UDOT
Keeping Utah Moving

Resilience within UDOT

Investing in Transportation Resilience:
A Framework for Informed Choices Workshop

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Definition of Resilience

UDOT has not adopted an official definition of Resilience.

Resilience Primer for Transportation Executives
NCHRP Report 976

RESILIENCE IS THE ABILITY . . .

to prepare and plan for, absorb, recover from, or more successfully adapt to adverse events.
—*Disaster Resilience: A National Imperative, National Research Council, 2012*

to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.
—*Federal Highway Administration Order 5520*

of the transportation system to recover and regain functionality after a major disruption or disaster.
—*American Association of State Highway and Transportation Officials*

of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience.
—*100 Resilient Cities*

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Risk and Resilience

"Traditional risk management focuses on planning and reducing vulnerabilities. **Resilience management** puts additional emphasis on **speeding recovery and facilitating adaptation**."
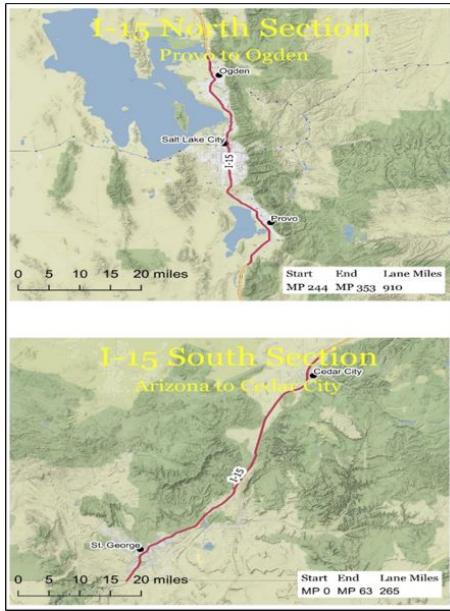
Dr. Igor Linkov - USACE
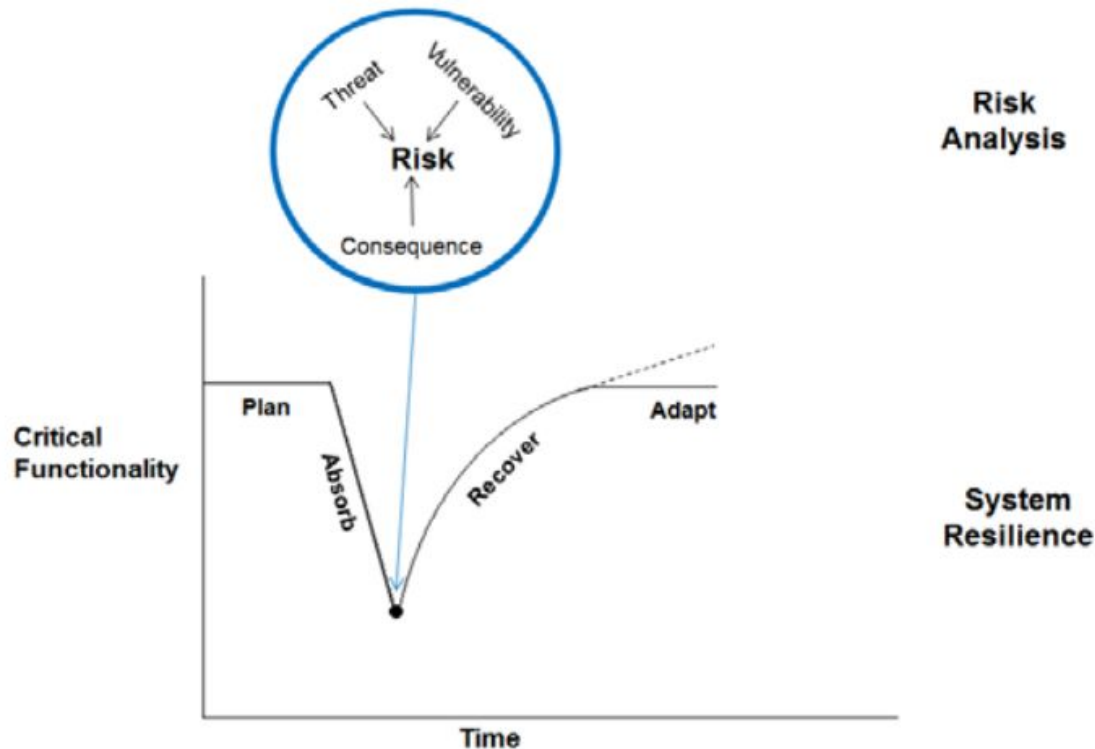
After Linkov et al, Nature Climate Change 2014

