Transportation Resilience & its impact on Project Determination

Theodore Zoli February 16, 2019

Resiliency vs Sustainability

Sustainability – systemic evaluation of future options and devising strategies to obtain a desired outcome

Resiliency – adaptive capacity and robustness to gracefully weather inevitable but unspecified shocks

Resiliency – Transportation Sector

- Network Behavior of the transportation system
 - Bridges, Detour Route, & Fragility
 - Evacuation Route & Emergency Access
 - Operational performance and mode shifts
 - The Advent of Superusers
 - The need for Hardened Corridors
- Interdependencies & Hyper-connectivity
 - Other lifelines & access for assessment / recovery
 - Transportation / Power / Internet cascading effects
- Non-stationarity
 - Changing return periods & deterministic design
 - Demographic shifts and unexpected behavior

Network Performance & Fragility



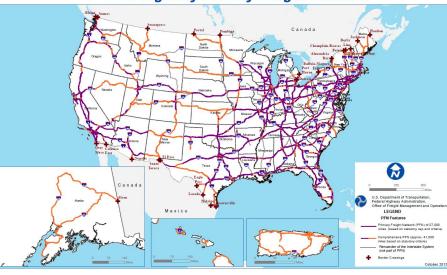
FRAGILE NETWORKS

Identifying Vulnerabilities and Synergies in an Uncertain World

Anna Nagurney / Qiang Qiang







WILEY

NIST Community Resilience Interdependencies



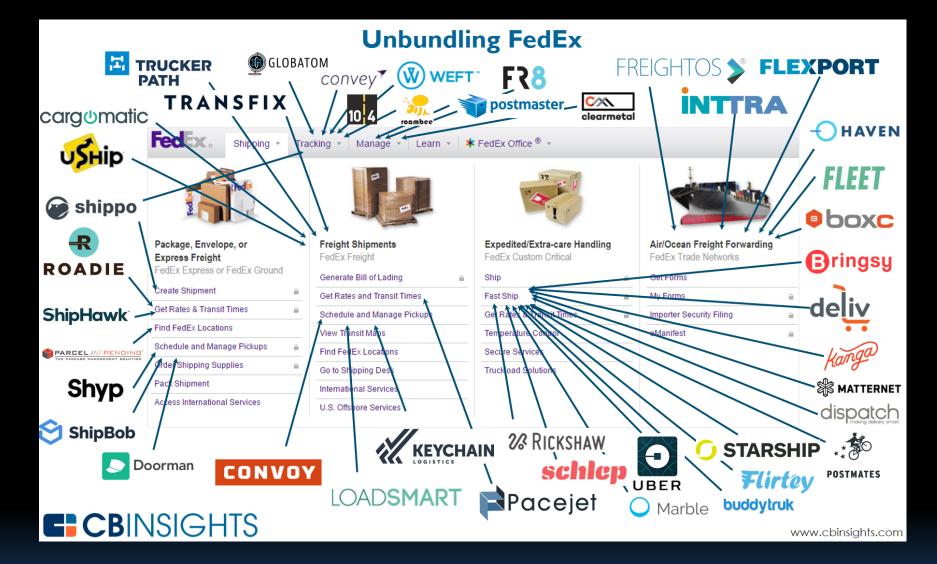
Functional vs Operational Fragility

- Disruption Time
 - Operational measured in minutes / hours
 - Functional Days/Weeks/Months
- Network Investment Strategies
 - Route flexibility network redundancy / modal redundancy
 - Corridor enhancement increased throughput
 - Selective de-commissioning

Superusers – Trucking Logistics

- Route Optimization
- Telematics & Instantaneous Feedback
- Durable Dataset
- How to Engage Trucking Industry to
 - Determine Investment Needs
 - Project Definition
 - Weight / Geometry / Robustness in Corridors
 - Influence not so super-users

