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TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Supply Chain Risk and Resilience—Linking Transportation and Economic Models

October 6, 2022

2:30 – 4:00 PM

NOVEMBER 2022 UPDATE

AICP Credit Information

1.5 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

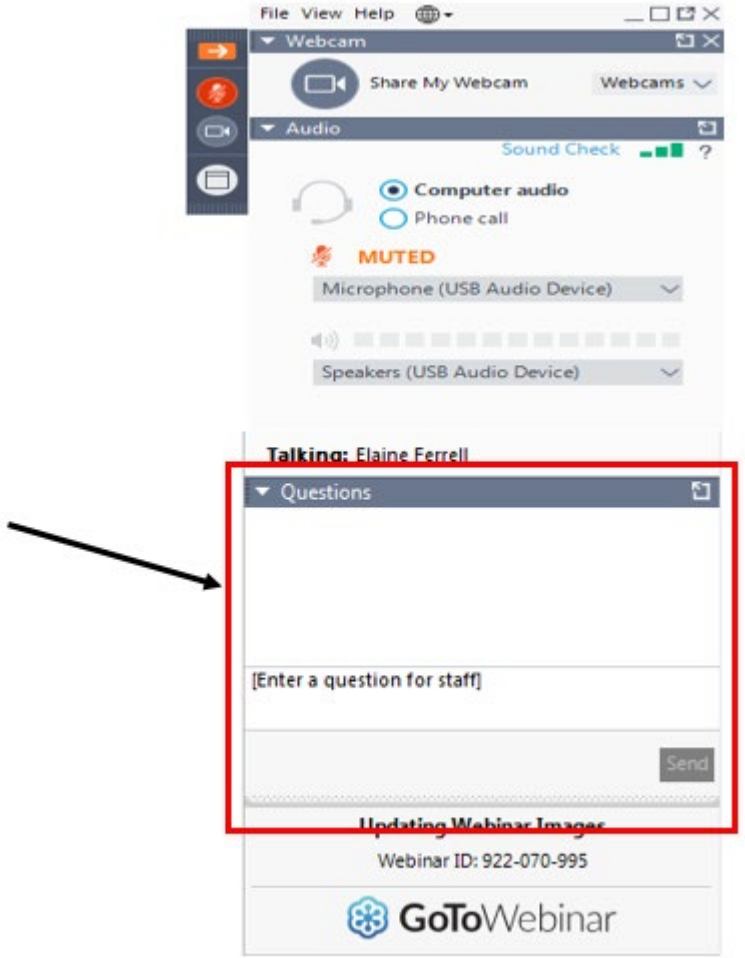
Contact AICP, not TRB, with questions

Learning Objectives

- Define resilience analytics relevant to the supply chain
- Apply causal analysis, especially with regard to the transportation industry
- Connect econometric measurements with transportation and sensor information

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Igor Linkov
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U.S. Army Corps of Engineers

Hannah Walter
hannah.walter@catc.ca.gov
California Transportation Commission

Kelsey Stoddard
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U.S. Army Corps of Engineers

Andrew Strelzoff
andrew.strelzoff@usace.army.mil
U.S. Army Engineer Research and Development Center

Port of LA photo – pier 400

California Transportation Commission and Freight Resiliency

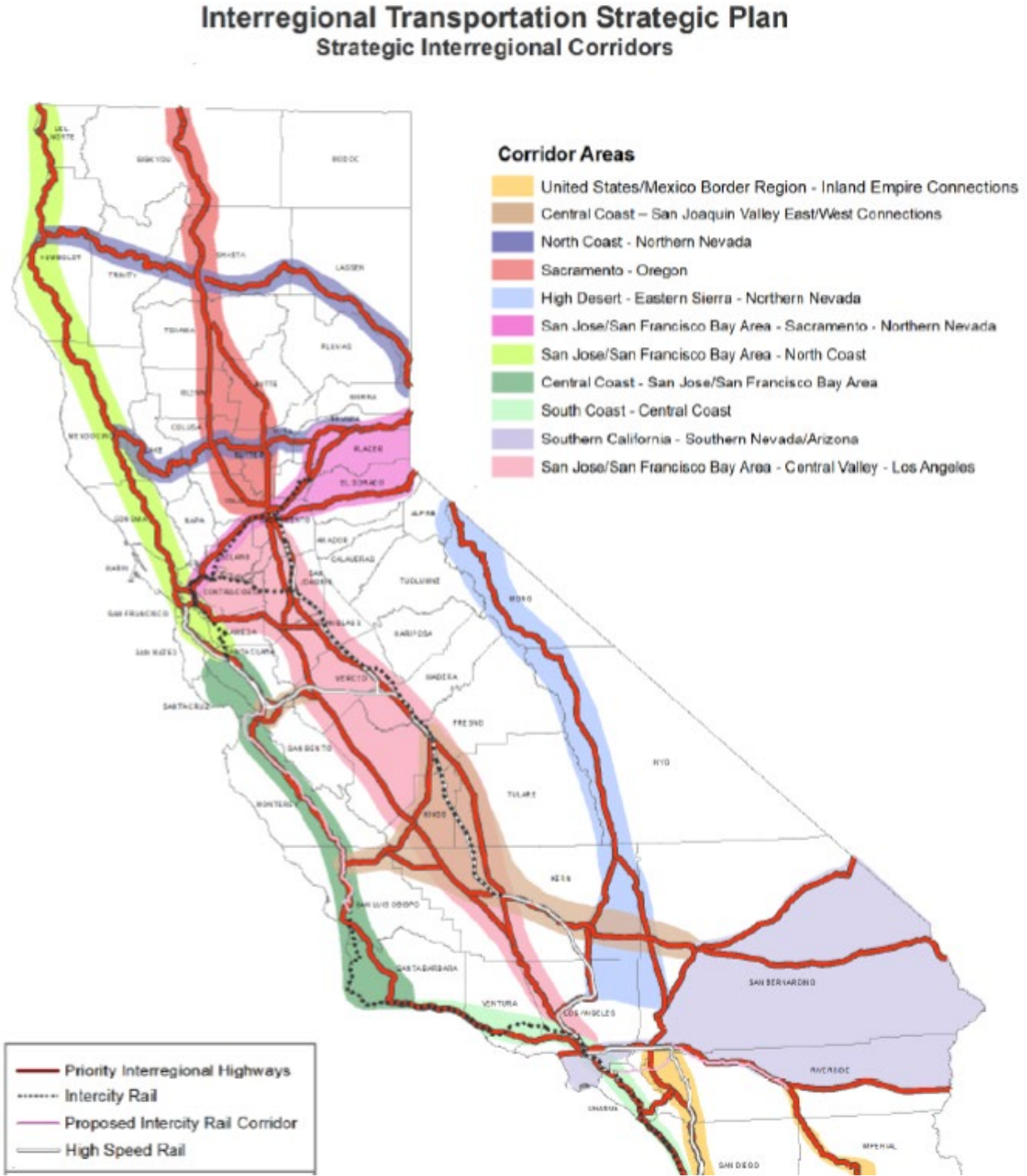
Hannah Walter

Associate Deputy Director, Programming

What are the impacts of supply chain disruptions in California?

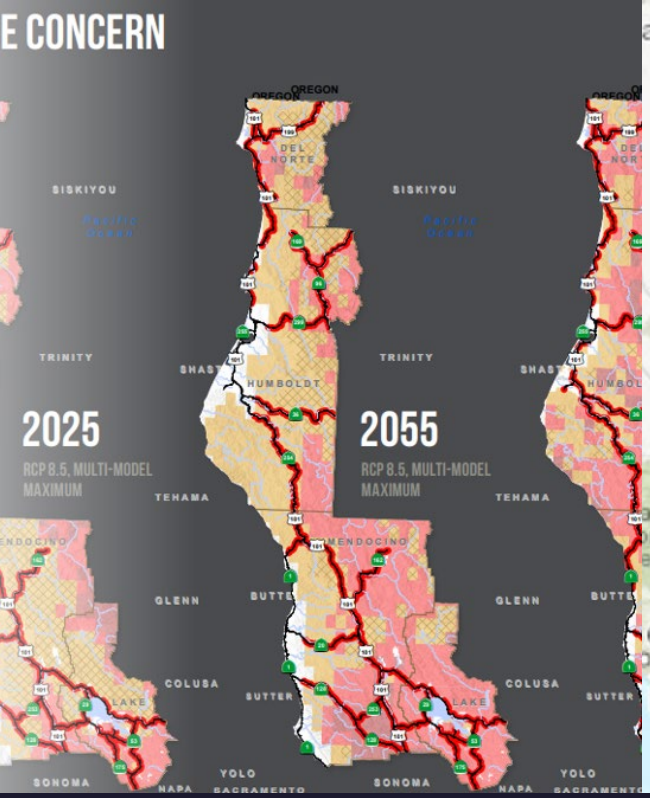
- Higher costs for consumers
- Delays of essential goods
- Revenue loss for freight related companies

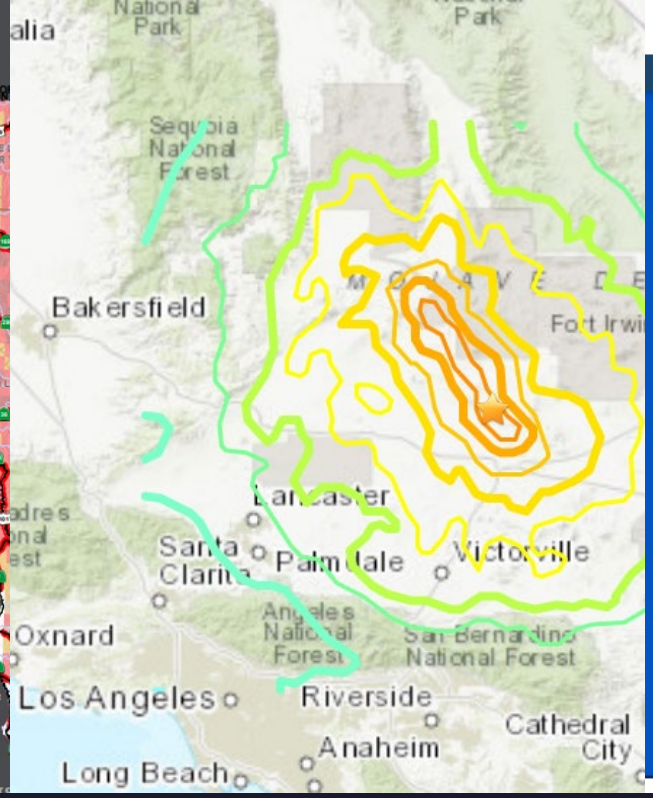
https://www.kqed.org/news/11816014/california-hospitals-begin-sterilizing-previously-worn-n95-masks-for-reuse-but-nurses-call-them-unsafe
https://patch.com/california/los-angeles/ca-inflation-40-year-high-costs-average-californian-thousands
https://calmatters.org/newsletters/whatmatters/2021/11/california-cost-of-living-skyrockets/

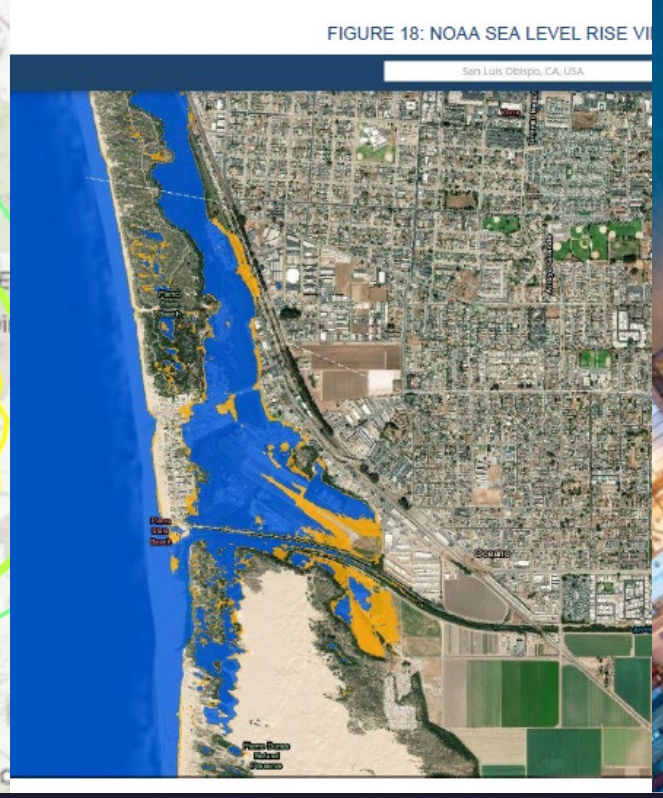


California's Supply Chain Impacts the National Supply Chain

- For example, about **40 percent** of **U.S. imports** and 25 percent of U.S. exports transit through California's San Pedro Bay ports.







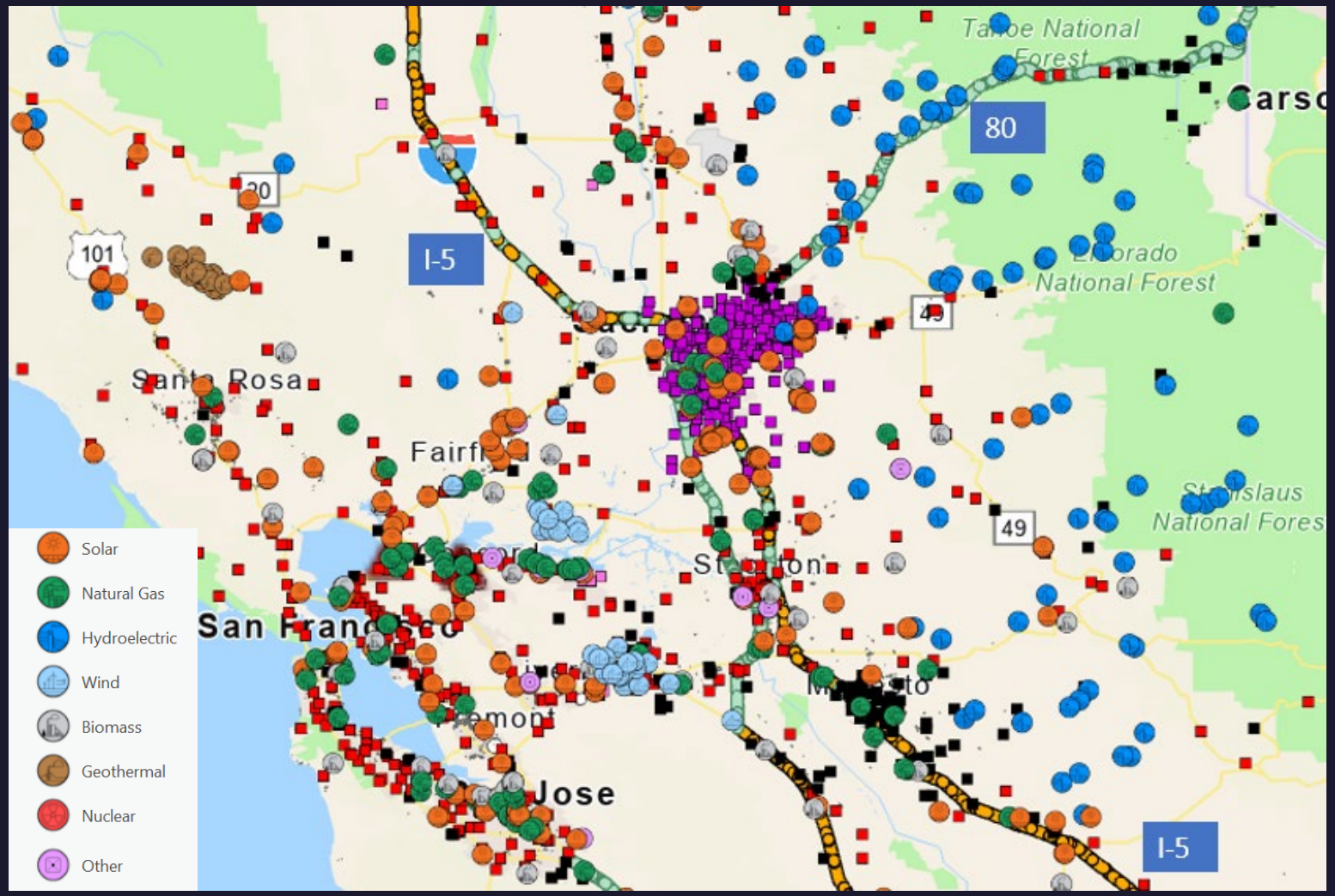
California Transportation Commission Goals

1. Identify the types, probabilities, & locations of disruptions
2. Plan the best response

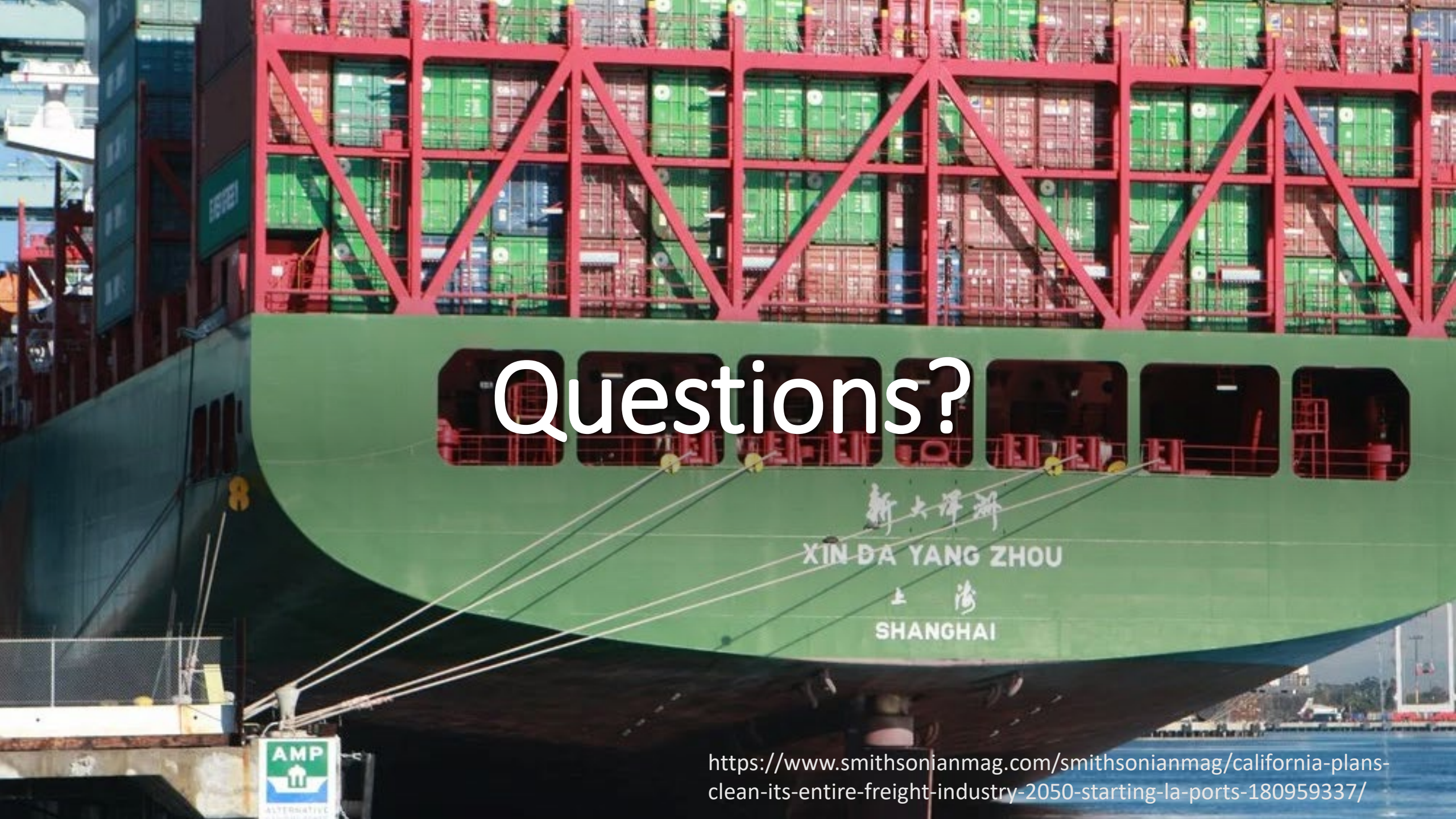
Zero-Emission Freight

- 100% zero-emission trucks by 2045
- Phased-in approach
- CTC planning supporting infrastructure

Combining Electric Infrastructure Data with Freight Model Data



Questions?



https://www.smithsonianmag.com/smithsonianmag/california-plans-clean-its-entire-freight-industry-2050-starting-la-ports-180959337/

Lack of Resilience in Transportation Networks: Economic Implications

Igor Linkov
US Army Engineer Research and Development Center Boston, MA
Igor.Linkov@usace.army.mil

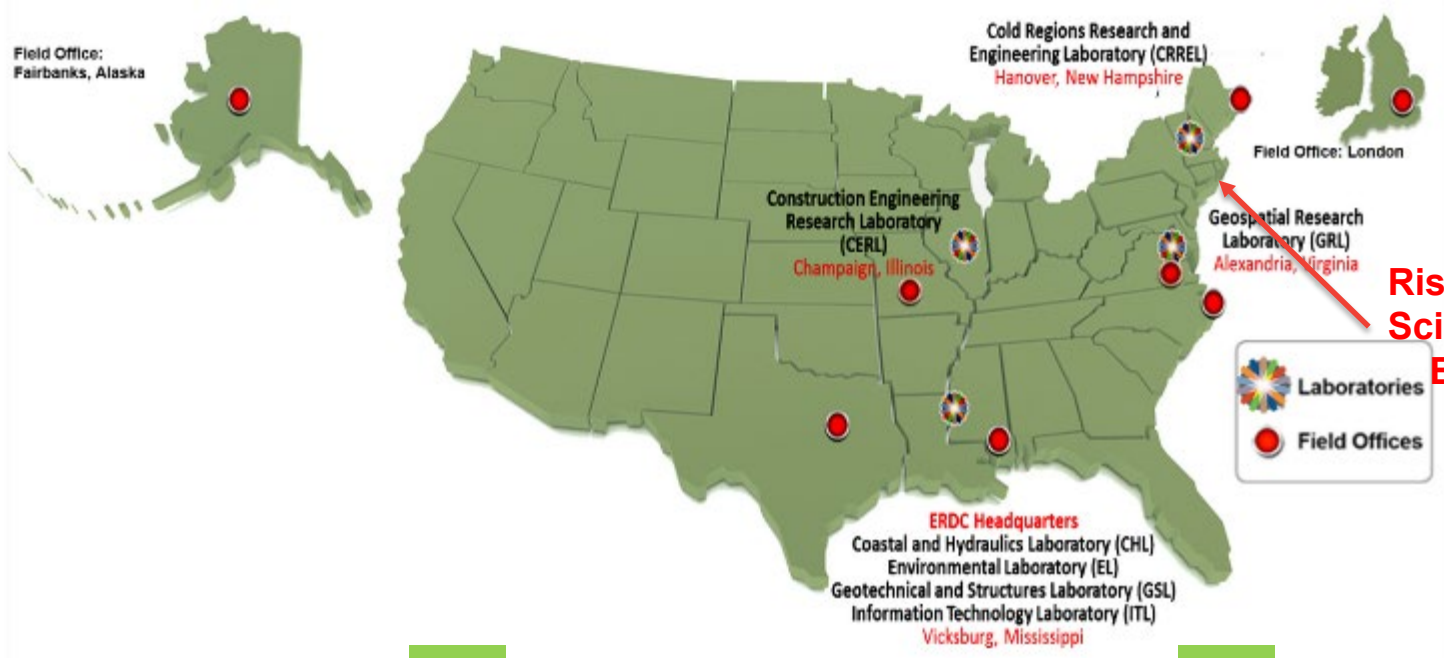
This presentation does not necessarily reflect the views of the United States Government, and is only the view of the author

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

Augusta Saraiva and Brendan Murray | Bloomberg News September 29, 2022 4:16 PM, EDT

Ian Triggers Port, Rail Closures, Straining Supply Chain

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If we don't reinvest in our supply chain now, then when?

eShipper | Sat., Oct. 1, 2022 | 4 min. read

A Resilient Supply Chain Starts With Full Visibility

Forbes Technology Council

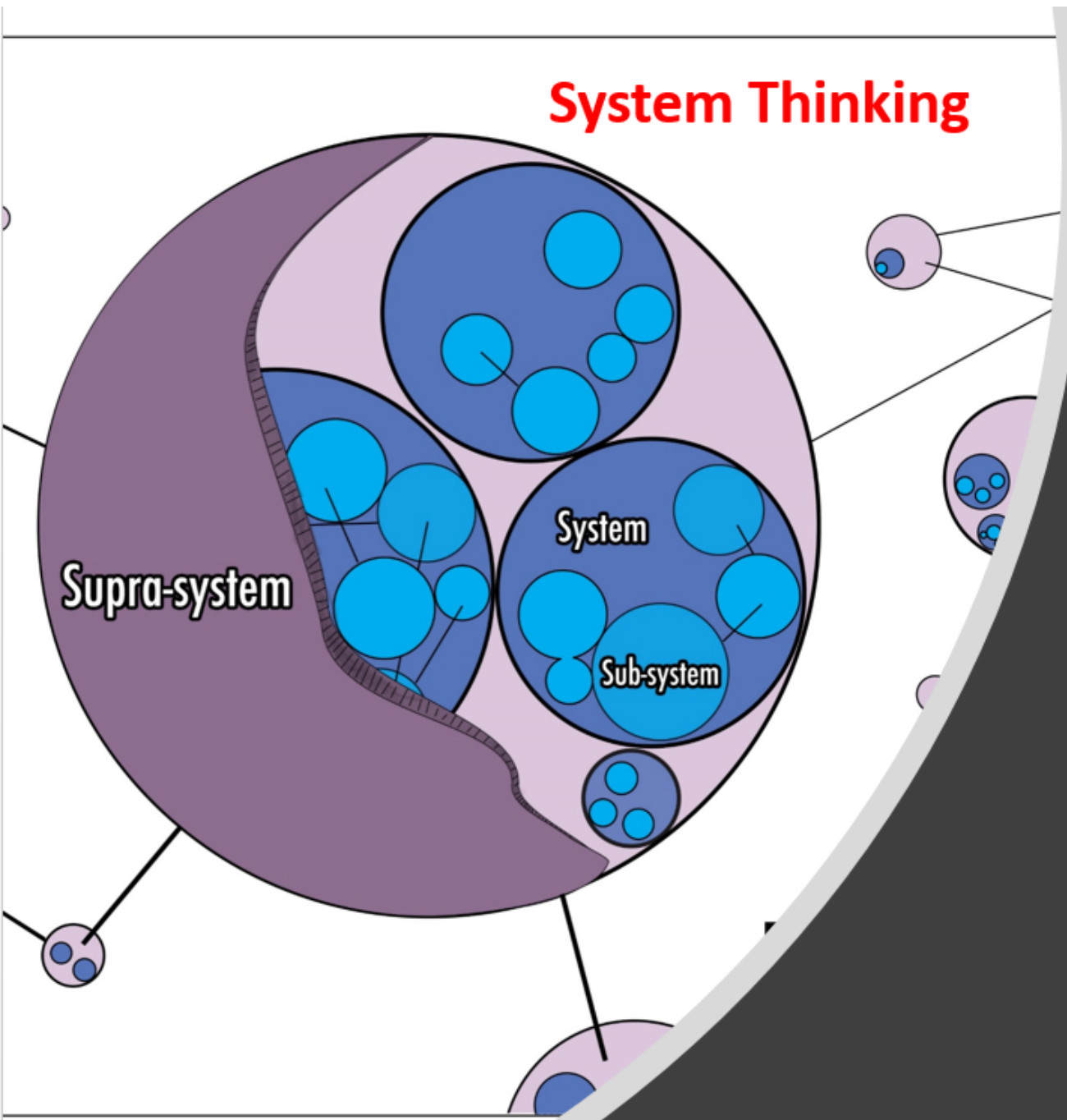
Dan Shey Forbes Councils Member
Forbes Technology Council
COUNCIL POST | Membership (Fee-Based)

Sep 30, 2022, 09:45am EDT

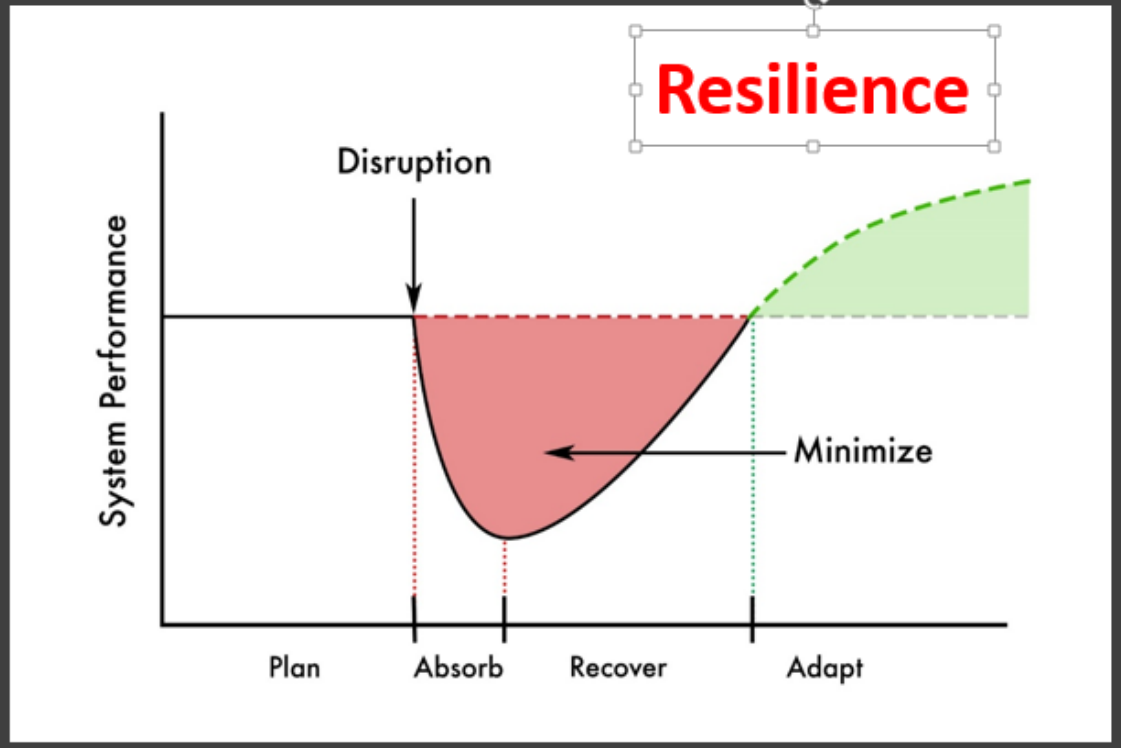
How leveraging connected experiences in logistics can build resilient supply chains

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

Outline

What Is Systemic Resilience?

One of many properties of System Affected by Threats

Differs from Risk

How Can it be Enhanced?

Refocusing from Efficiency towards Resilience

Resilience by Intervention and by Design

Future: Risk-based and Resilience-based approaches need to be integrated in comprehensive AI-enabled modeling framework to assure both efficiency and resilience in operation of transportation systems

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

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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Jeffrey Keisler *University of Massachusetts Boston, USA.*
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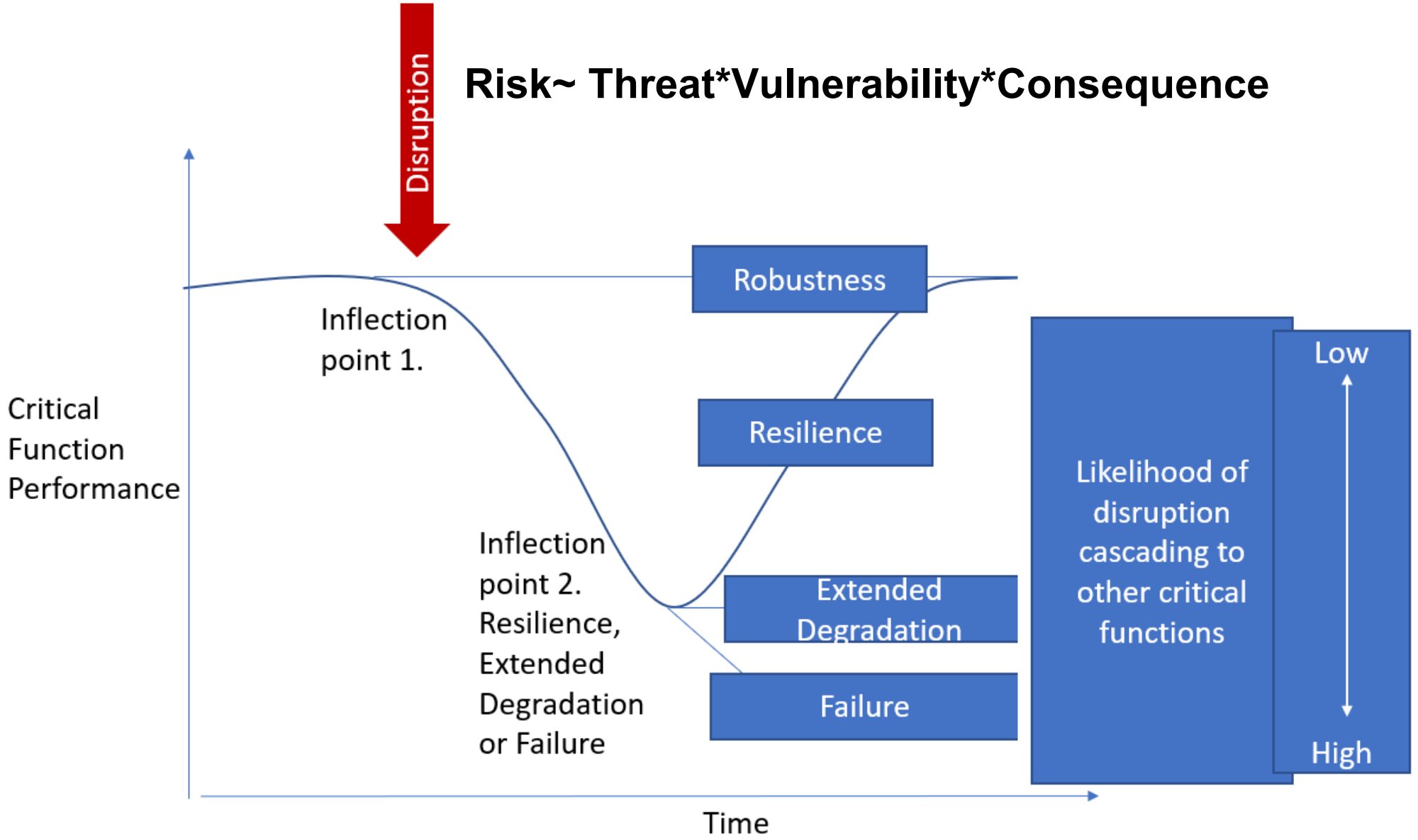
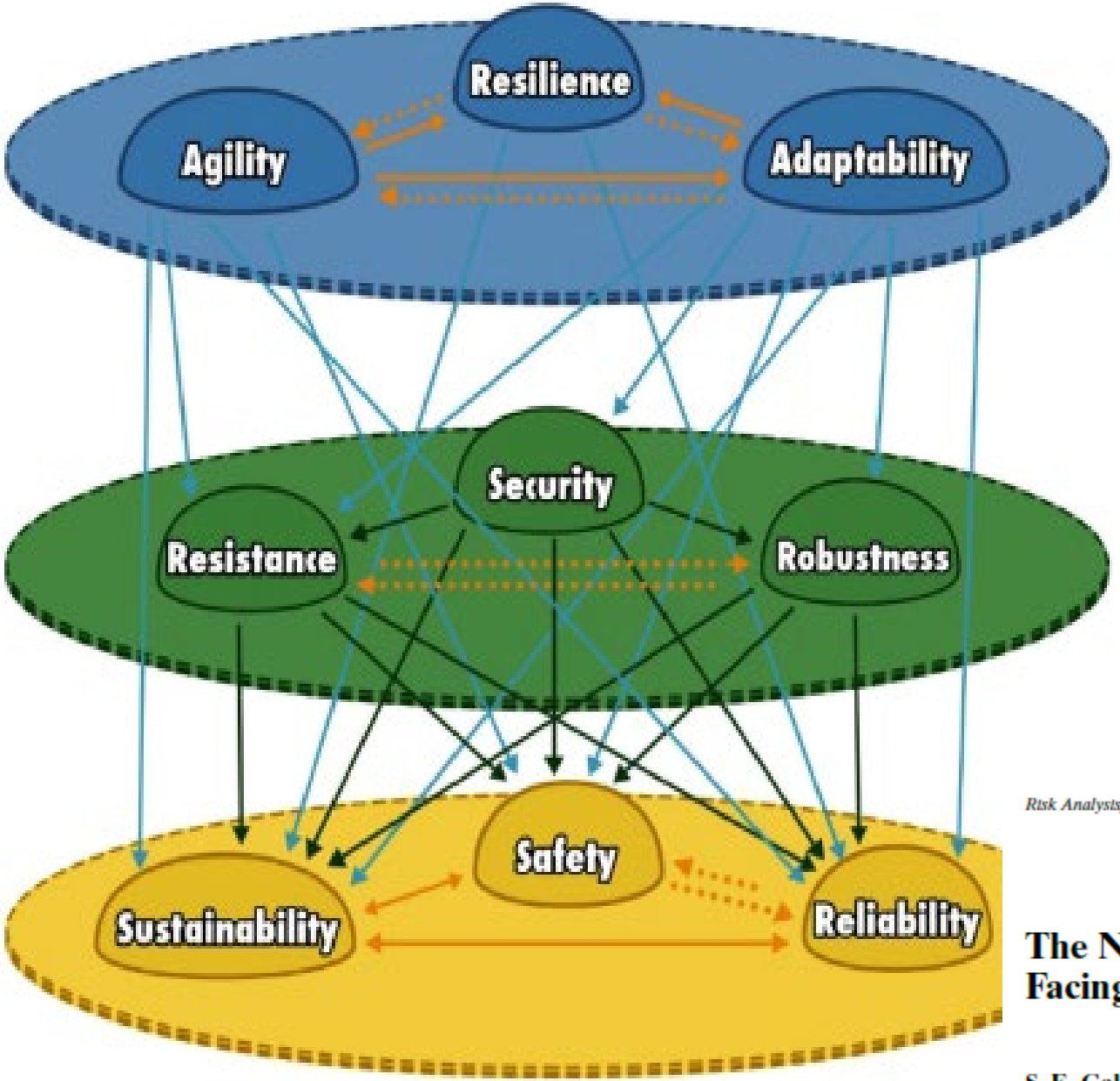
Crisis Management, Risk and Resilience