Risk Studies

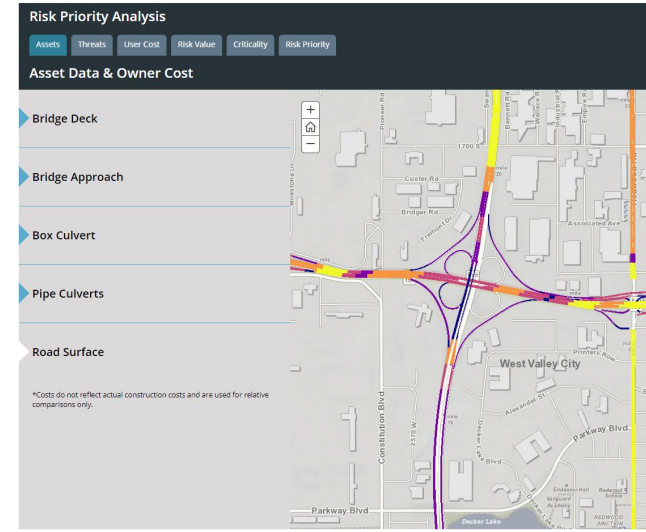### I-15 Corridor Risk and Resilience Pilot
2017

US-40 FHWA Extreme Weather and Durability Grant
2020

UDOT Efforts
Ongoing

Data Driven Focus + Institutional Knowledge

RAMCAP

1. Asset Characterization	• What assets exist, which are critical, and what should be considered?
2. Threat Characterization	• What threats and hazards should be considered?
3. Consequence Analysis	• What happens to assets if a threat or hazard occurs? What are the expected asset losses, economic impacts, injuries, and lives lost?
4. Vulnerability Analysis	• What are the asset vulnerabilities that would allow a threat or hazard to result in expected consequences? How vulnerable is the asset to the identified threat?
5. Threat Assessment	• What is the likelihood of the identified threat?
6. Risk/Resilience Assessment	• What is the anticipated asset total risk and resilience? • **Risk= Consequences x Vulnerability x Threat** • **Resilience= Service Outage x Vulnerability x Threat**
7. Risk/Resilience Management	• What options are there to reduce risk and increase resilience? What is the risk reduction? What is the economic analysis of mitigation alternatives?

Risk Management Working Group

UDOT Focus

Identify threat asset pairs

Compute the risk   **Risk = Impact * Probability * Vulnerability**

Compute criticality

Risk Priority = Risk * Criticality

Display on GIS map

Data for risk Calculations

- Asset location and condition (vulnerability)
- Threats and probabilities at the location
- Criticality
- Physical characteristics for **Replacement Cost** (Owner)
- **User Cost**
  - Dertour Times and Lengths
  - Traffic and Truck volumes

