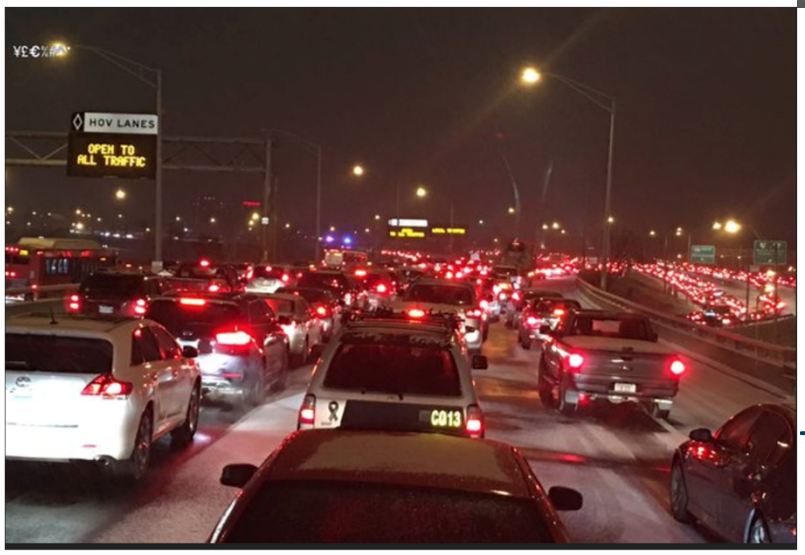
After Ganin et al., 2016

$$R = f(\mathcal{N}, \mathcal{L}, \mathcal{C}, \boldsymbol{E})$$

Poor Efficiency:

System cannot not accommodate a large volume of commuters driving at the same time.

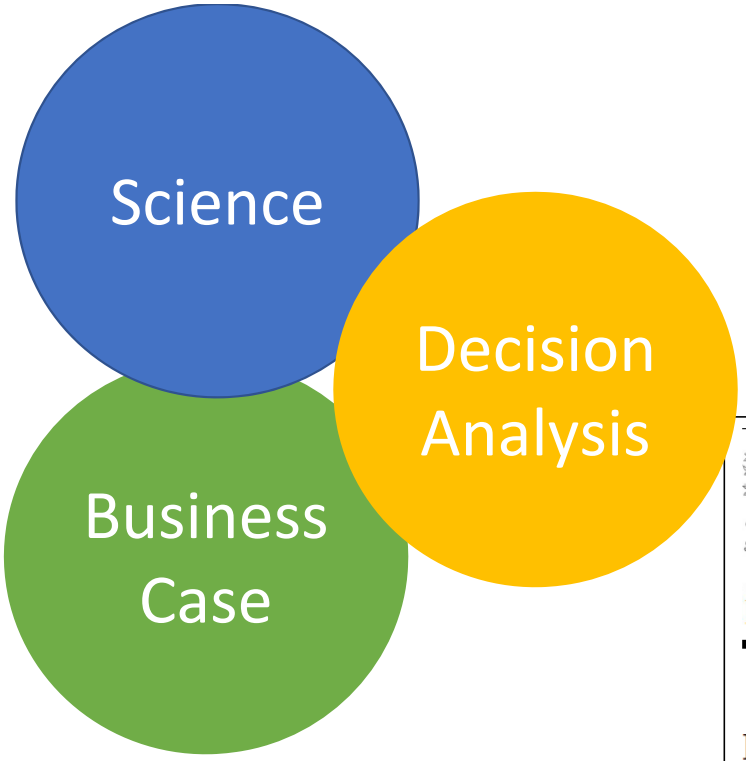
Traffic congestions are predictable and are typically of moderate level.



Lack of Resilience:

System cannot recover from adverse events
(car accidents, natural disasters)

Traffic disruptions are not predictable and of variable scale.



Transportation Network Model
+
Regional Economic Models, Inc.

ELSEVIER

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Lack of resilience in transportation networks: Economic implications

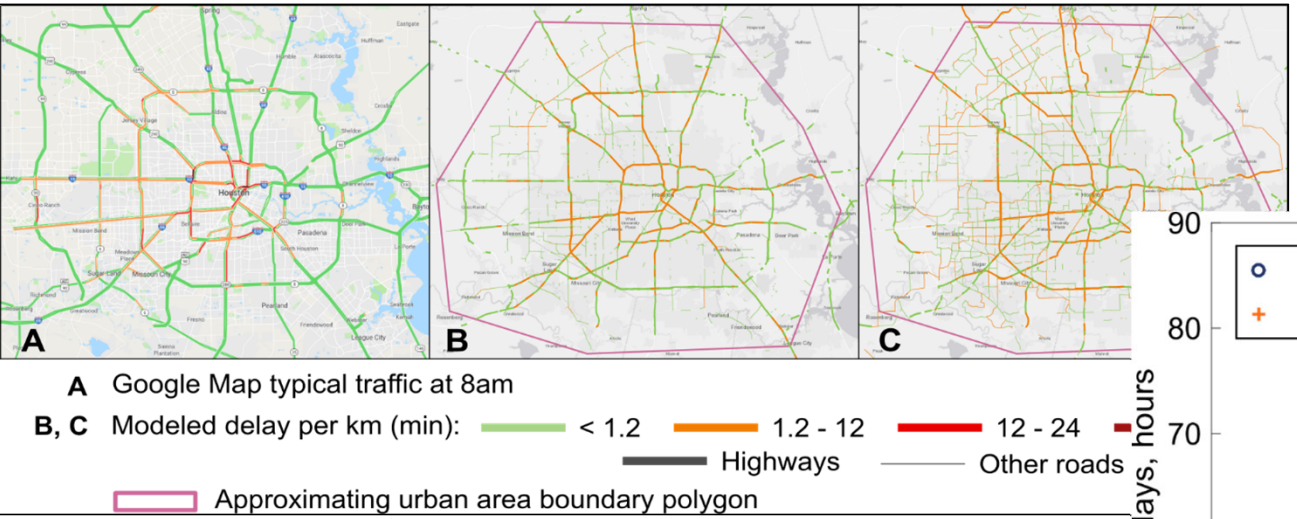
SCIENCE ADVANCES | RESEARCH ARTICLE

NETWORK SCIENCE

Resilience and efficiency in transportation networks

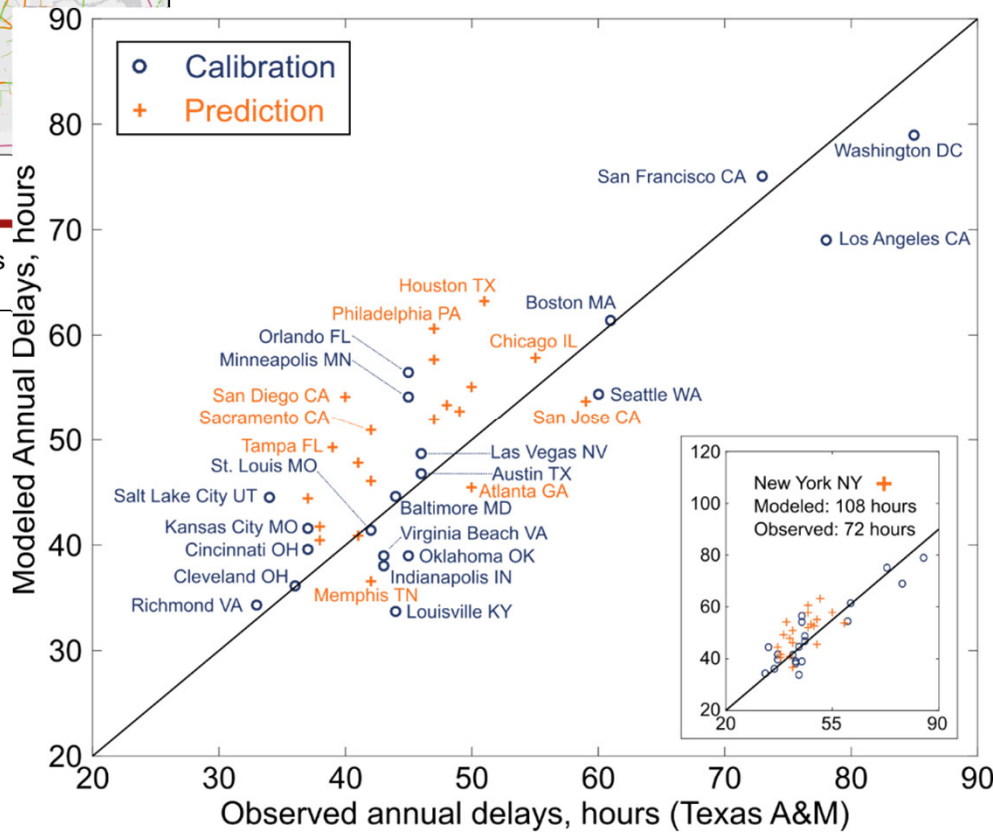
Alexander A. Ganin,[1,2] Maksim Kitsak,[3] Dayton Marchese,[2] Jeffrey M. Keisler,[4] Thomas Seager,[5] Igor Linkov[2]*

Transportation Network Model



1) Build networks comprise of road links and intersection nodes
2) Assign travelers and routes
3) Calculate free flow travel times and actual travel times
4) Calculate normal delay
5) Calibrate model to data