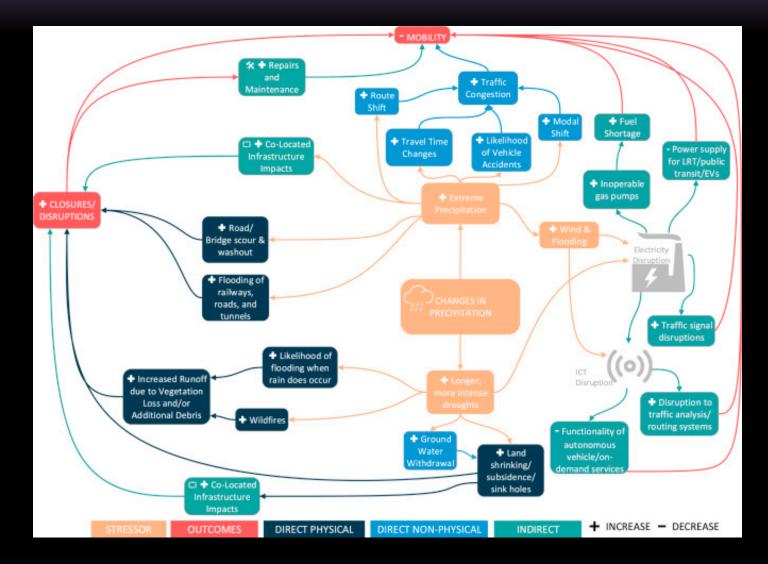
Explosion of Logistics Companies



Influence not so super-users thought experiment

- Is our commute time or are children any less valuable than our amazon package?
- What if bus routing was as sophisticated as UPS, USPS, Fedex?
- How to incentivize coordination between competing users
- How to better game repetitive trips, like our commute.
- Does this need to be fee based?

Pathways to Disruption



Markolf et al, Journal of Transport Policy, Nov 2018 *Transportation resilience to climate change and extreme weather events – Beyond risk and robustness*

Transportation Research Board Forecasting & Extreme Events

TABLE 1 Current Scientific Confidence in Attribution Results Varies for Different Types of Extreme Events

● = high ● = medium ○ = low	Capabilities of Climate Models to Simulate Event Type	Quality/Length of the Observational Record	Understanding of Physical Mechanisms that Lead to Changes in Extremes as a Result of Climate Change	
Extreme cold events	•	•	•	
Extreme heat events	•	•	•	
Drought	0	0	0	
Extreme rainfall	0	0	0	
Extreme snow	0	0	0	
Tropical cyclones	0	0	0	
Extratropical cyclones	0	0	0	
Wildfire	0	0	0	
Severe convective systems	0	0	0	

NOTE: Overall confidence in event attribution is strongest for extreme event types that are adequately simulated in climate models, have a long-term historical record of observations, and are linked to humancaused climate change through an understood and robustly simulated physical mechanism. The entries in this table, which are presented in approximate order of overall confidence, are based on the available literature and are the product of committee deliberation and judgement.

Built Environment – Beyond Code Investment in Buildings

Mitigation Category	Cost	Benefit	BCR
Riverine Flood	\$11.51	\$82.00	7:1
Wind	\$13.60	\$70.00	5:1
Earthquake	\$2.20	\$5.70	3:1
Wildland-Urban Interface Fire	\$0.06	\$0.17	3:1
Total for federal grants	\$27.40	\$157.90	6:1

Table 2. Costs and benefits associated with 23 years of federal grants (in \$ billions).

Emerging Trends - Large Fire Risk Evacuation & Emergency Response

Risk of 'Very Large Fires'

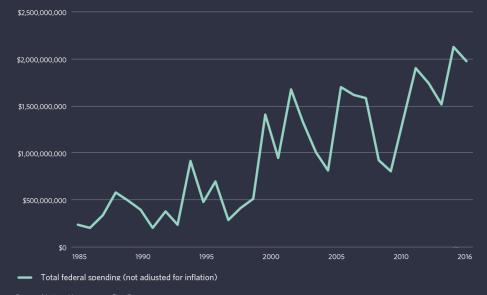
The wildfire season is likely to lengthen as the climate changes. By midcentury, the number of weeks when weather will be conducive to a very large fire — defined as a fire that spans over 100,000 acres — will increase sixfold in some parts of the United States.



Source: R. Barbero et al, "Climate change presents increased potential for very large fires in the contiguous United States," International Journal of Wildland Fire, 2015. © 2017 The Pew Charitable Trusts

Federal Spending on Wildfires

The federal government has spent over \$2 billion on wildfire suppression already in 2017, making it the most expensive wildland firefighting year in history.

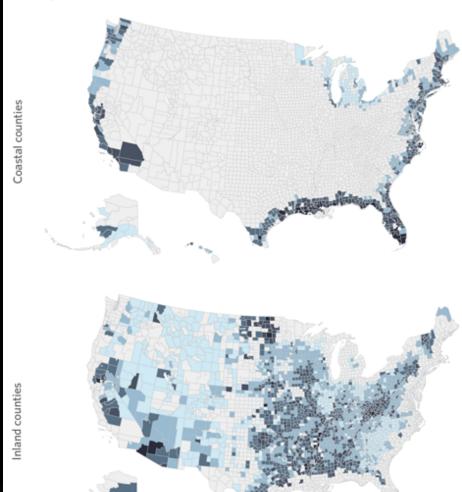


Dource: National Interagency Fire Center

Coastal vs Inland Flood Risk

Figure 2

High Flood Risk Scores Are Not Limited to the Coasts Composite flood risk scores for coastal and inland counties



Risk score

Lowest

Highest

Note: The National Oceanic and Atmospheric Administration defines inland counties as those located outside the watersheds adjacent to the Pacific Ocean, Atlantic Ocean, Gulf of Mexico, or one of the Great Lakes.