Data for risk Calculations

Part A - Asset Data and Owner Costs

- Roadway Geometry: UPLAN service [UDOT Linear Reference System](#)
- Bridge Deck and Approaches
  - Geometry: PONTUS database
  - Replacement Cost: UDOT Asset Owner and Cost Estimating Support Staff (Jason Henrie)
- Box Culverts
  - Geometry: PONTUS database
  - Replacement Cost: UDOT Asset Owner and Cost Estimating Support Staff
- Pipe Culverts
  - Geometry: Complex GIS
  - Replacement Cost: UDOT Asset Owner and Cost Estimating Support Staff
- Road Surface
  - Geometry: UPLAN service [FI Surface Area](#)
  - Replacement Cost: UDOT Asset Owner and Cost Estimating Support Staff

Data for risk Calculations

Part B - Natural Hazard Threat Data

- Flood Risk
  - Geometry: FEMA flood risk data
  - Risk probability: FEMA flood zones
- Rockfall Risk
  - Geometry: Utah State University Study (Pack et al.)
  - Risk probability: UDOT, Ari Menitove
- Avalanche Risk
  - Geometry: Utah Avalanche Center, Avalanche locations
  - Risk probability: Based on observed avalanche frequencies
- Earthquake Risk (bridges only)
  - Geometry and Impact: UDOT, Rebecca Nix
  - Risk probability: Utah Earthquake Probabilities report

Data for risk Calculations

Part B - Natural Hazard Threat Data Cont…

- Debris Flow Model
  - Geometry:
    - Stream centerline, catchment basins: National Hydrography Dataset
    - Precipitation: NOAA Hydrometeorological Design Studies Center
    - Soil: USDA and NRCS's Gridded National Soil Survey Geographic Database (gNATSGO)
    - Forest Cover: National Land Cover Database (NLCD) 2016
    - Slope: AGRC 30-meter statewide digital elevation model
    - Wildfire Threat: Utah Division of Natural Resources' Wildfire Risk Assessment Portal
  - Risk probability: United States Geological Survey (Stevens et al., 2008)

Data for risk Calculations

**Part B - Natural Hazard Threat Data Cont…**

- Debris Flow Model
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Data for risk Calculations

