Climate Change Adaptation: Quantifying Risks, Costs, and Benefits

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I'll Review Climate Change Risks, Costs, and Benefits of Adaptation by Discussing:

1. What are the infrastructure-related climate-change risks?
2. Worldwide trends in asset loss due to climate change events;
3. Trends in rising frequency and severity of disruptions in the U.S.;
4. Value of the U.S. transportation assets potentially at risk of damage;
5. Adaptation measures currently deployed to reduce vulnerability;
6. Meeting the challenge: catalyzing a more efficient approach to adaptation and bending the climate-change cost curve.

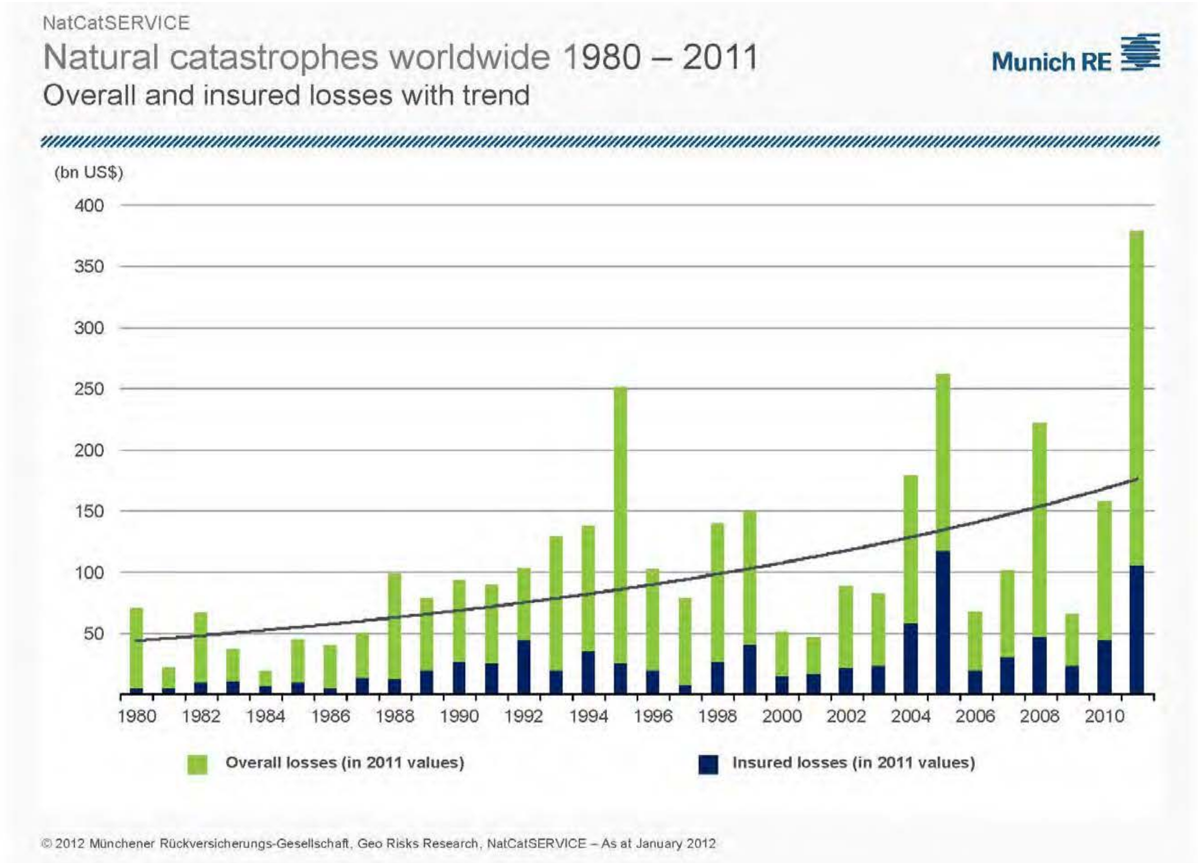
Climate-Change Risks Threatening the Transportation Infrastructure System

$\textit{Climate Risk} = \text{f}\ (\textit{Hazard Frequency}_{\textit{Probability per event}}\ x\ \textit{Asset Exposure}_{\textit{assets at risk of potential loss}}\ x\ \textit{Vulnerability}_{\textit{asset sensitivity}}\ x\ \textit{Consequences}_{\textit{\$ value of event severity}})$