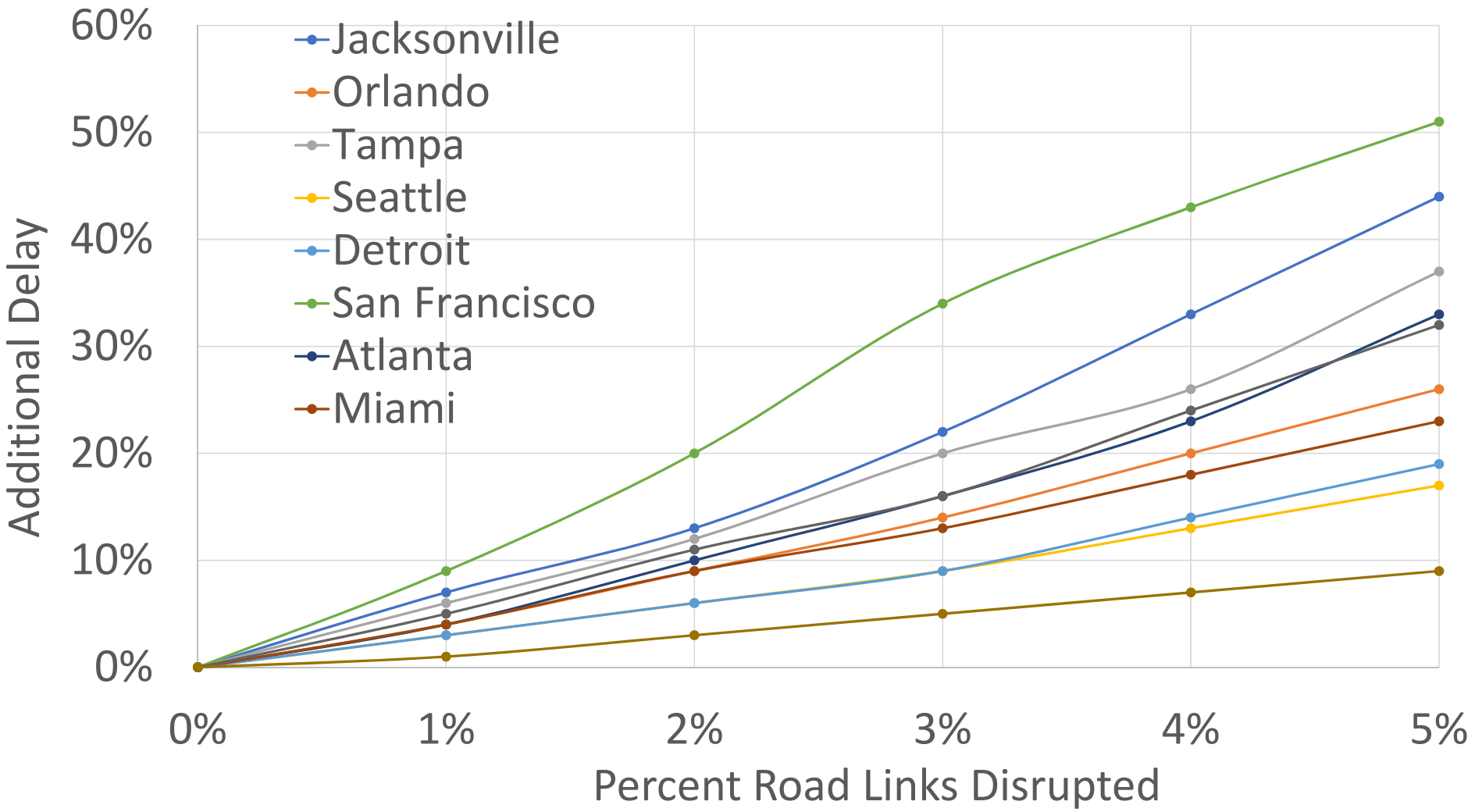
$$\langle \Delta T \rangle = \frac{1}{N_c} \sum_{\{ij\} \in \text{all roads}} L_{ij} \ell_{ij} \left(\frac{1}{v_{ij}} - \frac{1}{v_{ij}^0} \right)$$



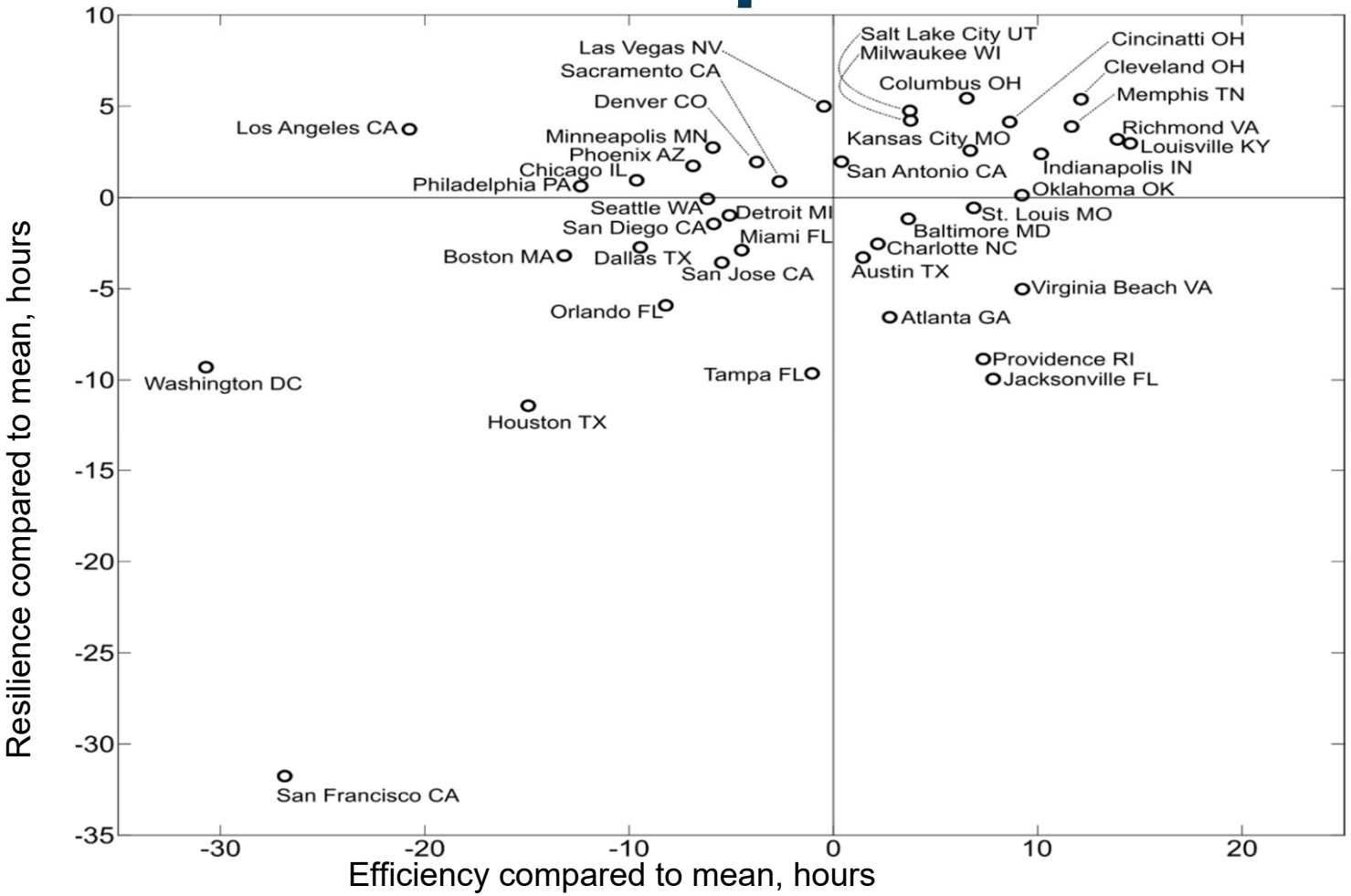
Modeling Disruptions

Case I Natural Disasters	Case II Random Disruptions	Case III Attacks Disabling Traffic Control	Case IV Attacks Locking Traffic Control
Links (Roadways) Only	Links (Roadways) and Nodes (Intersections)	Nodes (Intersections) Only	
Modeled Fractions of Affected Nodes/Links			
From 5% to 100% with the step of 5%			
Selection of Nodes/Links Affected by a Disruption			
Proportionally to Length at Random	Uniformly at Random Deterministically by Length, Load, and Betweenness		
Disrupted Roads and/or Intersections			
Speeds reduced to 1 km/h		Speeds reduced by 50%	Half of speeds are reduced 80%, the other half is increased 20%

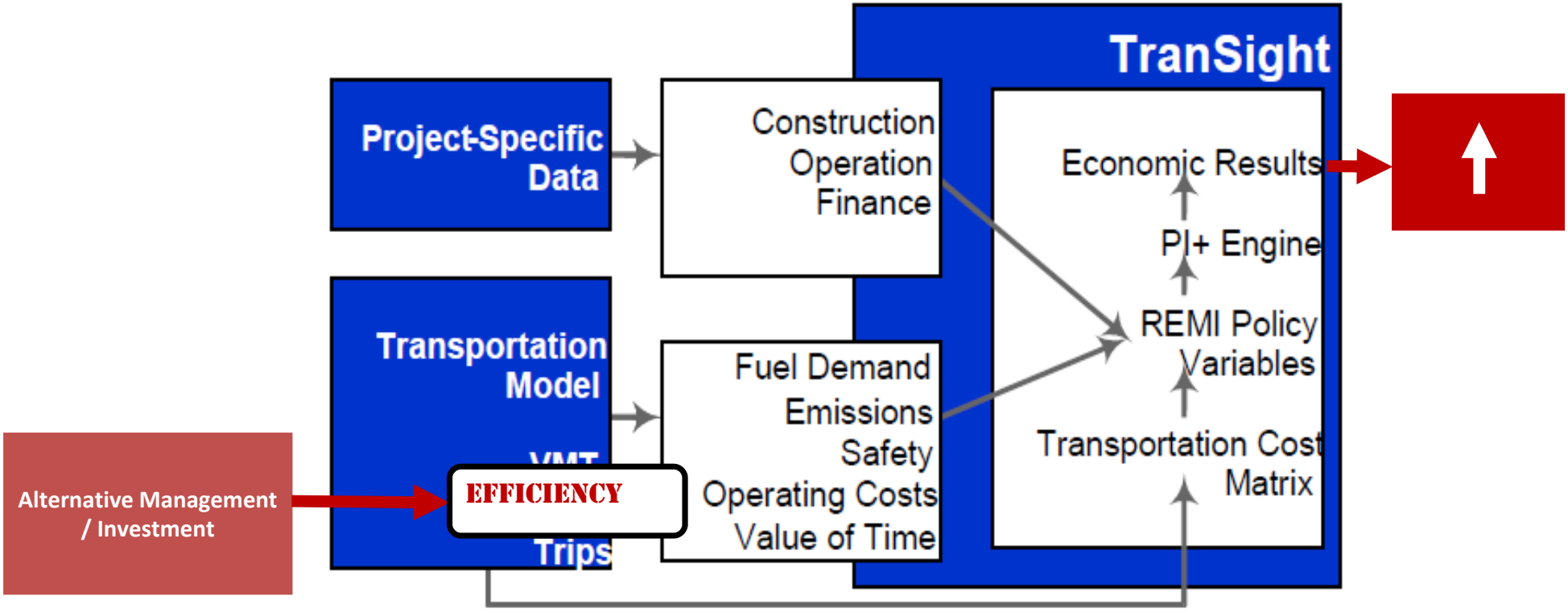
Impact of Transportation Network Disruptions on Travel Time