After Galaitsi, Linkov et al, 2022



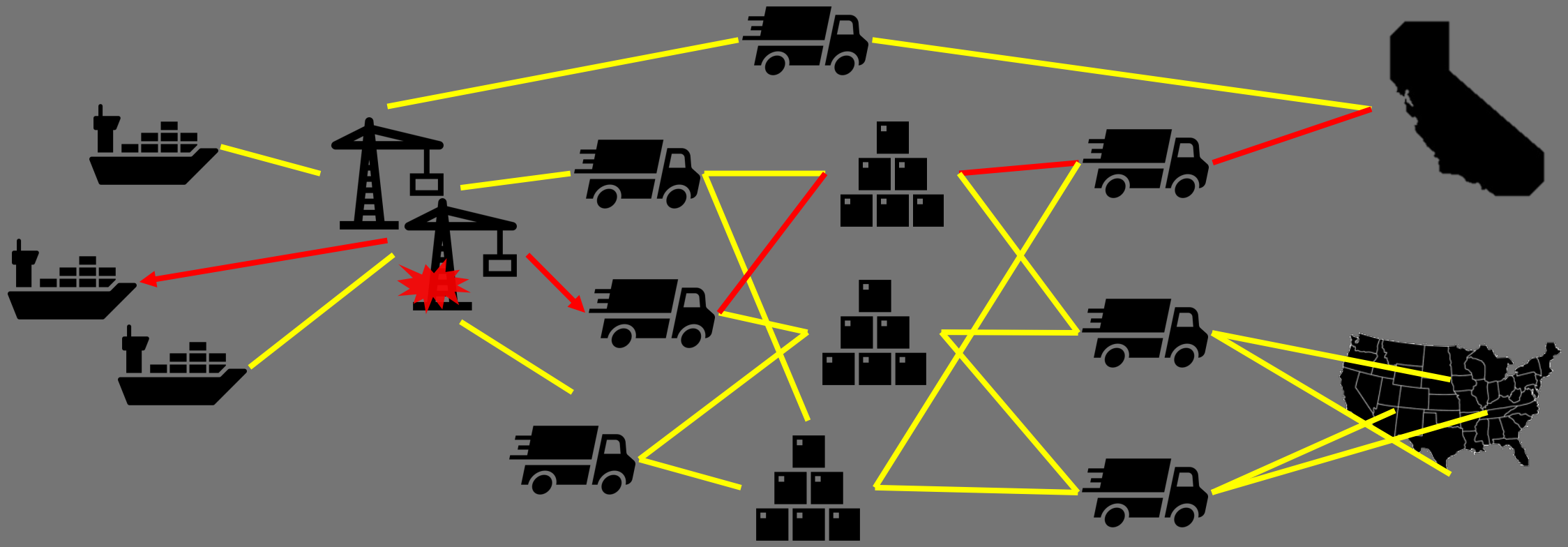
System Affected by Threats: Taxonomy

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

The Need to Reconcile Concepts that Characterize Systems Facing Threats

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

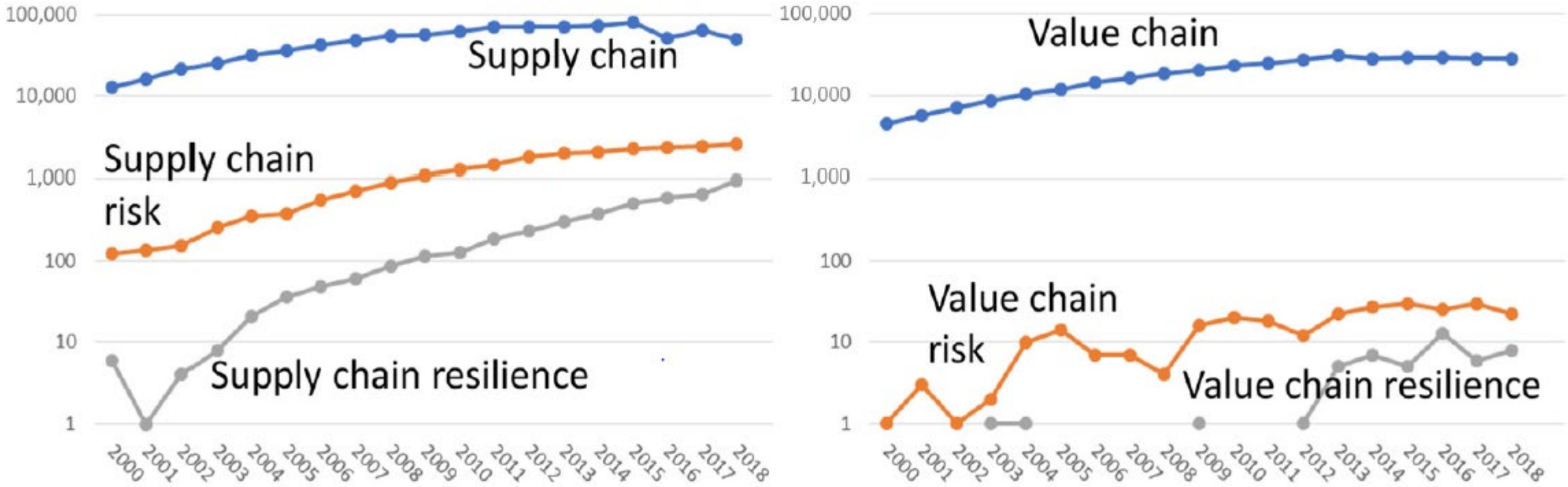
Supply Chain Resilience



ENVIRONMENTAL LABORATORY

Field of Supply Chain Resilience is New

Web of Science Publications



2020

The case for value chain resilience

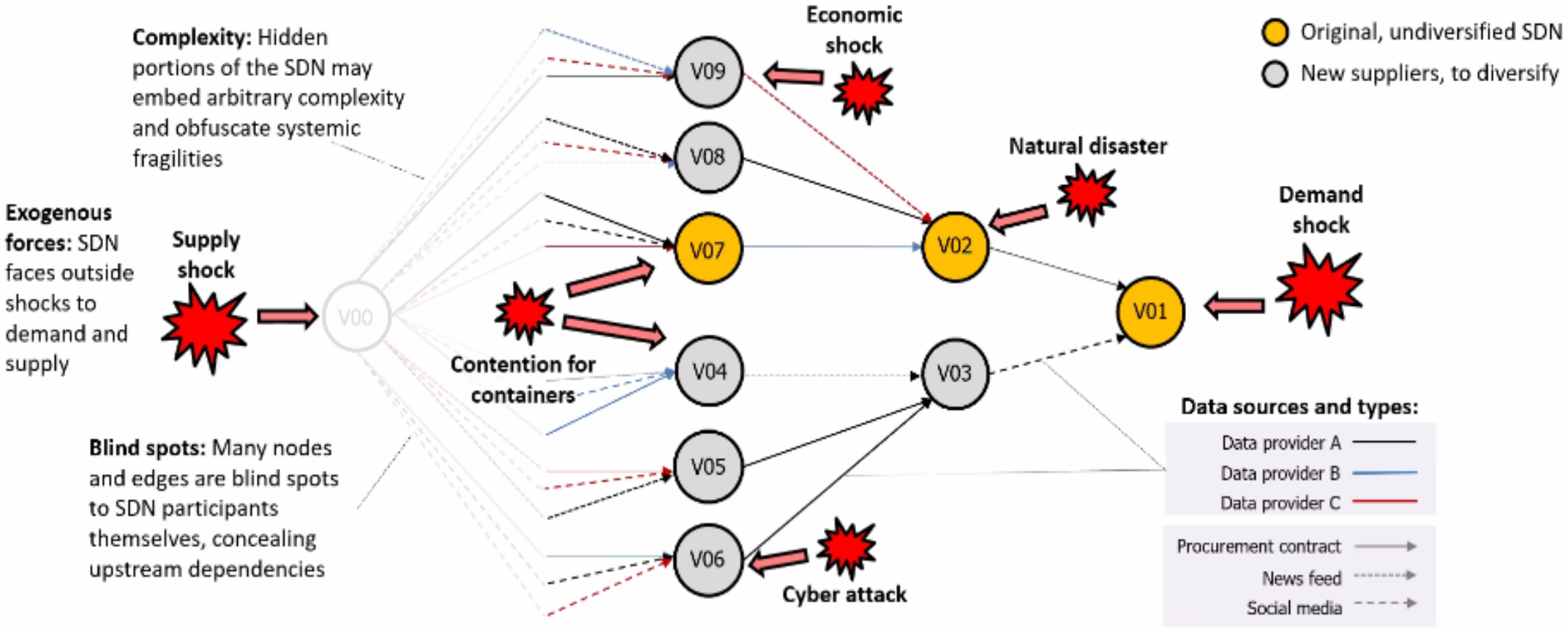
Igor Linkov, Savina Carluccio, Oliver Pritchard, Áine Ní Bhreasail, Stephanie Galaitsi, Joseph Sarkis and Jeffrey M. Keisler

Management Research Review

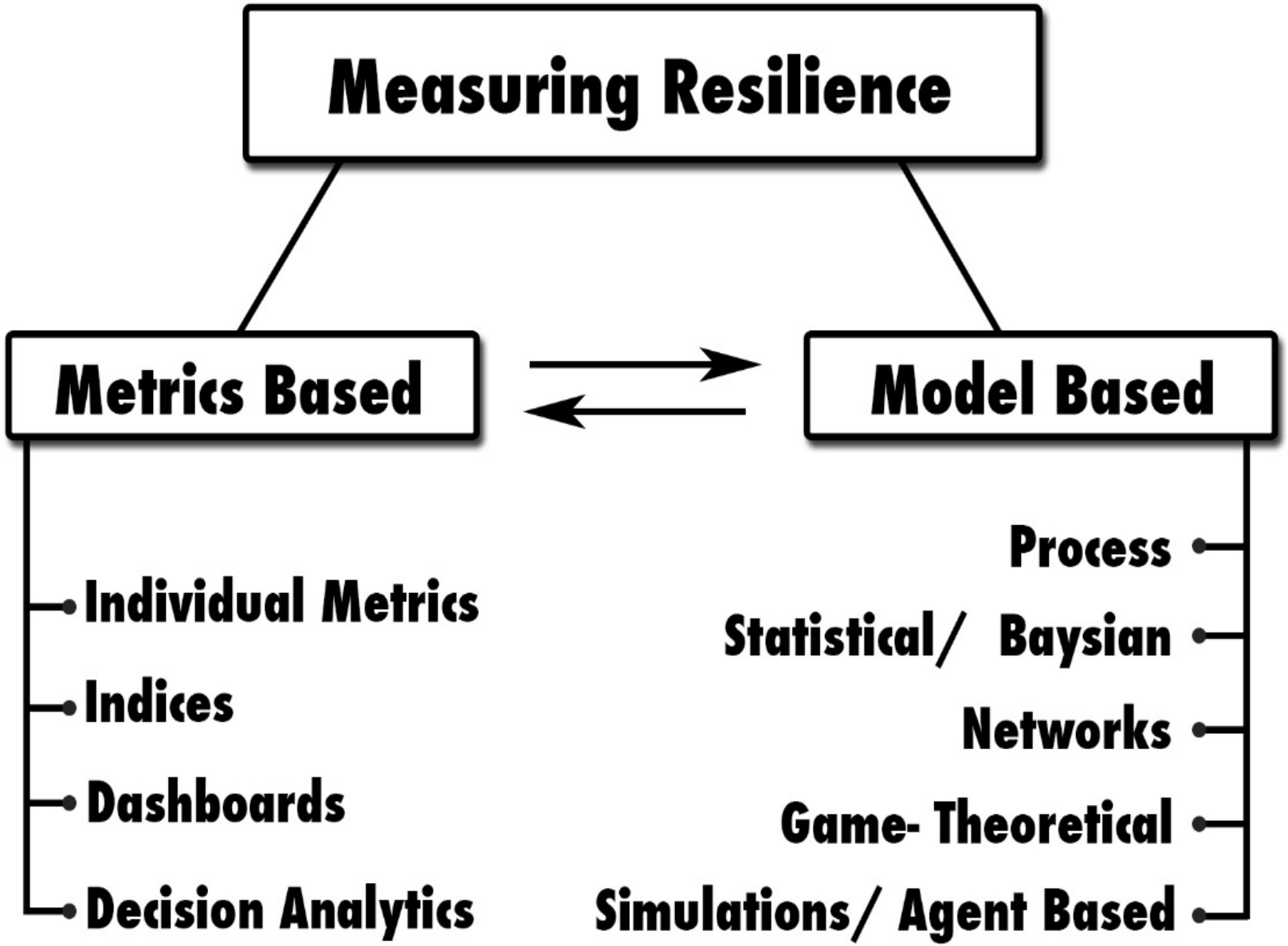
2040-8269
DOI 10.1108/MRR-08-2019-0353

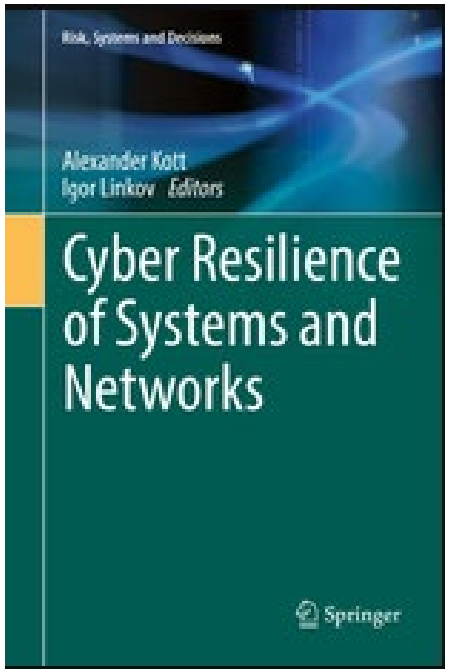
Supply-and-Demand Networks – challenges

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



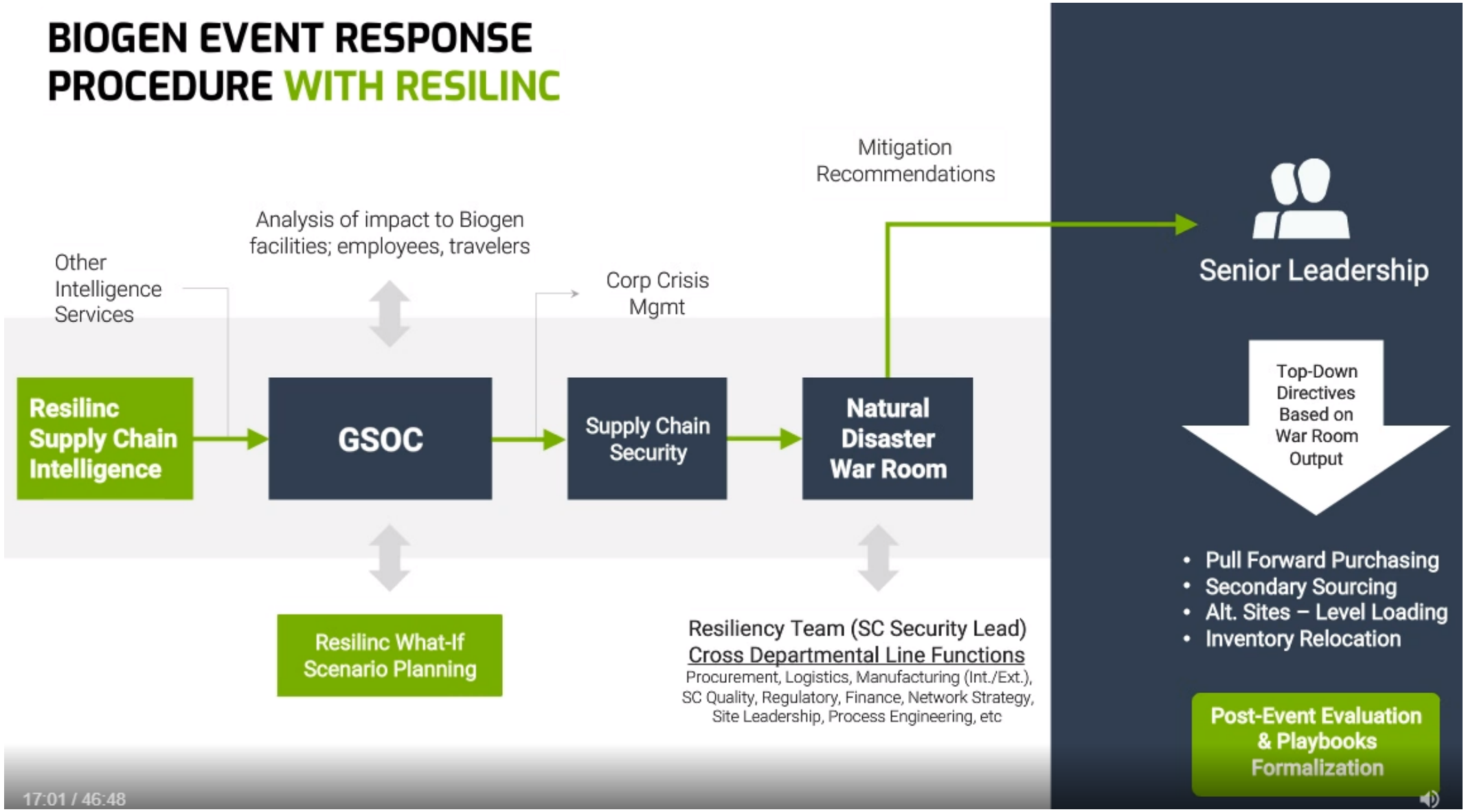
RSDN will explore SDN fragilities and possible mitigations – e.g., procurement policies, strategic reserves, etc.


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

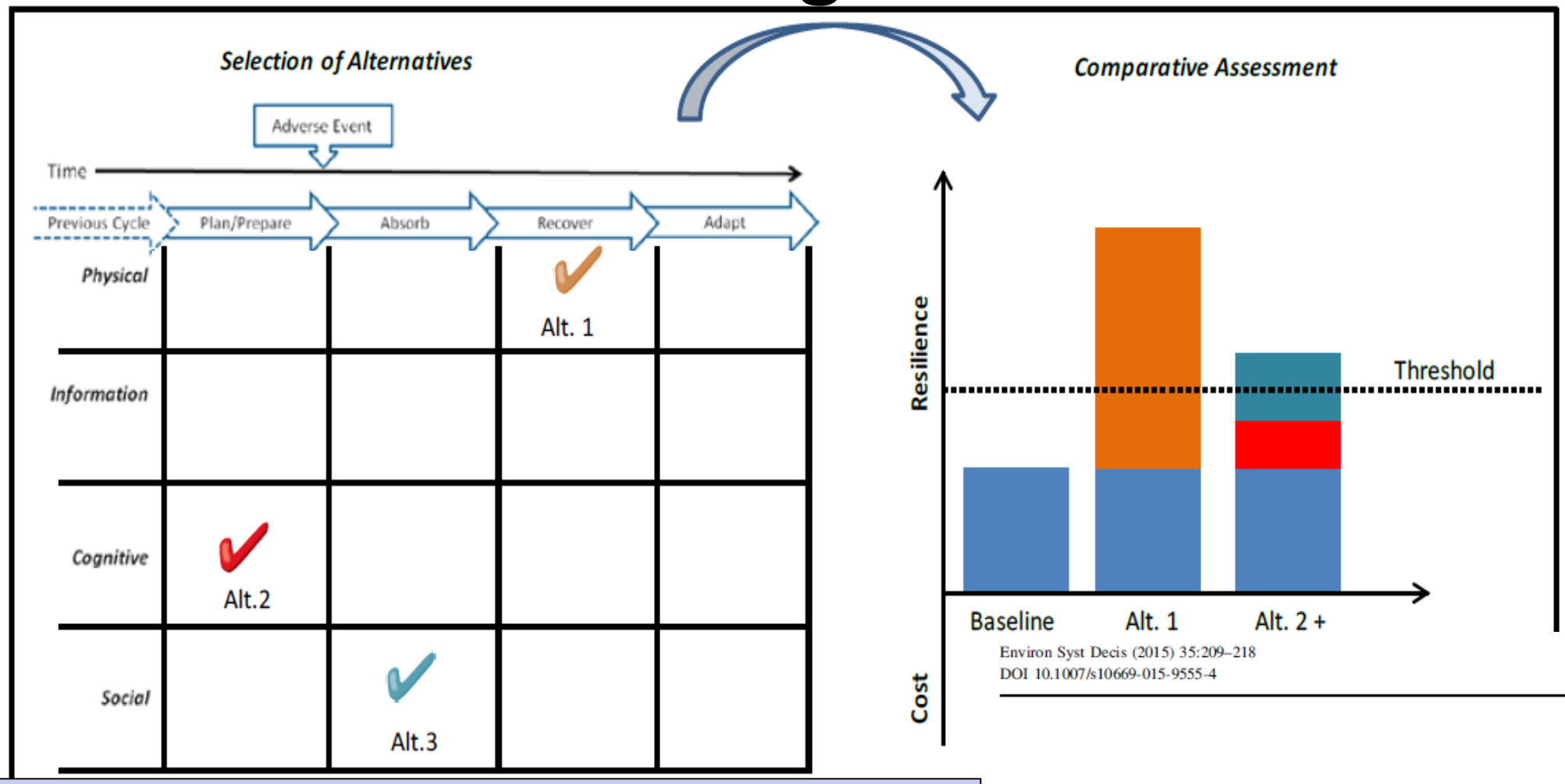

Risk, Systems and Decisions
Alexander Kott
Igor Linkov Editors
Cyber Resilience of Systems and Networks
Springer

After 2019

RESILINC – example of metric-based approach



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]

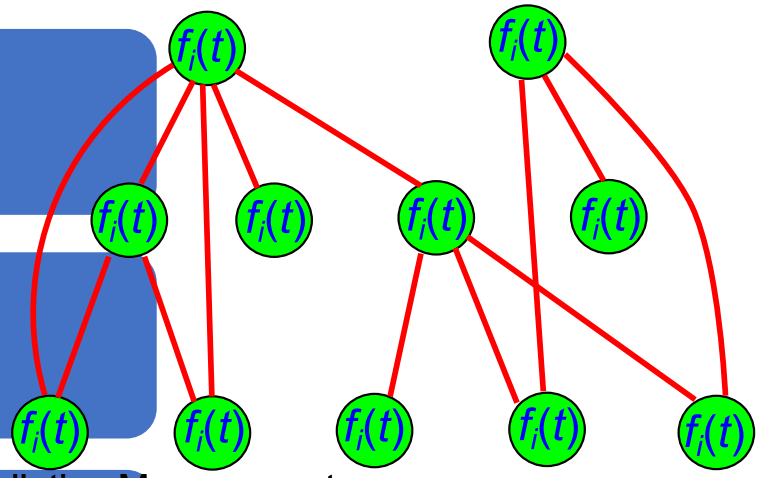
Network-based Resilience Theory?

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 ($\boldsymbol{E}$)



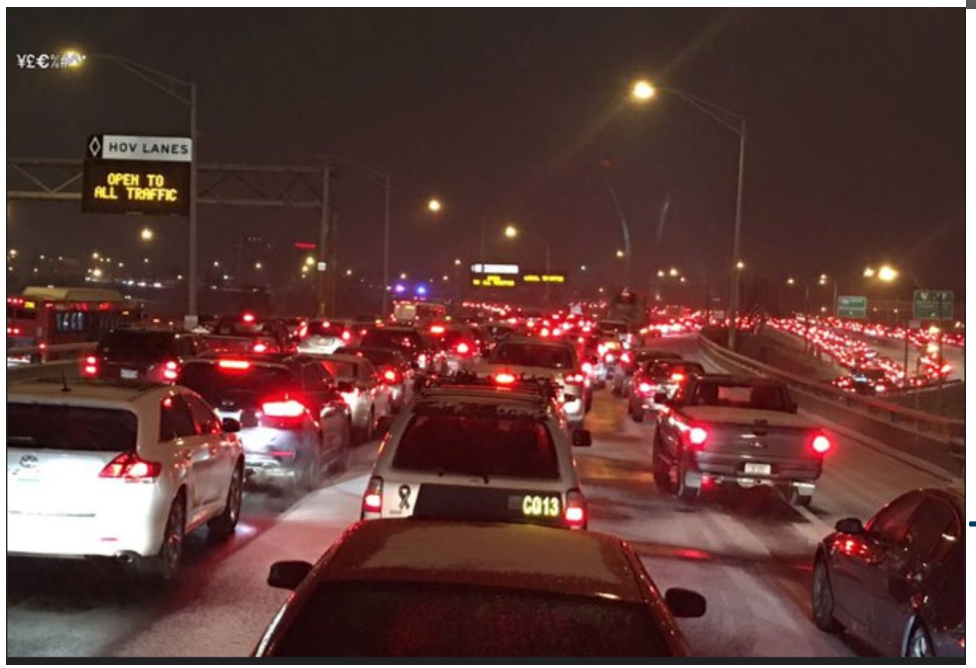
After Ganin et al., 2016

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

Poor Efficiency:

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

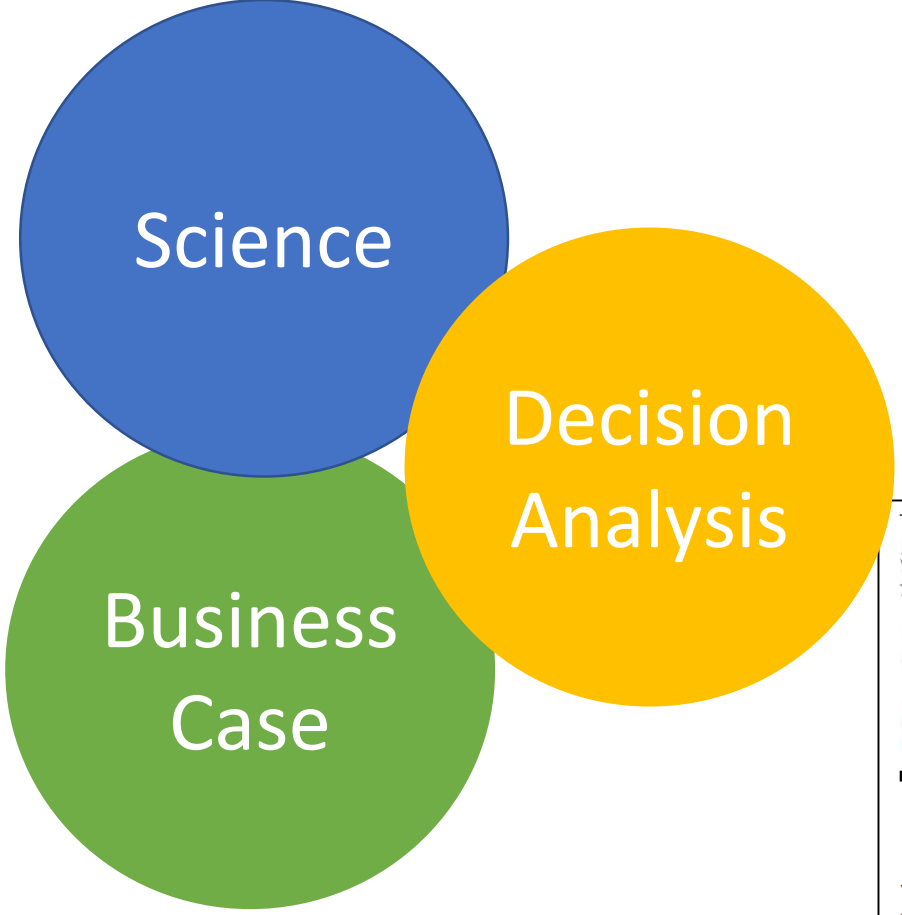
Traffic congestions are predictable and are typically of moderate level.



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

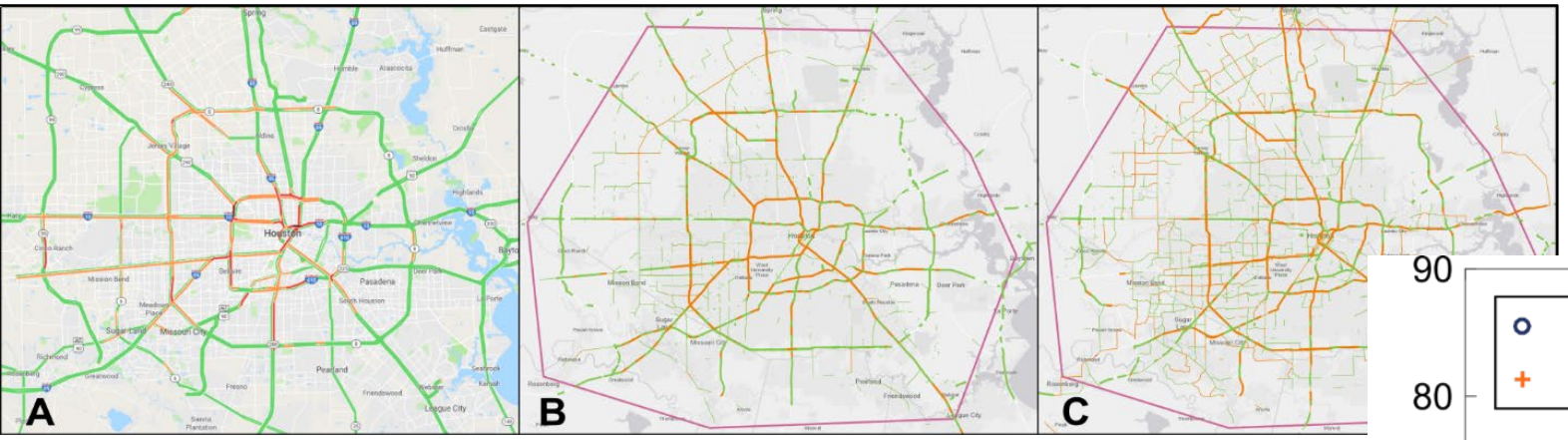
SCIENCE ADVANCES | RESEARCH ARTICLE

NETWORK SCIENCE

Resilience and efficiency in transportation networks

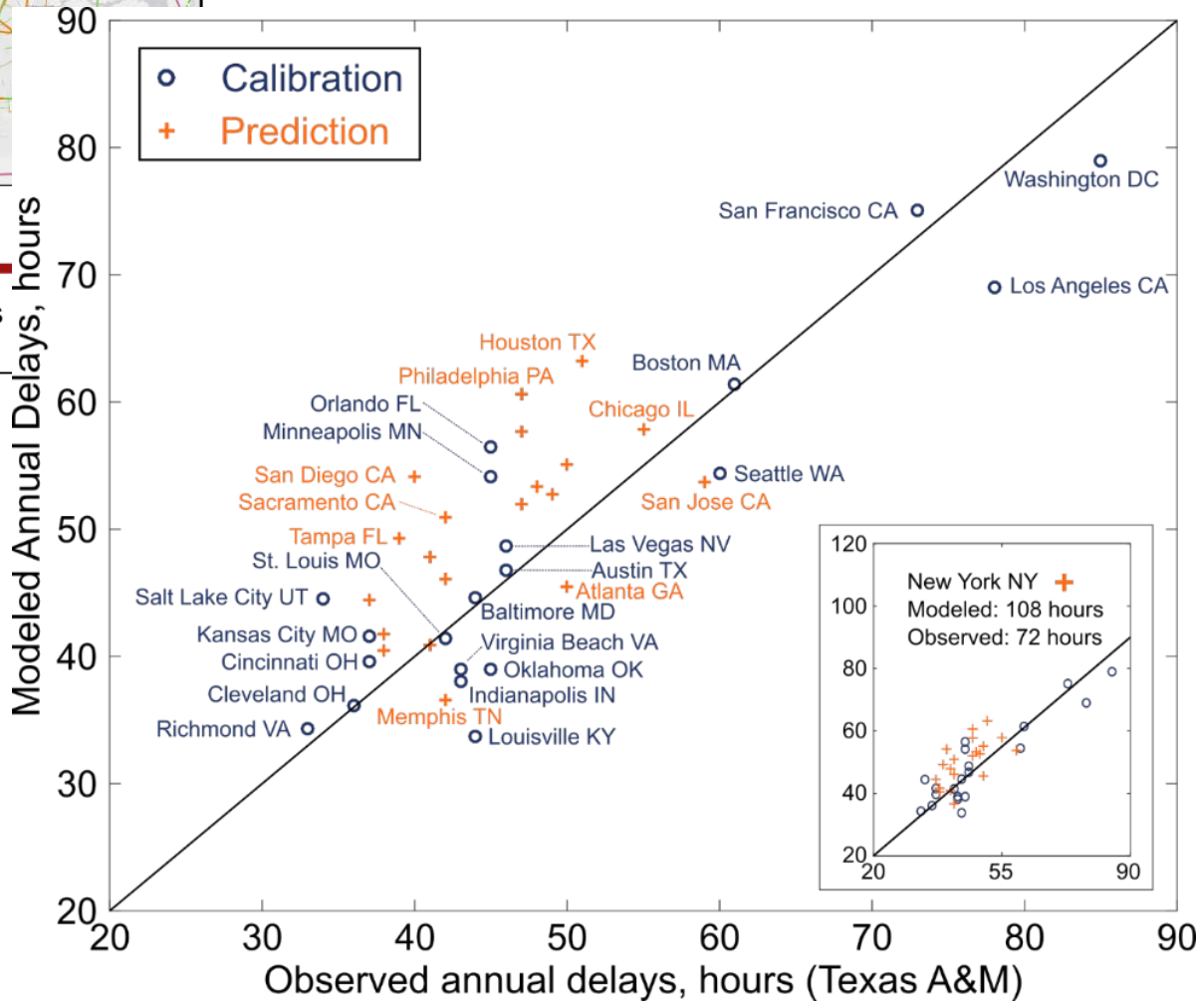
Alexander A. Ganin,[1,2] Maksim Kitsak,[3] Dayton Marchese,[2] Jeffrey M. Keisler,[4] Thomas Seager,[5] Igor Linkov[2]*