- *Hazard Frequency*: Probability of disruptive events due to higher temperatures; rising sea-levels; changing precipitation; greater severity of storms;
- *Asset Exposure*: A function of population growth (from 152M in 1950 to over 304M today) and coastal development (over 80% of activity growth in the U.S. has been in corridors within 100 miles of coastlines);
- *Vulnerability*: A function of greater asset sensitivity (e.g., high-rise urban structures); aging and inadequately maintained and protected structures (the 2013 ASCE Scorecard assigned a grade of D for dams; a D- for levees; and a C+ for bridges, with 1 in 9 ranked as "structurally deficient"); and increasing global interdependencies among technology-intensive subsystems that lead to cascading chain effects;
- *Consequences: A* function of severity and scale of asset loss; reflecting the rapid growth in GDP and market valuation of built assets. Just a stretch of coastal development from the Texas Gulf Coast to New York City has an asset concentration of over $8 Trillion.

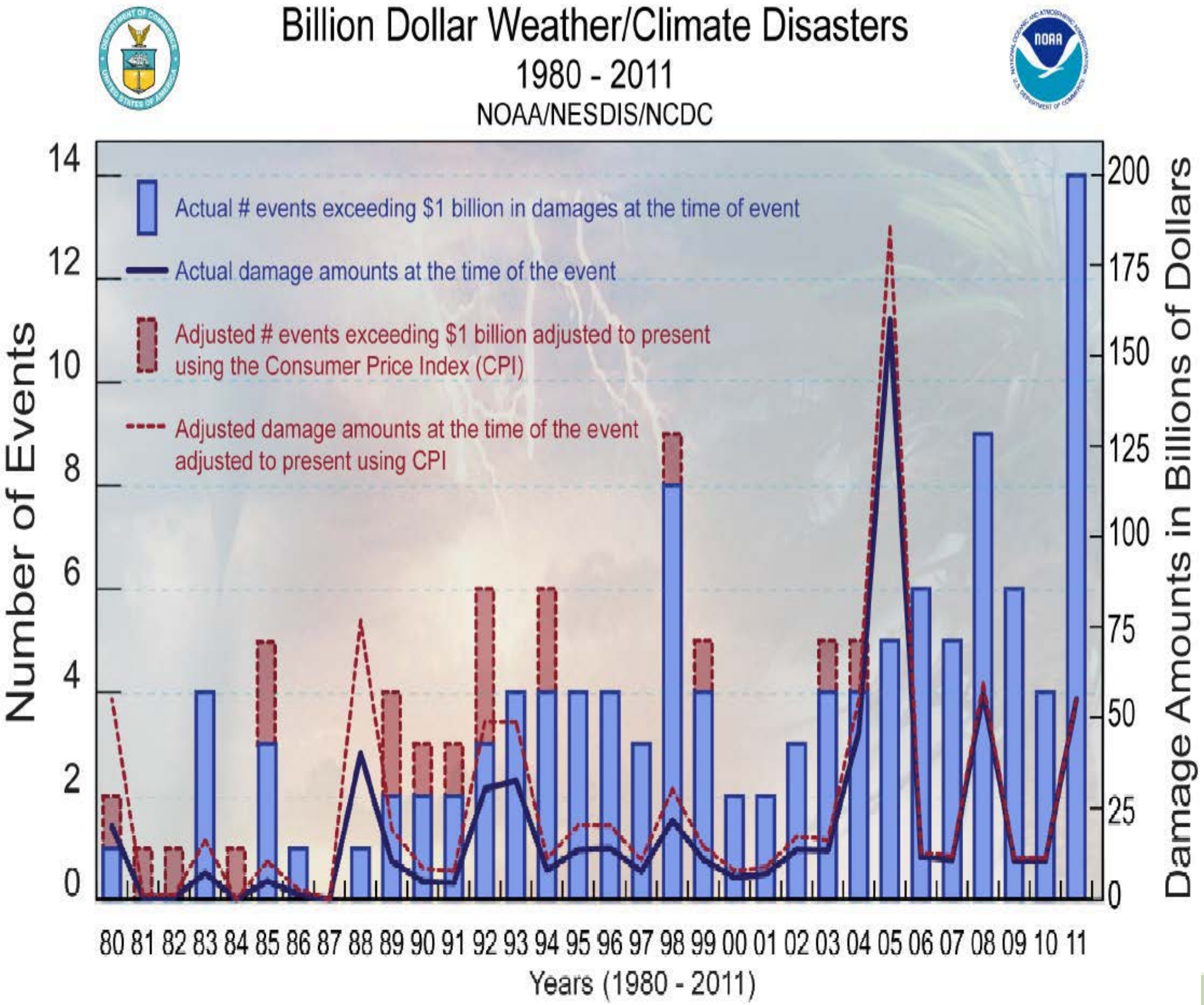
Worldwide, Losses from Climate-Related Events are Rising

Between 1980 and 2011, insured and uninsured global losses increased from $529B to $1.6T.