Resilience vs Efficiency at 5% disruption

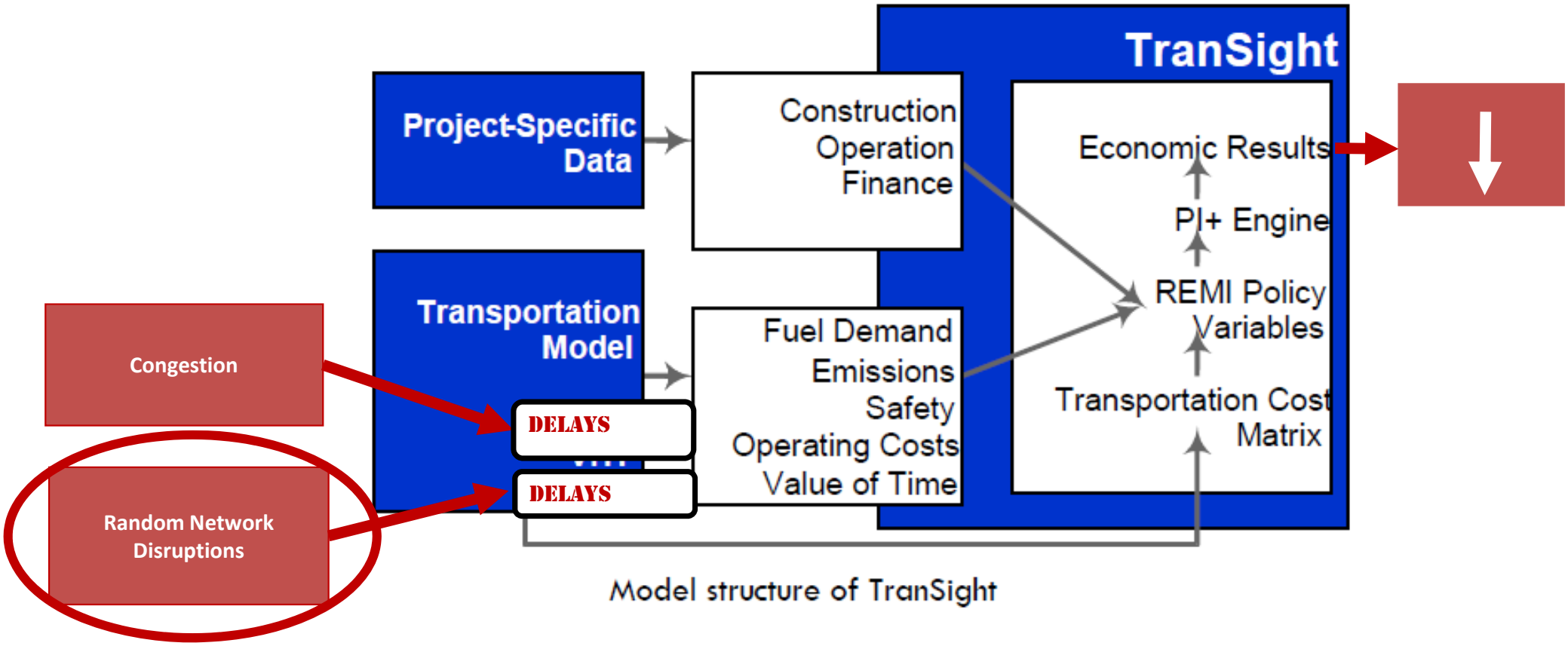


Integrating REMI Model



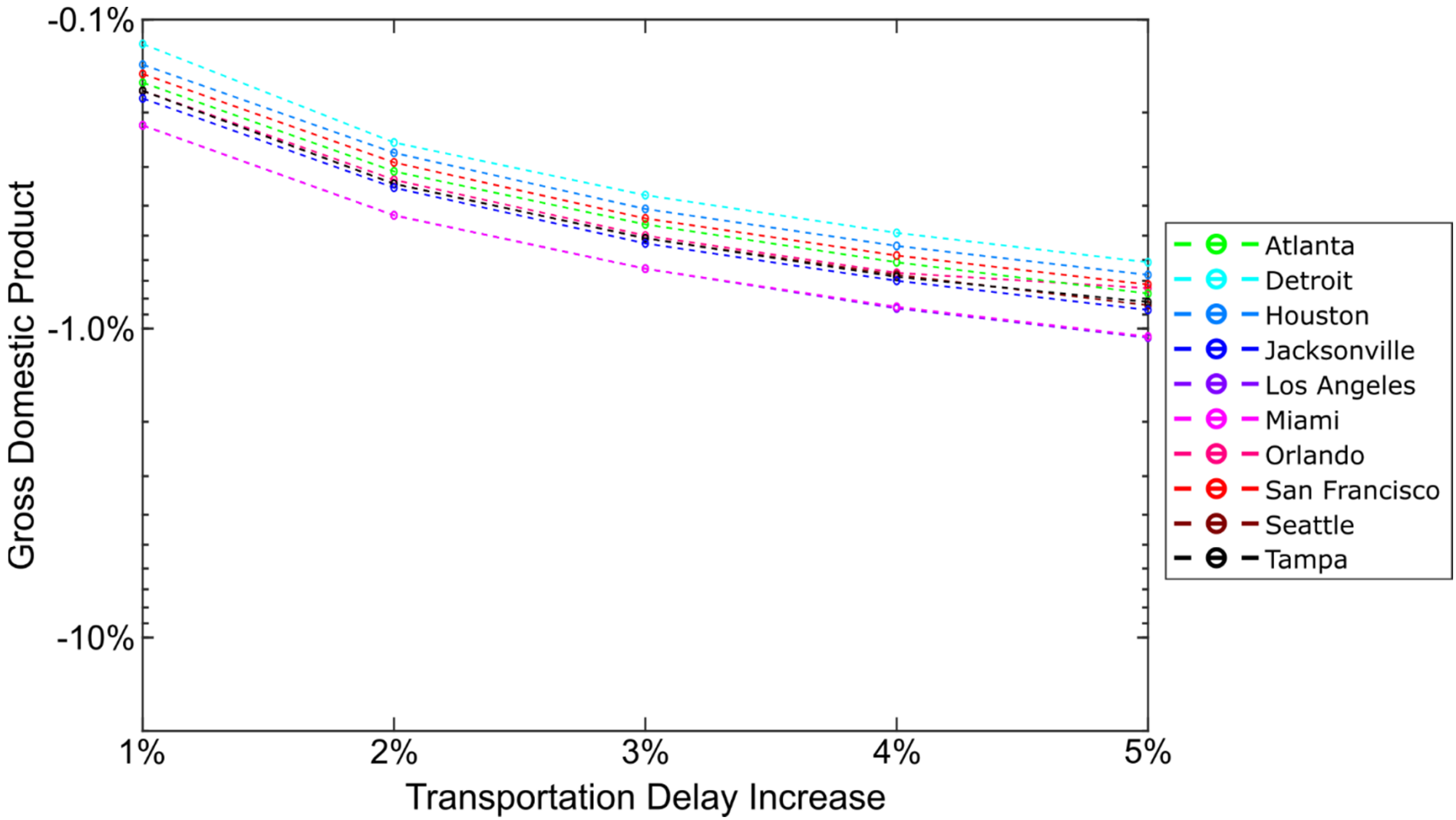
Model structure of TranSight

Repurpose to Study Economic Implications of Resilience (or lack thereof)