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

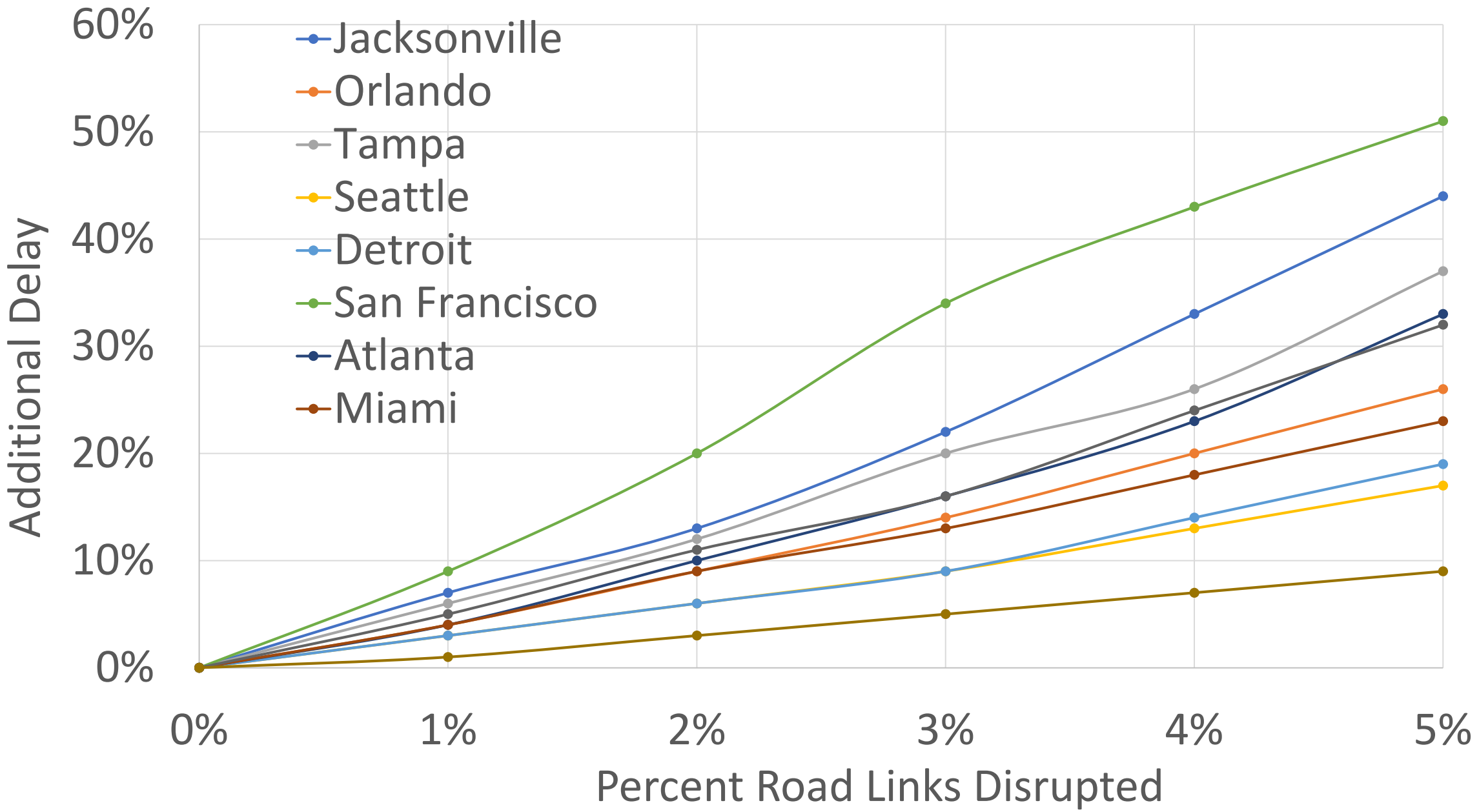
$$\langle \Delta T \rangle = \frac{1}{N_c} \sum_{\{ij\} \in \text{all roads}} L_{ij} \ell_{ij} \left(\frac{1}{v_{ij}} - \frac{1}{v_{ij}^0} \right)$$



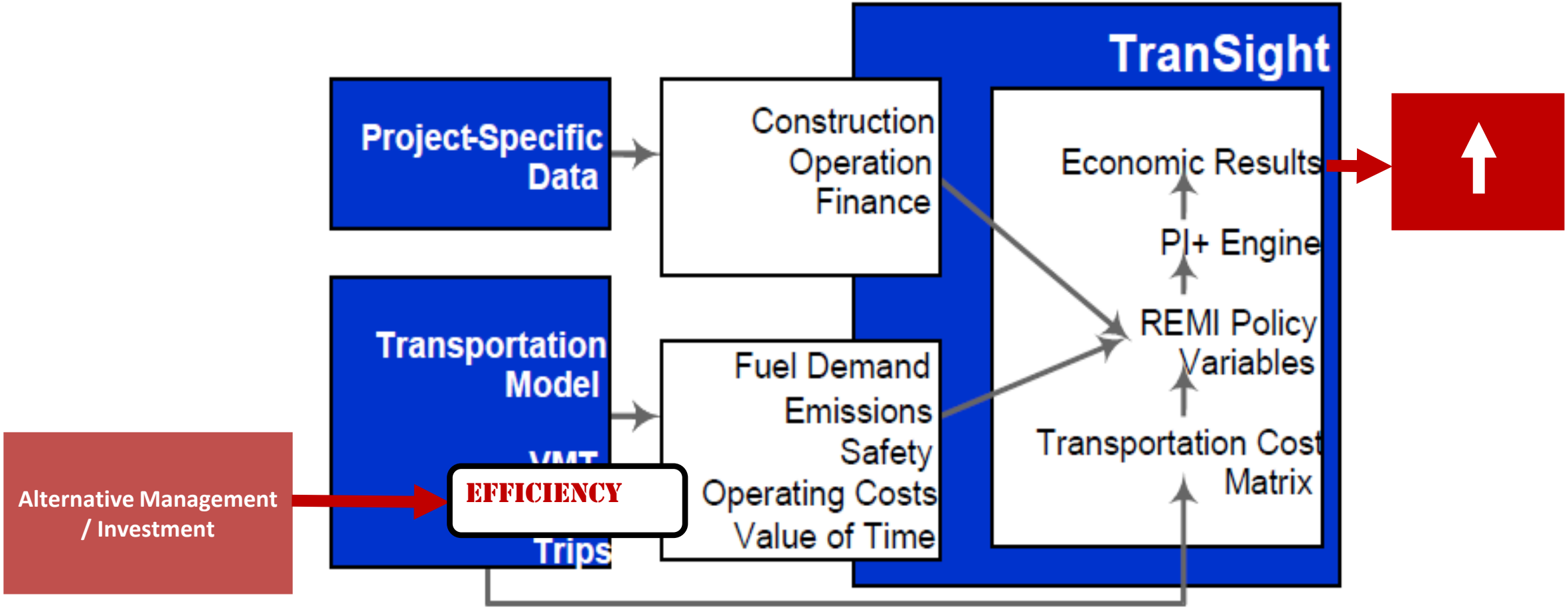
Modeling Disruptions

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

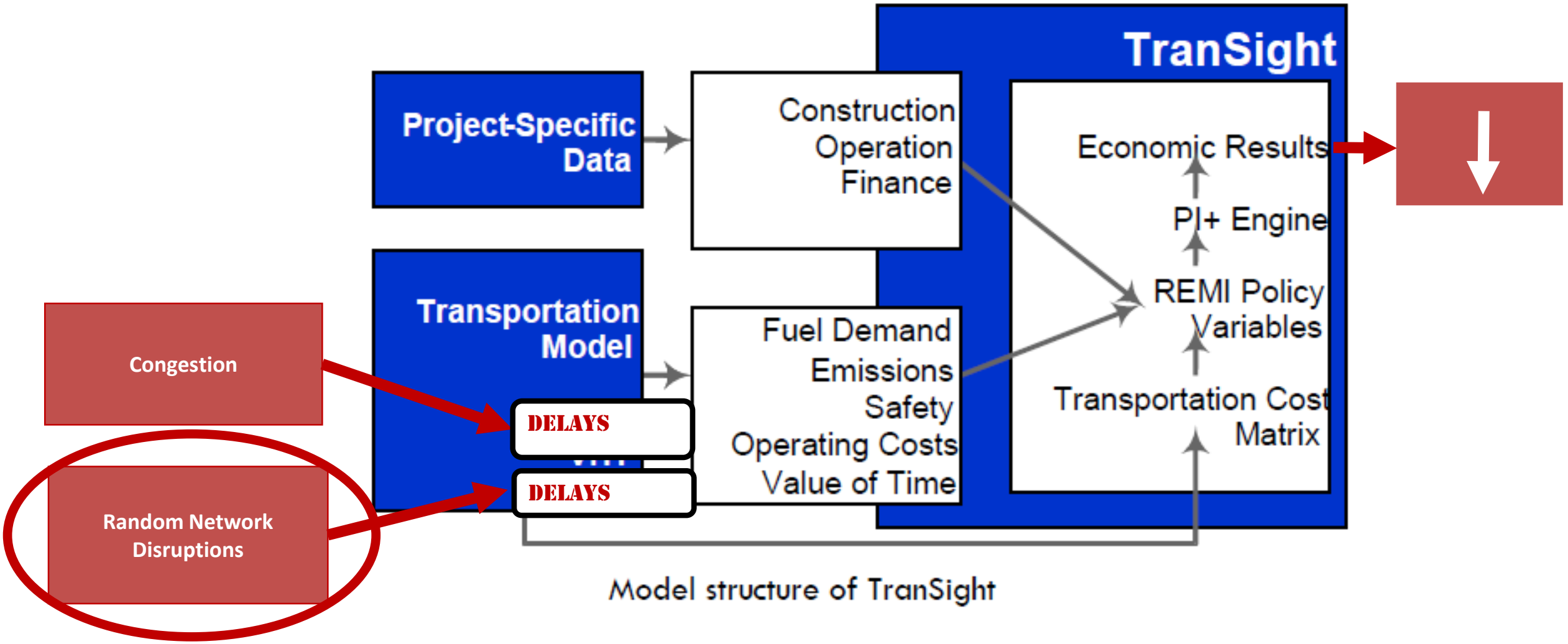


REMI = is a transportation upgrade a “winning proposition” relative to other initiatives?



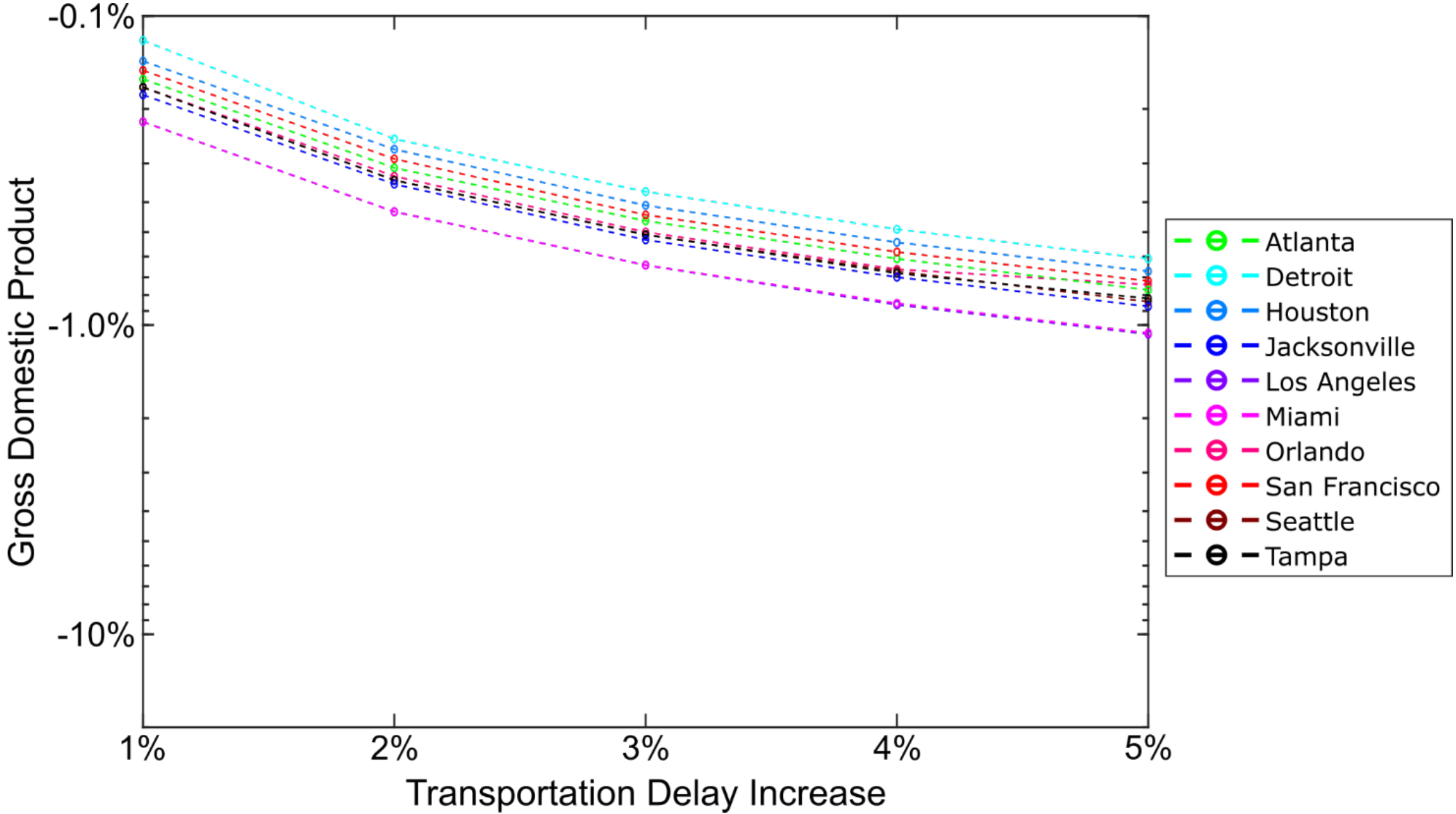
Model structure of TranSight

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

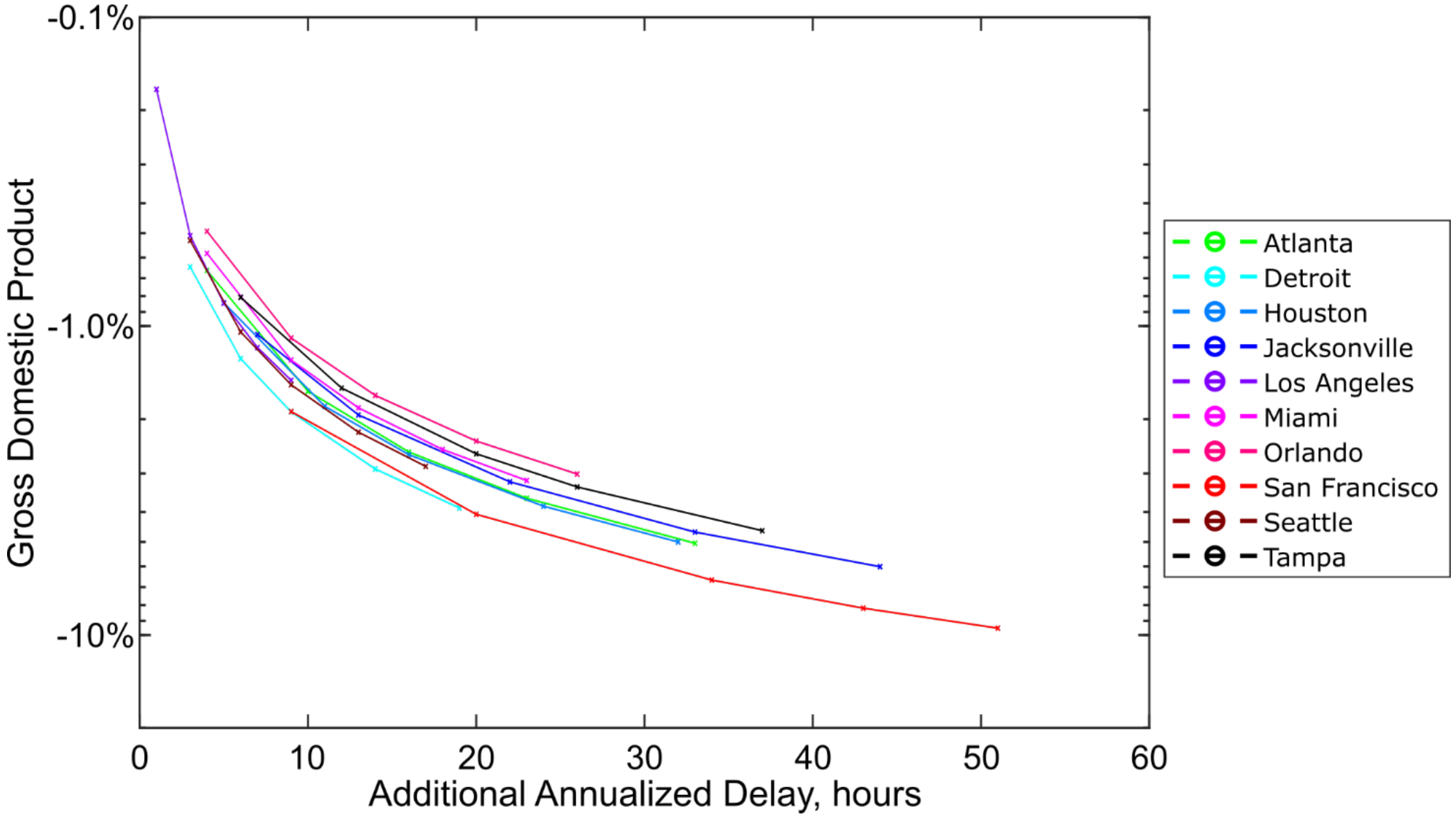


Model structure of TranSight

Impact of Efficiency-Related Delays

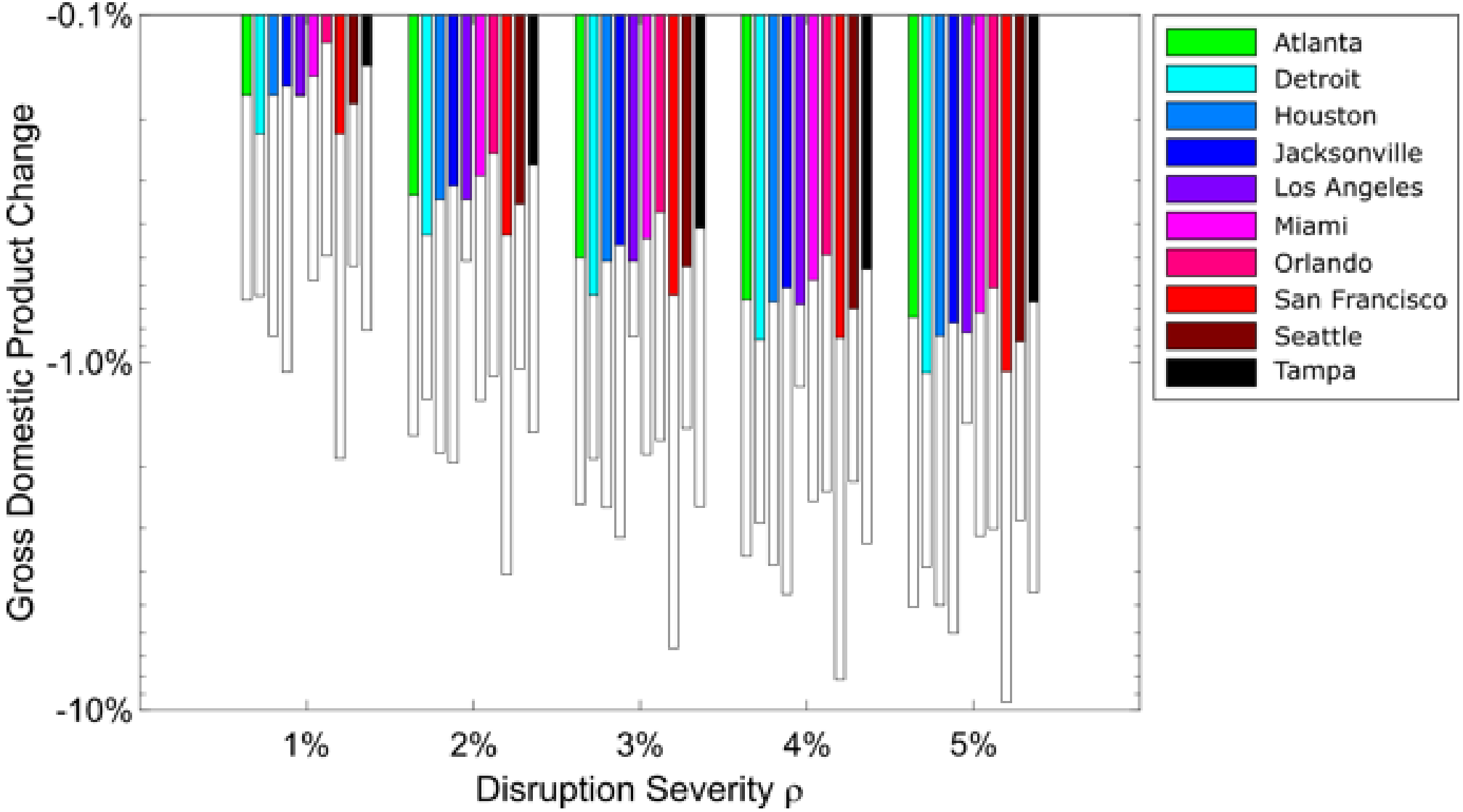


Impact of Resilience-Related Delays

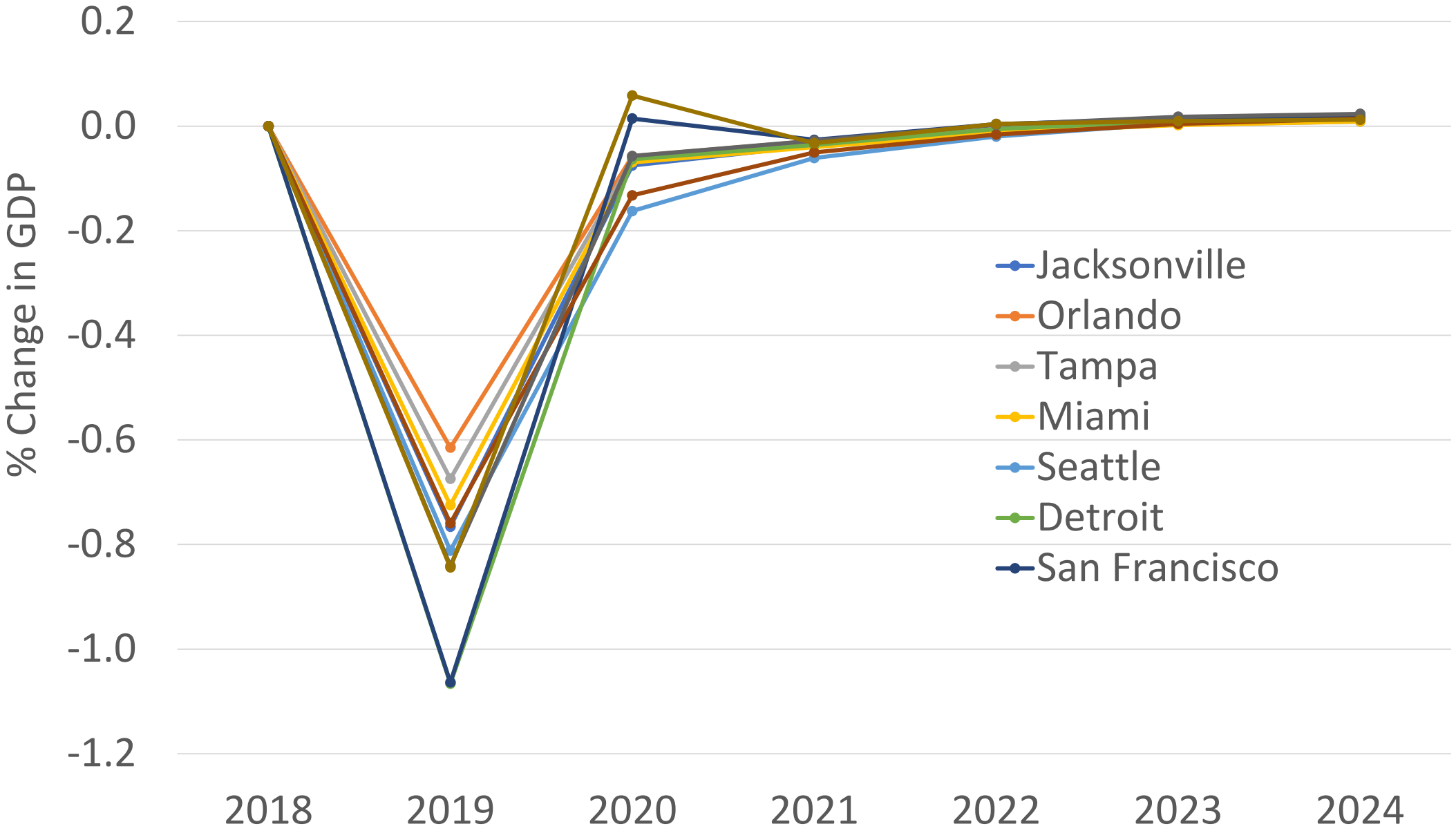


Lack of Resilience: Impact on GDP

Random Disruptions are Much More Consequential



Temporal Dimension



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

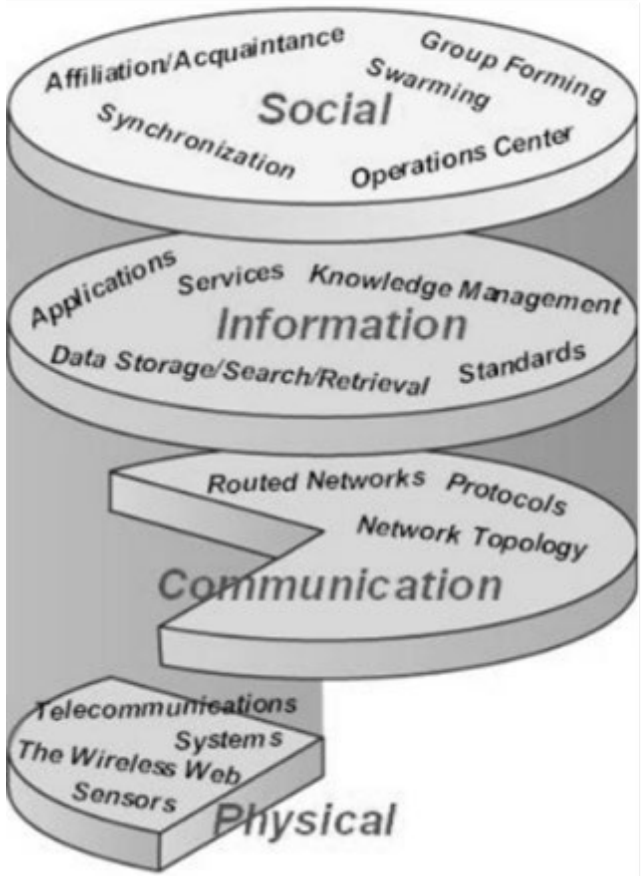
Change in Compensation by Industry Quintile
+0.022% to 0.061%

Participation Rates by Race
+0.002% to 0.024%

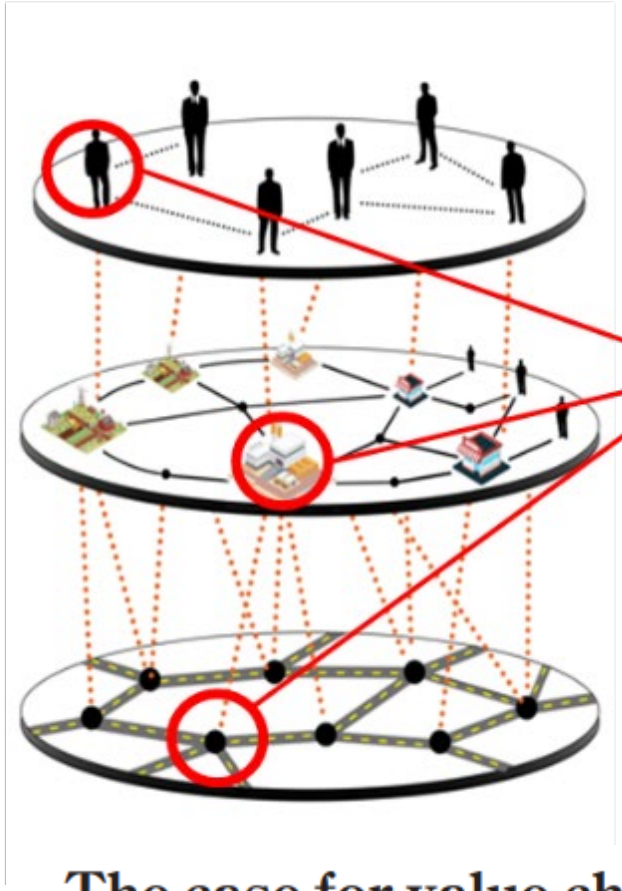
*what does REMI say?*sm

Vision for System Resilience

Real World



Model



Operations

Management Alternatives

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

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1) Linkov, I., Roslycky, L., Trump, B. (2020). **Resilience of Hybrid Threats: Security and Integrity for the Digital World.** IOS Press.
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3) Hynes, W., Trump, B.D., Linkov, I. (2020). **A Resilience Approach to dealing with COVID-19 and future systemic shocks.** Environment, Systems, Decisions, 40(2).
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7) Kurth, M., Keenan, J.M., Sasani, M., Linkov, I. (2019). **Defining resilience for the US building industry**. Building Research and Innovation. 47**:** 480.
8) Linkov, I., Trump, B.D., Keisler, J.M. (2018). **Risk and resilience must be independently managed**. Nature 555:30.
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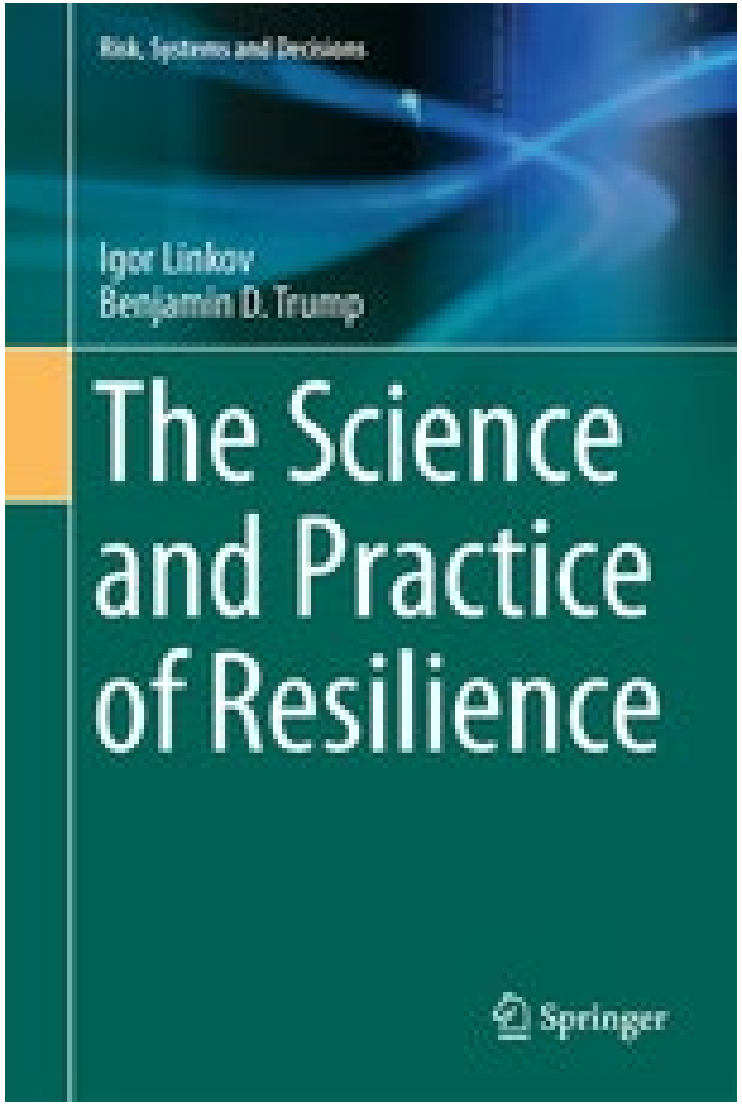
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The Science and Practice of Resilience
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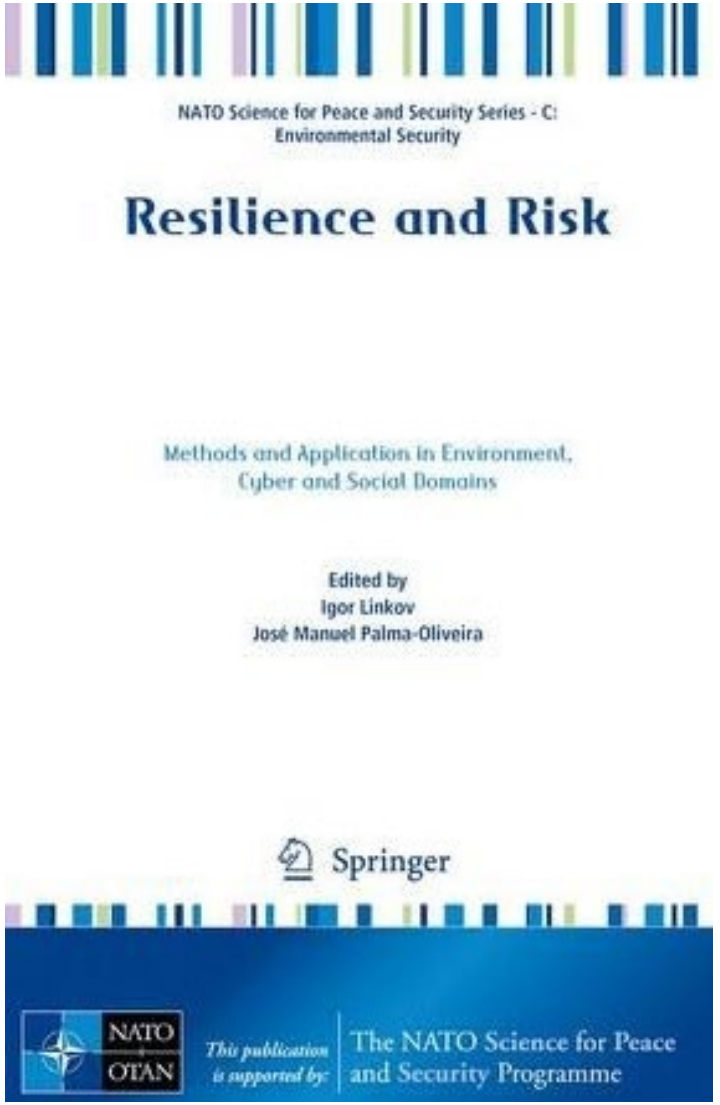
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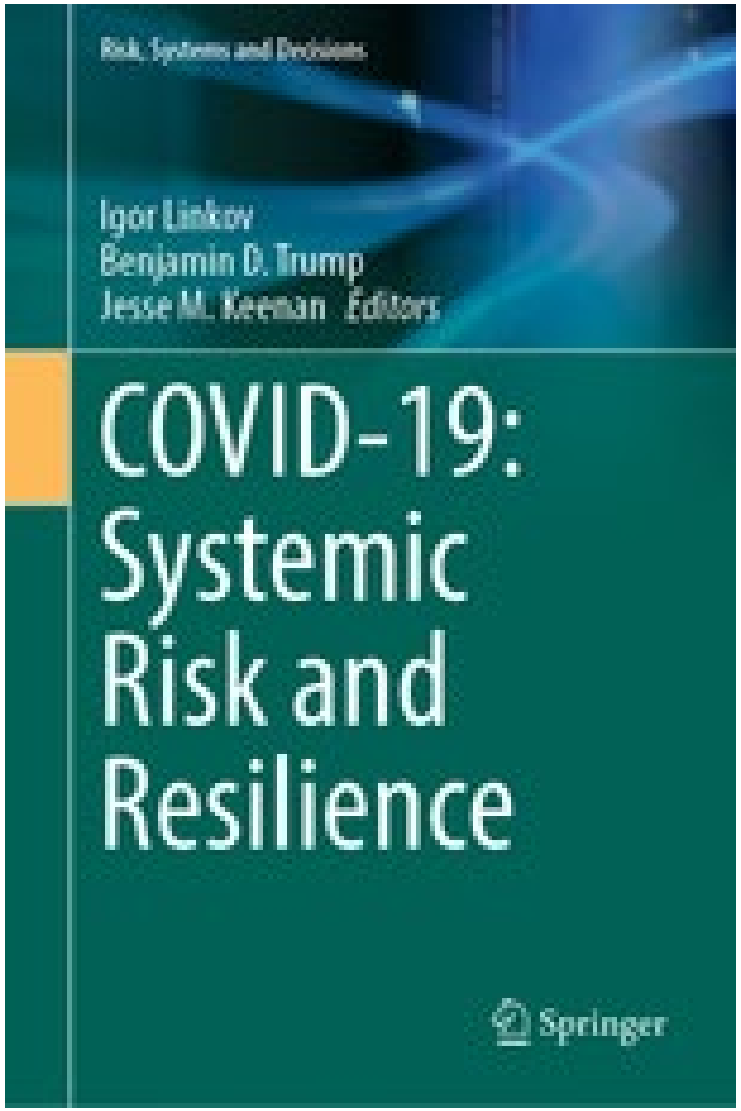

Risk, Systems and Decisions
Igor Linkov
Benjamin D. Trump
Jesse M. Keenan Editors
COVID-19: Systemic Risk and Resilience
Springer

Case Study 1: Artificial Intelligence for Supply Chain Resilience

Presenter: *Dr. Andrew Strelzoff*[2] : andrew.Strelzoff@erdc.dren.mil
POC: *Dr. Igor Linkov*[1] : igor.linkov@usace.army.mil
Dr. Kelsey Stoddard[1] , *Sam Dent*[2]

October 6, 2022

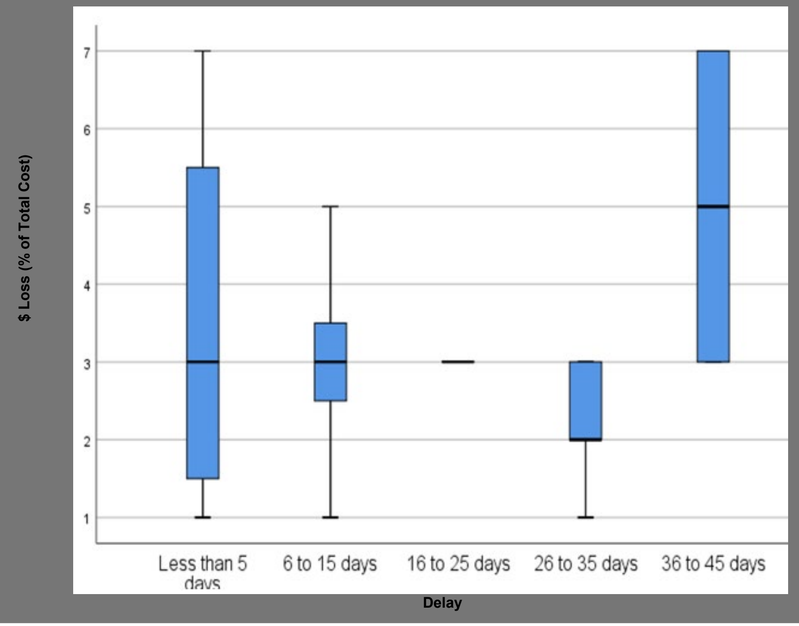
ERDC EL[1] , *ERDC ITL*[2]