Part C - User Costs

- System Redundancy (delay/reroute times): BIO-WEST Network Analysis
- Hourly User Time (passenger vehicle and trucks): UDOT Traffic Management Division
- AADT: UDOT traffic counts
- Asset Temporary Fix Estimates: UDOT engineering judgment through coordination with the Risk Management Workshop Group
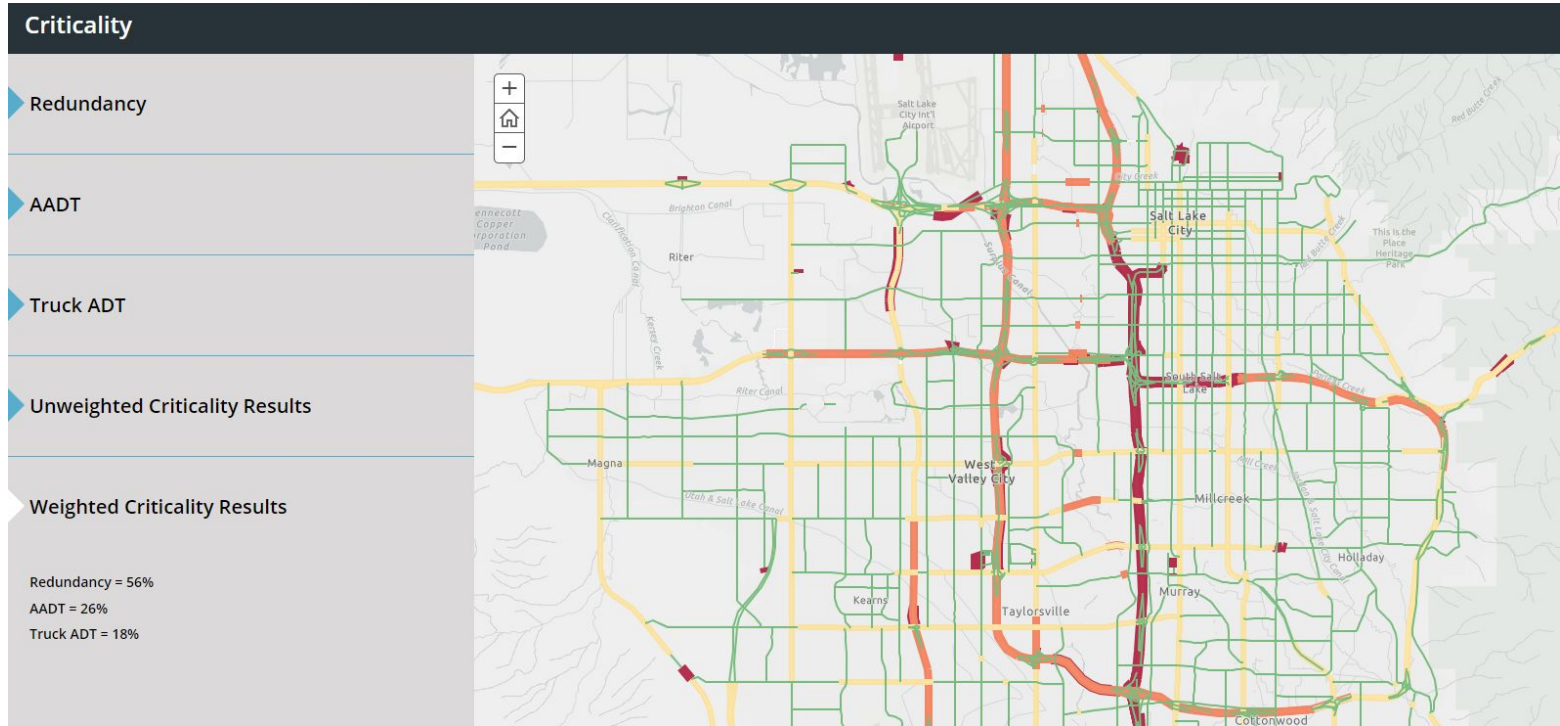
Degradation Curves