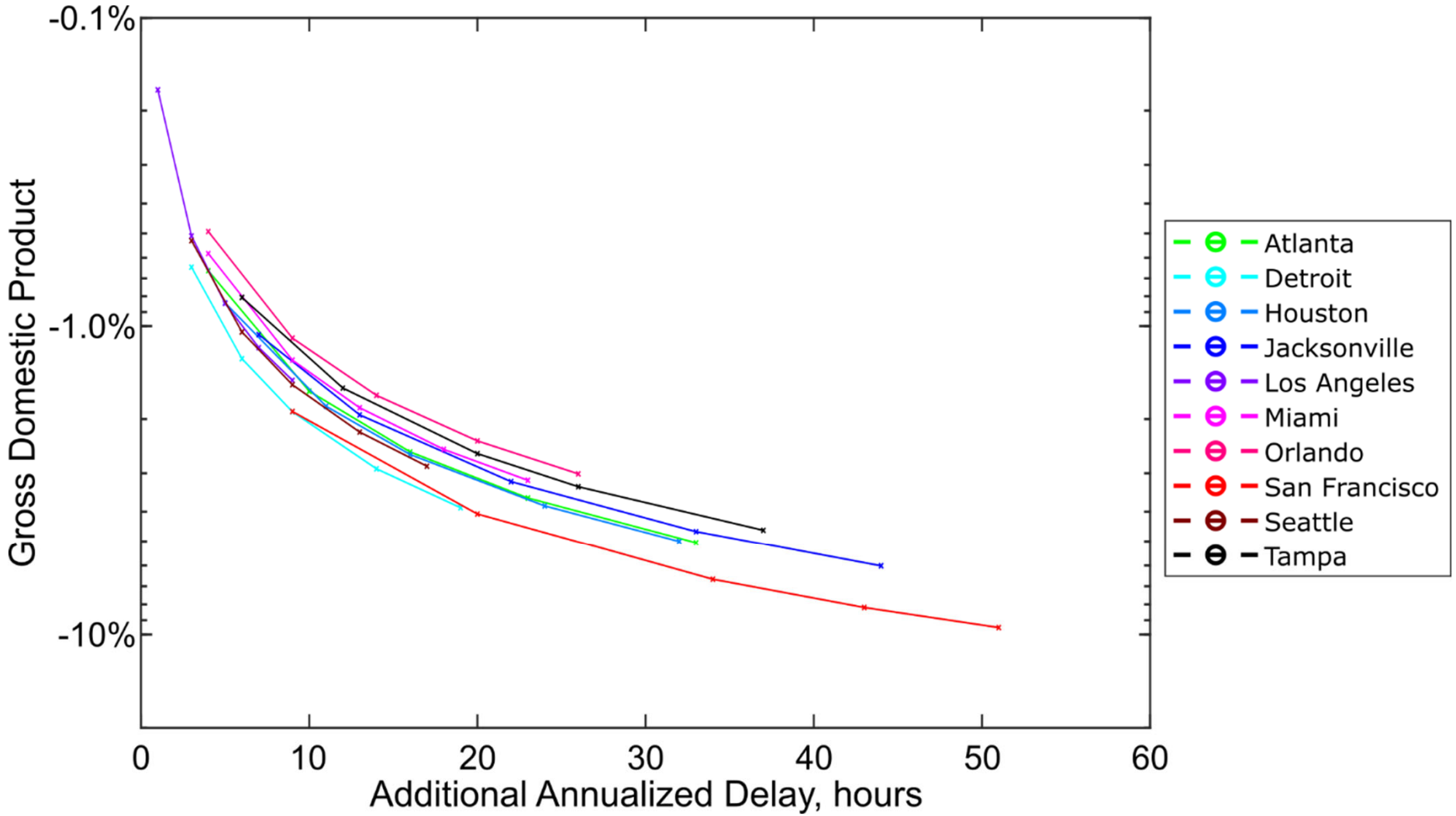


Model structure of TranSight

Impact of Efficiency-Related Delays

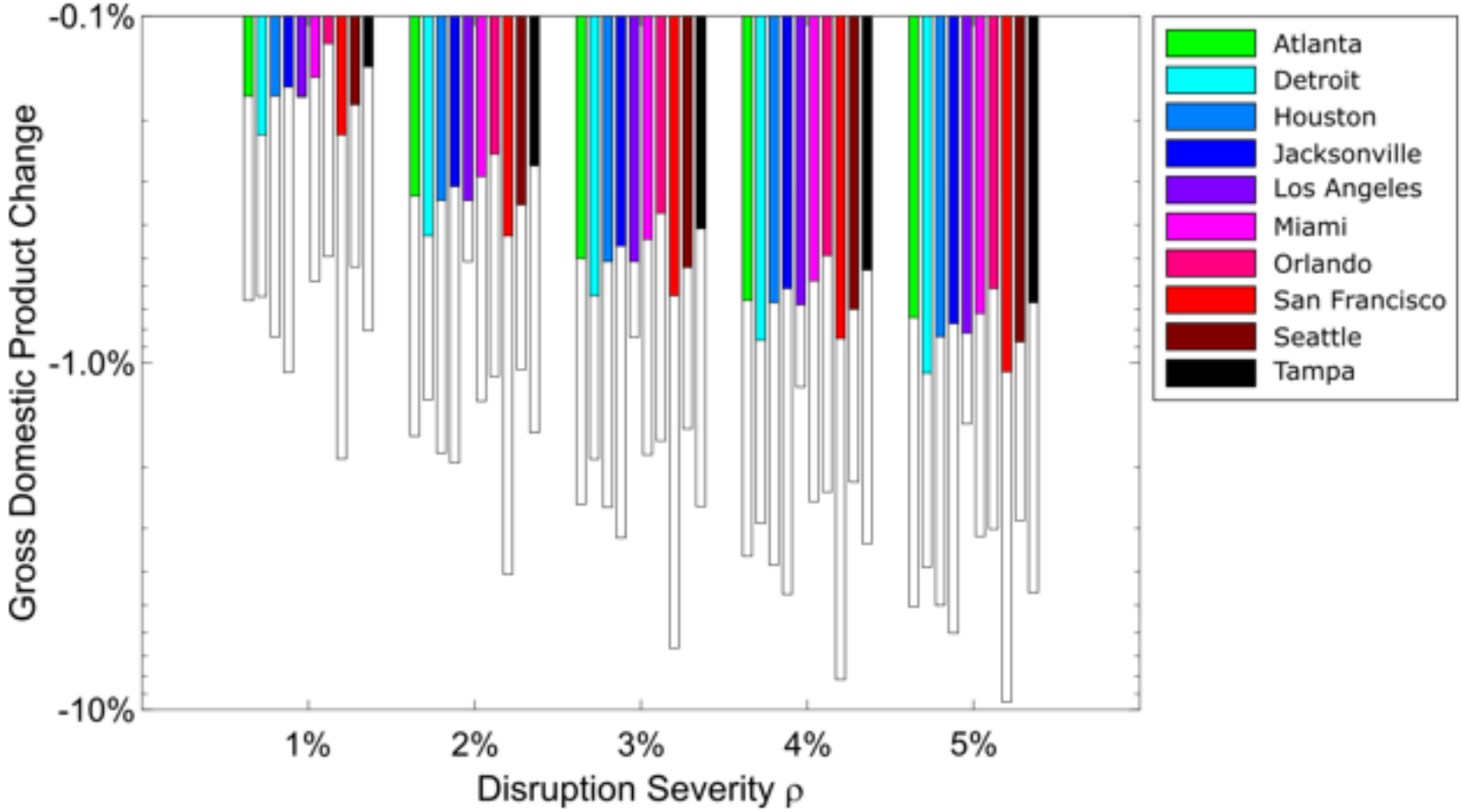


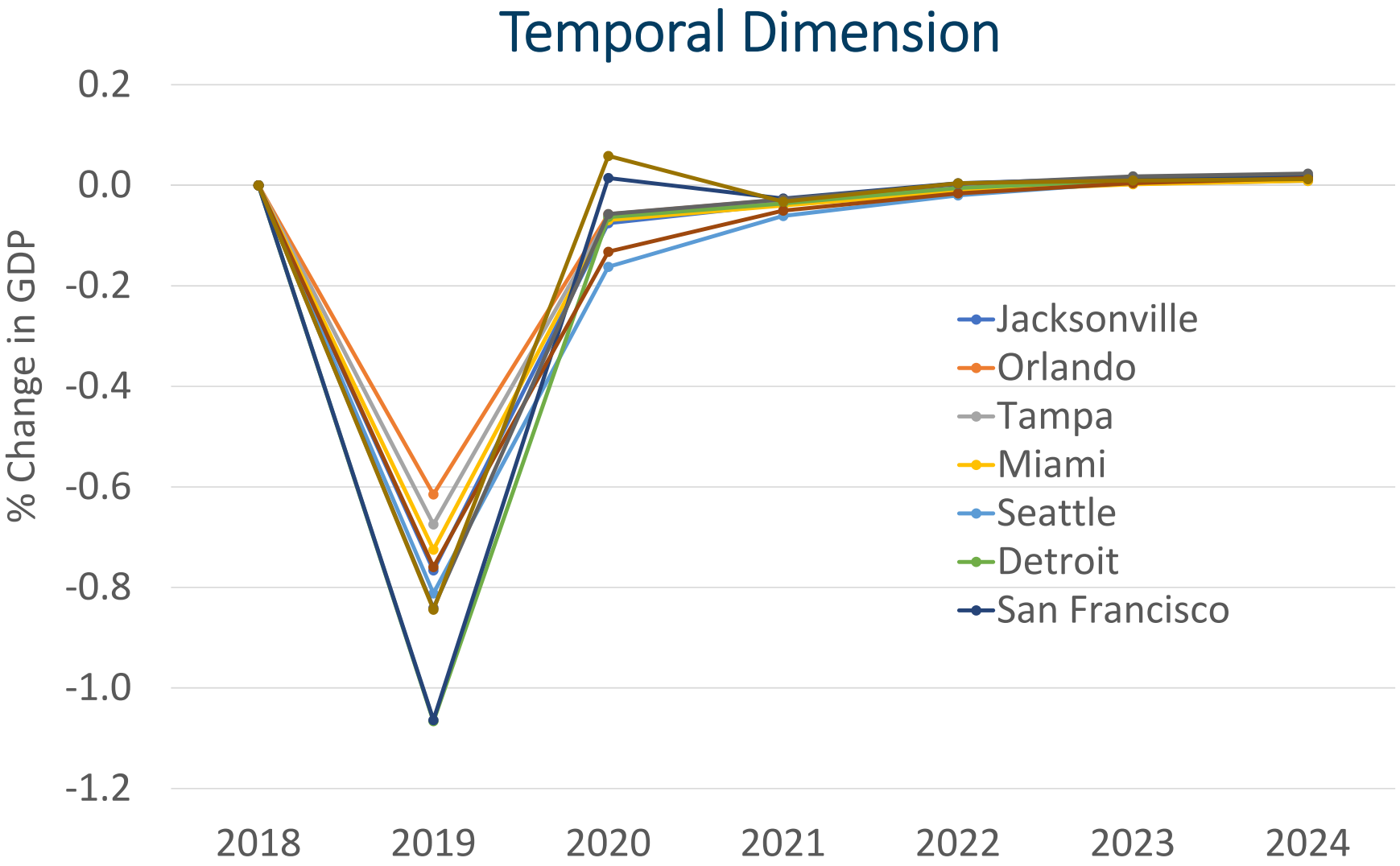
Impact of Resilience-Related Delays



Lack of Resilience: Impact on GDP

Random Disruptions are Much More Consequential




Temporal Dimension
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
% Change in GDP
2018
2019
2020
2021
2022
2023
2024
Jacksonville
Orlando
Tampa
Miami
Seattle
Detroit
San Francisco

Economic Impact – Travel Sector in Georgia

Shock to Commodity Access and Output for the Travel Sector

- 1% decrease in Commodity Access
- 1% decrease in Output for:
  - Air Transportation
  - Amusement, gambling, and recreation
  - Accommodation
  - Food services and drinking places

Commodity Access and Output
-1%

Commodity Access increase from resilience measures
+0.1%

Results

Immediate Effect (2025) (Change from Baseline)

In the short run, the decreased Commodity Access and Output causes the following:

Change in GDP
-$652 Million

Change in Employment
-6,892 Jobs

Change in Compensation by Quintile
-0.01% to -0.56%

Increase in Unemployment Rate
0.095% to 0.100%

Long Term Effect (2060) (Change from Baseline)

In the long run, socio-economic indicators reach their new market equilibrium and are measured in 2060

Change in GDP
+526 Million

Change in Employment
+2,868 Jobs

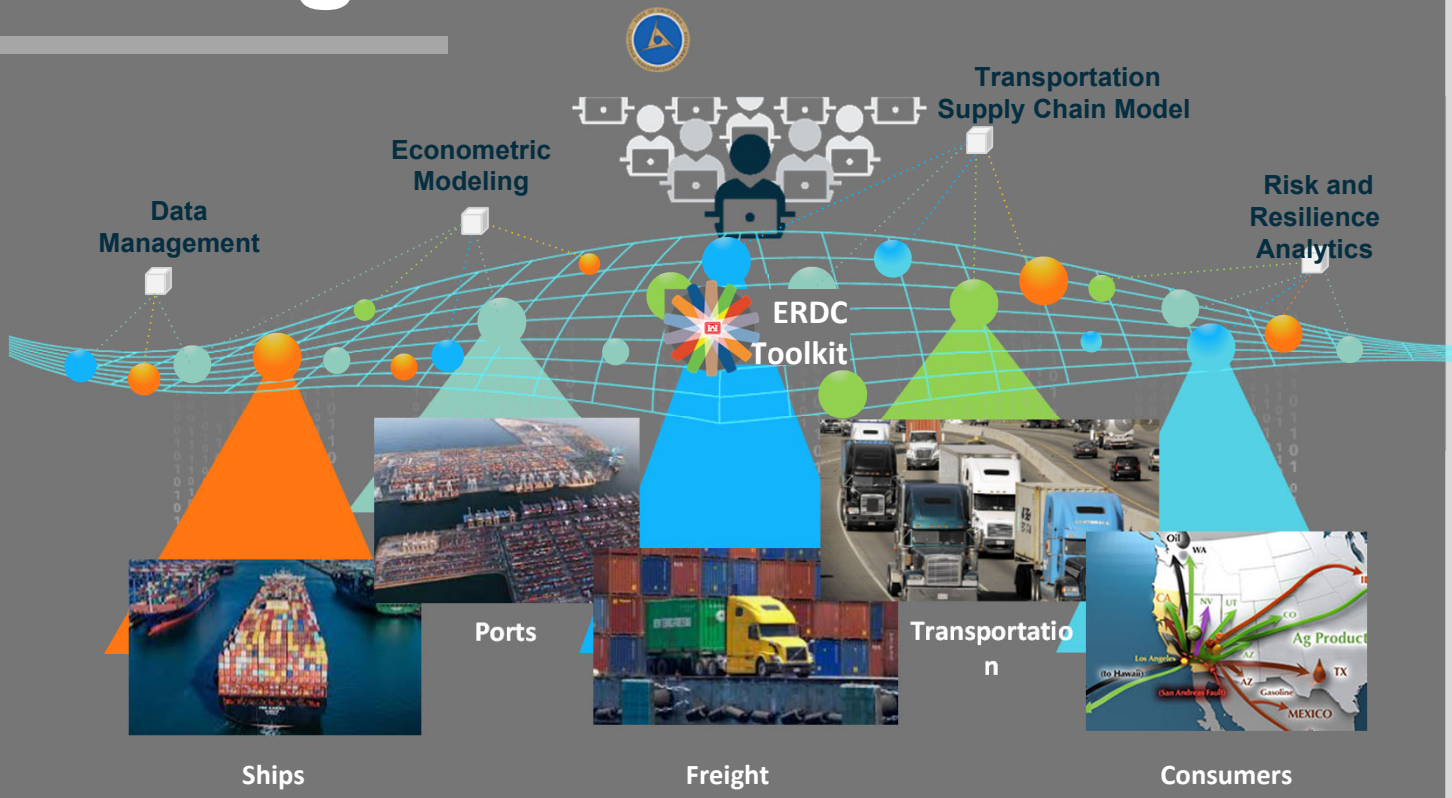
Change in Compensation by Industry Quintile
+0.022% to 0.061%

Participation Rates by Race
+0.002% to 0.024%

what does REMI say?[sm]