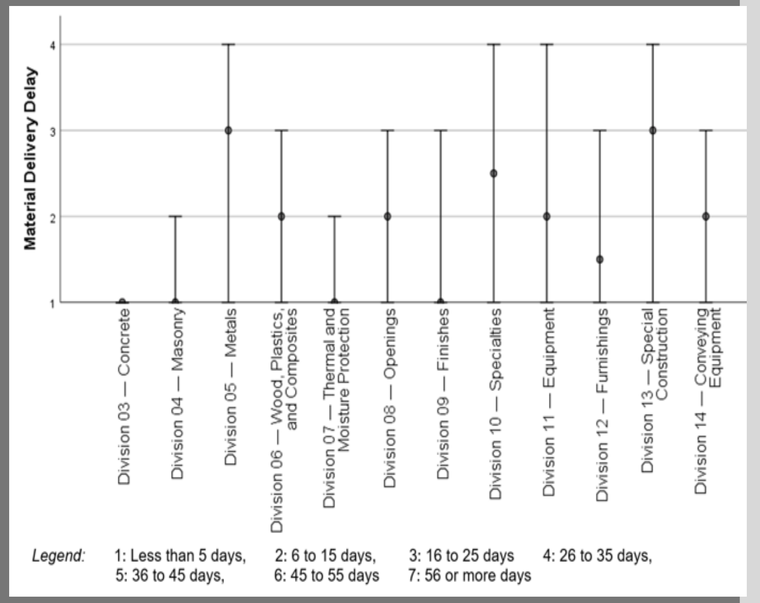
Use Case 1: USACE Projects - Challenges

Supply Chain is Already an Issue for On-going Projects

- COVID-related delays have manifested across construction industry
- Materials shortage is the main issue
- USACE is affected, Division reports material shortages and lack of contractor availability

- USACE is receiving $17B increase for CW and over $64B in MIL funding
- Massive increase in resources needed
- USACE will compete with States and Municipalities for resources
- Current optimization is based on costs, but optimization based on scheduling and materials is required
- Current optimization is at project level, resource limitation requires coordination at District and Division levels





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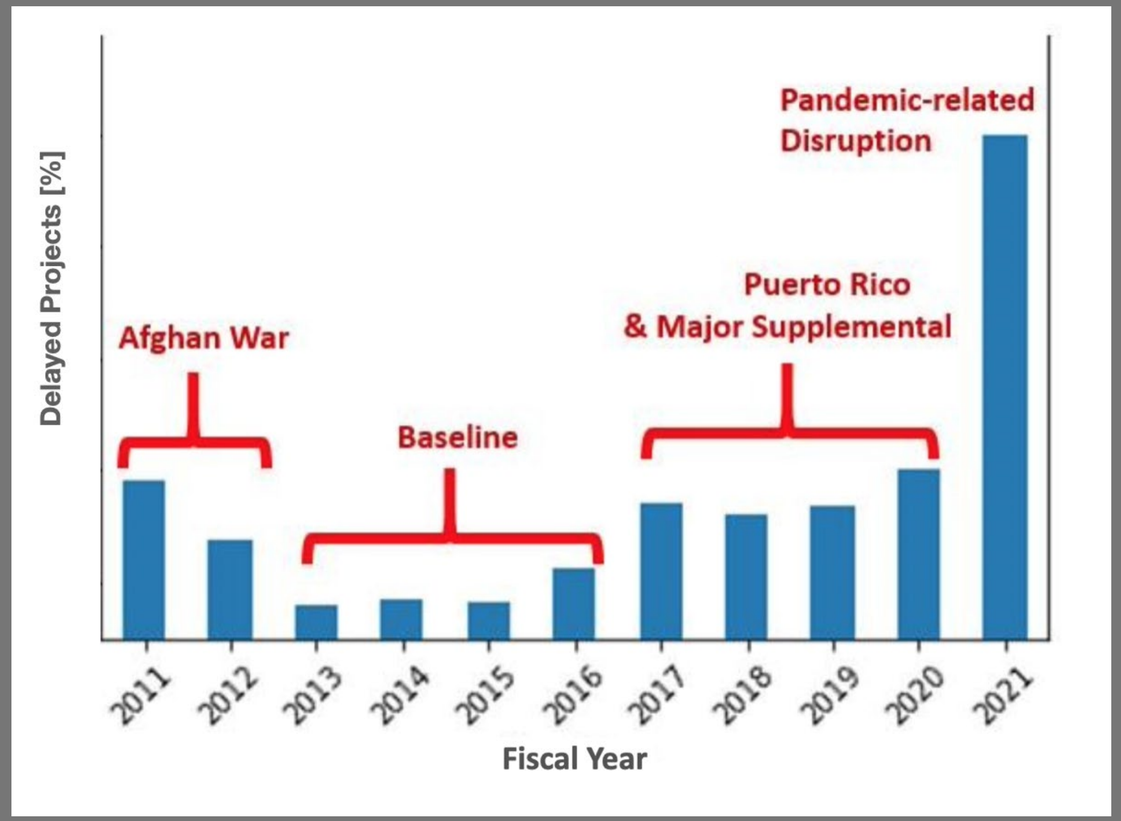
Use Case 1: USACE Projects
Three Results

1. Examining Historical Trends
    - Identify and track historical trends in tasks in project types for divisions projects
2. Identifying Material Requirements
    - Modify initial contract to account for potential delays
3. Identifying Material Requirements by Task
    - Modify project planning and timing to account for potential delays

Result 1: Historic Trends
USACE Project Delays

- Examined 5,000 projects from the last decade
  - USACE NWD projects

- Scale and magnitude of overruns in 2021 is **double** the baseline amount observed in the last 10 years



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Result 2: Material Requirements
How do we predict a future shock (before it hits us)?

For this Economic Bin

Widely used Commodity Life Cycle Model

- EPA EEIO Tables

Unnamed: 0	1111A0/US	1111B0/US	111200/US	111300/US	111400/US
Iron ore/resource/ground/kg	2.067140e-04	3.857260e-04	2.025340e-04	1.349760e-04	1.538790e-04
Nickel/resource/ground/kg	3.418990e-08	5.411910e-08	3.137640e-08	2.057260e-08	2.461800e-08
Phosphate ore/resource/ground/kg	2.877245e-03	1.623147e-02	3.128757e-03	2.100242e-03	2.244069e-03

How Much Nickel?

- NAICS Category Descriptions

NAICS Code 1114 Description

This industry group comprises establishments primarily engaged in growing crops of any kind under cover and/or growing nursery stock and flowers. "Under cover" is generally defined as greenhouses, cold frames, cloth houses, and lath houses. The crops grown are removed at various stages of maturity and have annual and perennial life cycles. The nursery stock includes short rotation woody crops that have growth cycles of 10 years or less.

Data Routinely Available on USACE Projects

- USACE Project Description

```
SELECTED PROJECT This project entails clearing and grubbing hybrid poplars, blackberry plants and far
m debris from approximately 45 acres of land.  Disposal of material cleared and grubbed, tillage of a
pproximately 71 acres, seeding of grasses on approximately 66 acres, and seeding of fall oats on appr
oximately 5 acres designed for future establishment of riparian trees and shrubs.  Approximately 6,70
0 lineal feet of silt fence will be installed.
```

Result 2: Material Requirements
How do we predict a future shock (before it hits us)?

NAICS
Economic “Bins”
Descriptions

USACE Project Description
this project entails clearing and grubbing hybrid poplars, blackberry plants and farm debris…

SBERT.net

For this project which NAICS Economic Bins are most applicable ? Score all 400+ bins.

Neural Network Based
Natural Language Processing (NLP) Model

Trained on ALL Wikipedia Entries

Greenhouse, nursery, and floriculture producti...	0.727693
Vegetable and melon farming. This industry gro...	0.712372
Other crop farming'. This industry group compr...	0.709028
Farm machinery and equipment manufacturing'. T...	0.676935

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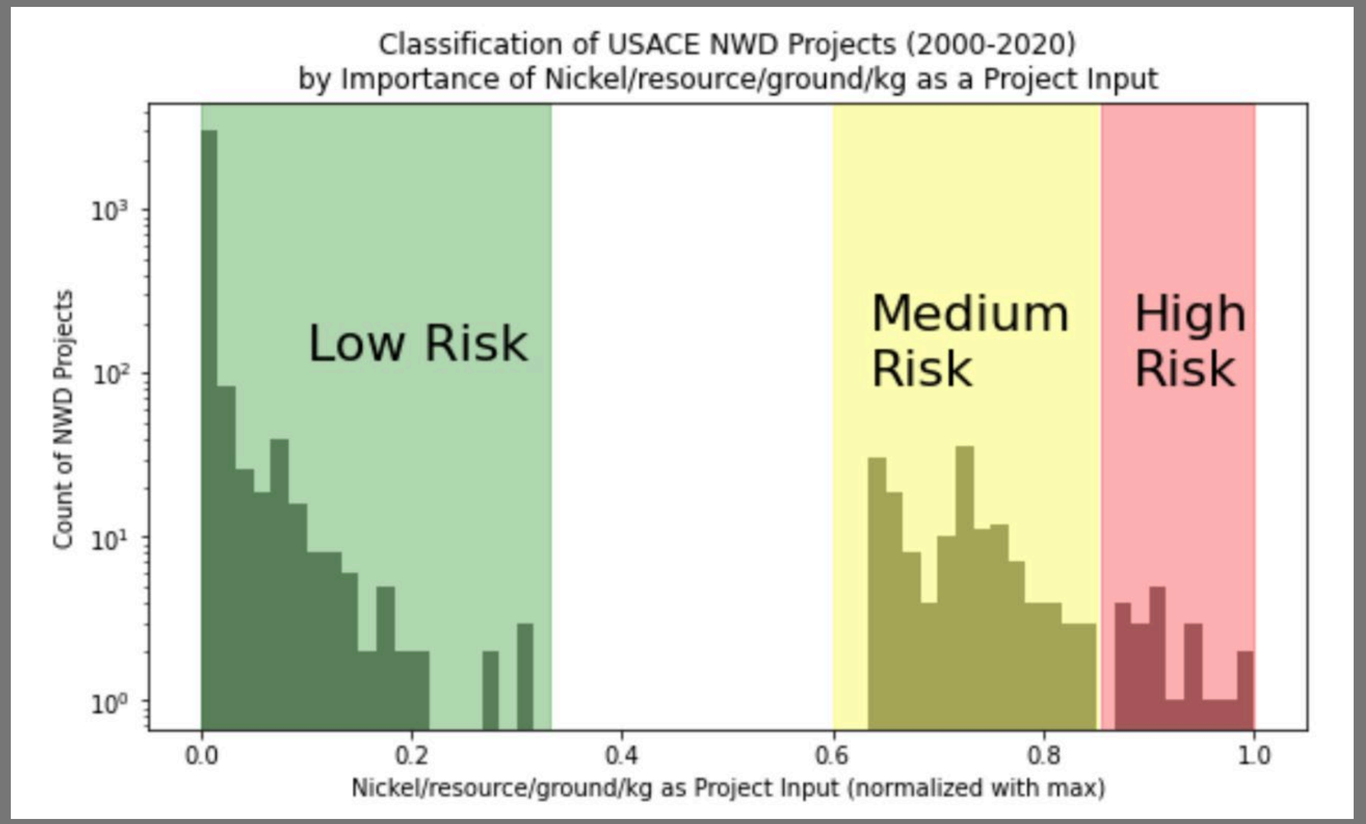
Result 2: Material Requirements
Project Reliance on Foreign-Sourced Minerals - Nickel

- **Base Project**: USACE NWD Projects (2000 - 2020)



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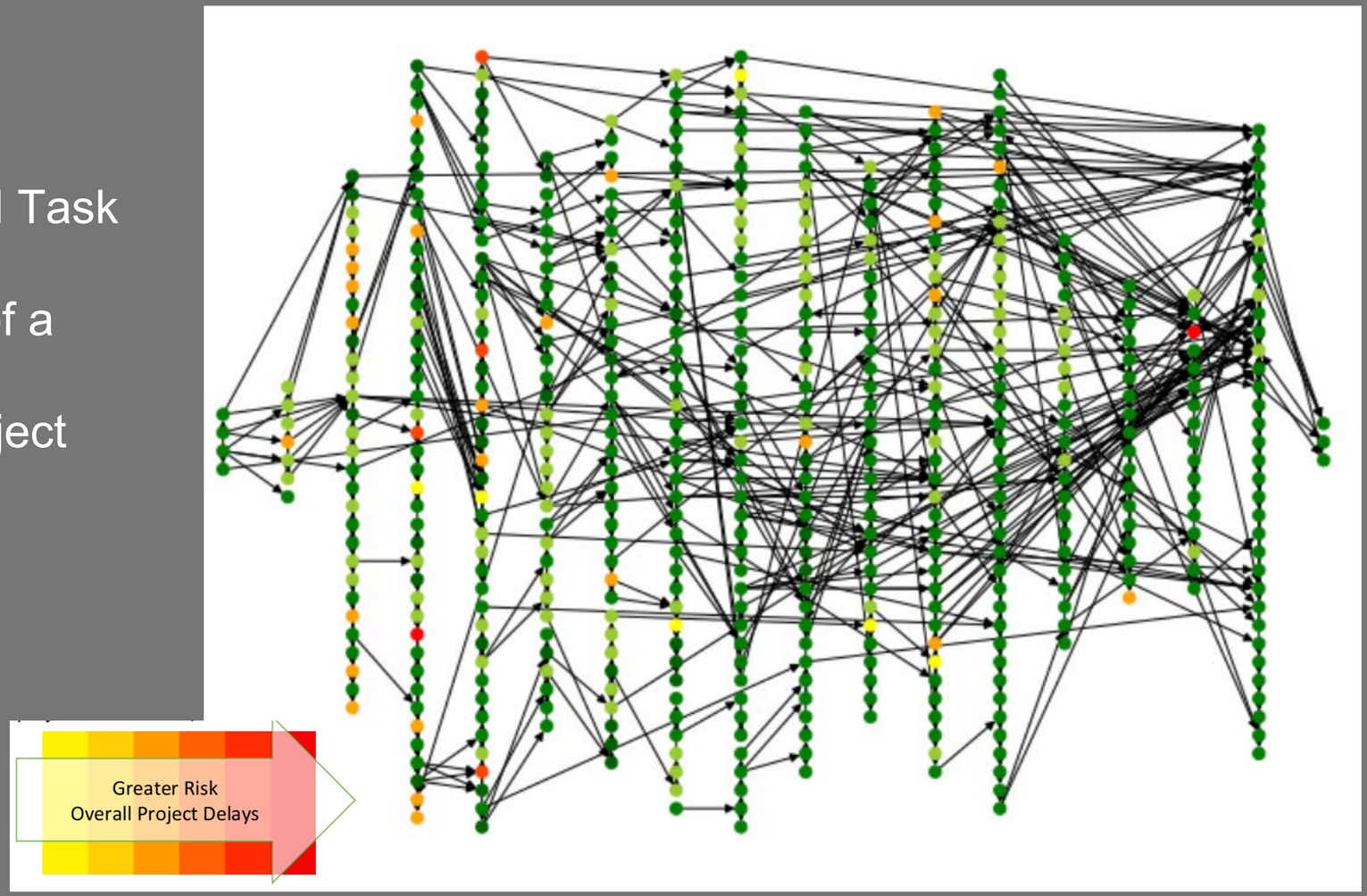
Result 3: Material Requirements by Task
Relating Task to Foreign-Sourced Minerals - Nickel

- Combined Nickel Sensitivity and Task Flow Importance for each task of a large historical Construction project from the JBF/UK database



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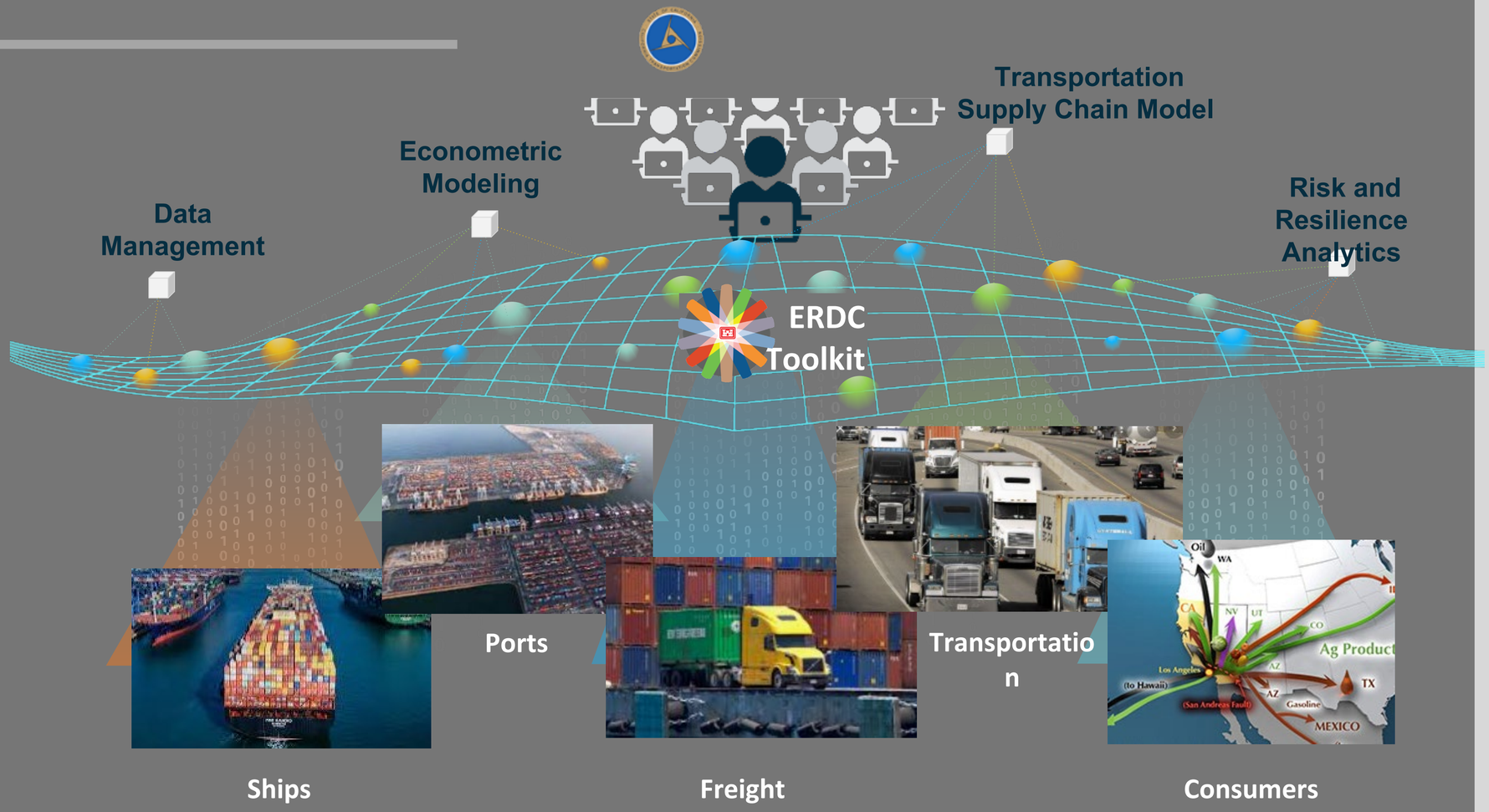
Army Corps HPC Planning | Examination of Specific Tasks

Use Case 2: Freight Modeling in CA Two Results

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



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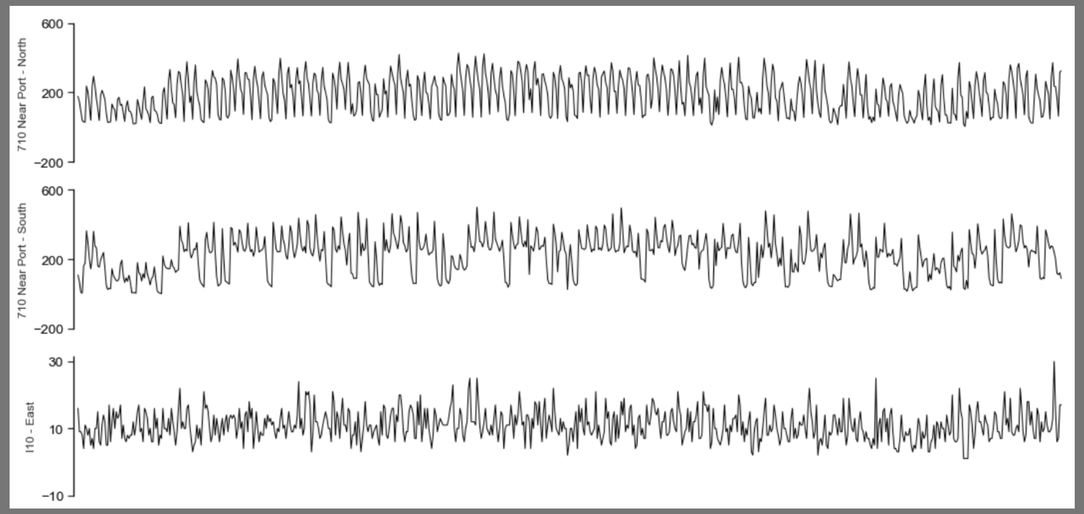
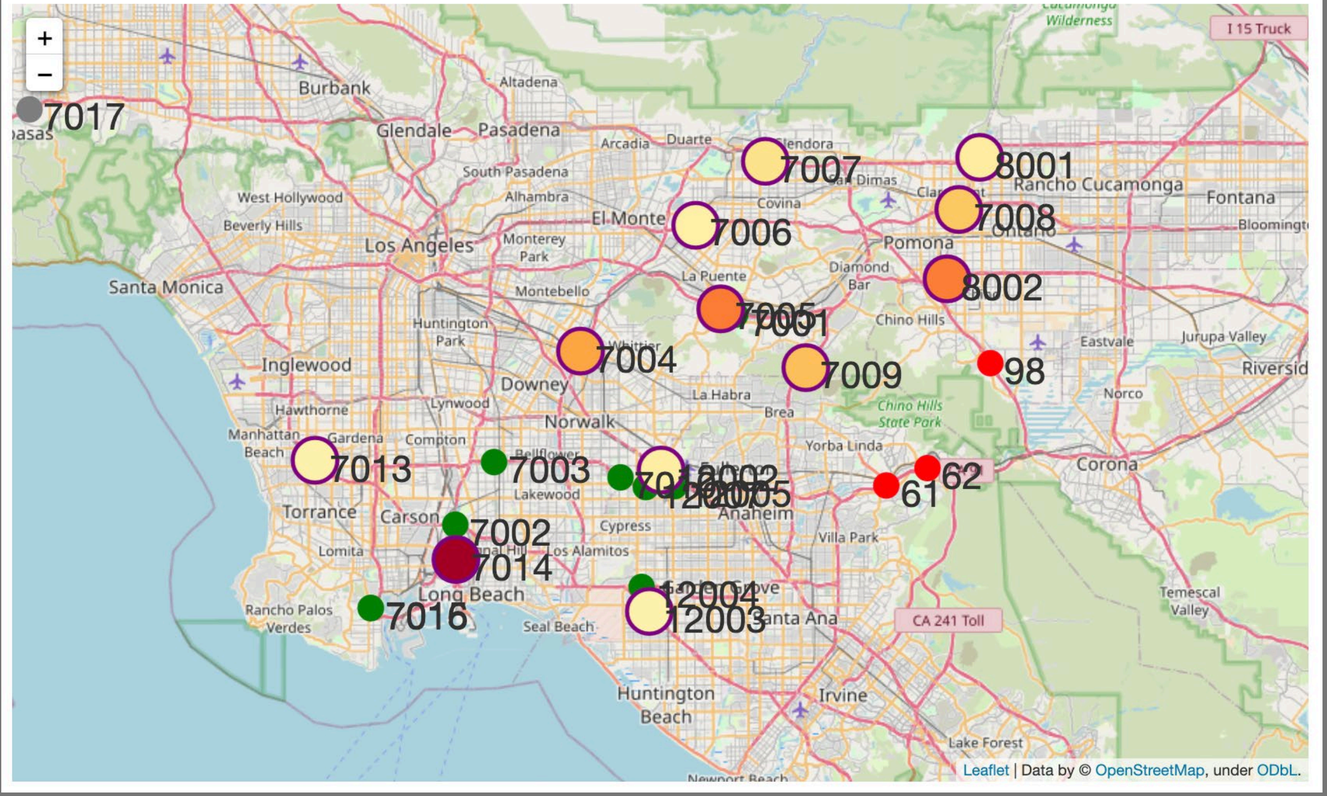
Result 1: Data Connections
TAMS Freight Data

UC IRVINE



Number of Trucks on Highways Heading Away From Port



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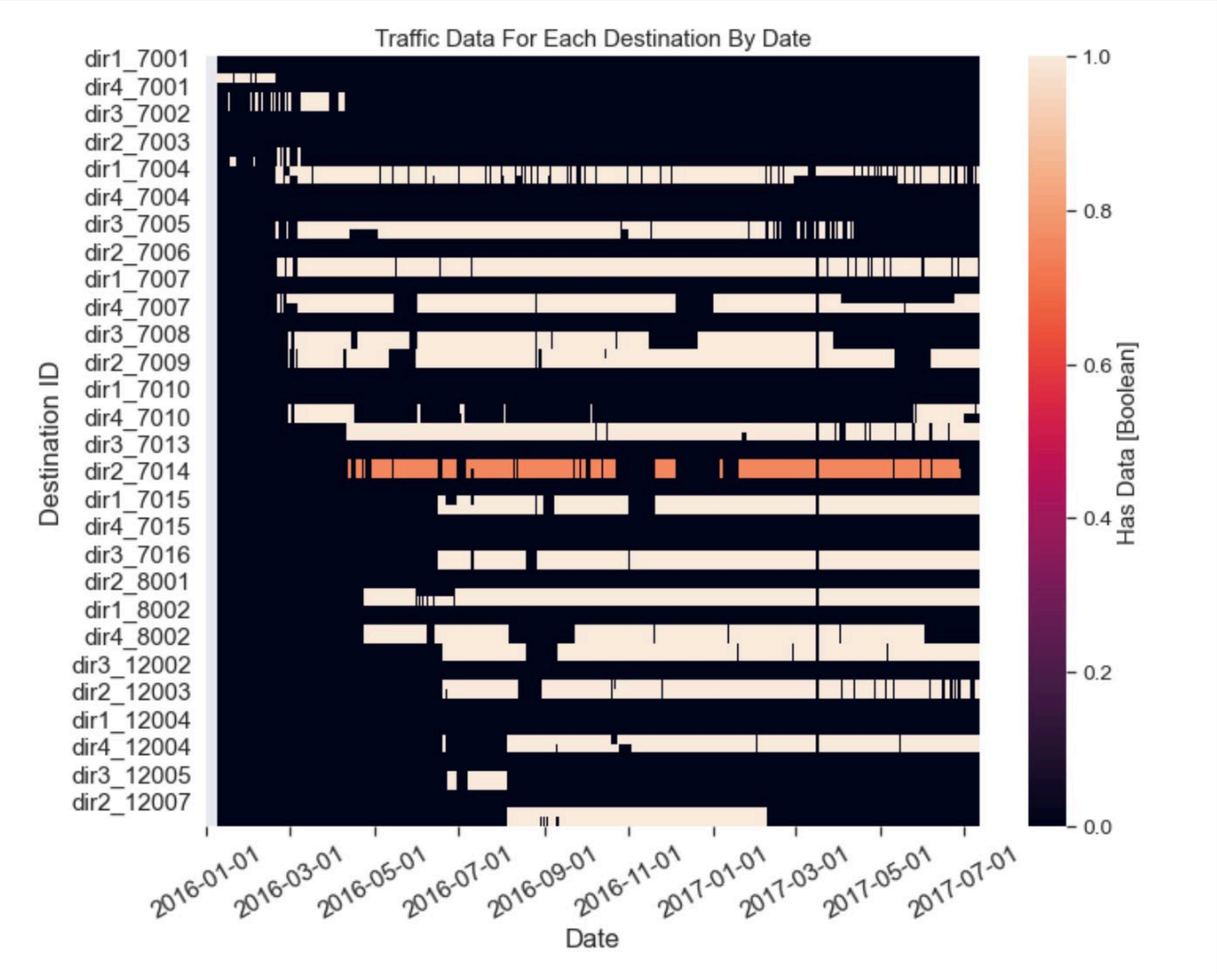
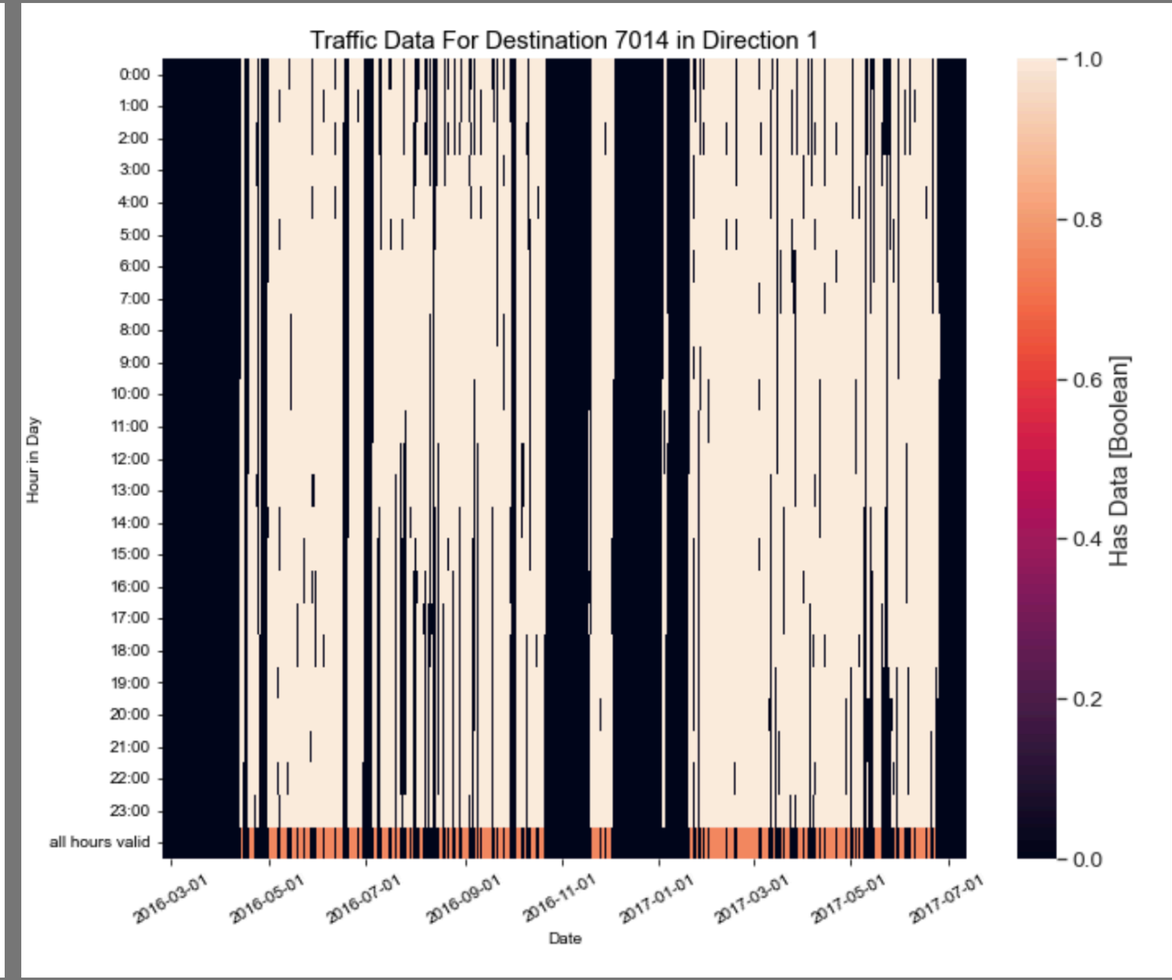
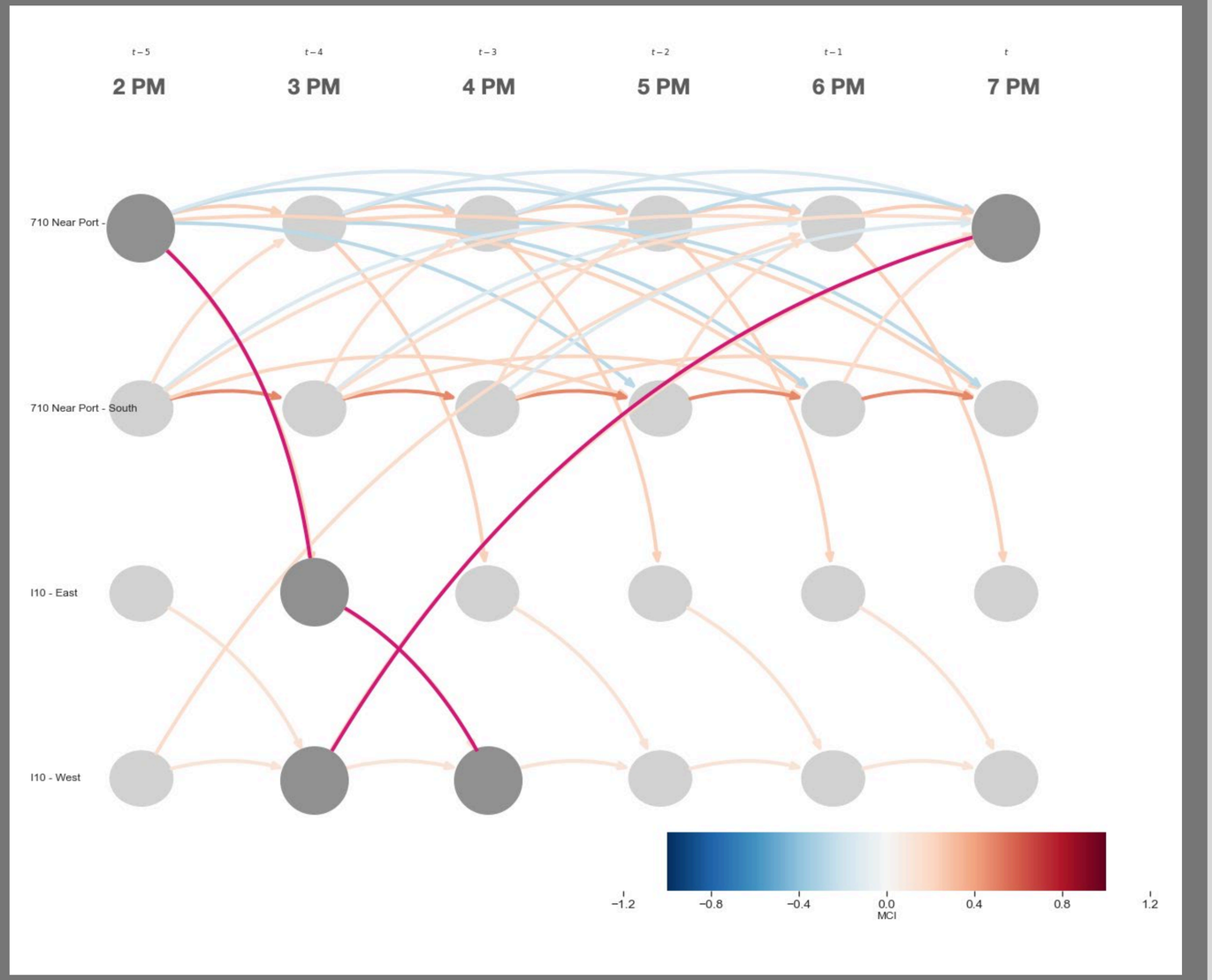
Result 1: Data Connections
TAMS Data Challenges: Completeness





Result 1: Data Connections Deriving Freight Trips

- Used correlation analysis to find correlations between nodes
- Time Dependent
- Were able to find both time delayed as well as concurrent correlations



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Result 1: Data Connections
Deriving Freight Trips with Concurrent Correlations

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Result 1: Data Connections
Replica Data: Truck Routing

Map | Dataset

6.48m trips • Medium certainty

Trips | People

The trip table represents the traveling population for your selected geo. The rows below are a preview of the data that meets the applied set of filters including origin, destination, mode, and distance. Learn More