Risk = Impact * Probability * Vulnerability
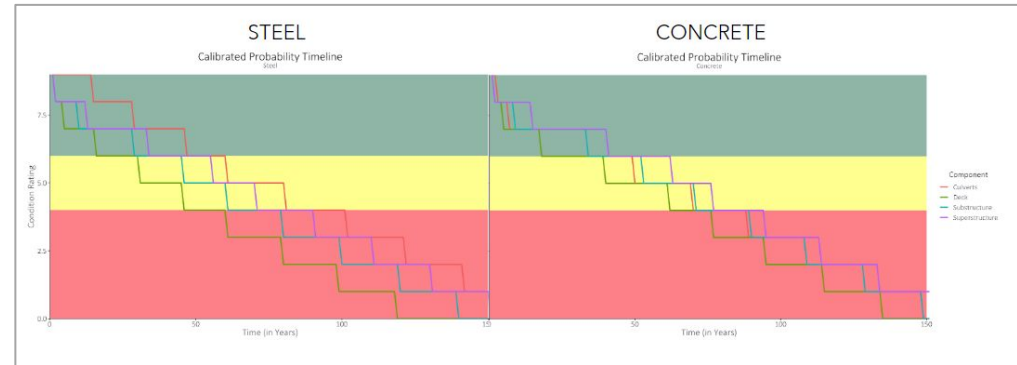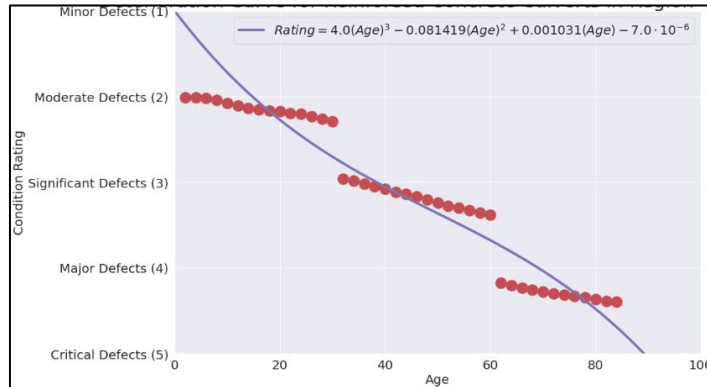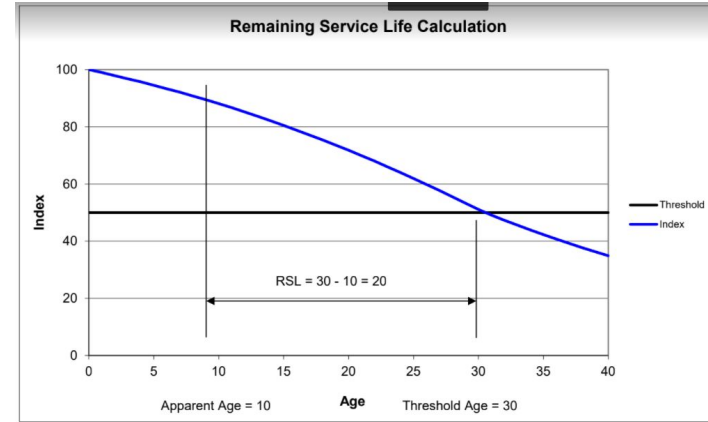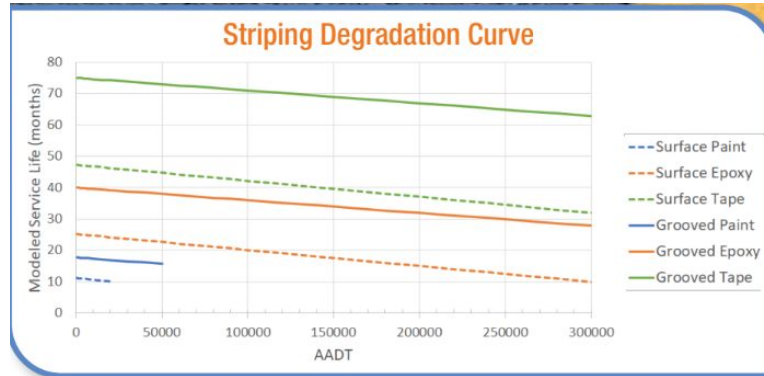
Threat-Asset Matrix

Threat/Asset	Bridge	Bridge Approach	Roadway Prism	ATMS	Fiber					Wall	NBI Culvert	Non-NBI Culvert
					Line	Conduit	Box	Cabinet	Splice			
Earthquake & Liquefaction	✓	✓	✓	---	✓	✓	---	---	---	---	✓	✓
Fire (Wildland)	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Flood-Debris/Overtop	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Flood-Scour	✓	---	---	---	---	---	---	---	---	---	---	---
Railway	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oil/Gas Pipeline	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H2O Pipeline	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H2O Canal/Ditch	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Criticality