Freight Modeling in CA

1. Data Connections
   - Identify Interconnections
2. Data Confidence
   - Derive known commodity flows from data



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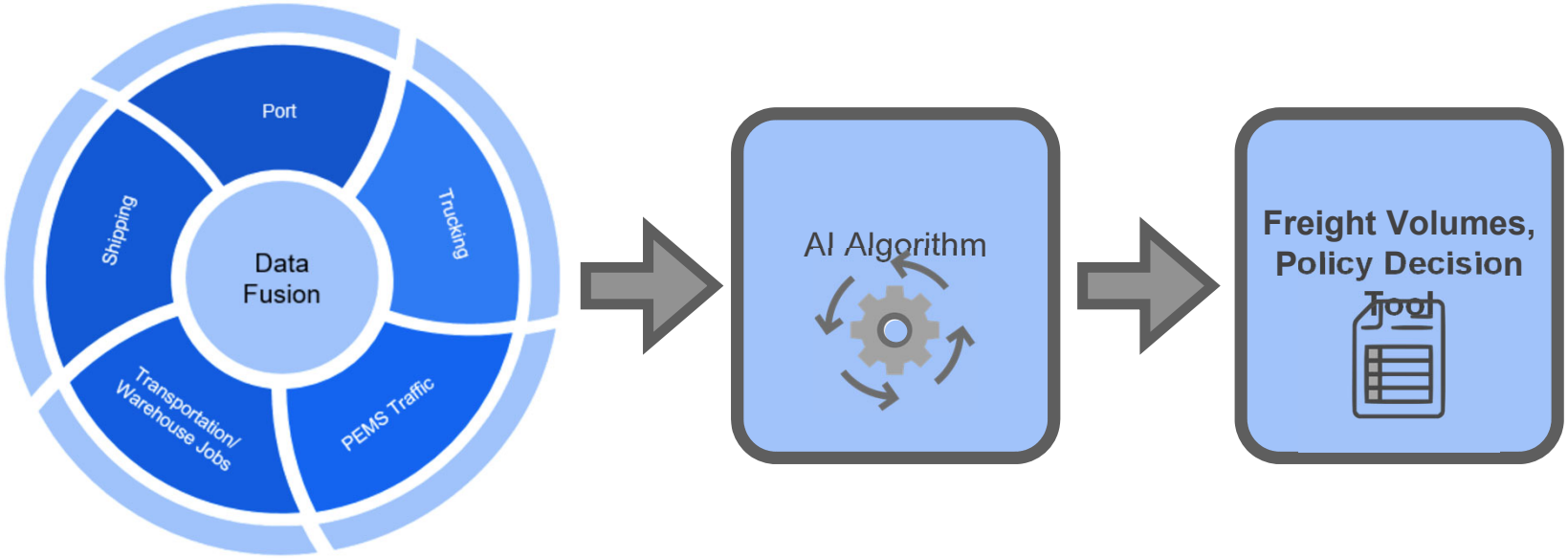
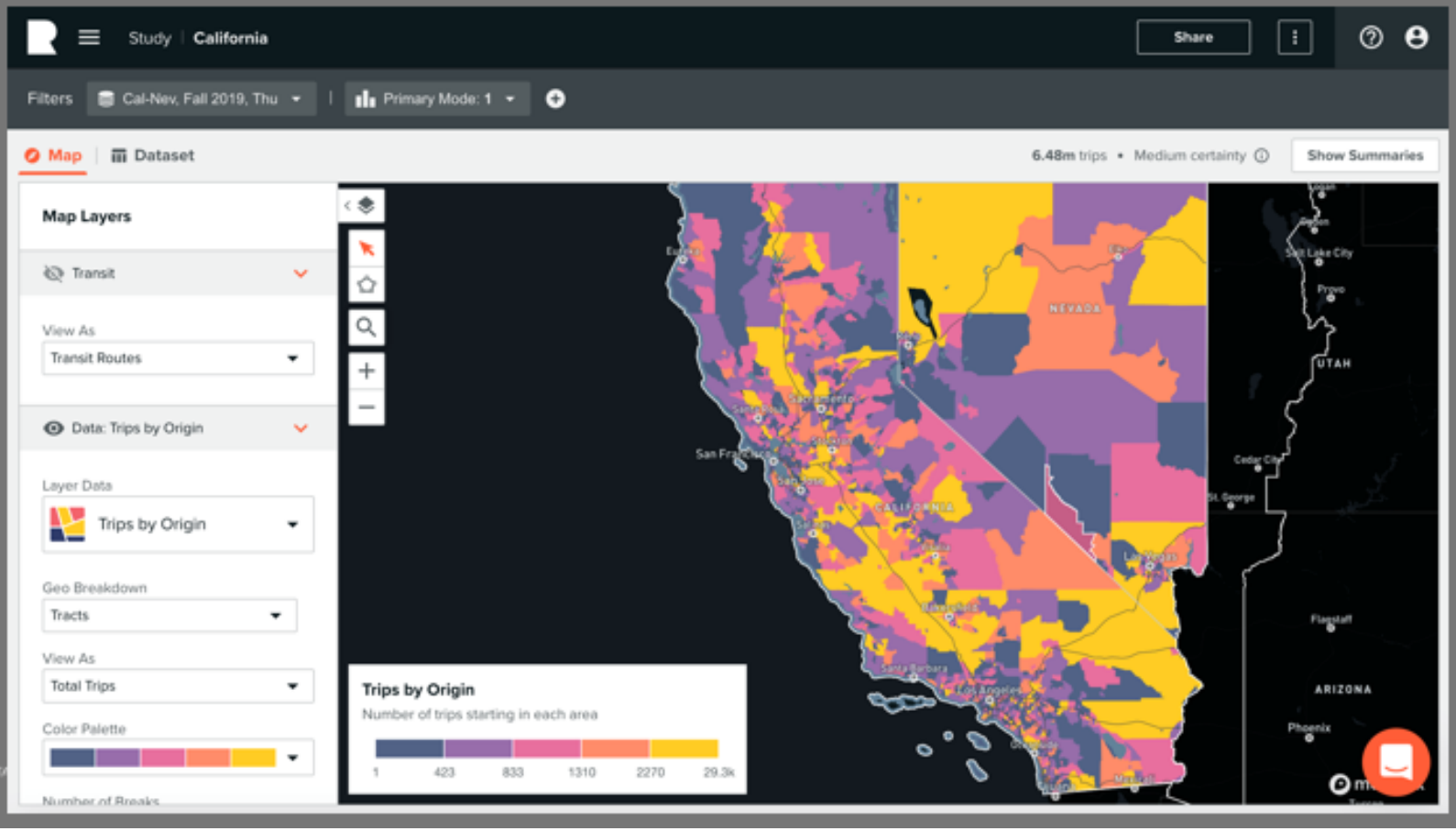
Data Fusion and Optimization Using AI and Resilience Modeling



Replica Data:
Connecting Entry Points, Warehousing and Consumers



EL ENVIRONMENTAL LABORATORY

Presentation Overview

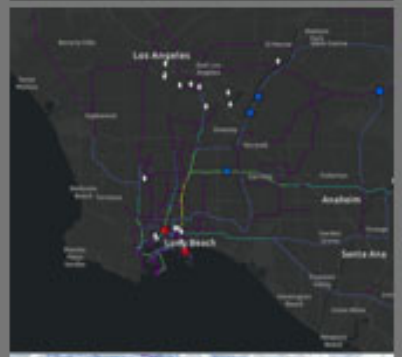
- Tools:
  - Freight Volumes
  - Scenario Comparison Tool

- Problems we are addressing:
  I. Supply Chain Resilience Quantification
  II. Natural Disaster Risk and Resilience
  III. Zero-Emission Refueling Station Prioritization
  IV. Multi-Objective Equity Optimization