Manage Attributes | Download

Showing first 100 of all 6,479,725 rows

Activity ID	Trip Origin Block Group	Trip Origin Tract	Trip Origin County	Trip Origin State	Trip Destination Block Group	Trip Destination Tract	Trip De County
8196442598900375000	2 (Tract 218.27, Orange, CA)	218.27 (Orange, CA)	Orange County, CA	California	2 (Tract 219.05, Orange, CA)	219.05 (Orange, CA)	Orange
14407987220099370000	1 (Tract 218.13, Orange, CA)	218.13 (Orange, CA)	Orange County, CA	California	1 (Tract 218.13, Orange, CA)	218.13 (Orange, CA)	Orange
6846575075641834000	1 (Tract 218.13, Orange, CA)	218.13 (Orange, CA)	Orange County, CA	California	1 (Tract 117.14, Orange, CA)	117.14 (Orange, CA)	Orange
12193735969462860000	1 (Tract 117.14, Orange, CA)	117.14 (Orange, CA)	Orange County, CA	California	2 (Tract 218.21, Orange, CA)	218.21 (Orange, CA)	Orange
12147415876704453000	3 (Tract 219.24, Orange, CA)	219.24 (Orange, CA)	Orange County, CA	California	2 (Tract 218.21, Orange, CA)	218.21 (Orange, CA)	Orange
10845215704359877000	1 (Tract 219.03, Orange, CA)	219.03 (Orange, CA)	Orange County, CA	California	1 (Tract 218.07, Orange, CA)	218.07 (Orange, CA)	Orange
99457241558227860	1 (Tract 117.14, Orange, CA)	117.14 (Orange, CA)	Orange County, CA	California	3 (Tract 218.15, Orange, CA)	218.15 (Orange, CA)	Orange
8751726289717313000	2 (Tract 219.23, Orange, CA)	219.23 (Orange, CA)	Orange County, CA	California	3 (Tract 219.24, Orange, CA)	219.24 (Orange, CA)	Orange
12522627138176920000	1 (Tract 218.24, Orange, CA)	218.24 (Orange, CA)	Orange County, CA	California	1 (Tract 218.23, Orange, CA)	218.23 (Orange, CA)	e
12401083620655362000	1 (Tract 219.18, Orange, CA)	219.18 (Orange, CA)	Orange County, CA	California	2 (Tract 762.01, Orange, CA)	762.01 (Orange, CA)	Orange

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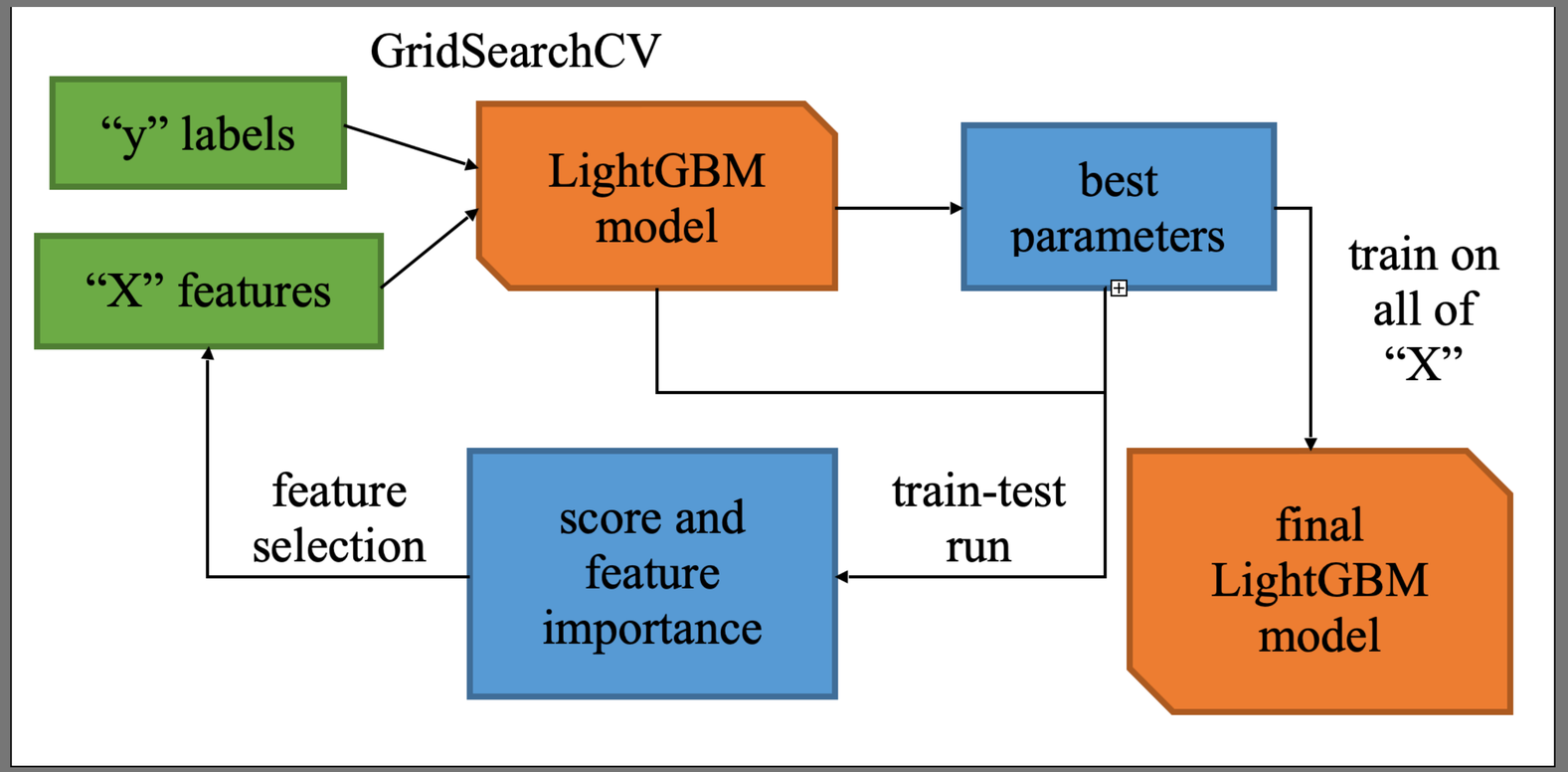
Result 2: Data Confidence
Deriving warehouse locations

- Using Replica data to find heavy warehouse census blocks
- Using LightGBM Model



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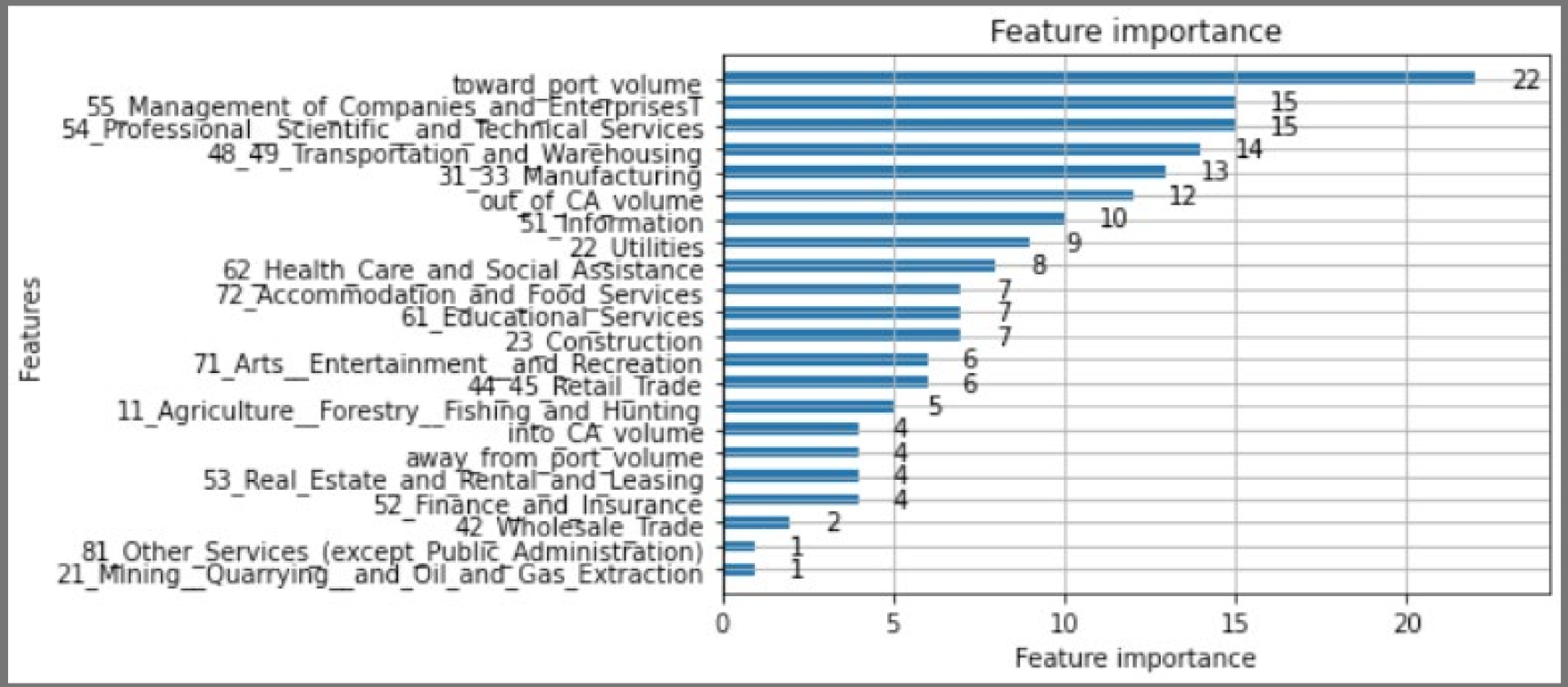
Result 2: Data Confidence
Deriving warehouse locations



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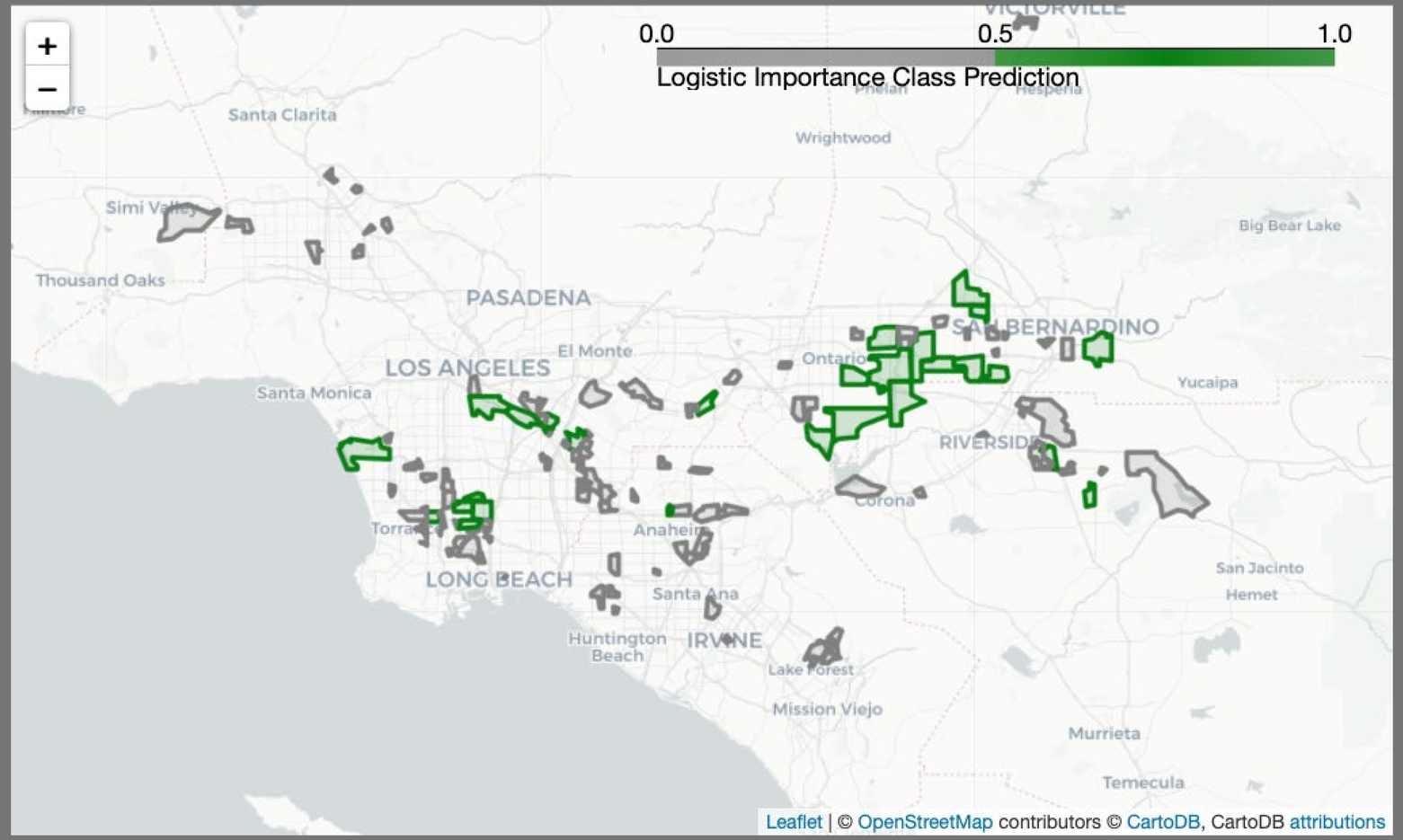
Result 2: Data Confidence
Validation against known warehouse locations



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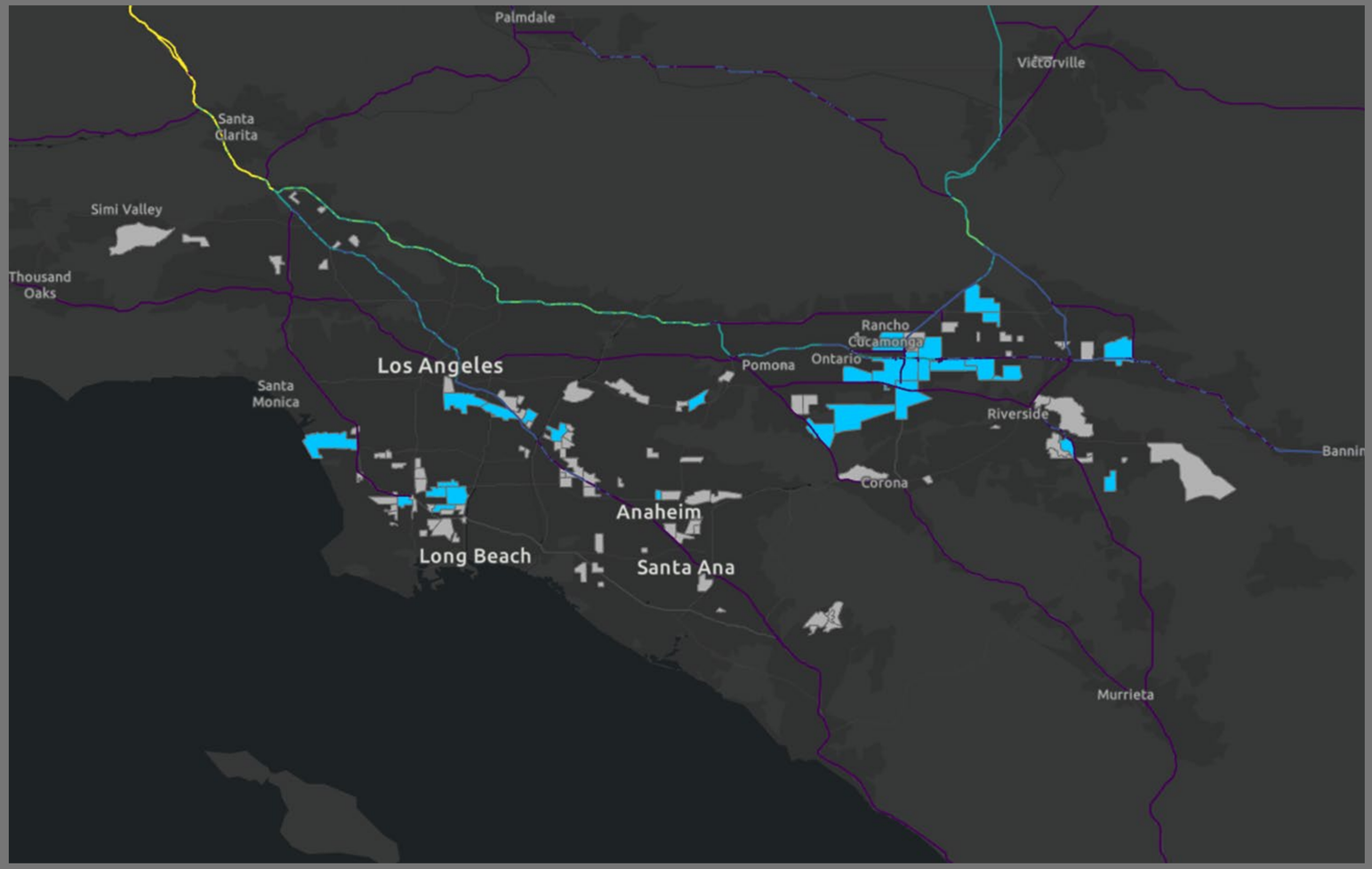
Result 1: Data Confidence
Validation against known warehouse locations



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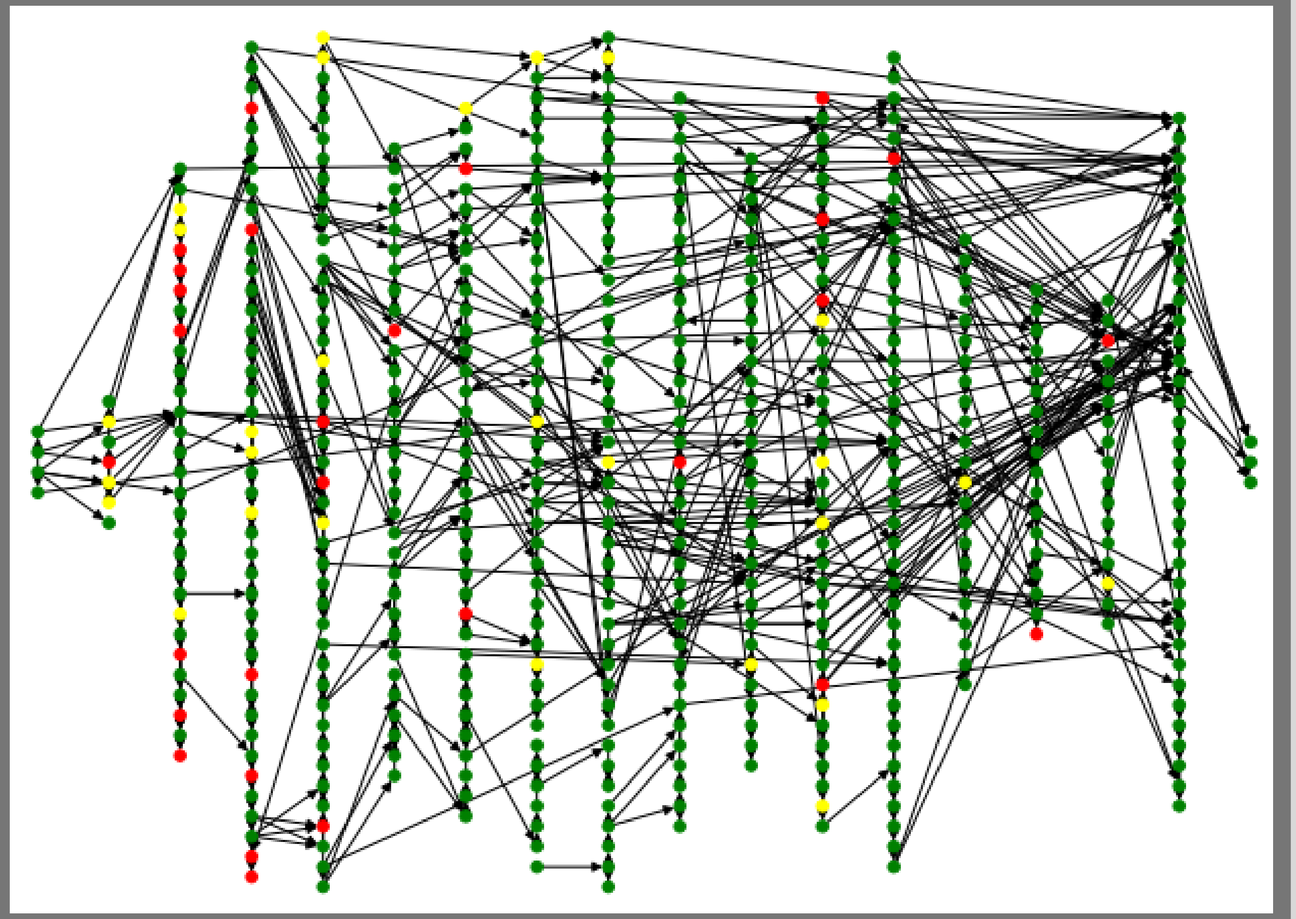
Key Findings

- Supply Chain impacts can be measured
- Potential future supply chains disruption can be anticipate
- AI has the ability to assist with understanding connections and dependencies in many parts of the supply chain



Army Corps HPC Planning | Examination of Specific Tasks

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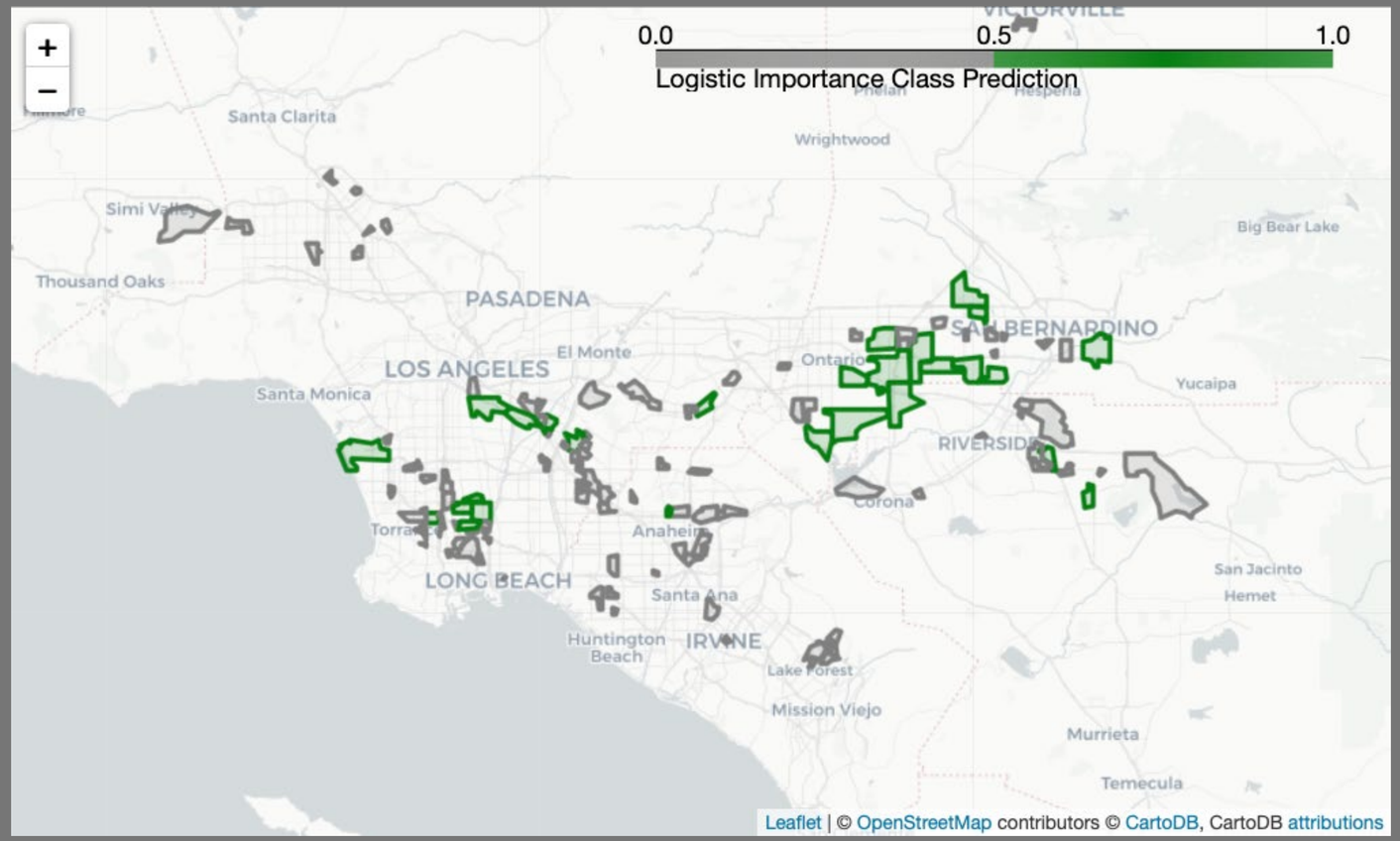
Questions

Dr. Igor Linkov -
igor.linkov@usace.army.mil



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Case Study 2: Risk and Resilience Analytics and Supply Chains

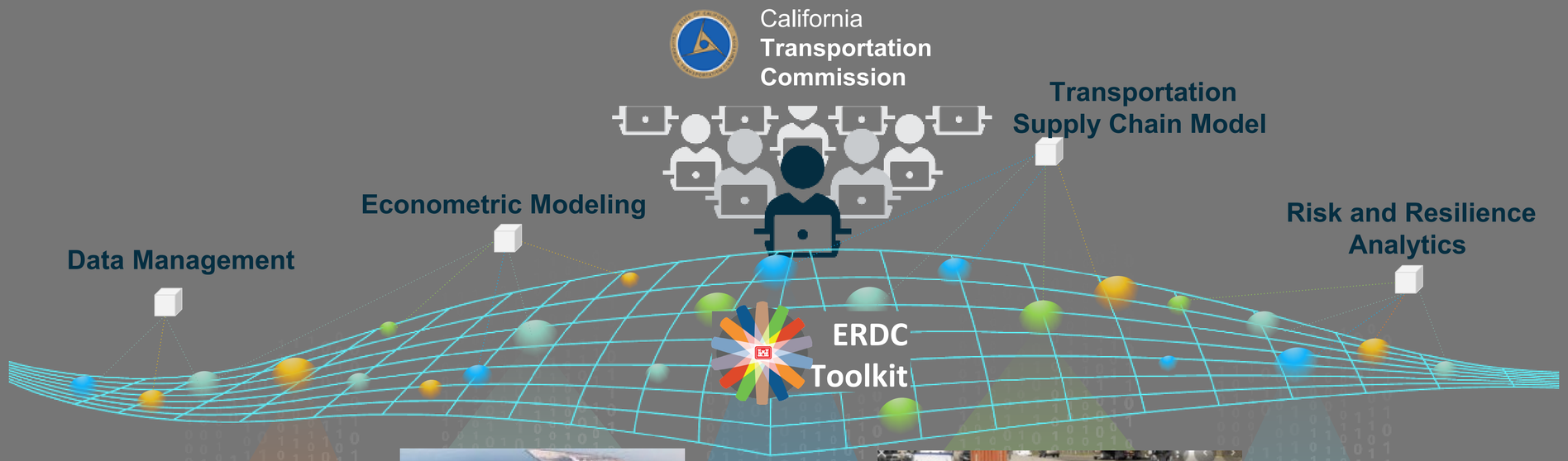
Applications to Freight Modeling in CA

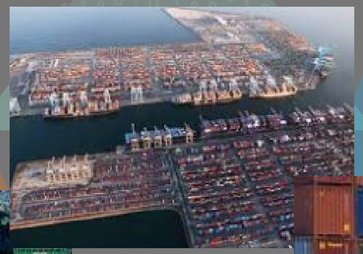
Presenter: *Dr. Kelsey Stoddard*[1] : kelsey.s.stoddard@usace.army.mil
POC: *Dr. Igor Linkov*[1] : igor.linkov@usace.army.mil
Dr. Andrew Strelzoff[2] , *Sam Dent*[2]

October 6, 2022

ERDC EL[1] , *ERDC ITL*[2]

Project Goal: Increase Resilience in CA Transportation Networks





Ports

Transportation

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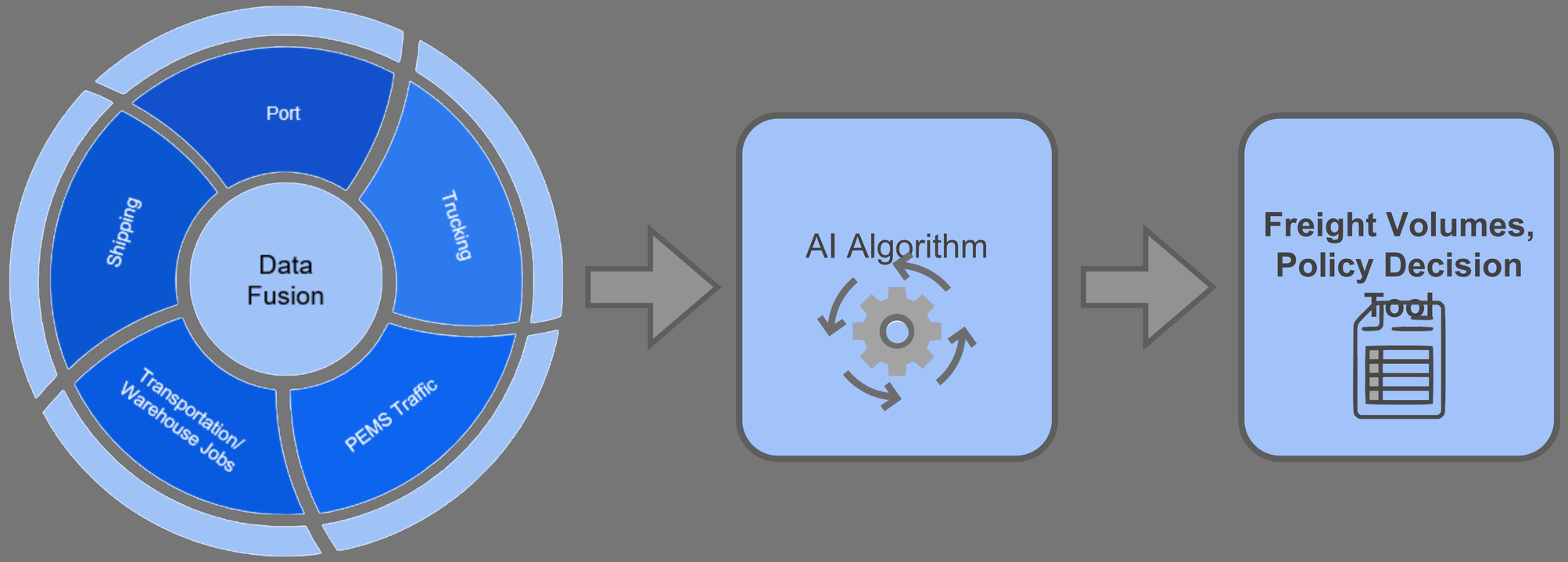
Ships | Freight | Consumers

US Army Corps of Engineers • Engineer Research and Development Center

Methodology:
Data Fusion and Optimization Using AI and Resilience Modeling



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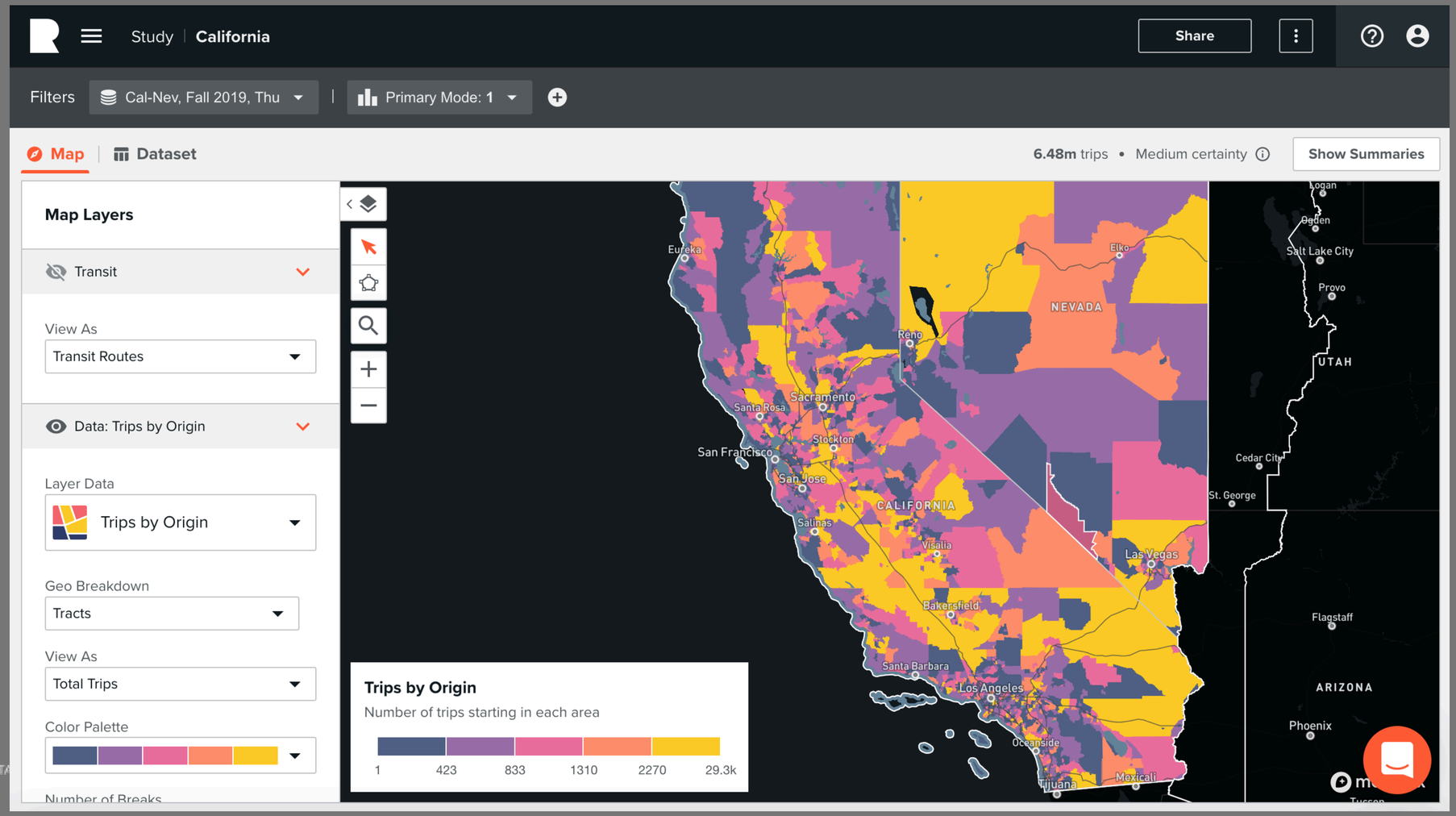
Replica Data:
Connecting Entry Points, Warehousing and Consumers



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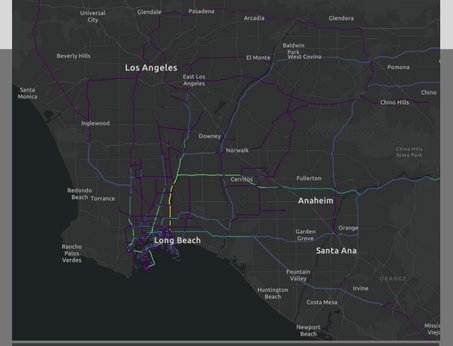
Presentation Overview

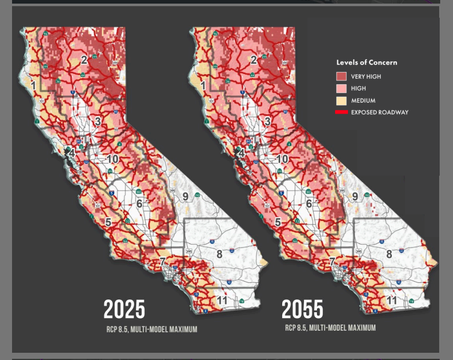
- Tools:
  - Freight Volumes
  - Scenario Comparison Tool

- 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

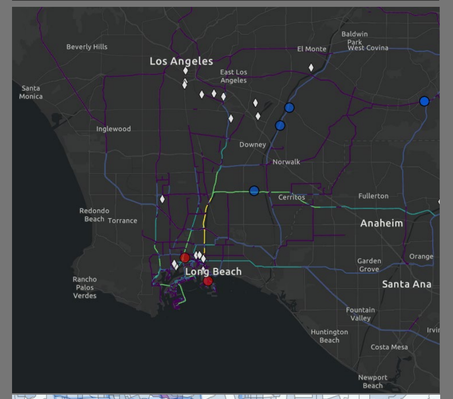
Supply Chain Resilience



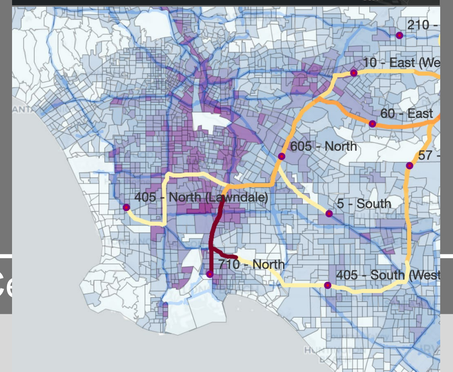
Natural Disaster Risk and Resilience



Zero Emission Refueling Station



Multi-Objective Equity Optimization



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Tool 1:
Freight Volumes

- Tools/Impacts can be understood for:
  - Long Haul
  - CA External Goods:
    - Ports
    - Airports
    - Land Points of Entry
- Future Work:
  - Aggregate Flows
  - Medium vs Heavy Trucks