AADT	26%
Truck Traffic	18%
Redundancy	56%

Criticality

Redundancy

AADT

Truck ADT

Unweighted Criticality Results

Weighted Criticality Results

Redundancy = 56%
AADT = 26%
Truck ADT = 18%

Risk Priority = Risk * Criticality
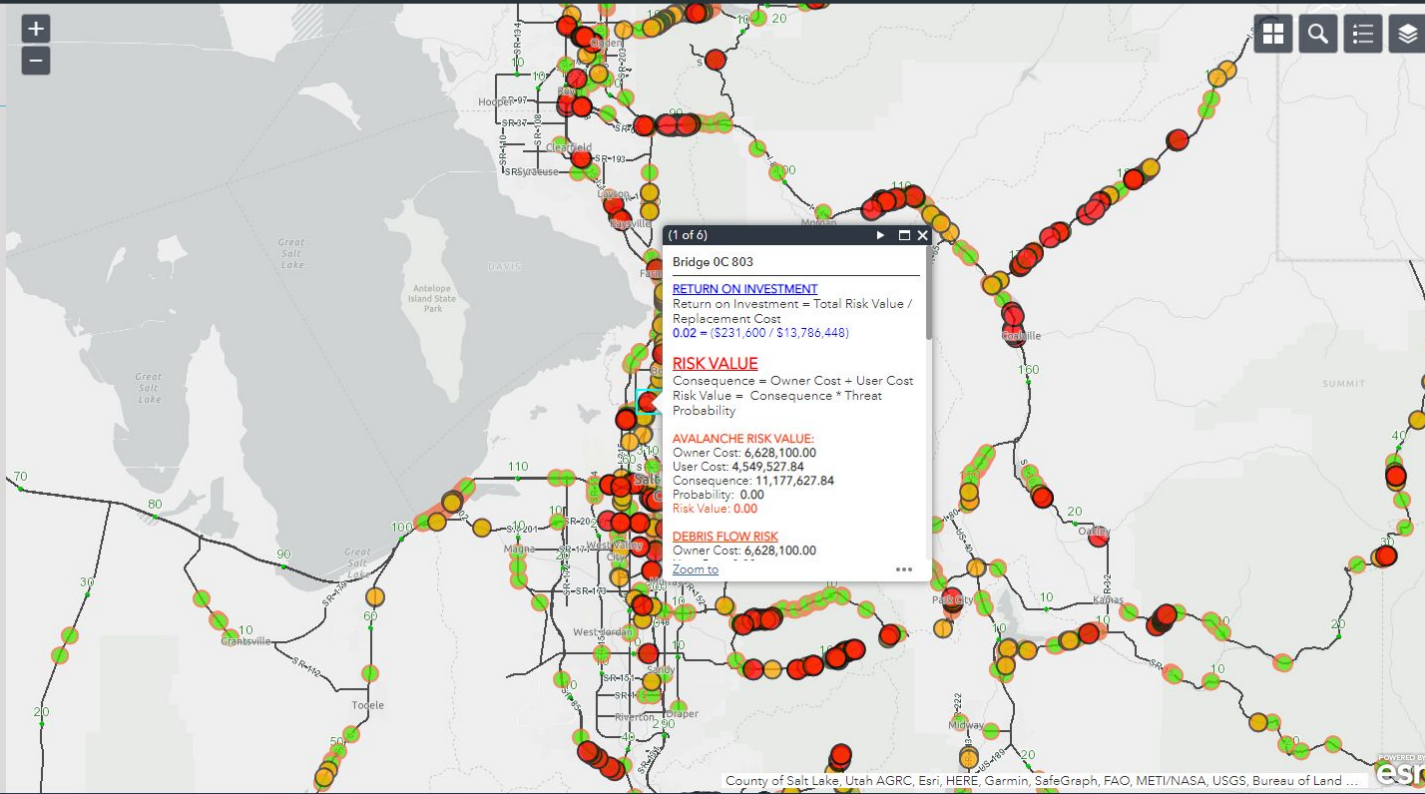
Map Risks are Relativistic

- Based on available threat data

- Risk values are relative -- not absolute

- Asset design sets our risk tolerance

- Risk increases with asset deterioration

- Risk increases with climate change

Resiliency Calculation

$$\text{Resiliency} = \frac{1}{\text{Risk} * \text{Criticality}} = \frac{1}{\text{Risk Priority}}$$

Risk = Impact * Probability * Vulnerability

Risk Priority = Risk * Criticality

Resilience

The four R's of resilience

✓ **Robustness:** *ability of the system to withstand a given level of stress and/or demand*