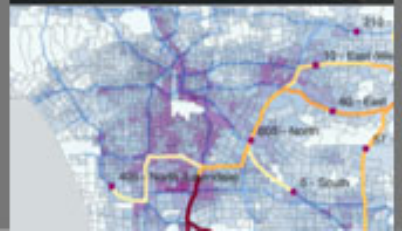
Supply Chain Resilience

Natural Disaster Risk and Resilience

Zero Emission Refueling Station



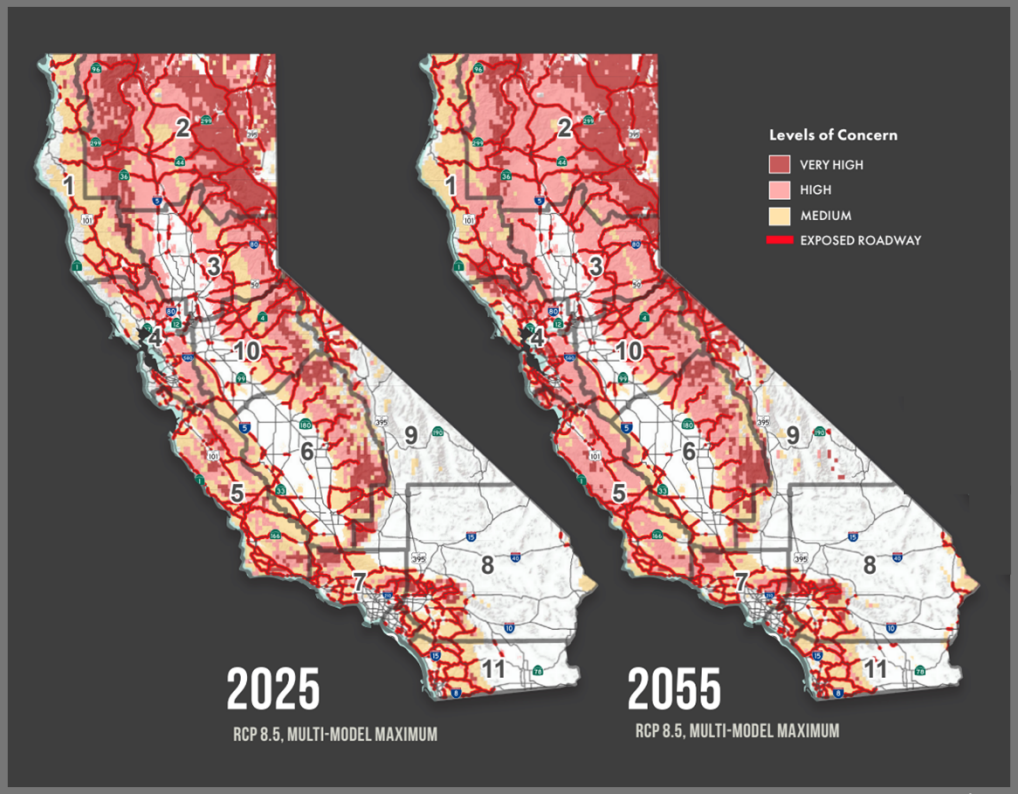
Multi-Objective Equity Optimization



EL ENVIRONMENTAL LABORATORY

Multi-Treat Natural Disaster Resilience Quantification

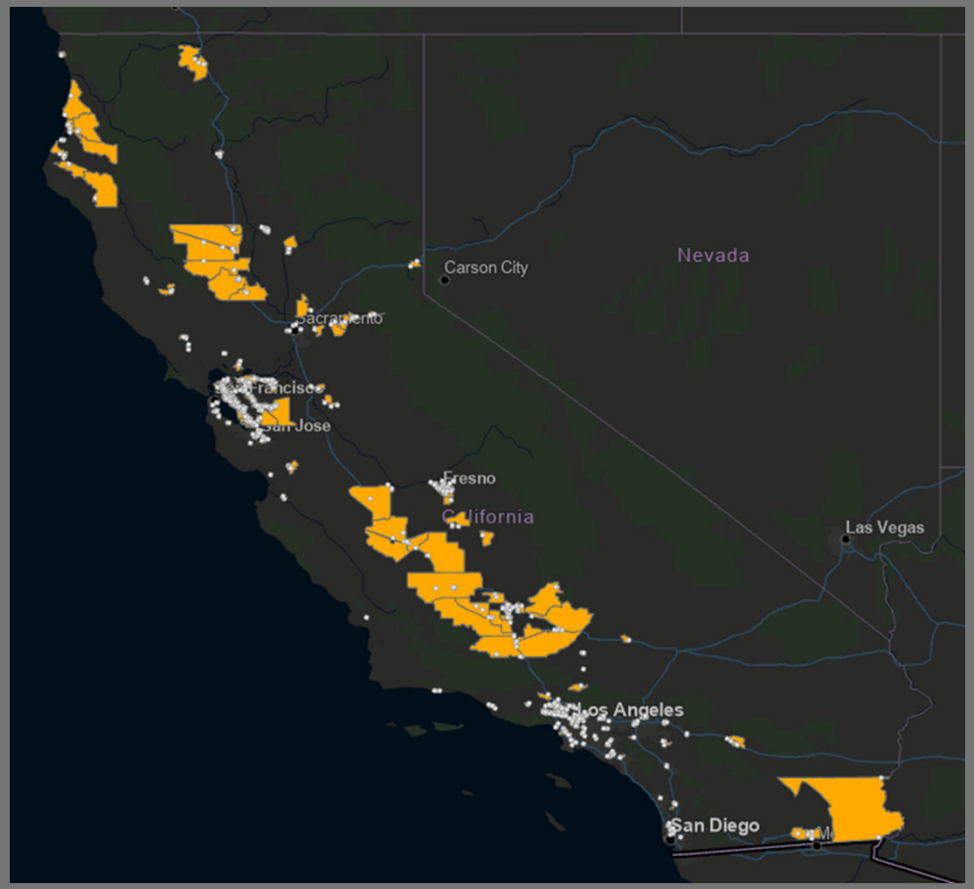
- Climate events will be simulated based on existing road vulnerability assessments:
  - Precipitation
  - Wildfire
  - Sea level rise
  - Storm Surge
  - Cliff Retreat
  - Earthquakes



Changing Level of Wildfire Concern | Caltrans Climate Change Vulnerability Assessment

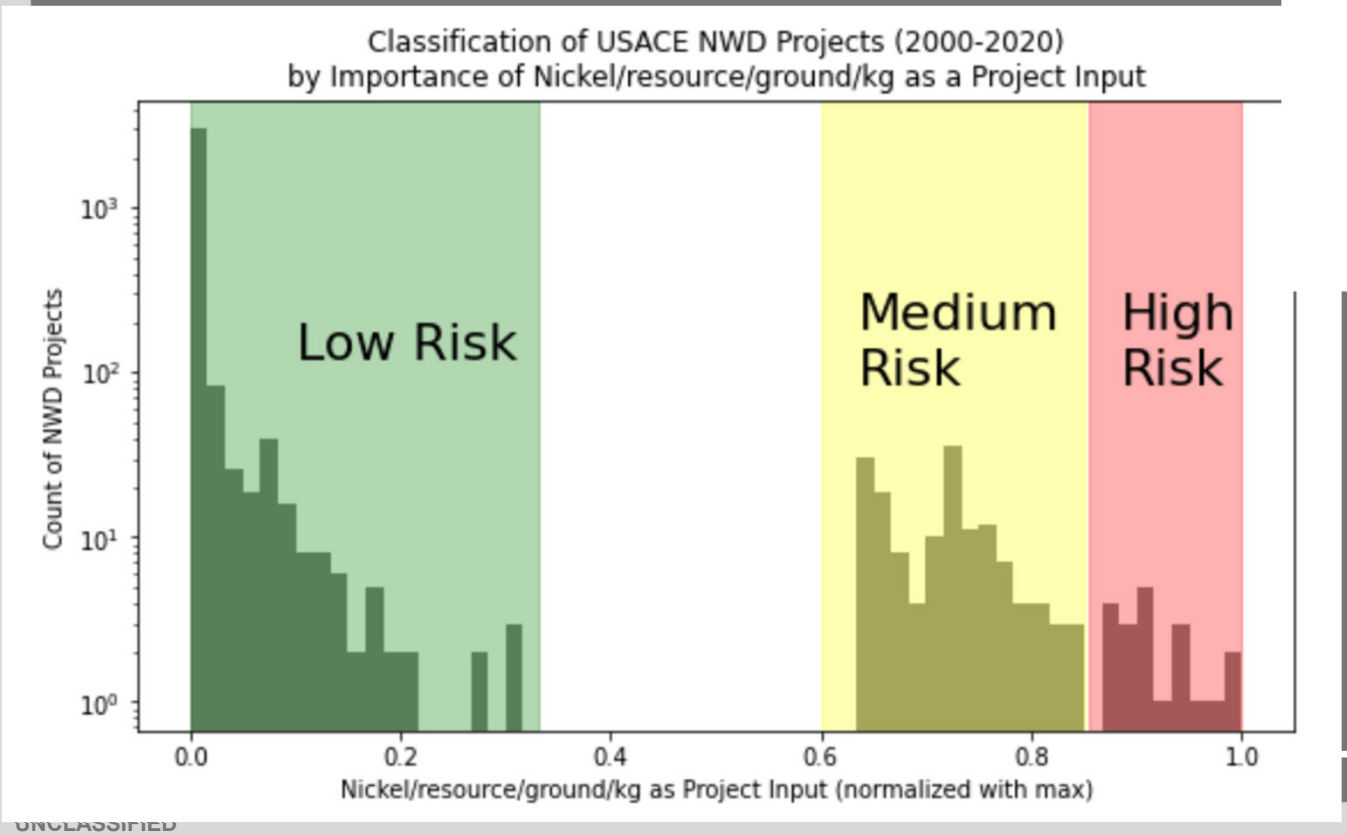
Hydrogen Refueling Stations: Candidate Locations

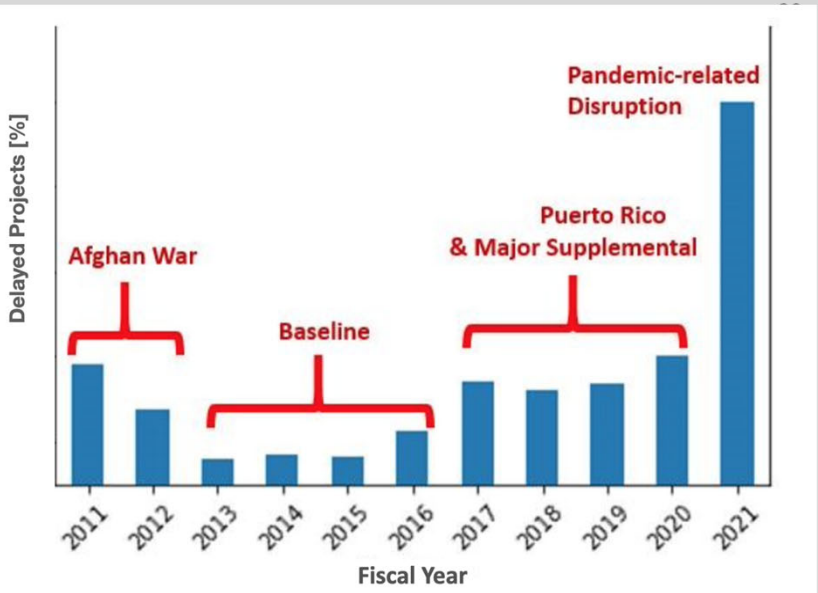
- **Identified:**
  500 Candidate Census tracts which, together minimize freight diversion
- **Details:**
  - 500 tracts were identified based on CTC input
  - Gas and Service stations within census blocks were also identified

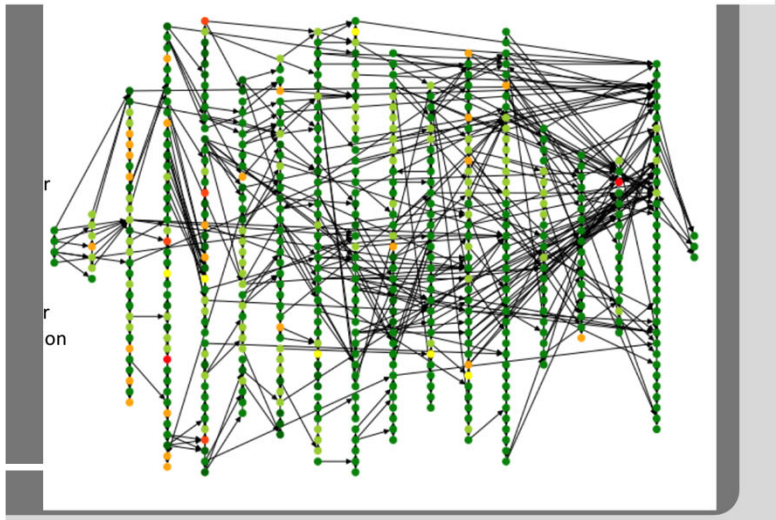


ENVIRONMENTAL LABORATORY

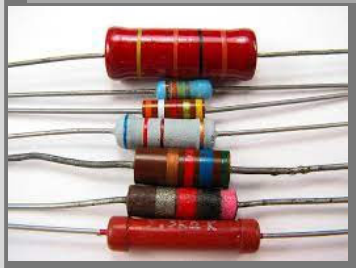
USACE Project Reliance on Foreign-Sourced Minerals