In the U.S. as well, the Frequency and Severity of High-Impact Events are Rising

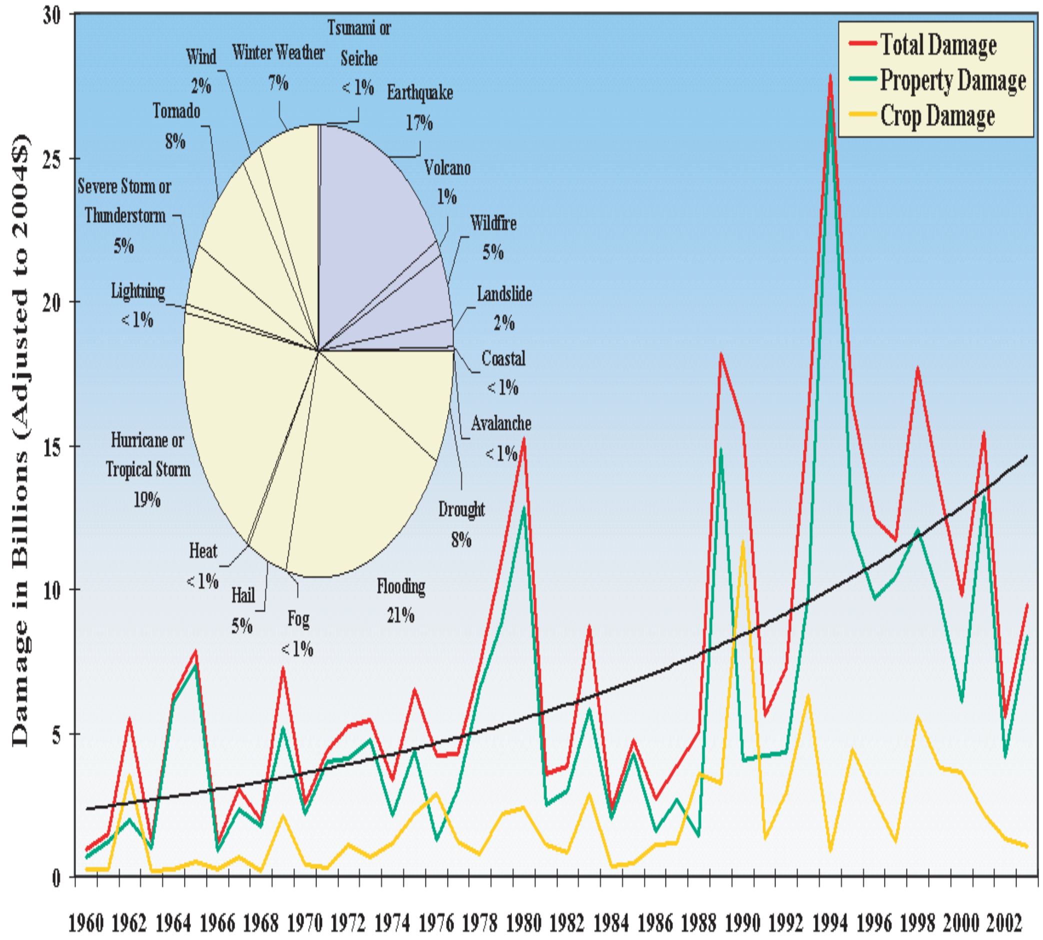
NOAA climate databases show that between 1980 and 2013, there were 170 *Billion-Dollar-Weather-Events,* leading to $1.04T in damage (CPI-adjusted 2005 dollars); Indicating a rise in both frequency and outcome severity.