ENVIRONMENTAL LABORATORY

Tool 1:
Freight Volumes - Long Haul

- Tools/Impacts can be understood for:
  - Long Haul
  - CA External Goods:
    - Ports
    - Airports
    - Land Points of Entry
- Future Work:
  - Aggregate Flows
  - Medium vs Heavy Trucks

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Tool 1:
Freight Volumes - Long Haul

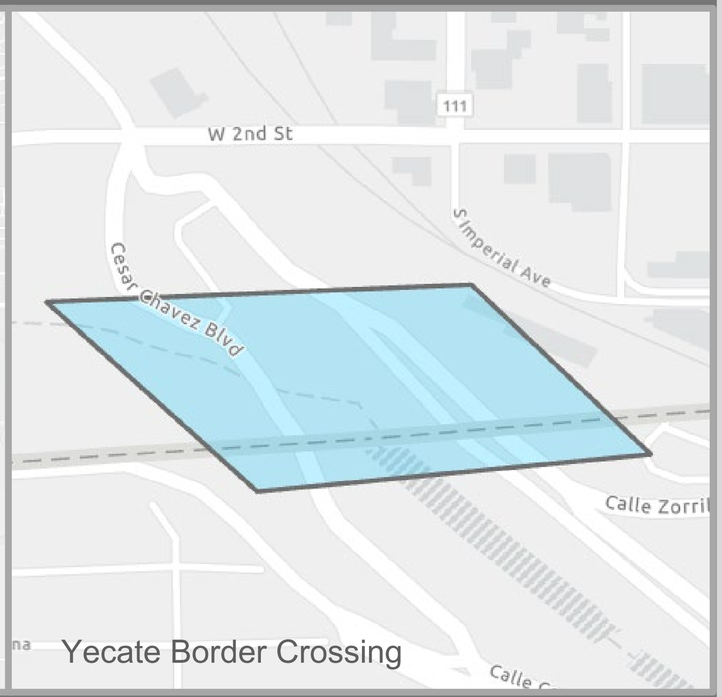
	Origin: Inside State	Origin: Outside CA
Destination: Inside State	Internal to CA	Entering CA
Destination: Outside CA	Exiting CA	External to CA

ENVIRONMENTAL LABORATORY

Tool 1:
Freight Volumes - External Goods

- Tools/Impacts can be understood for:
  - Long Haul
  - CA External Goods:
    - Ports
    - Airports
    - Land Points of Entry
- Future Work:
  - Aggregate Flows
  - Medium vs Heavy Trucks

Fresno Airport



Yecate Border Crossing

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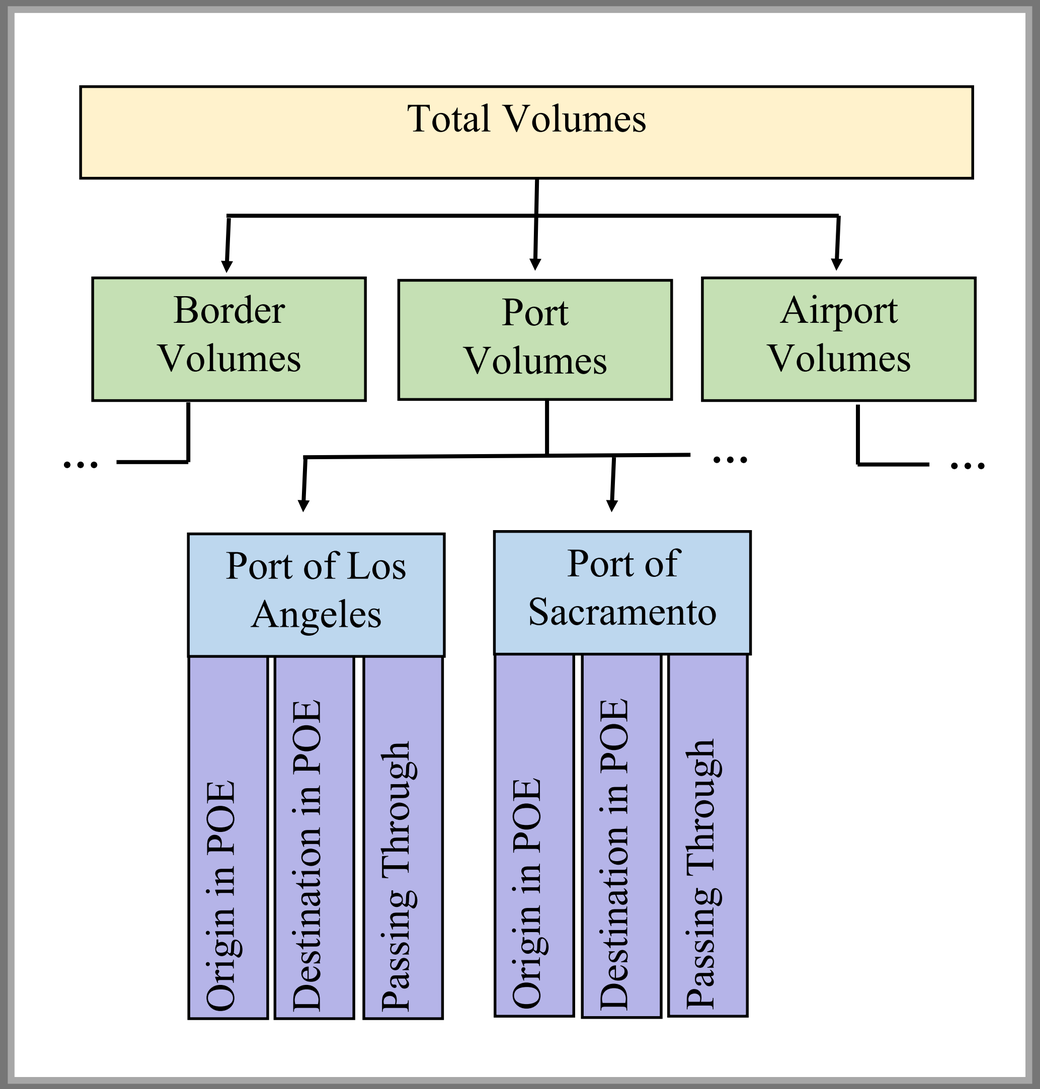
Tool 1:
Freight Volumes - External Goods

- Tools/Impacts can be understood for:
  - Long Haul
  - CA External Goods:
    - Ports
    - Airports
    - Land Points of Entry
- Future Work:
  - Aggregate Flows
  - Medium vs Heavy Trucks



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Tool 1:
Freight Volumes - External Goods

- Tools/Impacts can be understood for:
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    - Land Points of Entry
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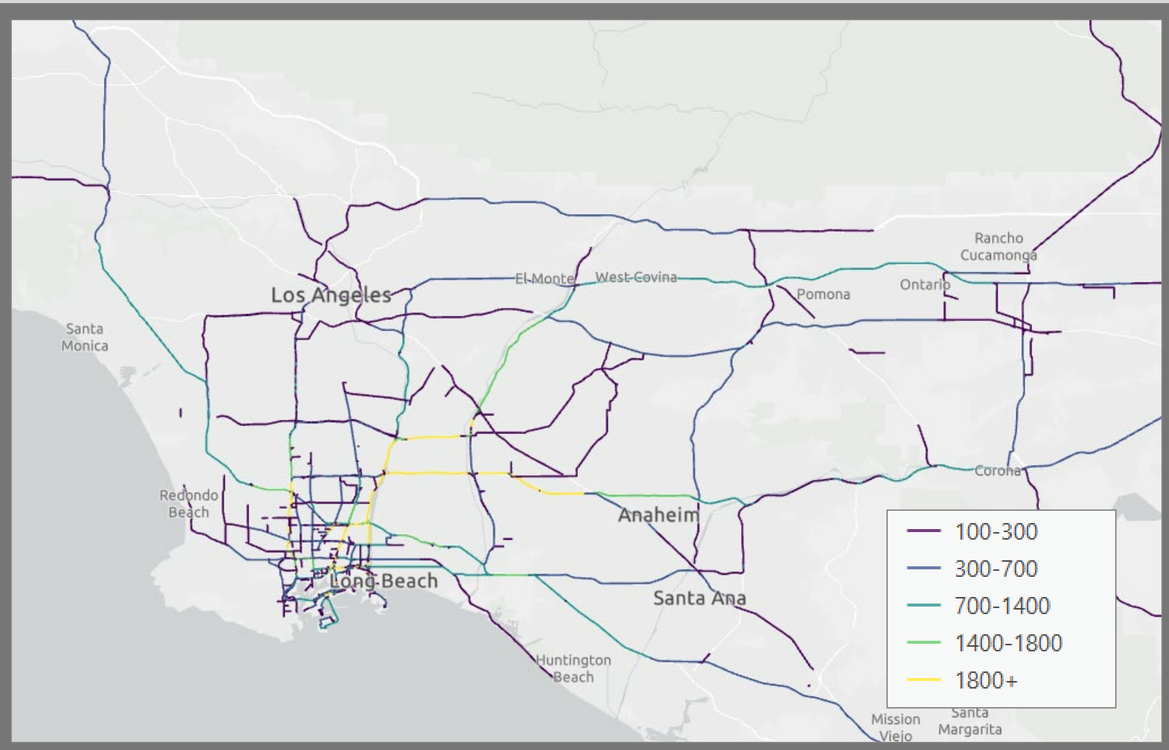
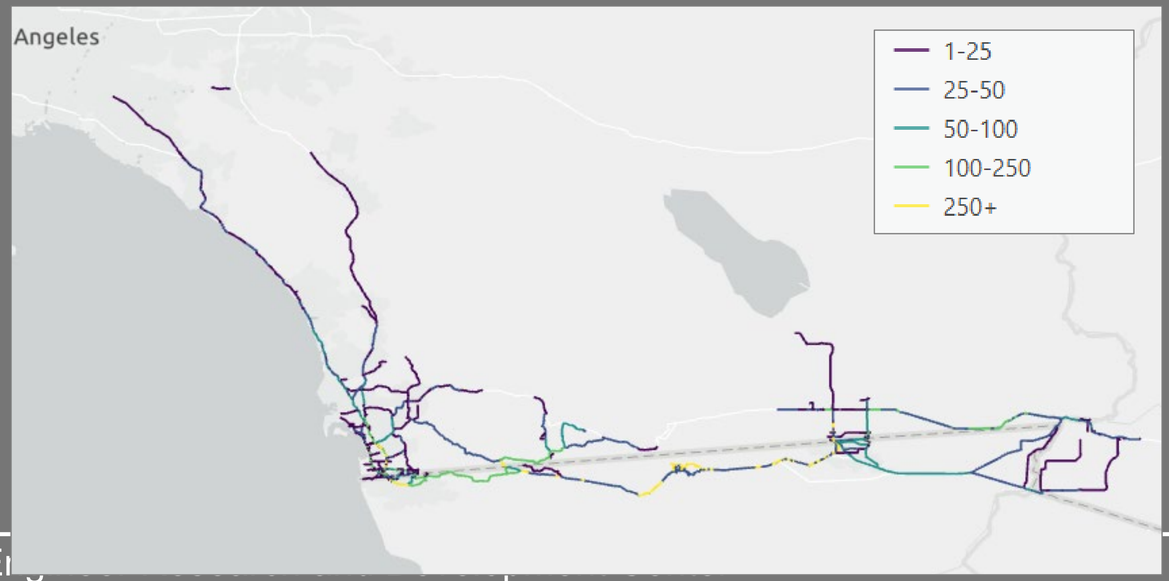
  - Medium vs Heavy Trucks





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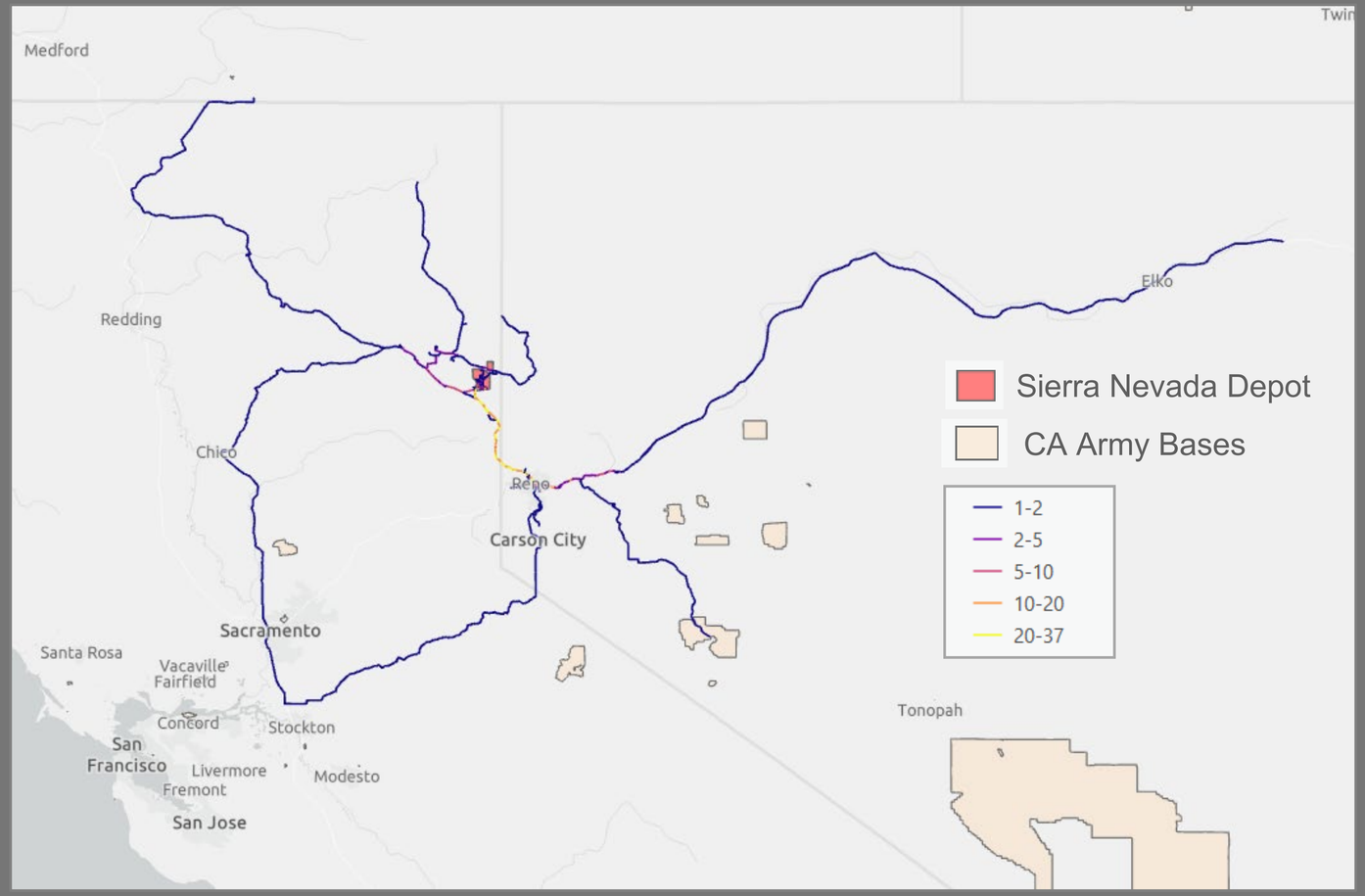
Tool 1:
Freight Volumes - Army Depots

- **Concerns:**
  Similar exercises could be preformed for other groups, including army sites
- **Initial Examination:**
  Identify army bases and depots in CA
  - Extract commercial vehicle trips overlapping those locations
  - Volumes for Sierra Nevada Army Depot are shown



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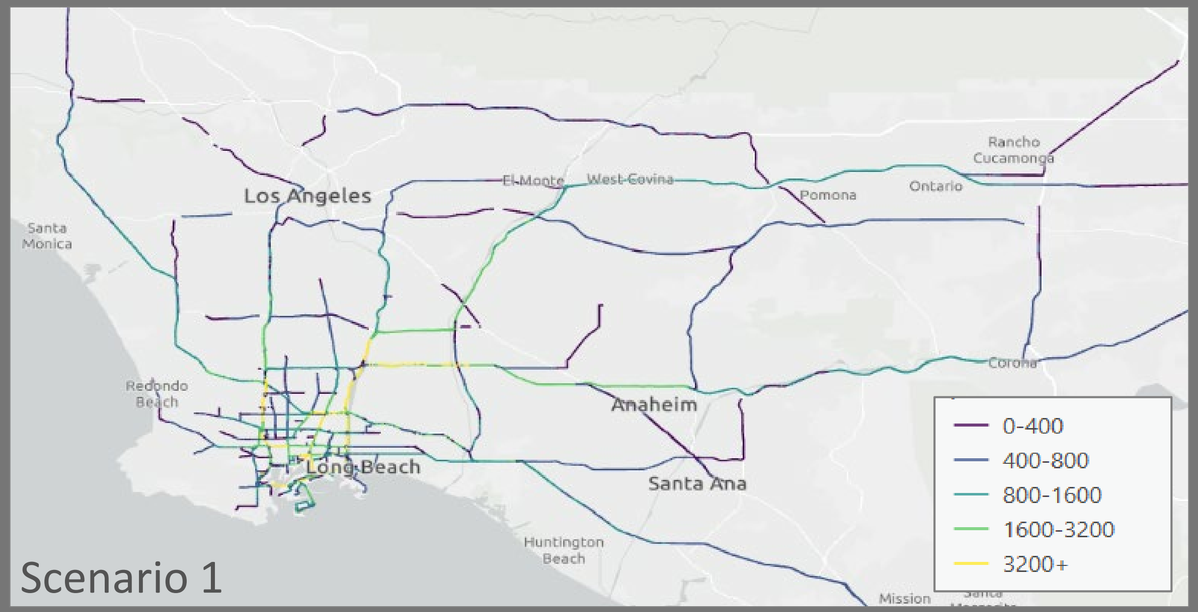
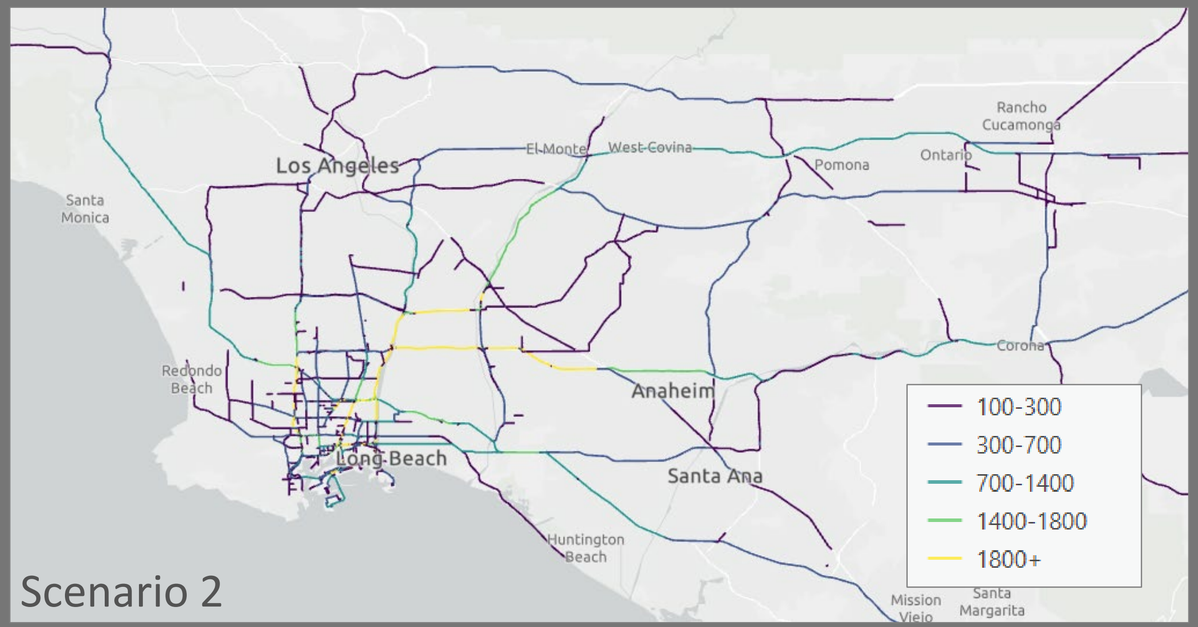
Tool 2:
Scenario/Policy Comparison Tool

- Scenario comparison tool compares new road volumes based on changes to roads
  - Does not: Recalculates by assuming cars will divert around the disrupted road
  - Does: Re-calculates by defining completely new routes for impacted vehicles
  - Modeling includes how re-routing increases congestion and vehicle speeds
  - Finds added congestion and travel time

* This work is currently in development



Scenario 1



Scenario 2

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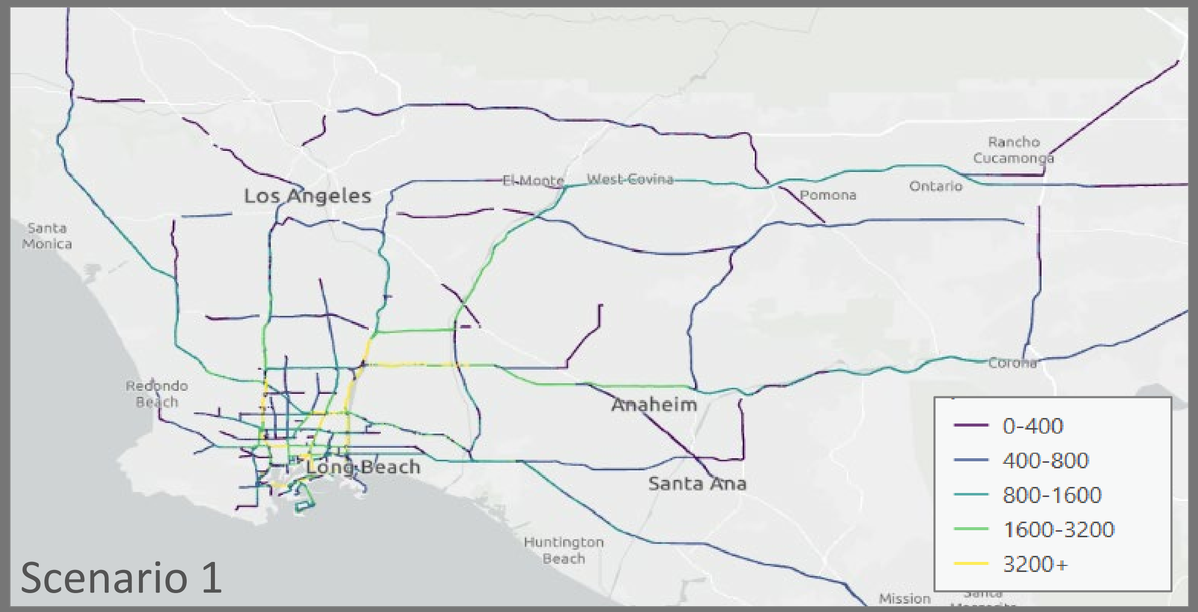
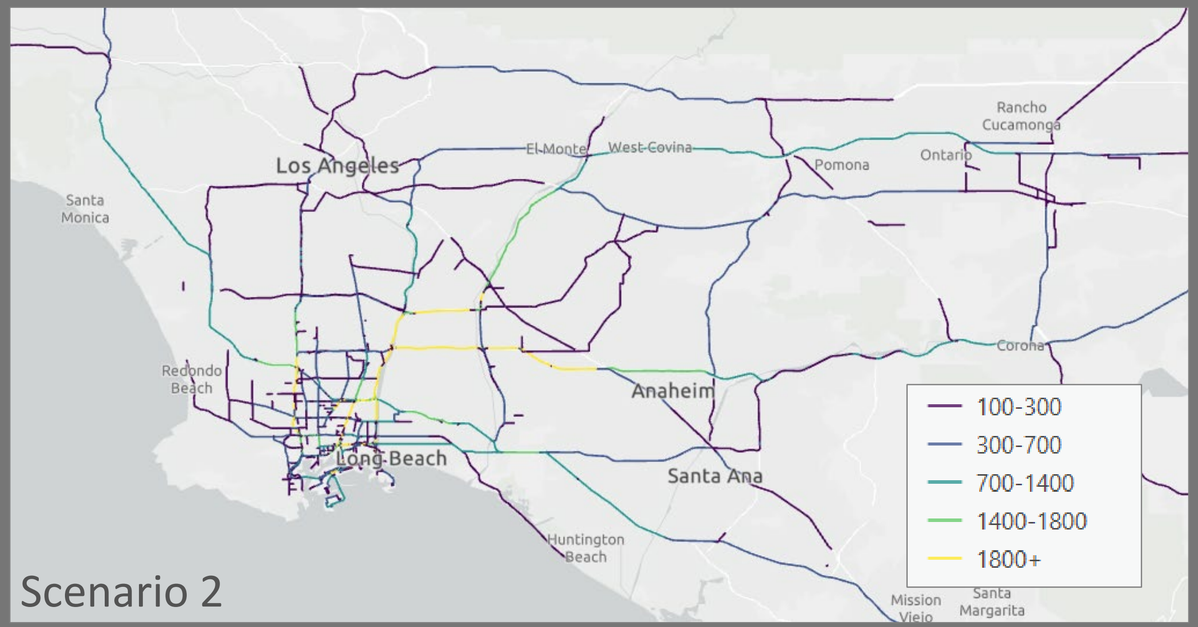
Tool 2:
Scenario/Policy Comparison Tool

- Ranks scenarios based on freight diversion and congestion
  - Capacity Expansion: Adding roads
    Increasing lane
  - Capacity Reduction: Road closures
    Lane closures



Scenario 1



Scenario 2

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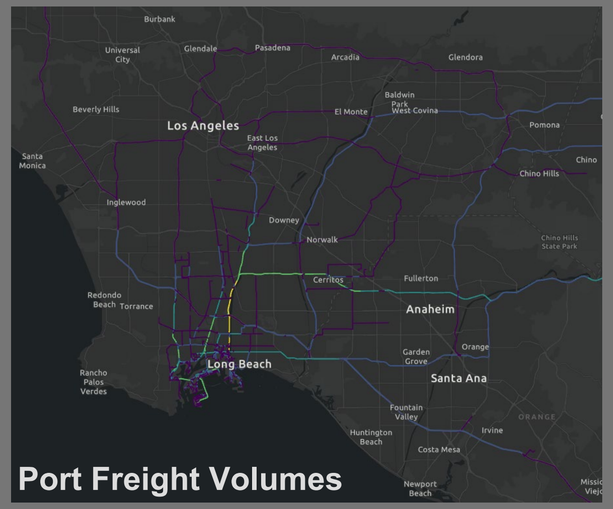
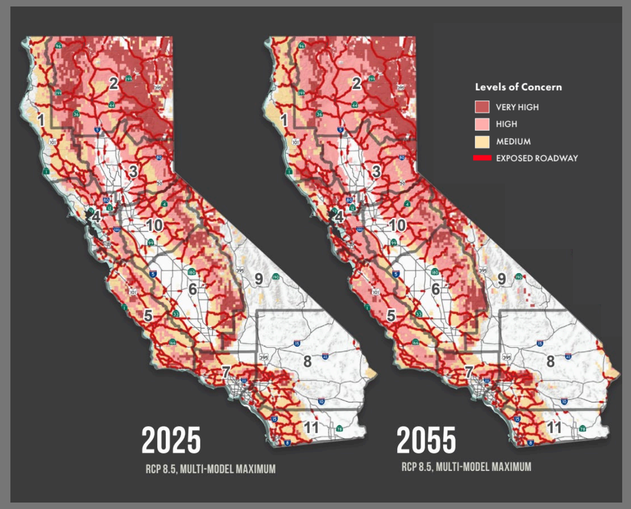
Addressed Problems: Overview

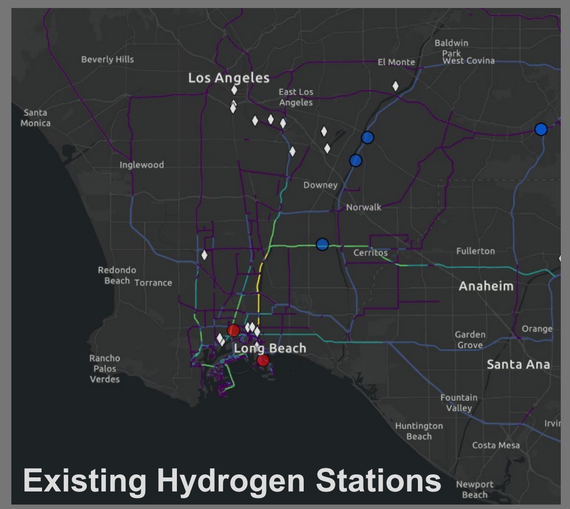
Supply Chain Resilience Quantification



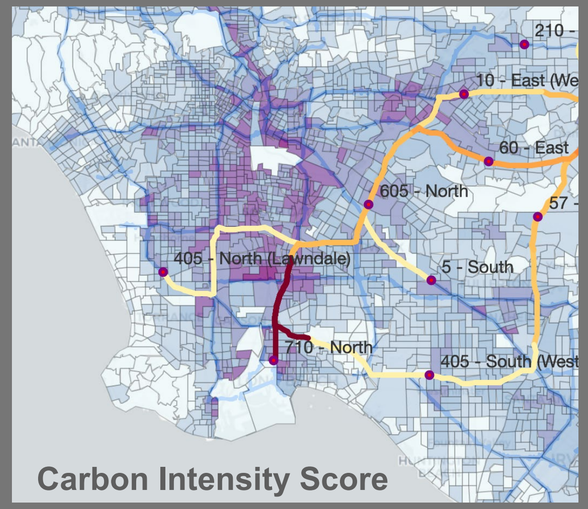
Multi-Treat Natural Disaster Risk and Resilience



Zero Emission Refueling Station



Multi-Objective Equity Optimization



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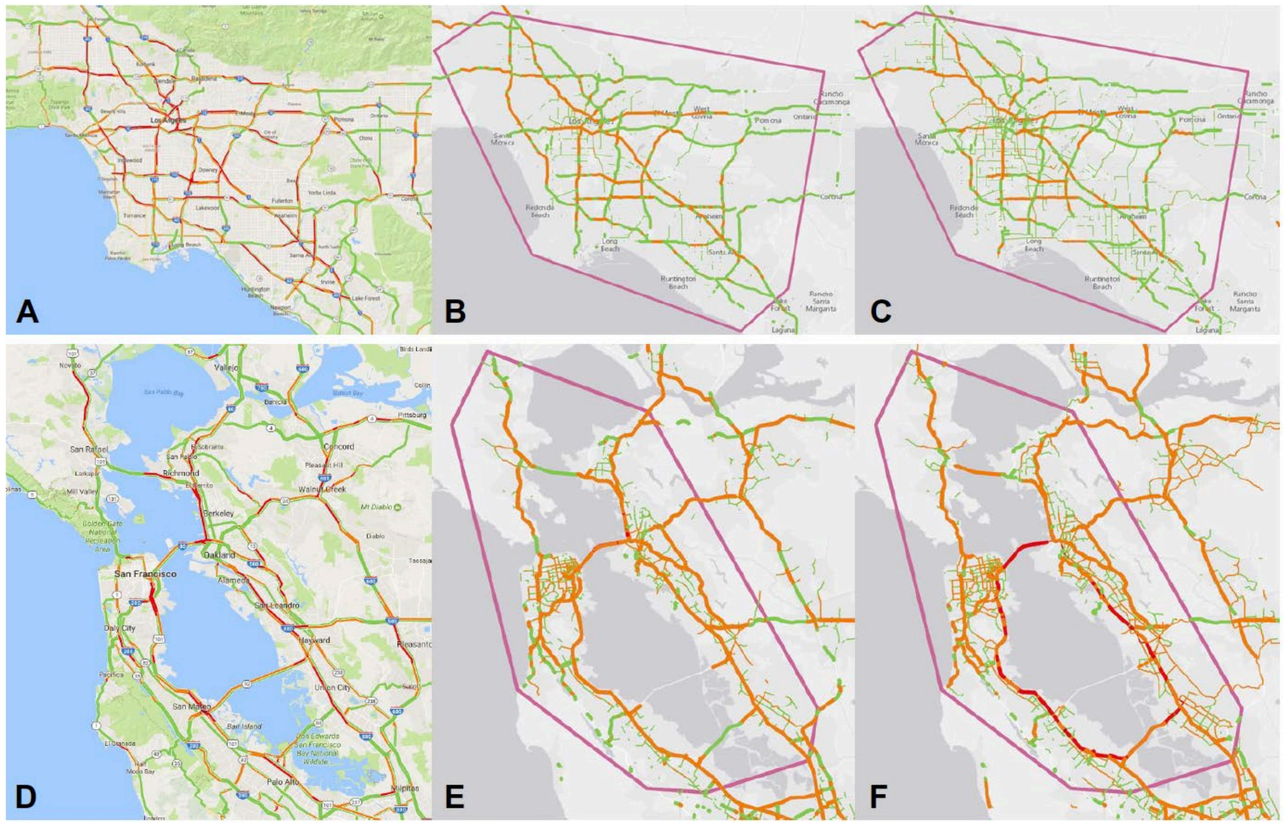
US Army Corps of Engineers • Engineer Research and Development Center

I. Problems:
Supply Chain Resilience Quantification

Ganin et al., Sci. Adv. 2017;3: e1701079 20 December 2017

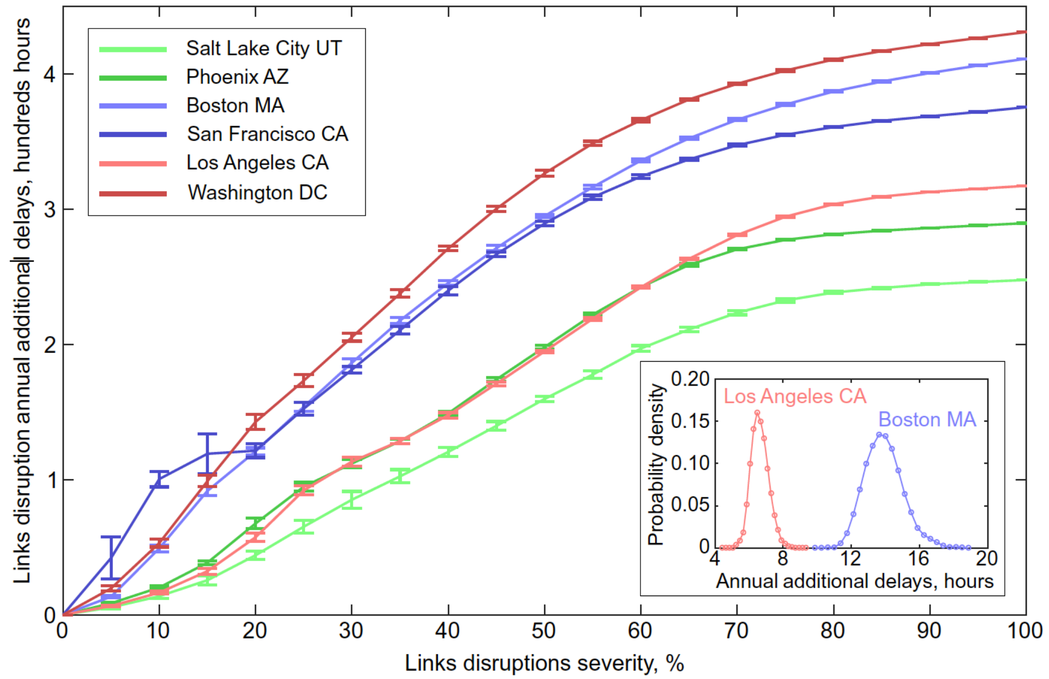


SCIENCE ADVANCES | RESEARCH ARTICLE

NETWORK SCIENCE

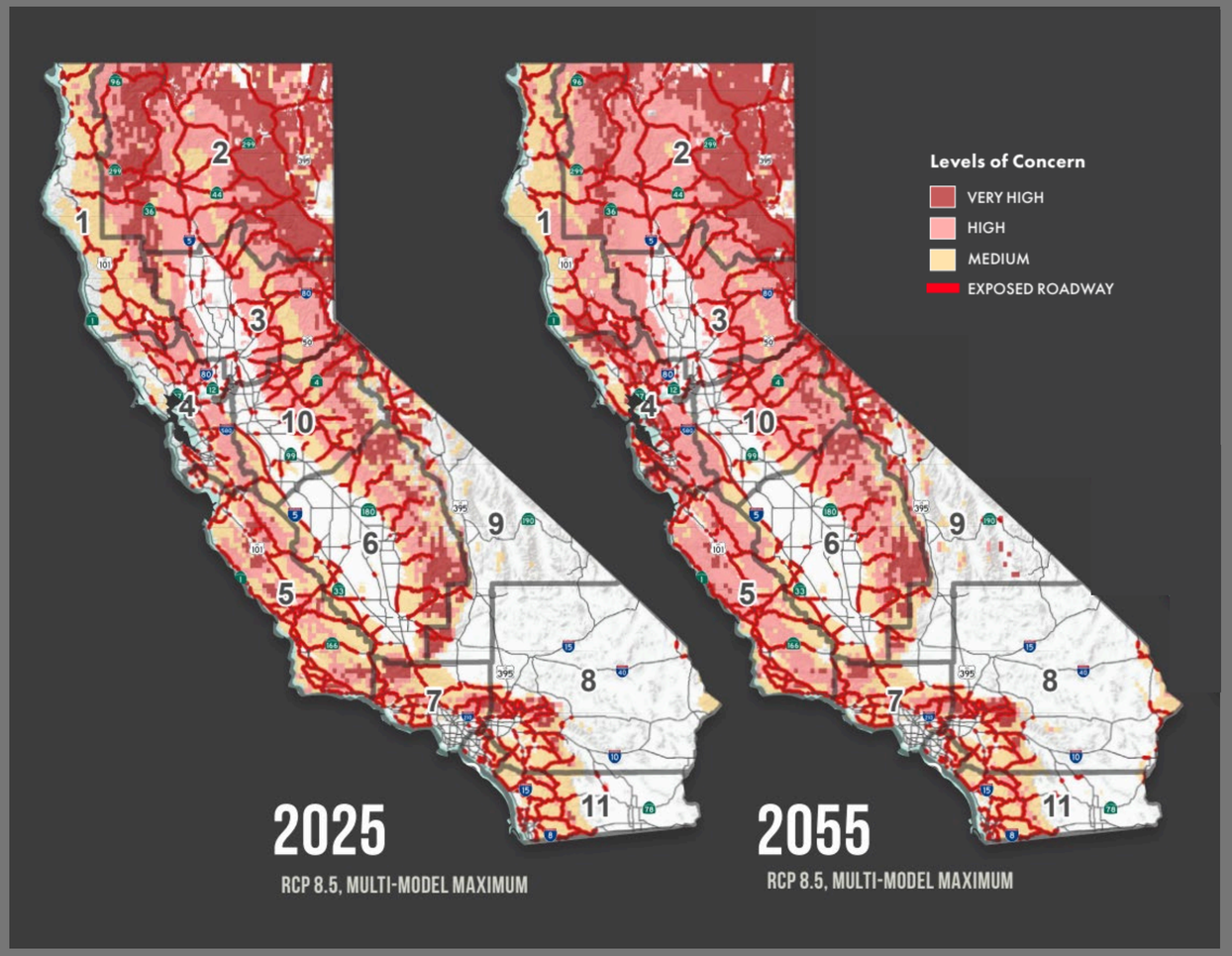
Resilience and efficiency in transportation networks