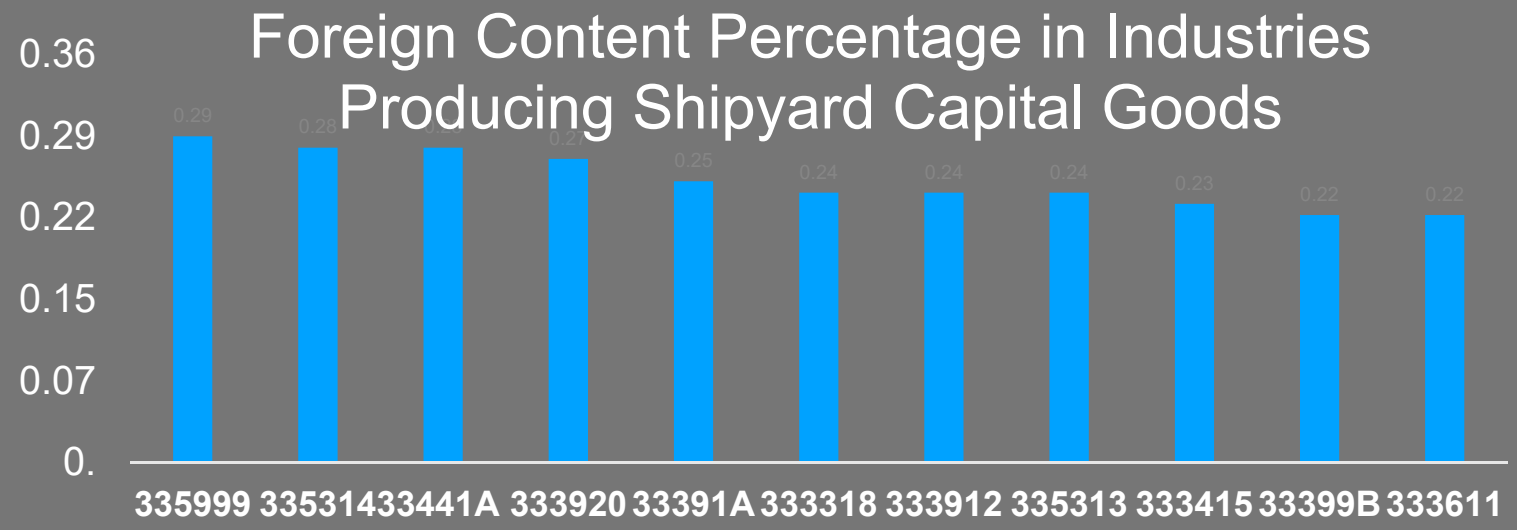


Estimates of Foreign-Sourced Content in Capital Goods



Item Level

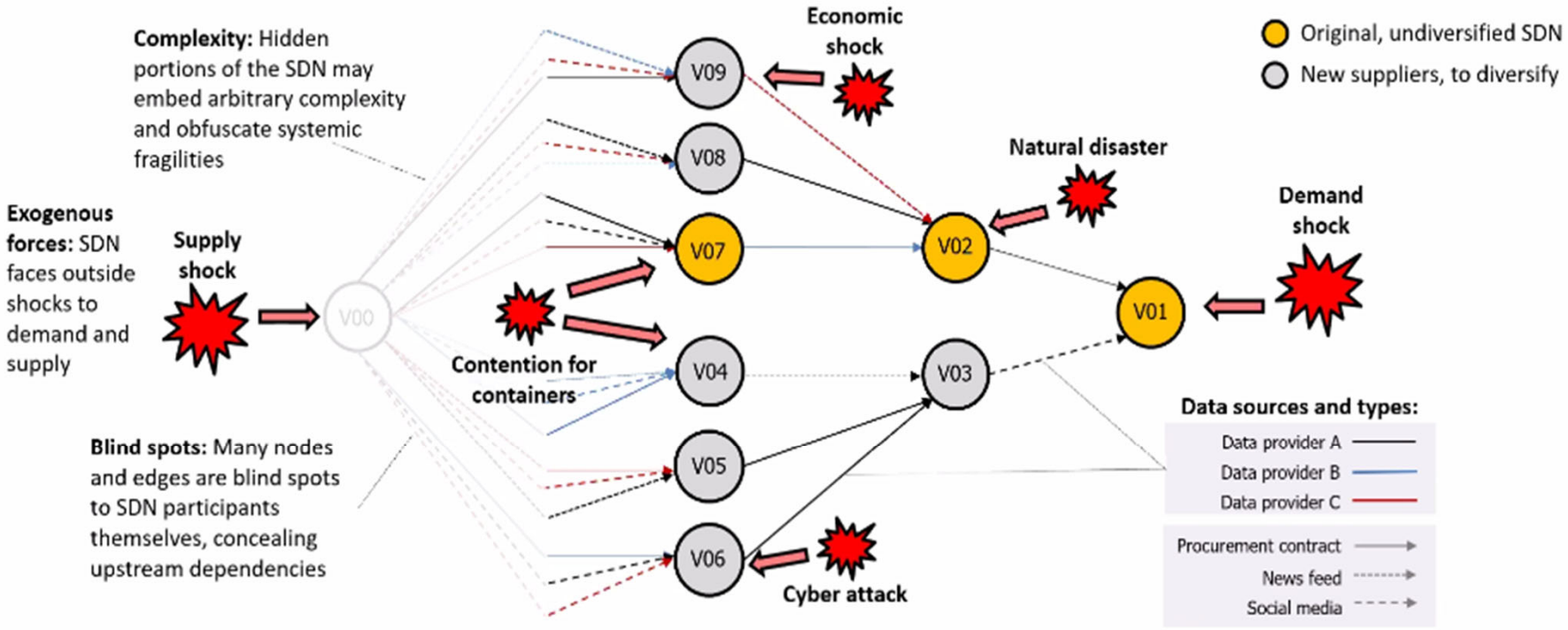
System Level



ENVIRONMENTAL LABORATORY

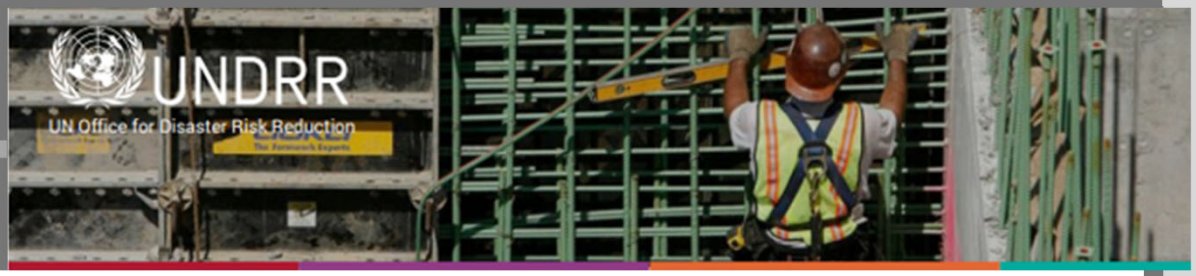
Supply-and-Demand Networks – challenges

SDNs operate as engines for strategic surprise – many critical vulnerabilities emerge only at the system level



RSDN will explore SDN fragilities and possible mitigations – e.g., procurement policies, strategic reserves, etc.

Resilience Stress Testing

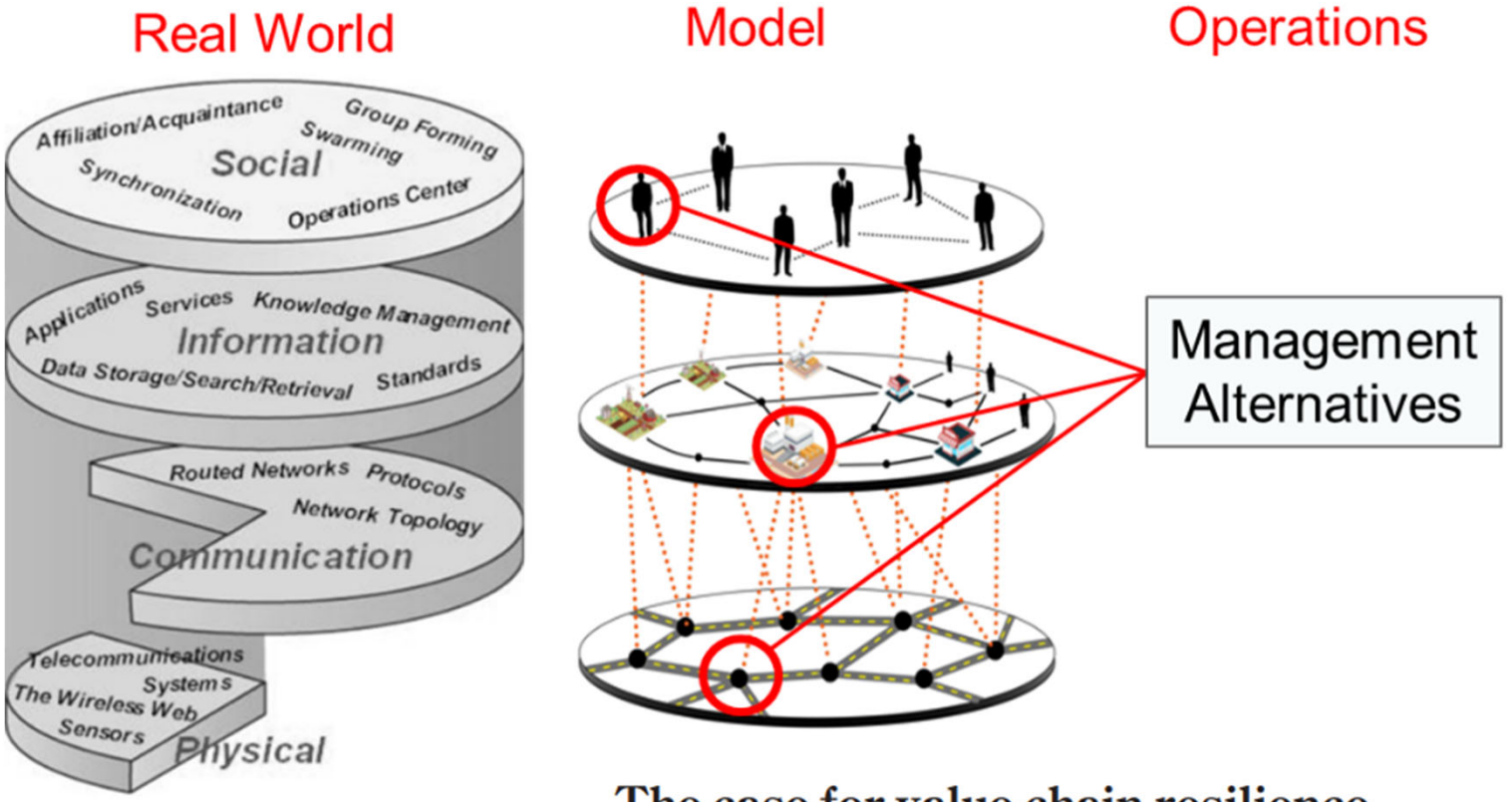


INTEGRATED RISK/RESILIENCE STRESS TESTING

578 | Nature | Vol 603 | 24 March 2022

WHO DOES ANALYSIS?		"Identify the functions and failures" INPUTS	"Perform the stress test" RISK	RESILIENCE	"Fortify the system" OUTPUTS
Policy Analysts, Generalists	TIER 1	Qualitative information, component data	Develop scenarios for shocks and stresses affecting specific vulnerabilities	Identify critical functions of systems and cascading failures	"Quick win" improvements
Risk Assessors, engineers, decision analysts	TIER 2	System structure, connectivity	Assess risk of component failure under stress scenario separately per domain	Identify connections across multiple system domains that are difficult to recover	System wide resilience strategy
Specialists, modelers	TIER 3	Detailed system information, advanced data	Advance probabilistic risk assessment across multiple domains/compounding threats	Network science/AI techniques to assess failures in interconnected networks	Targeted Changes + Interventions