Magnitude and Composition of Losses due to Climate Events have been Changing

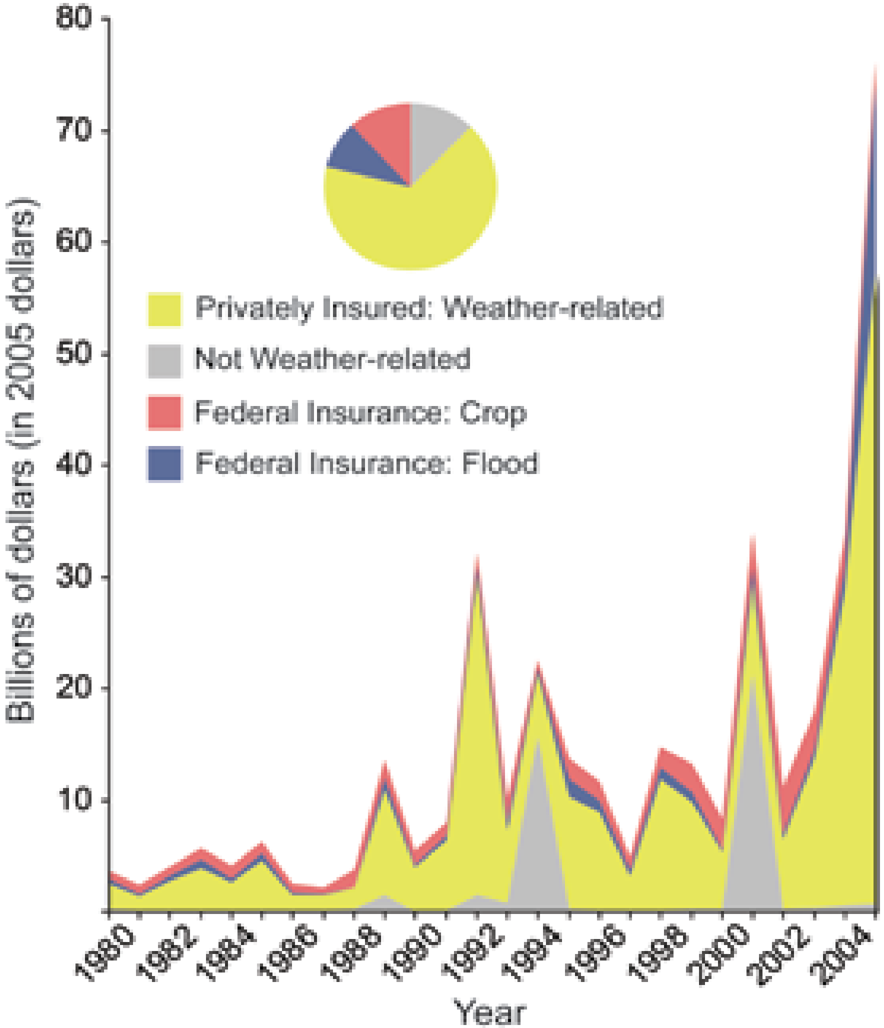
Spatial Hazard Events and Loss Database for the U.S. (SHELDUS^{TM}) data show:

- Average annual losses from natural hazards rose ($1B to $28B, in CPI-adjusted 2004 $);
- Property damage accounted for ~80% (8% of which was drought-related crop damage);
- Non-climate-related natural events accounted for 22%.



Only Half of the Costs of Climate Events are Borne by Insured Properties

- Insured losses, 1980-2004, were $320B (CPI-adjusted 2005$): accounting for only 50% of total damages;
- 90% of the insured catastrophic losses were climate-related;
- Non-weather-related events, depicted in gray, related to two major non-climate events;
- Cost burden of uninsured properties, and the share of Federal Crop and Flood Insurance policies are rising.



Source: 2009 U.S. Global Change Research Group (USGCRP) Climate Change Assessment

Half of the Nation's Transportation Assets are Publicly Owned

- Total value of the nation's transportation assets ~$7.4T
- $3.7T owned (and/or funded) by public sector government entities;
- BEA does not provide breakdown of non-highway publicly-owned assets;
- $1.1T in privately-owned commercial service-provider assets;
- Infrastructure assets include another $9T in non-transportation assets, more than half privately owned;
- Blurred lines of protection responsibility for vast private assets;

	Publically-Owned	Privately-owned
Highways	$3,100 B	NA
Equipment/Real Property/Assets for Commercial Services	$600 B	$1,100 B
Private Motor Vehicles	NA	$1,300
In-House Transportation Service	NA	$1,300
Total Transportation Asset	$3,700B	$3,700 B

Source: Fixed Value of Transportation Assets, *Bureau of Economic Analysis* (BEA) 2011