✓ **Redundancy:** *measure of the inherent substitutability*

✓ **Resourcefulness:** *measure of the capacity to mobilize resources in the event of disruption*

✓ **Rapidity:** *measure of the capacity to contain losses or prevent further degradation in a timely manner*

Source: Minsker, Barbara & Baldwin, Lily & Crittenden, John & Kabbes, Karen & Karamouz, Mohammad & Lansey, Kevin & Malinowski, Patricia & Nzewi, Emmanuel & Pandit, Arka & Parker, John & Rivera, Samuel & Surbeck, Cristiane & Wallace, William & Williams, John. (2015). **Progress and Recommendations for Advancing Performance-Based Sustainable and Resilient Infrastructure Design**. Journal of Water Resources Planning and Management. 141. A4015006. 10.1061/(ASCE)WR.1943-5452.0000521.

Resiliency Component Measures

Rapidity:

- Measured by user cost
- Unit is difference from standard response time
- Reduces Impact

Resourcefulness:

- Measured by user costs and tied to rapidity
- Reduces Impact
- May also reduce criticality

Redundancy:

- Set benchmark based on travel demand model redundancy
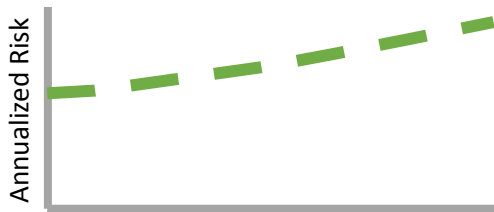- Track yearly change in benchmark
- Reduces Criticality

Robustness:

- Hardening of the asset
- Reduces Vulnerability
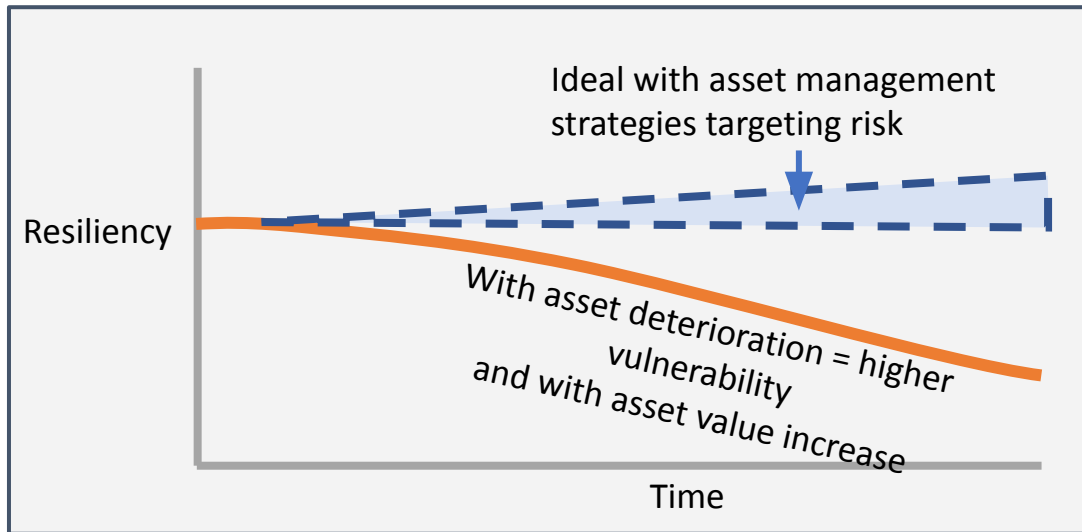
Resiliency Performance Measure

$$\text{Resiliency} = \frac{1}{\text{Risk (\$) * Criticality}}$$

⬆ Robustness
Rapidity
Resourcefulness

⬆ Redundancy

Annualized Risk

Asset value from expansion brings an increase in risk value which has a direct relationship to resiliency decline

Ideal with asset management strategies targeting risk

Resiliency

With asset deterioration = higher vulnerability and with asset value increase

Time

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