Vision for System Resilience

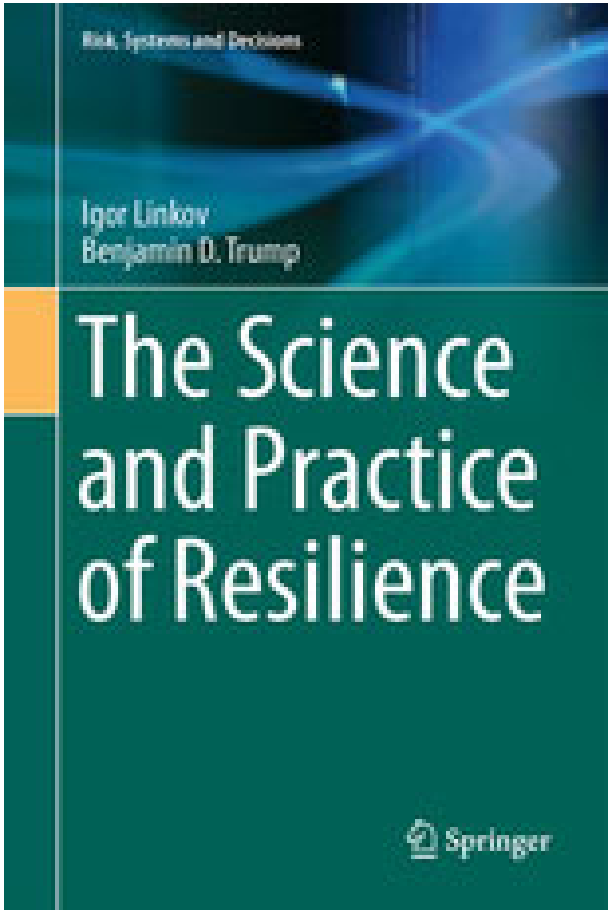


The case for value chain resilience

Igor Linkov, Savina Carluccio, Oliver Pritchard, Áine Ní Bhreasail, Stephanie Galaitsi, Joseph Sarkis and Jeffrey M. Keisler

Management Research Review

2040-8269
DOI 10.1108/MRR-08-2019-0353


Risk, Systems and Decisions
Igor Linkov
Benjamin D. Trump
The Science and Practice of Resilience
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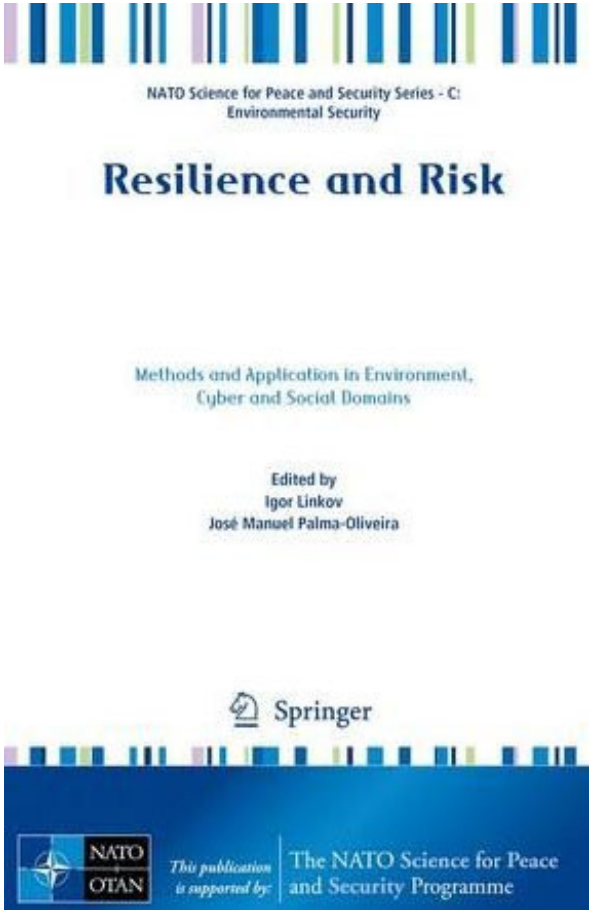
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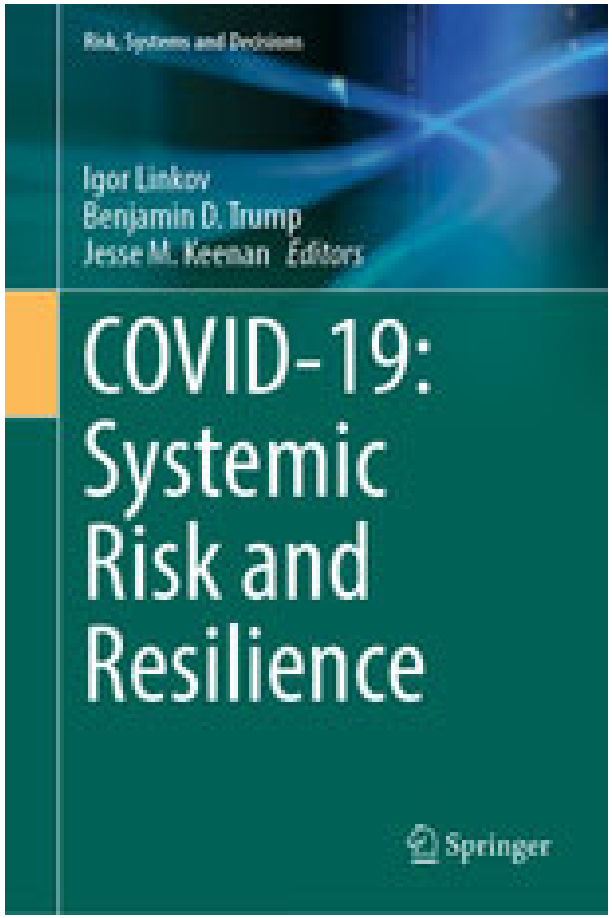
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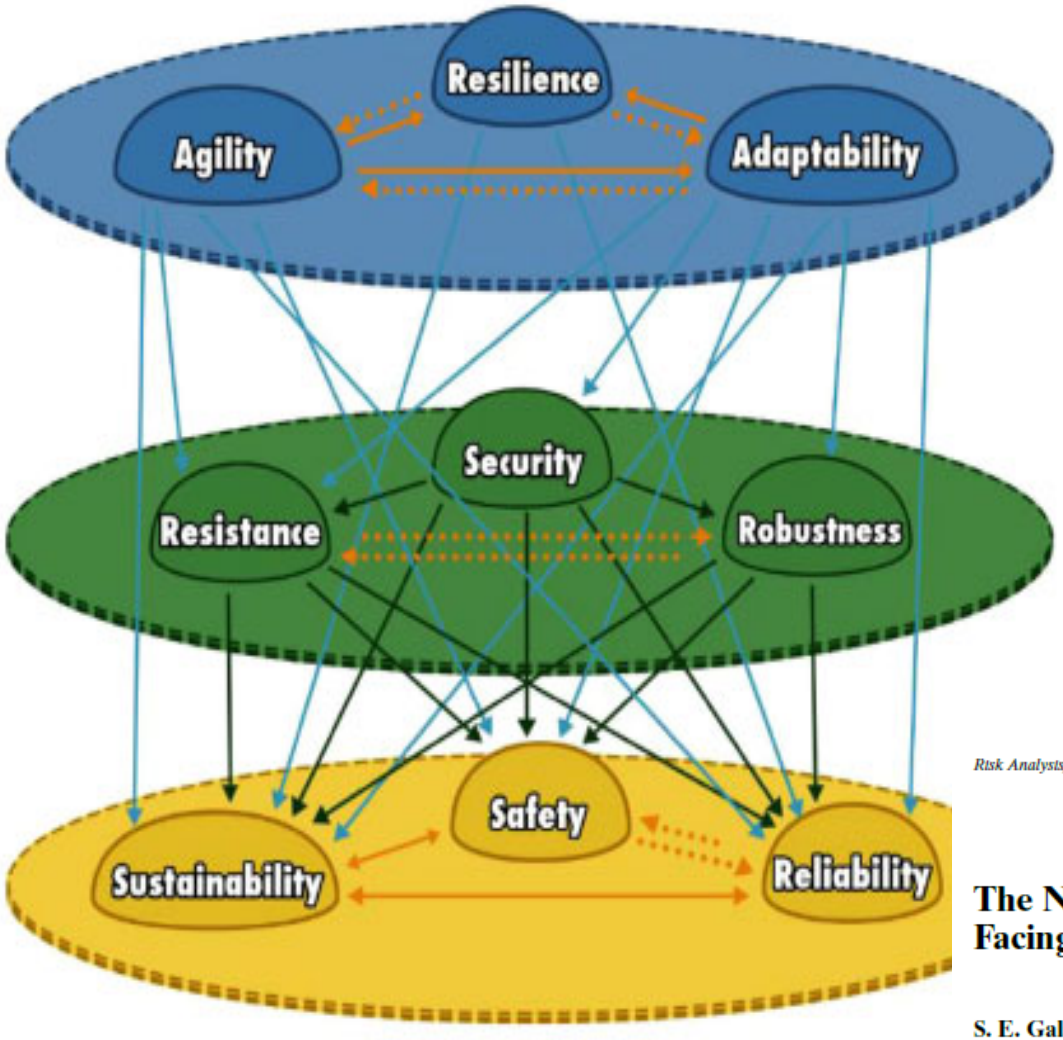

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Risk Analysis, Vol. 0, No. 0, 2020 DOI: 10.1111/risa.13577

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S. E. Galaitsi,[1] Jeffrey M. Keisler,[2] Benjamin D. Trump,[1] and Igor Linkov[1,*]

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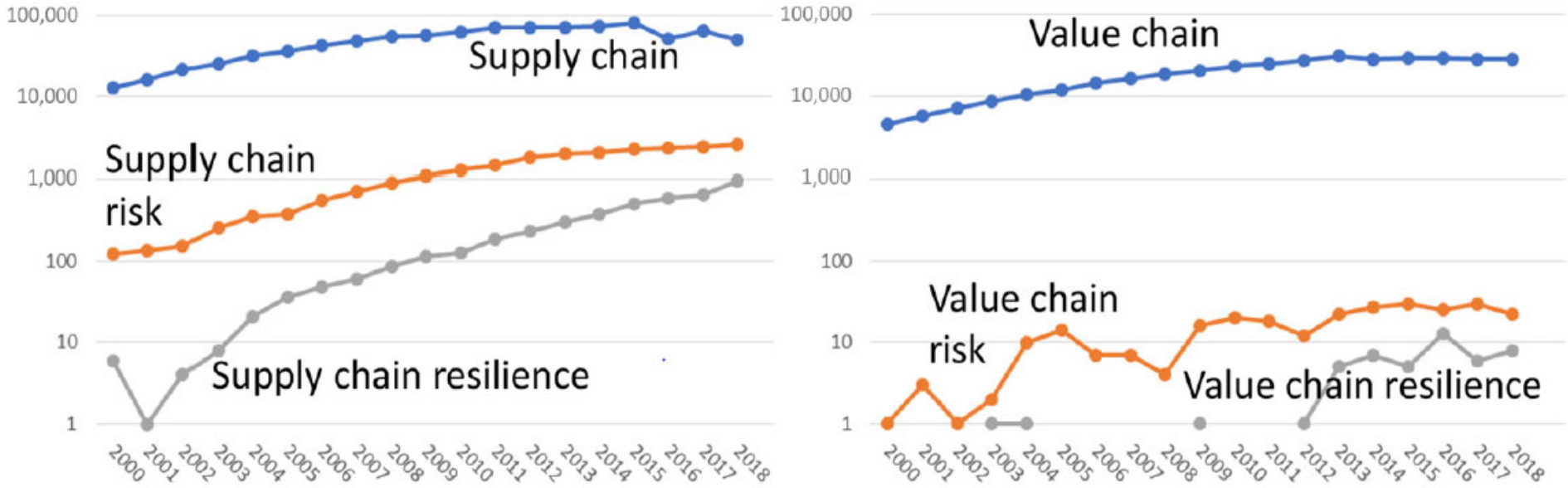

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