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



II. Addressed Problems:
Multi-Treat Natural Disaster Resilience Quantification

- Roads impacted by climate events will have reduced capacity from either:
  - Capacity Reduction: Road closures
    Lane closures
- Resilience will be studied by simulating increasingly large climate events & examining changes

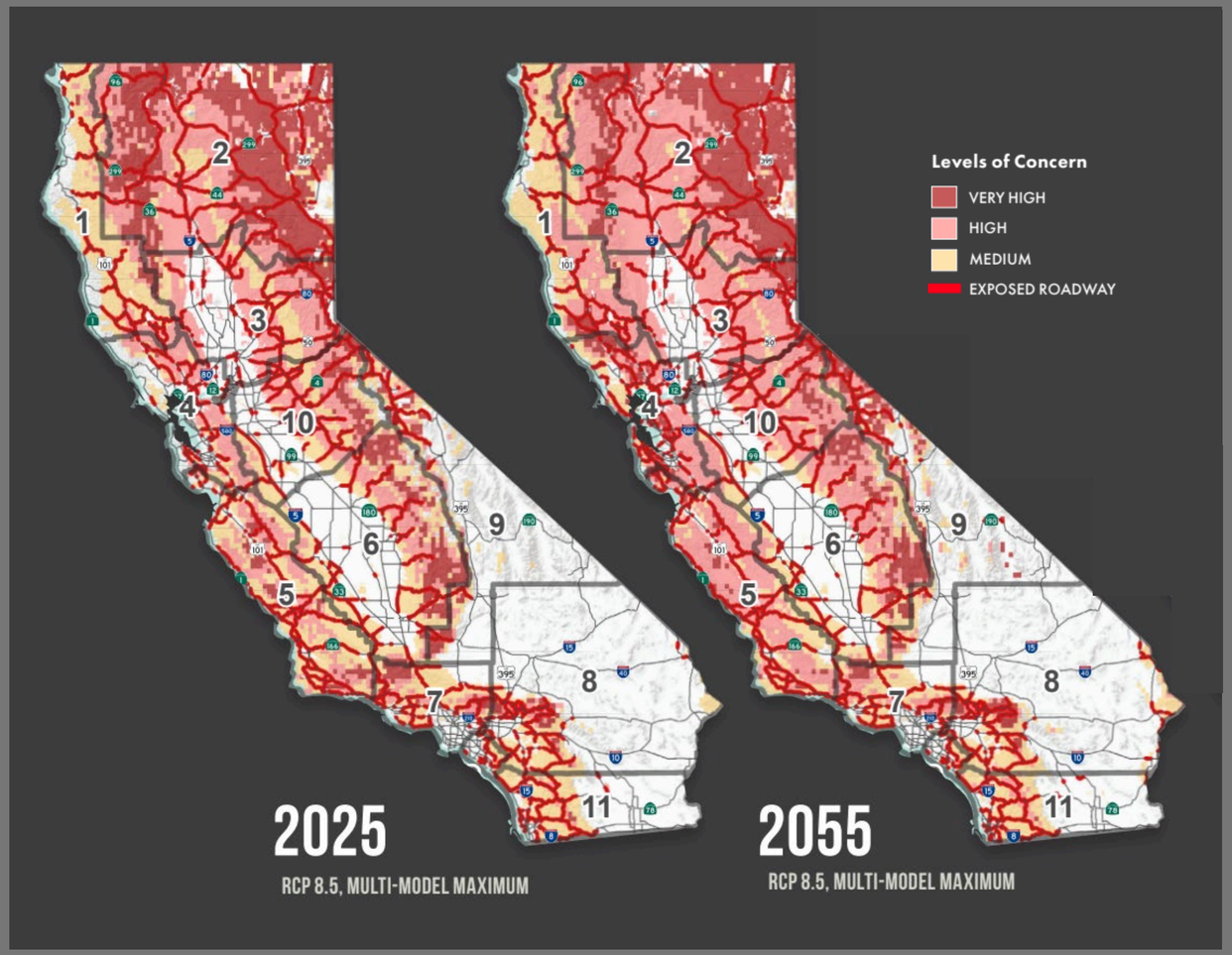


Changing Level of Wildfire Concern |
Caltrans Climate Change Vulnerability Assessment

ENVIRONMENTAL LABORATORY

II. Addressed Problems:
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

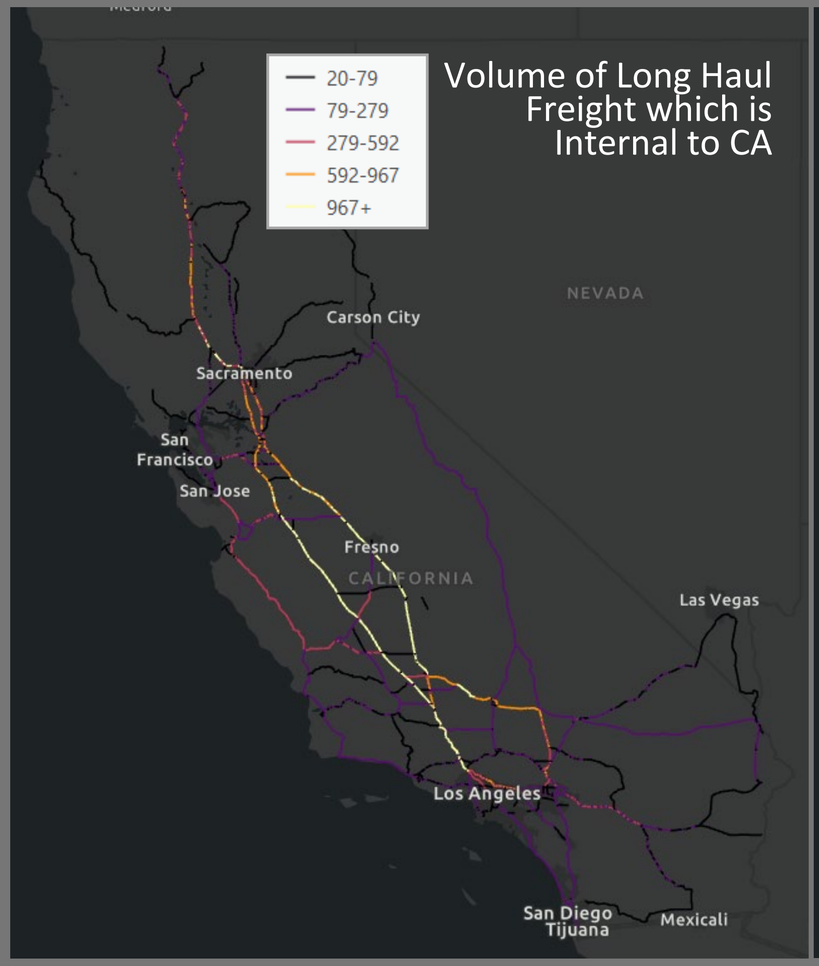


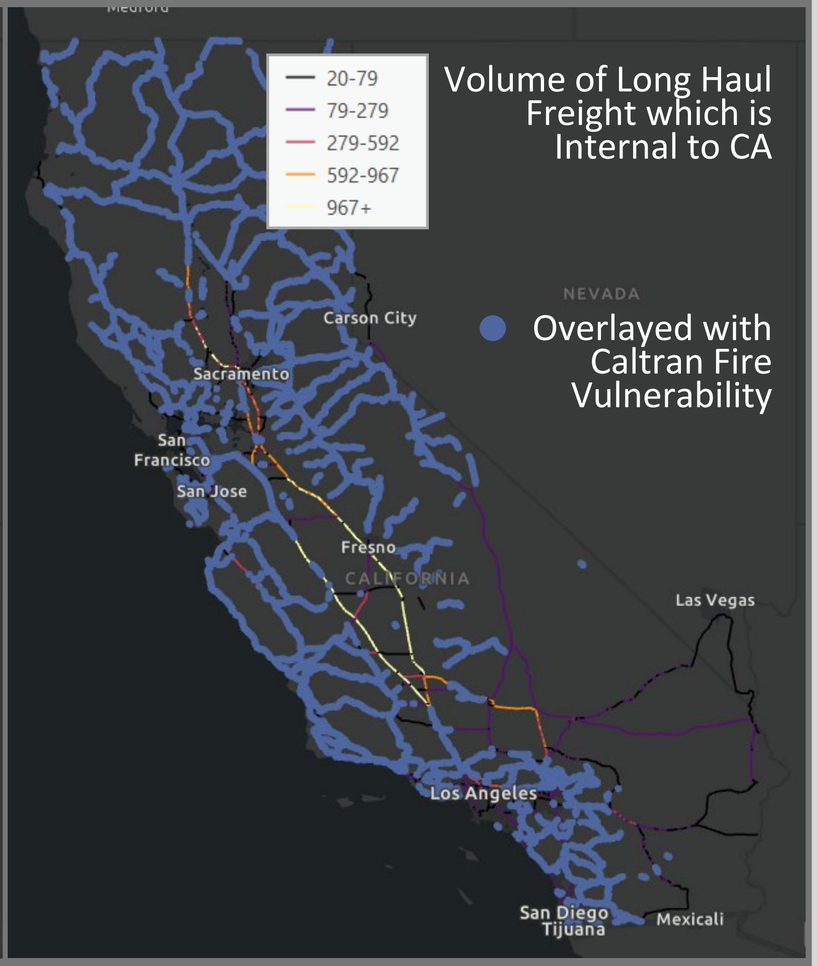
Changing Level of Wildfire Concern | Caltrans Climate Change Vulnerability Assessment

ENVIRONMENTAL LABORATORY

II. Addressed Problems:
Multi-Treat Natural Disaster Resilience Quantification

- Overlaying freight volumes with climate change vulnerabilities:
  - Wild Fires - Early 2045
- Result: While routes taken by long haul exiting/entering the state have a lot of fire vulnerability, the internal routes do not



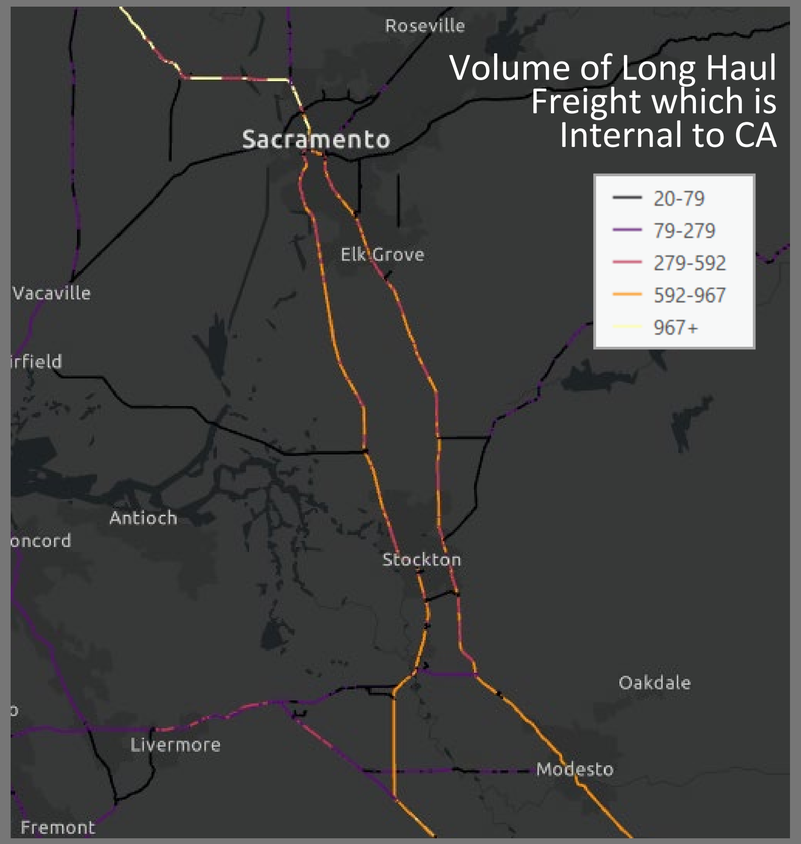


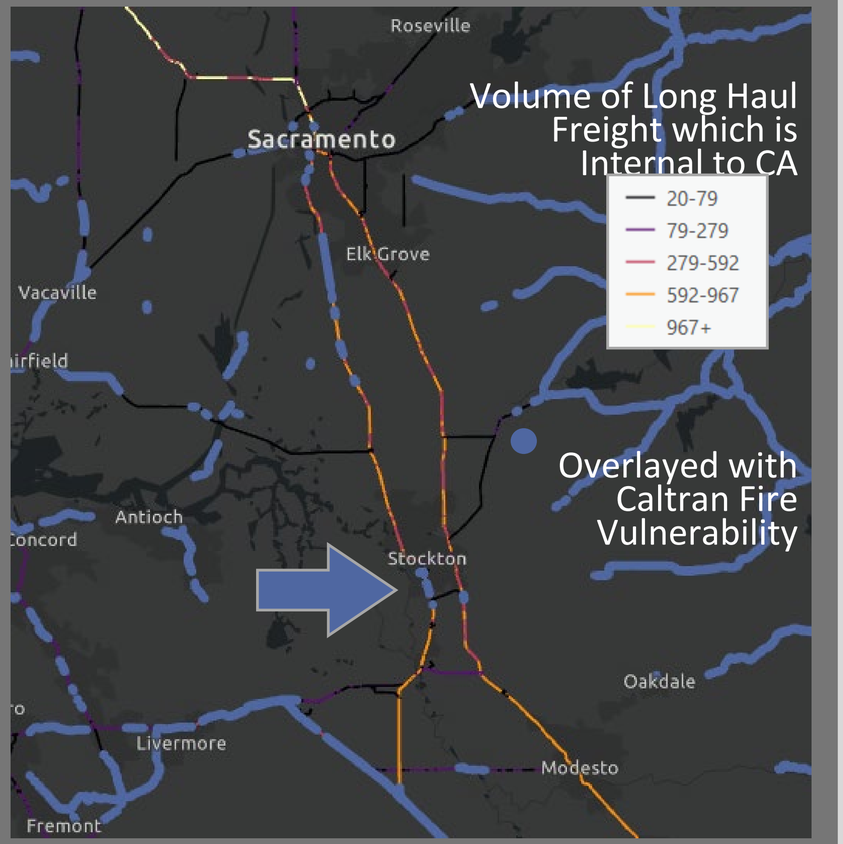
Changing Level of Wildfire Concern | Caltrans Climate Change Vulnerability Assessment

ENVIRONMENTAL LABORATORY

II. Addressed Problems:
Multi-Treat Natural Disaster Resilience Quantification

- Overlaying freight volumes with climate change vulnerabilities:
  - Wild Fires - Early 2045
- Result: Near Stockton
  - N/S fright corridors are close
  - Near-term Fire risk





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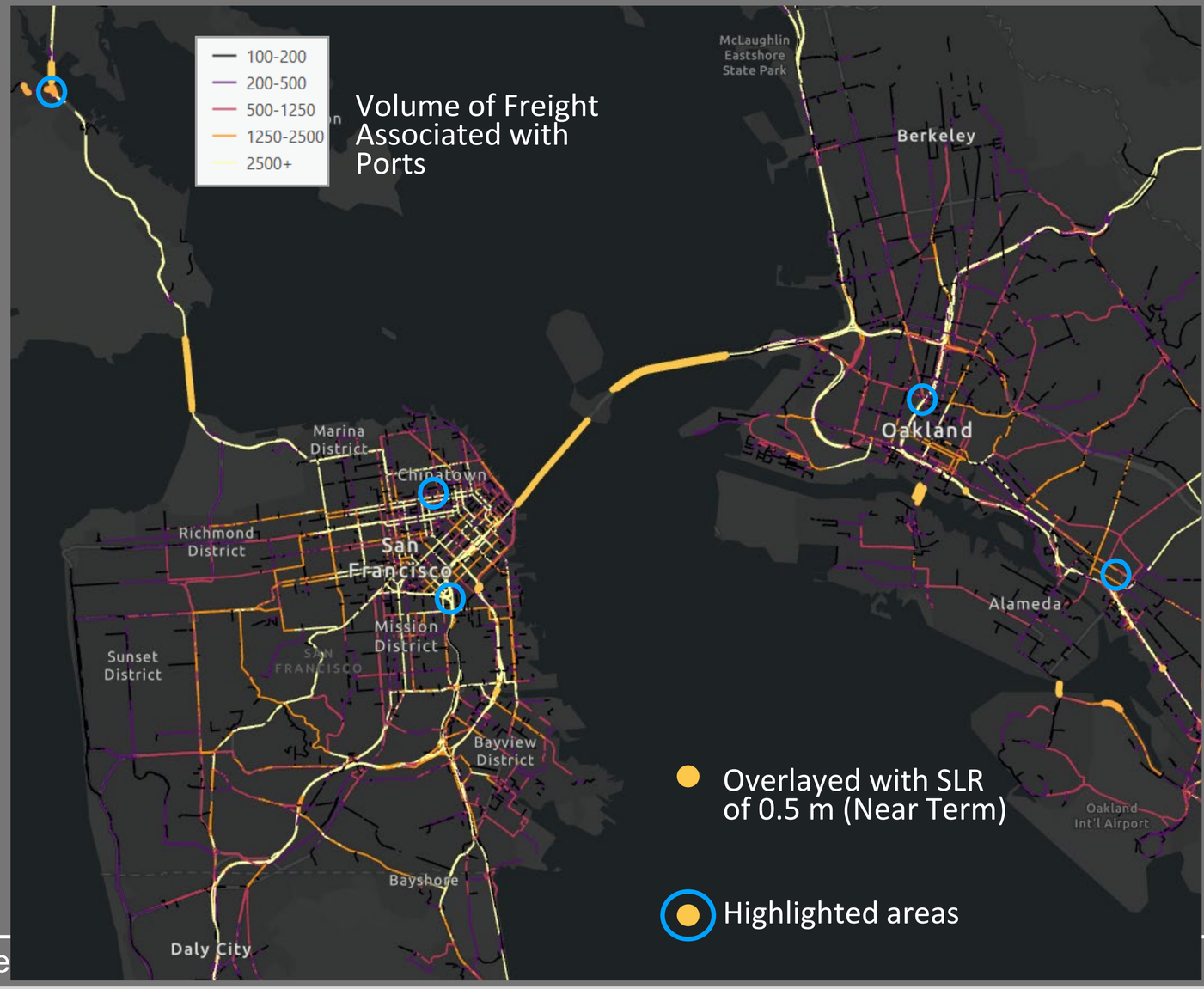
II. Addressed Problems:
Multi-Treat Natural Disaster Resilience Quantification

- Overlaying freight volumes with climate change vulnerabilities:
  - Sea Level Rise in the Near Term (0.5 m)
- Result: San Francisco/Oakland
  - Very high freight volumes from ports
  - Risk of Near-term Sea Level Rise



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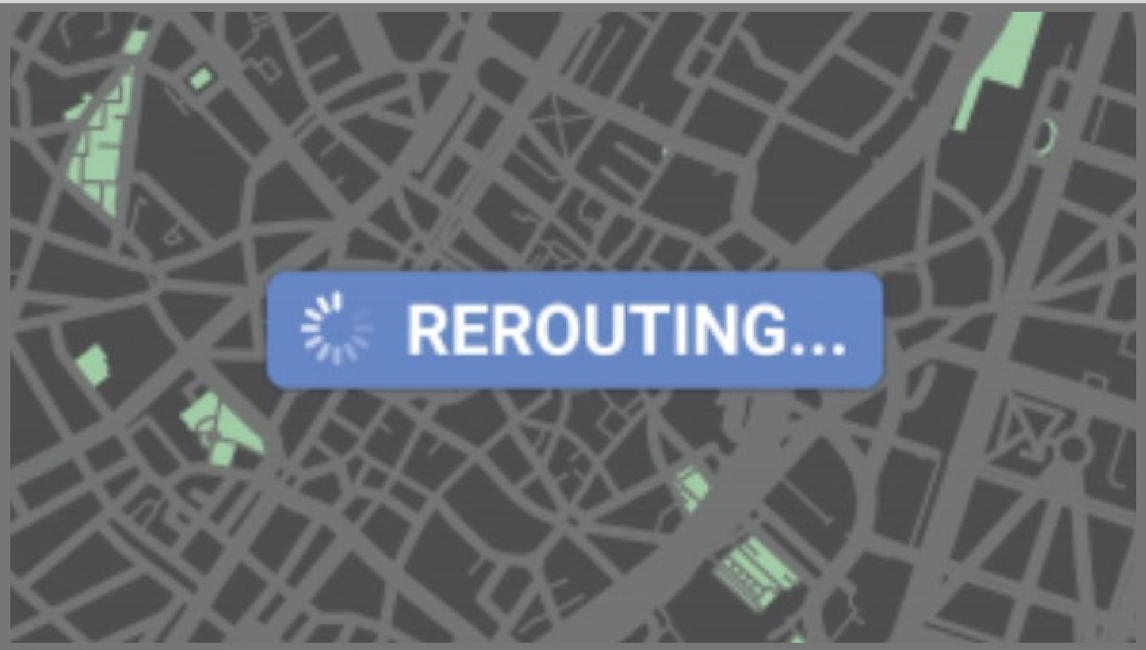
US Army Corps of Enginee

III. Addressed Problems: Zero Emission Refueling Station

- **Challenge:**
  Minimize the diversion of freight routes caused by fuel conversion

- **Solution:**
  Identify gas stations that could be converted to dispensing stations:

  - minimize freight displacement
  - scalable



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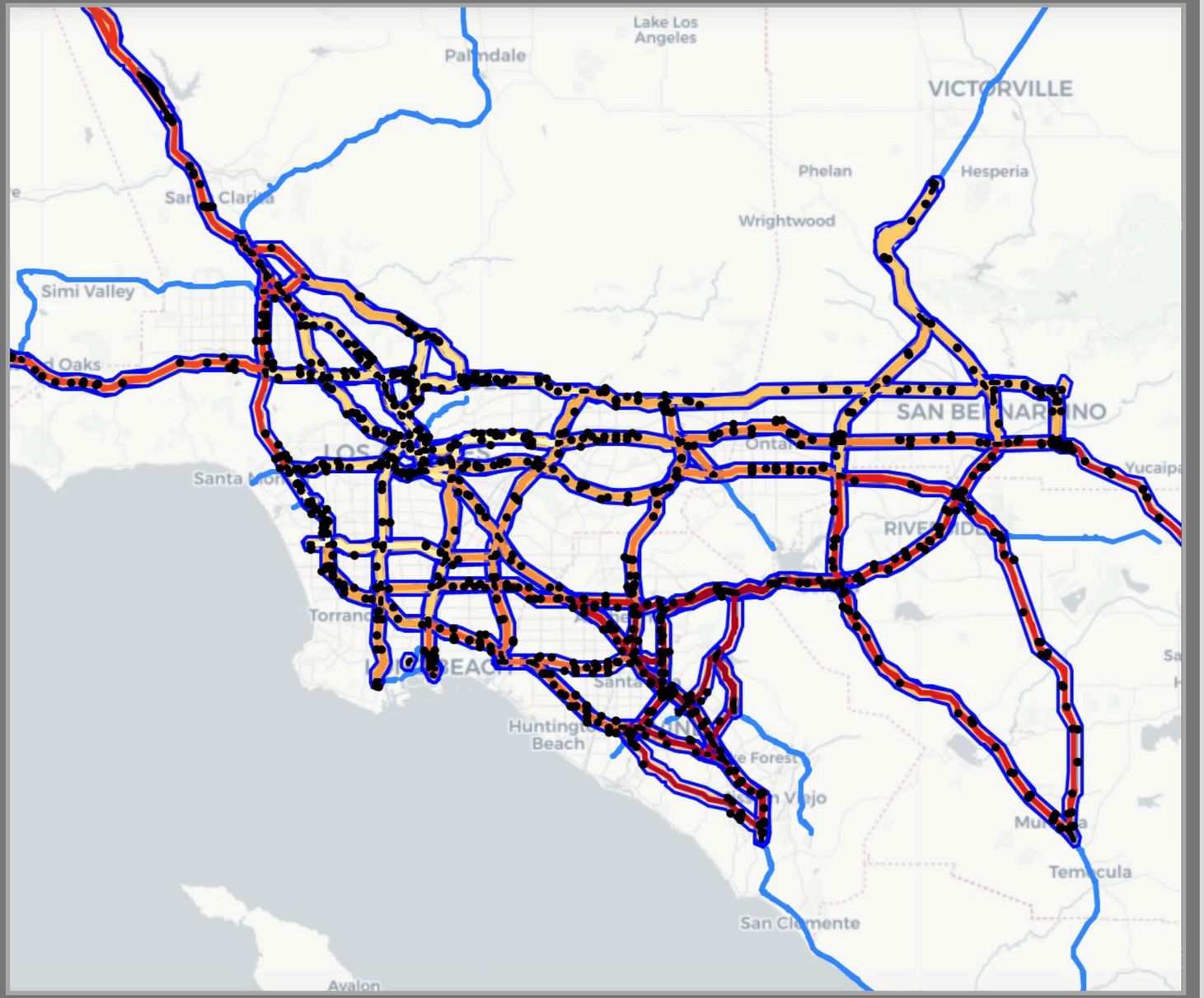
III. Addressed Problems: Zero Emission Refueling Station

1. Define gas stations which are candidates for conversion



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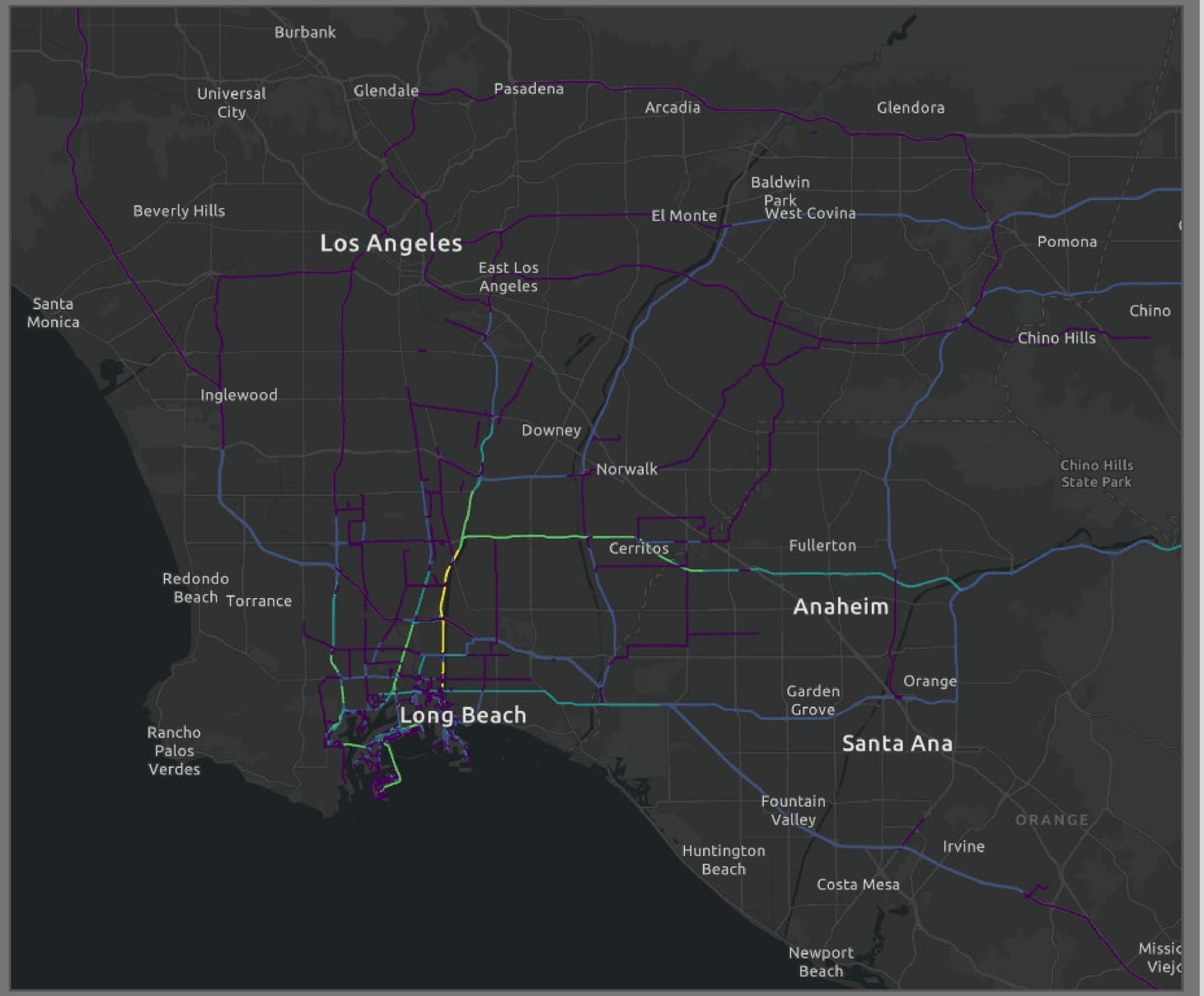
III. Addressed Problems: Zero Emission Refueling Station

1. Define gas stations which are candidates for conversion

2. Leverage State-Wide freight flows



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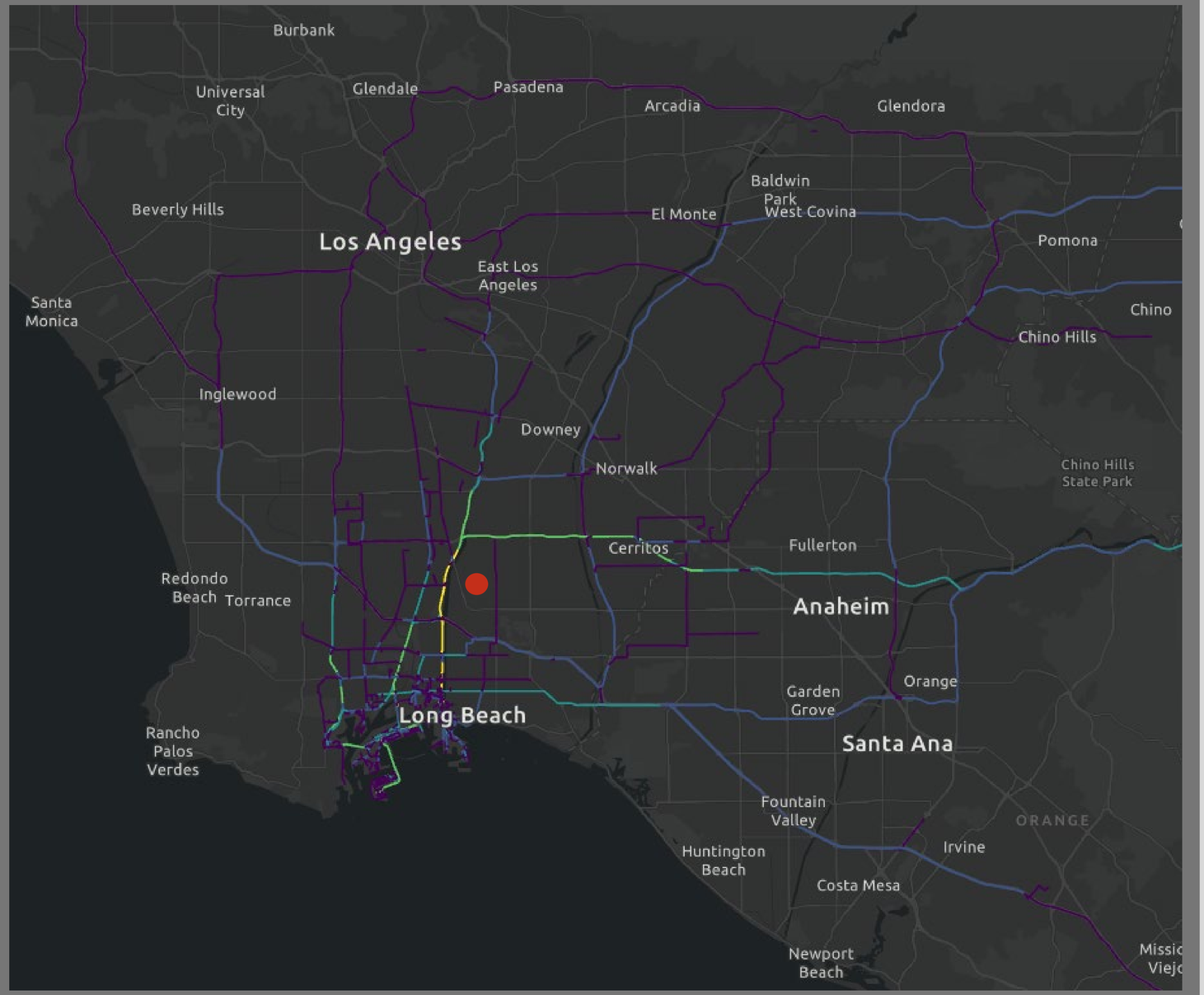
III. Addressed Problems: Zero Emission Refueling Station

1. Define gas stations which are candidates for conversion

2. Leverage State-Wide freight flows

3. Compute added travel time from making all truck routes pass through a set of gas stations
   - Distance
   - Drive Time