Source: ICF

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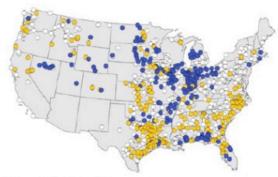
Extreme Precipitation Frequency & Bridge Risk

FIGURE 1. Heavy Rainfall and Flooding Trends in the U.S.



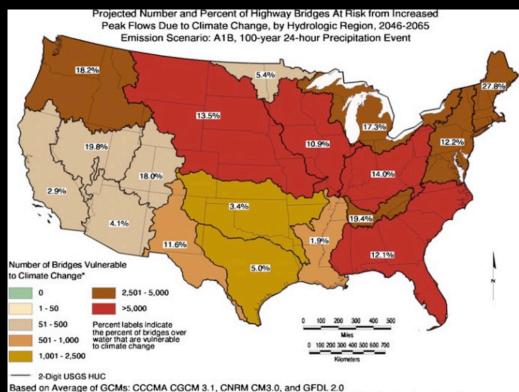
Rainfall increase (%) in heaviest events

0 - 9 10 - 15 16 - 25 26 - 35 36 - 45



Trends in flood frequency

Decrease Increase No significant trend



"includes currently deficient bridges identified from National Bridge Inventory and located within hydrologic regions with a projected increase in modeled flow of greater than 20 percent, plus currently acceptable bridges located on non-sandy soil with a projected increase in modeled flow of greater than 60 percent, plus currently acceptable bridges located on sandy soil with a projected increase in modeled flow of greater than 100 percent from time period 1981-2000 to 2046-2065.

Inland Flooding & VTrans Hurricane Irene – August 28th 2011

- 13 communities inaccessible for days
- State Highway System
 - 500 miles of roadway
 - 200 bridges
- Municipal System
 - 2000 roadway segments
 - 280 bridges
 - 960 culverts



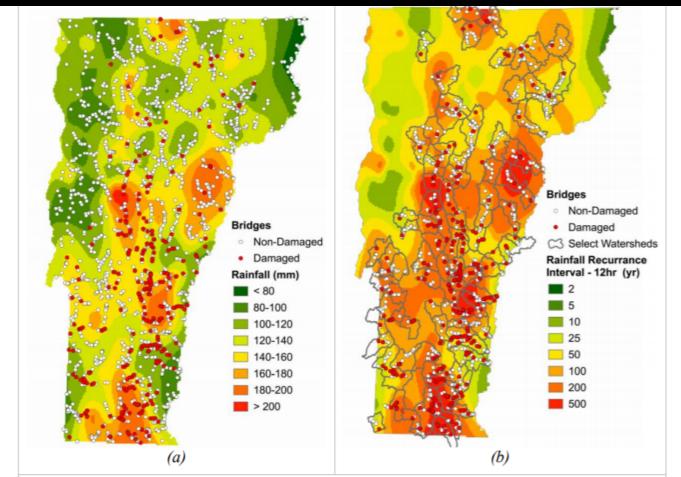
Hurricane Irene Airlift resources to isolated towns

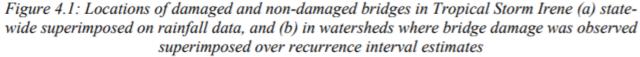


Hurricane Irene Rapid Road Reconstruction Efforts



Hurricane Irene Extensive Bridge Damage Throughout State

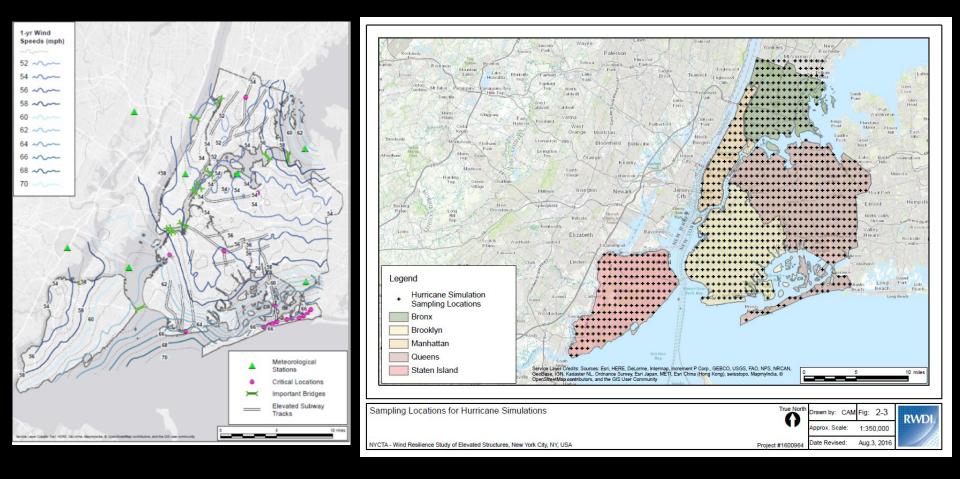




Hurricane Irene How should we have built it? How do we build it back?

- Post Damage Reconstruction
 Need for speed, replace in kind
- Riverine corridor improvements?
 - Hydraulics & bridge damage
 - -Emergent Risk with Climate Change
 - -Bridge as dam & property damage

Operational Decision-Making & Blowover Risk Severe Convective Systems



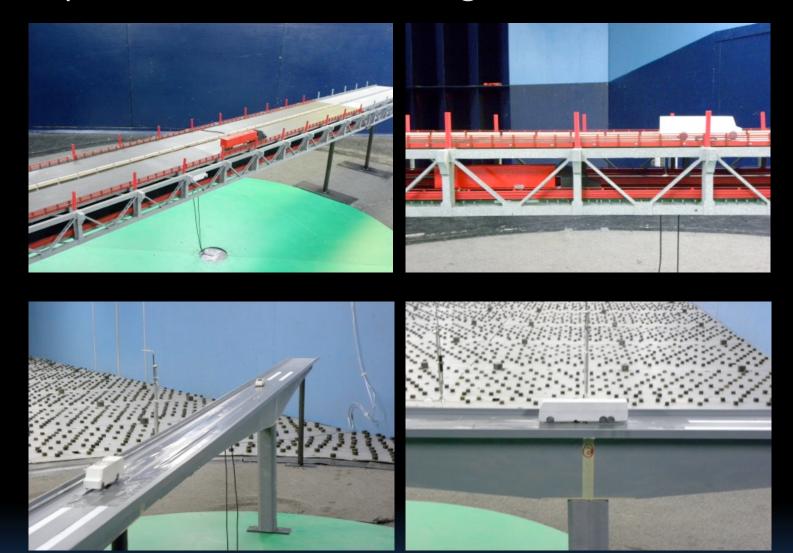
Severe Convective Systems (High Winds) Operational Decision-making & Blowover Risk



The Weather Channel

weather.com

Severe Convective Systems (High Winds) Operational Decision-making & Blowover Risk



b) Test on Confederation Bridge, NB to PEI, Canada

Severe Convective Systems (High Winds) Operational Decision-making for Transit Systems





Adaptive strategies

Role of Adaptive Strategies and Tactics in Reducing Impacts and Consequences

Climate Changes

- Extreme precipitation
- Rising sea levels
- Temperature spikes

Impacts on Transportation

- Roadway flooding
- Damage/destruction of bridges
- Pavement and rail buckling
- Subway flooding
- Seaport and airport flooding
- Slope failures
- Curtailment of barge operations



Consequences

- Freight traffic disrupted for days or weeks
- Power plants, water facilities, homes businesses, hospitals cut off
- Passenger travel delays
- Higher transportation costs for government, businesses, and households
- Evacuation of urban areas

Adaptive Strategies to Reduce Impacts

- Retrofit facilities
- Relocate facilities
- Upgrade stormwater drainage facilities
- Build new facilities to climate-ready standards
- Protect existing infrastructure
- Incorporate climate change into maintenance cycles

Adaptive Strategies to Reduce Consequences

- Re-route freight and passenger flows
- Shift to alternative modes
- Land-use regulations relating to development in vulnerable areas
- Evacuation/contingency strategies
- Building in network flexibility
- Traveler information systems
- Rapid rebuilding of damaged facilities
- Improved air traffic management

Resiliency in Transportation

- Operational Decision-Making Driving Needs Assessment
 - Evacuation Routes & Timing + Emergency Response
 - Disaster Logistics, Preplacement of Key Assets
 - Network Performance & Hardened Corridors
- Enhanced Infrastructure Robustness
 - Damage tolerant structural systems
 - Design for Repairability
- Emergency Bridge Replacement Designs
 - Dramatic Reduction in Time to Fabricate, Ship & Erect
 - Modularity & One-size fits all