ENVIRONMENTAL LABORATORY

III. Addressed Problems: Zero Emission Refueling Station

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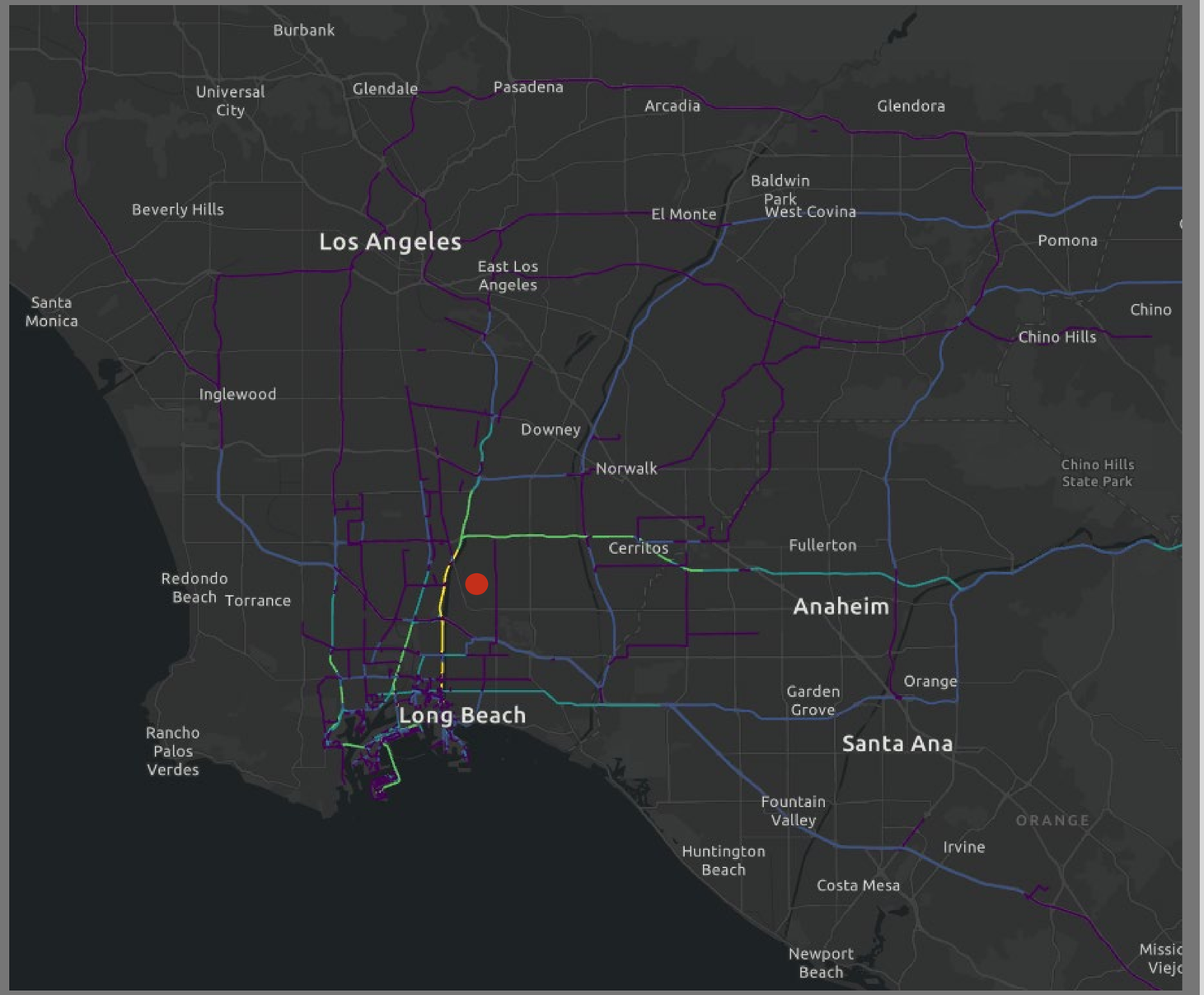

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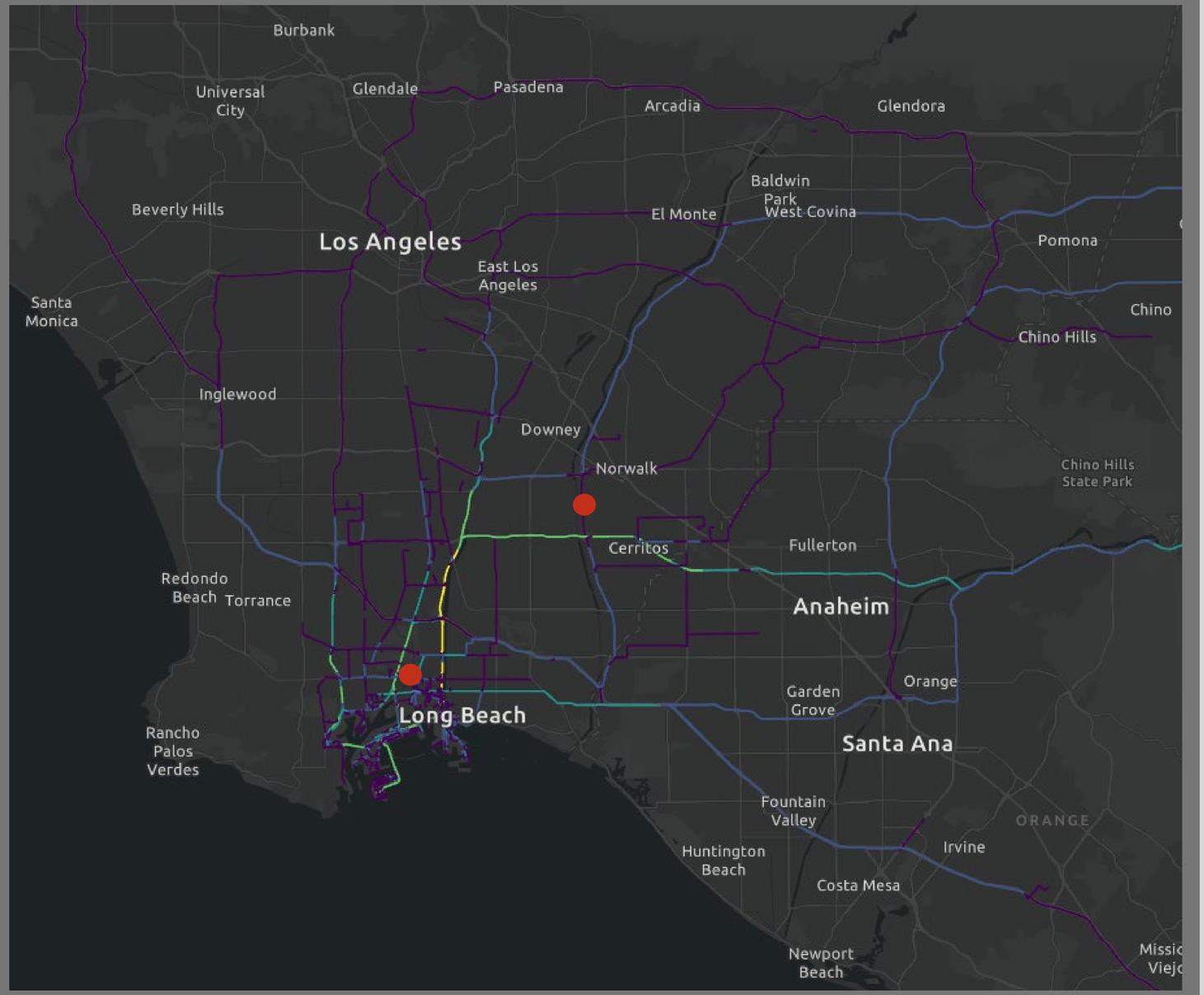

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III. Addressed Problems: Zero Emission Refueling Station

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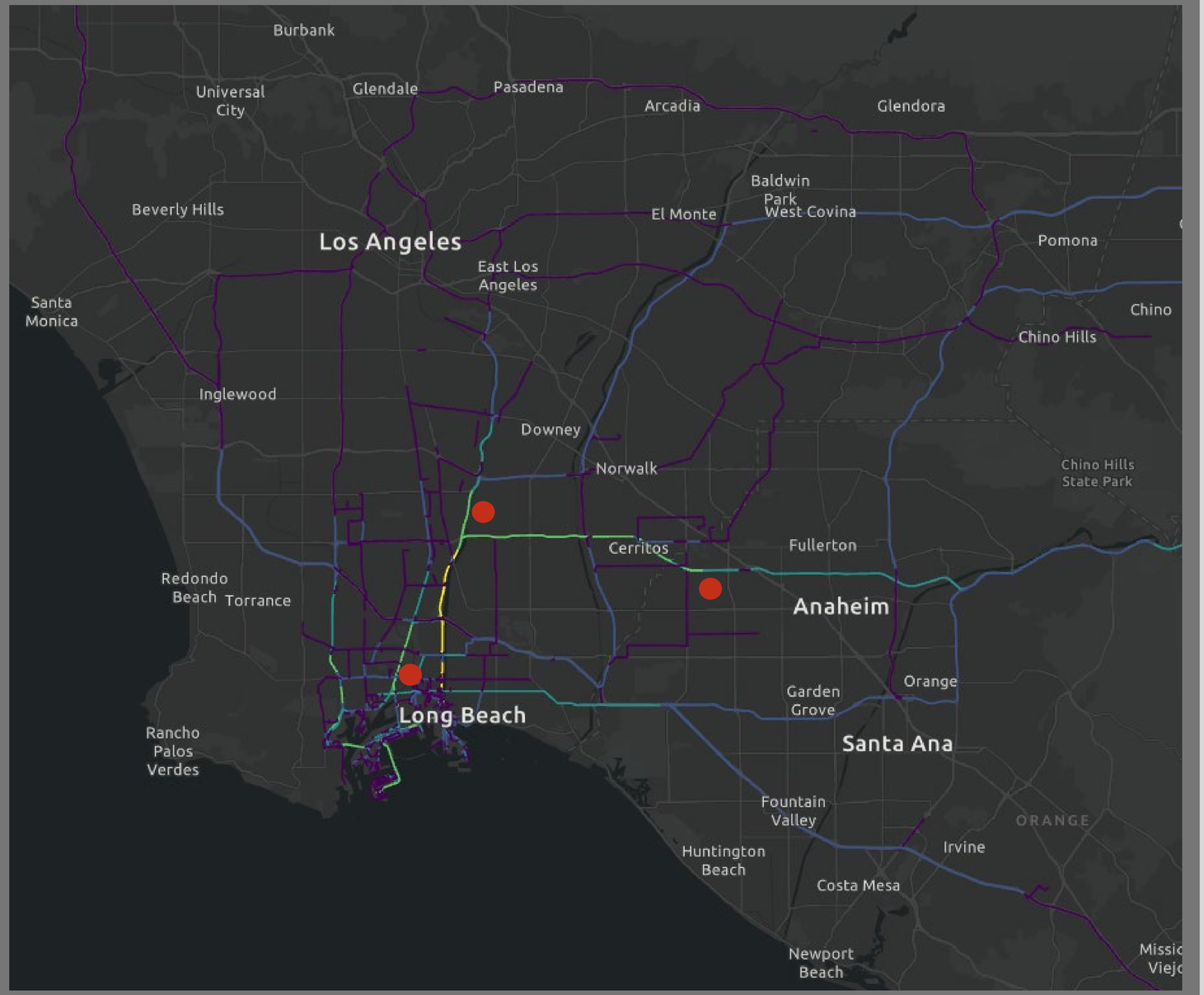
2. Leverage State-Wide freight flows

3. Compute added travel time from making all truck routes pass through a set of gas stations
   - Distance
   - Drive Time

4. Find the set of gas stations which minimize the additional travel time



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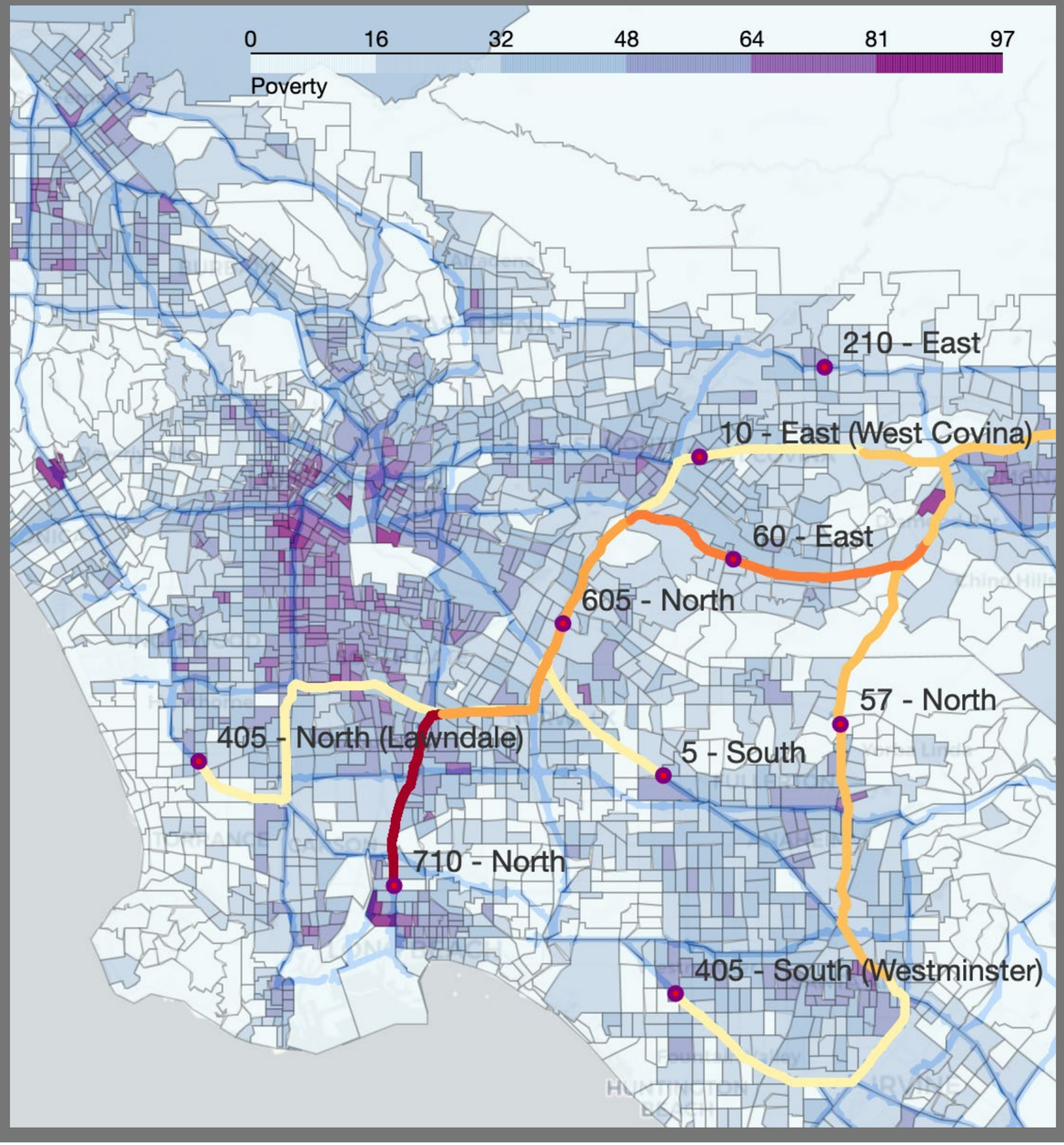
III. Addressed Problems: Zero Emission Refueling Station

1. Define gas stations which are candidates for conversion
2. Leverage State-Wide freight flows
3. Compute added travel time from making all truck routes pass through a set of gas stations
4. Find the set of gas stations which minimize the additional travel time
5. Overlap results with additional information



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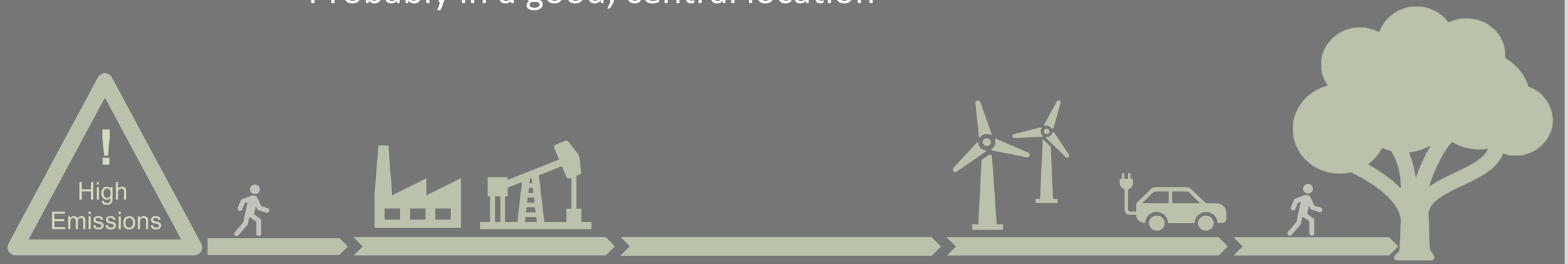
III. Addressed Problems:
Zero Emission Refueling Station - Scalability

Want: Gas stations to be in locations that will still minimize deviation as more are added

Solution: Rank solutions by hubness

Hubness: A measure of how many solutions contain a station
- One which appears many sets would have a high score
- Probably in a good, central location



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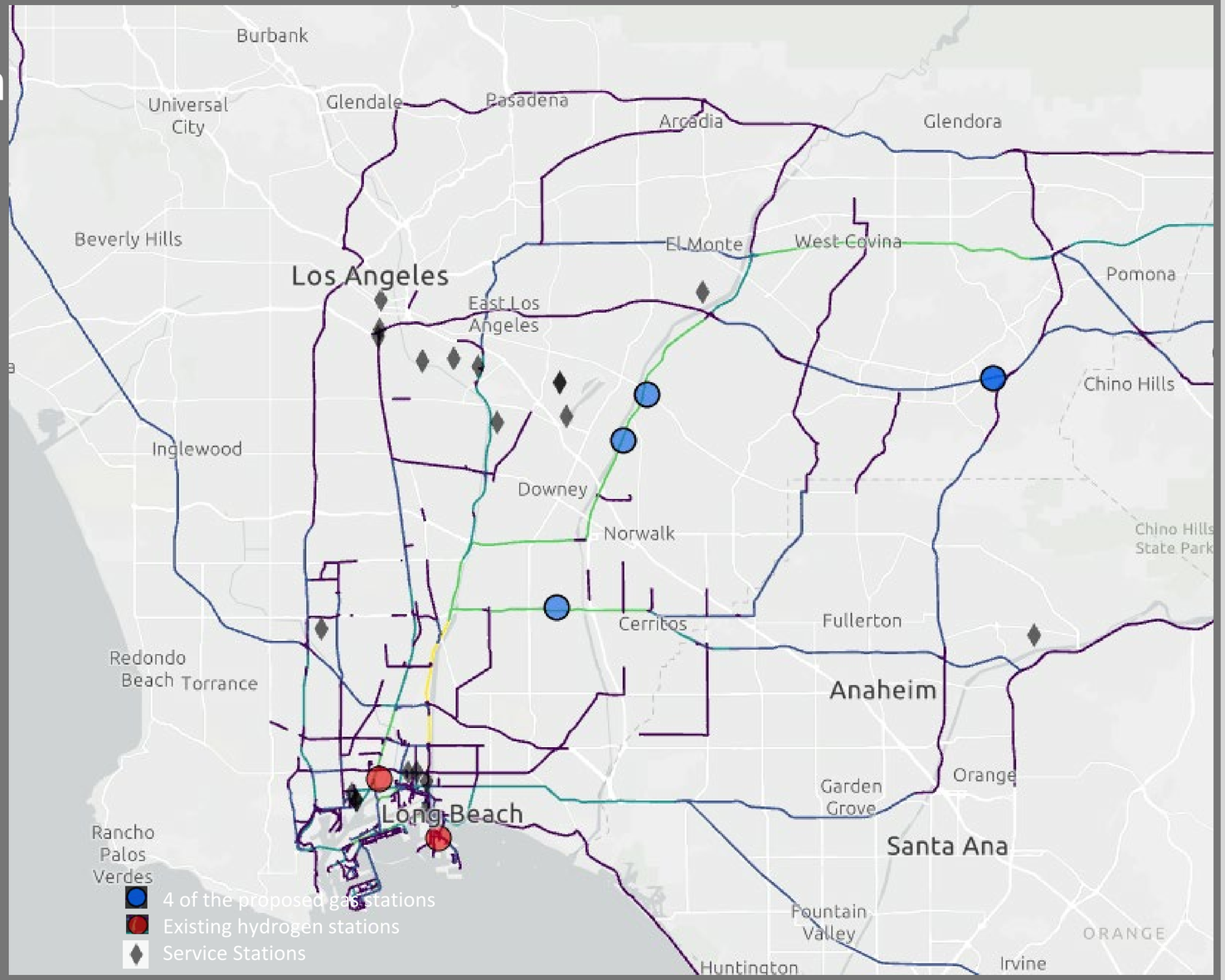
III. Addressed Problems: Zero Emission Refueling Station

- Initial Testing of methodology was done using older data
- We were able to identify 4 proposed gas stations
- Currently scaling solution up to the system level



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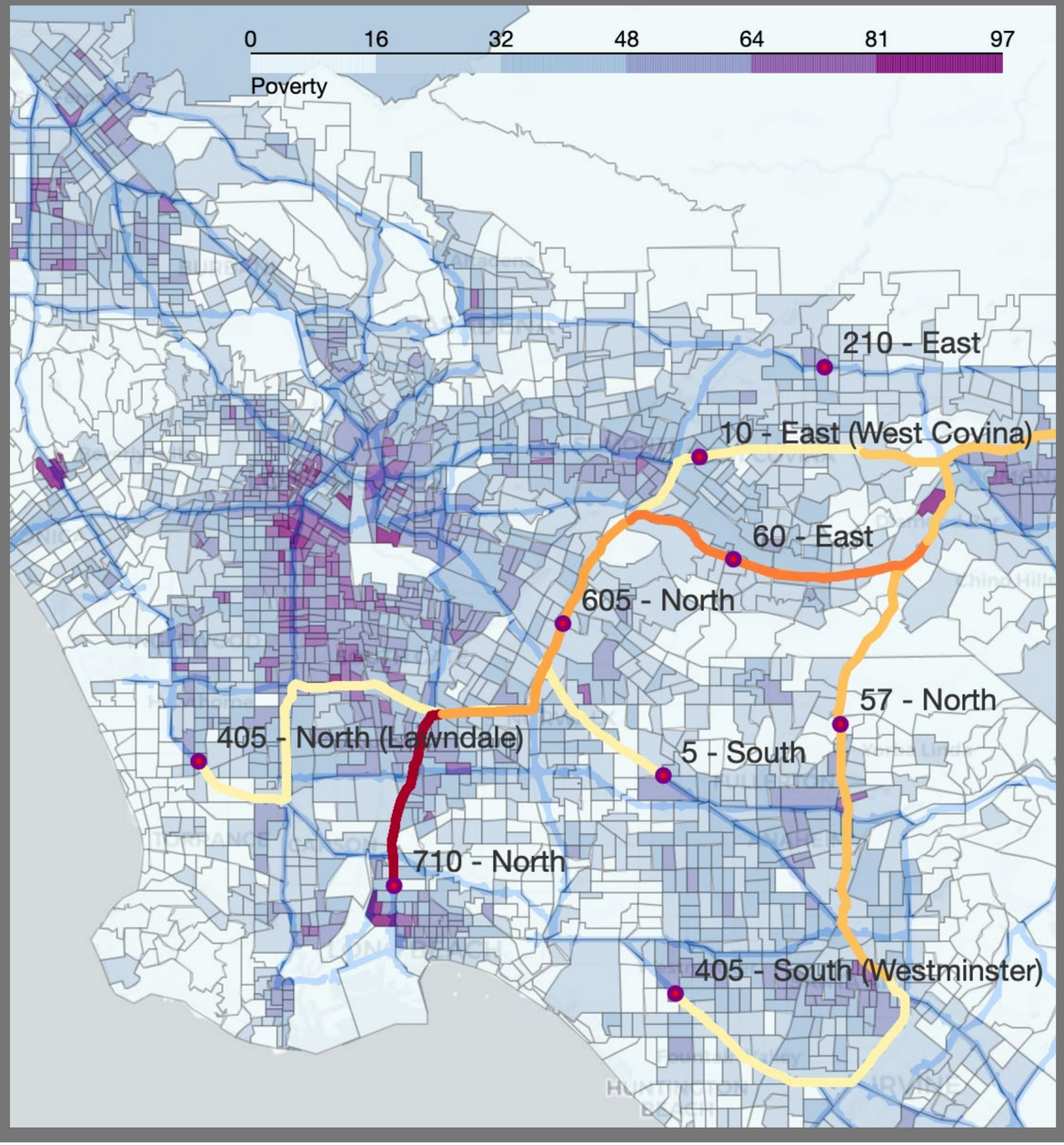
IV. Addressed Problems: Multi-Objective Equity Optimization

- **Examined Concerns:**
  Define a set of equity concerns which can be weighed against each other
- **Solution:**
  Preform Multi-Objective Optimization:
  - Gets you a range of answers so decision makers can weight different options



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Approach Summary

- Benefits of Approach:
  - System-level
  - Links Supply Chain/Freight with policies and risks
  - Quantifies Resilience
  - State-wide approach

- Limitations of Approach:
  - Doesn’t quantify impacts at a fine level
  - Currently limited to freight
  - Doesn’t include passenger vehicles & other transportation modes

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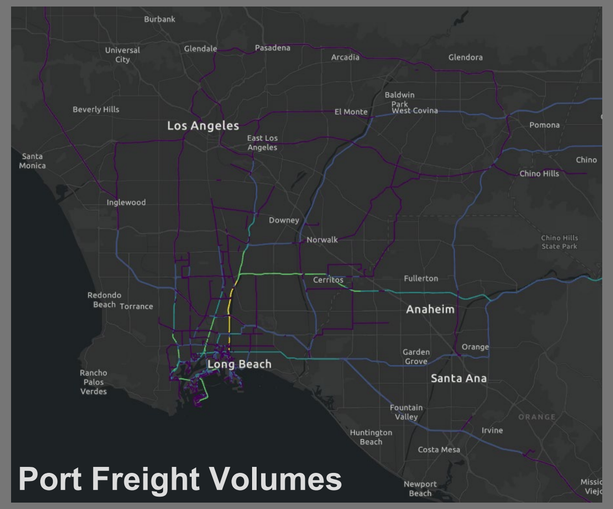
Tools and Applications: Summary

Tools:

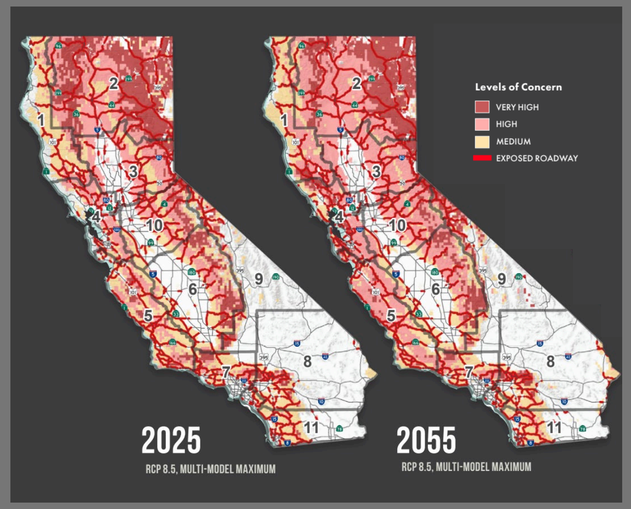
I. Freight Volumes

II. Policy Comparison Tool

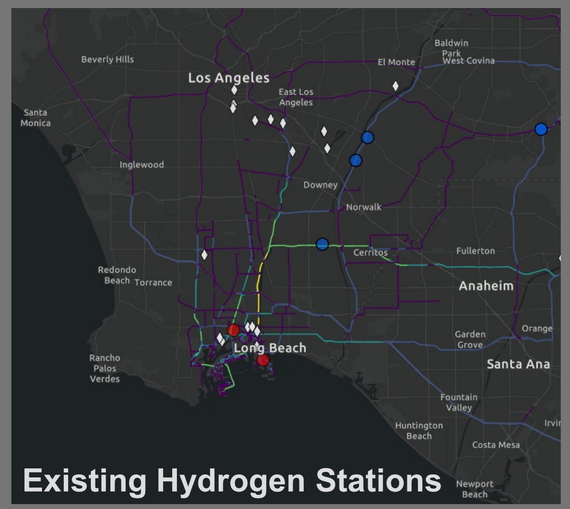
Supply Chain Resilience Quantification



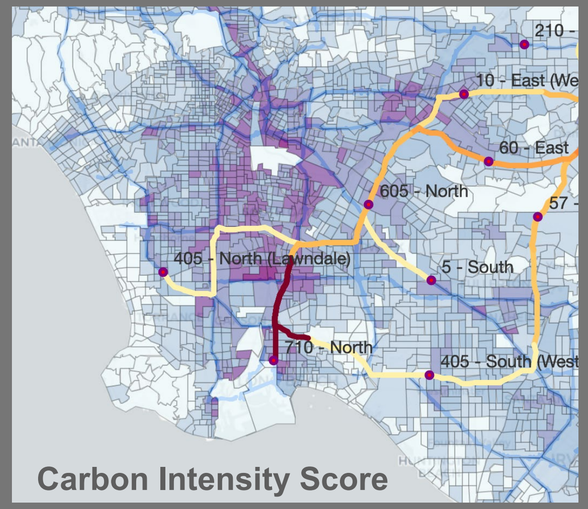
Multi-Treat Natural Disaster Risk and Resilience



Zero Emission Refueling Station



Multi-Objective Equity Optimization



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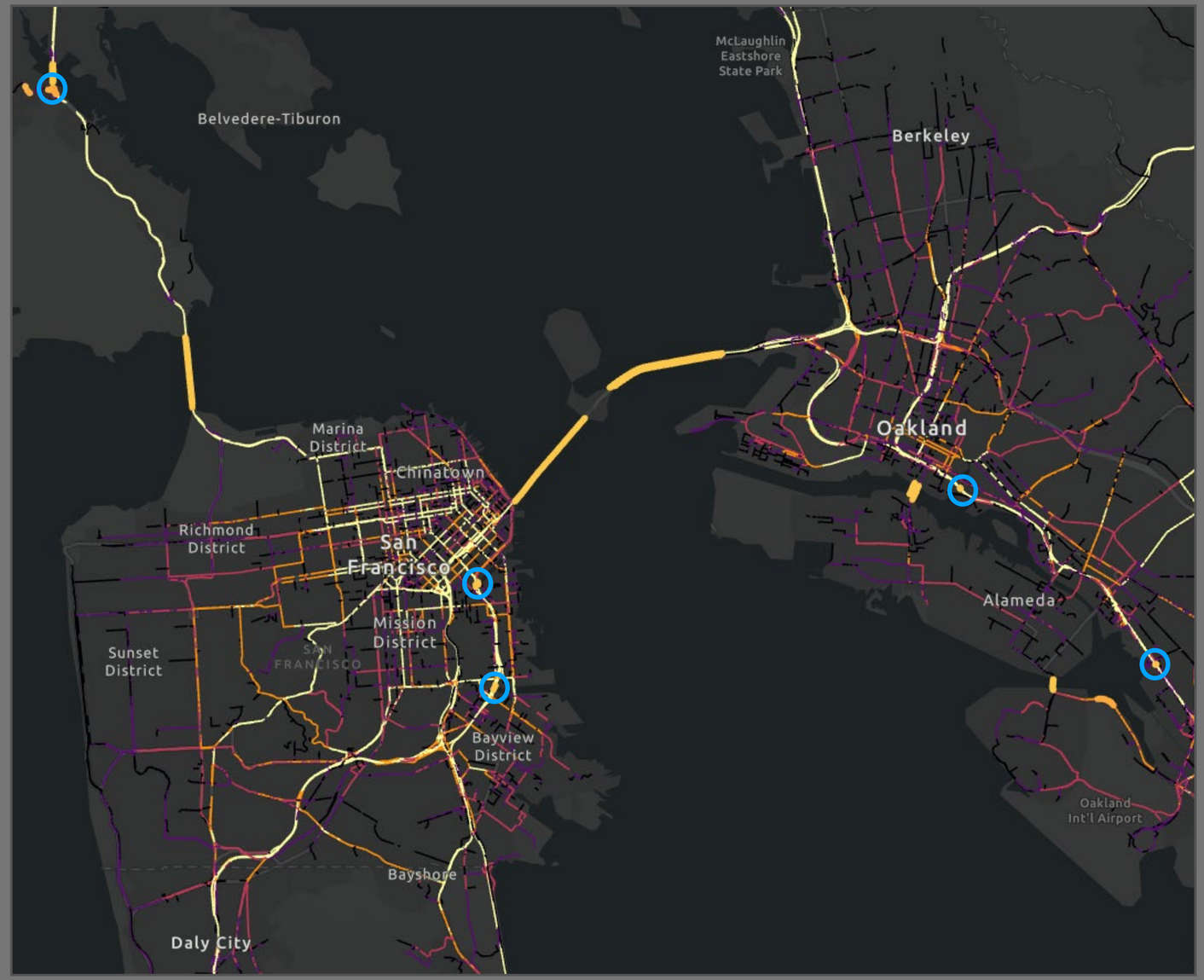
Questions

Dr. Igor Linkov -
igor.linkov@usace.army.mil



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Andrew Strelzoff
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U.S. Army Engineer Research and Development Center

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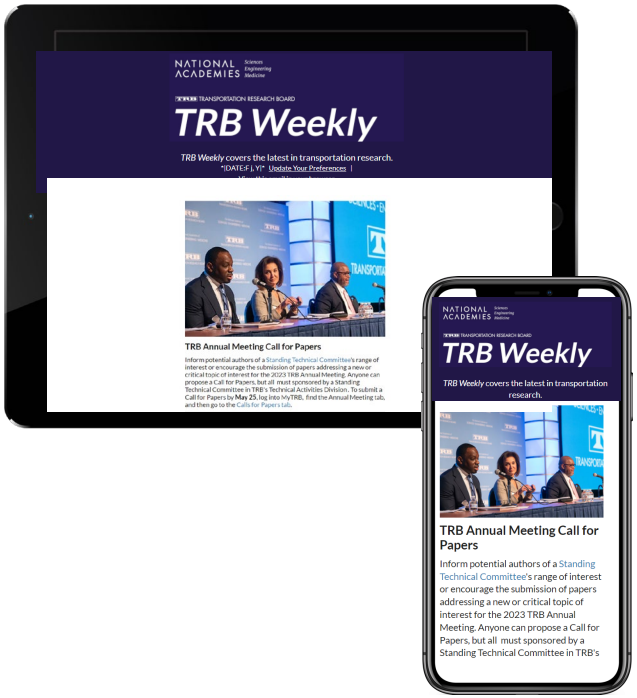

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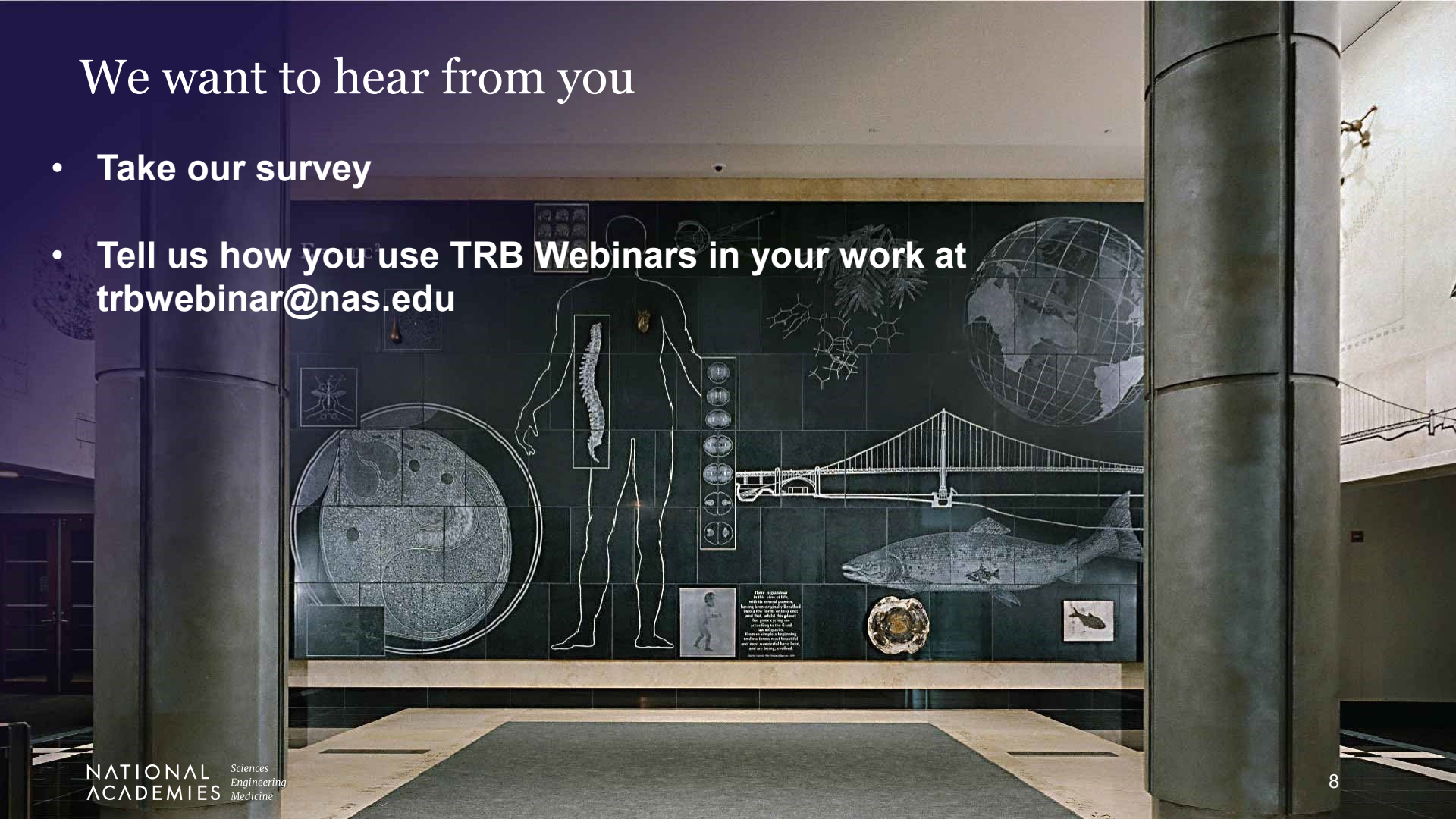

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