Adaptation Has Significant Applications for Reducing Climate-Change Impacts and Consequences

Role of Adaptive Strategies 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
- Retrofitting facilities
- Relocation of facilities
- Upgraded stormwater drainage facilities
- Building new facilities to climate-ready standards
- Protect existing infrastructure

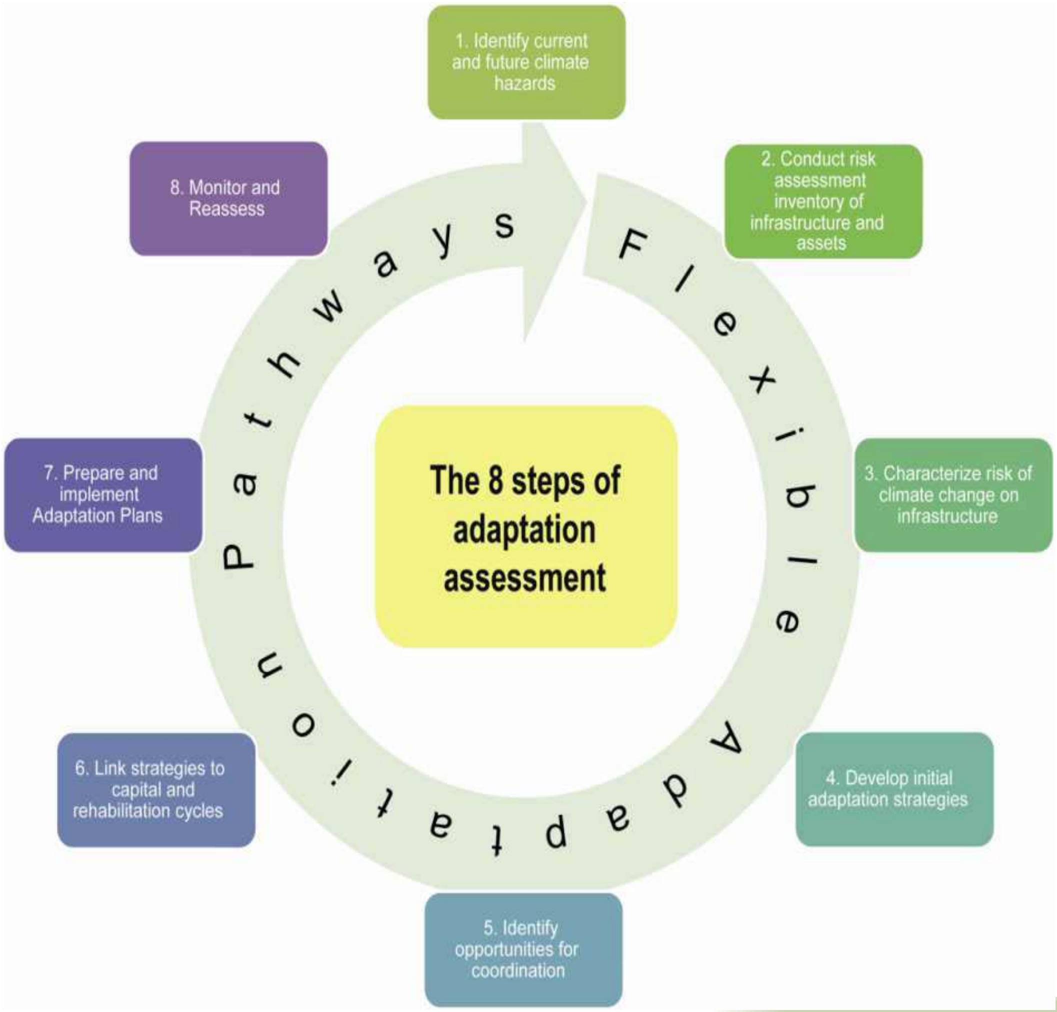
Adaptive Strategies to Reduce Consequences
- Re-route freight and passenger flows
- Shift to alternative modes
- Land-use regulations relating to development in vulnerable areas
- Evacuation/contingency strategies
- Building in network flexibility
- Traveler information systems
- Rapid rebuilding of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

Source: The 2009 National Climate Assessment and Development Advisory Committee (NCADAC), under the auspices of the USGCRP

Climate-Change Adaptation Process for New York City Panel on Climate Change (NPCC)

The 2008 NYC Adaptation Task Force implemented three strategies:

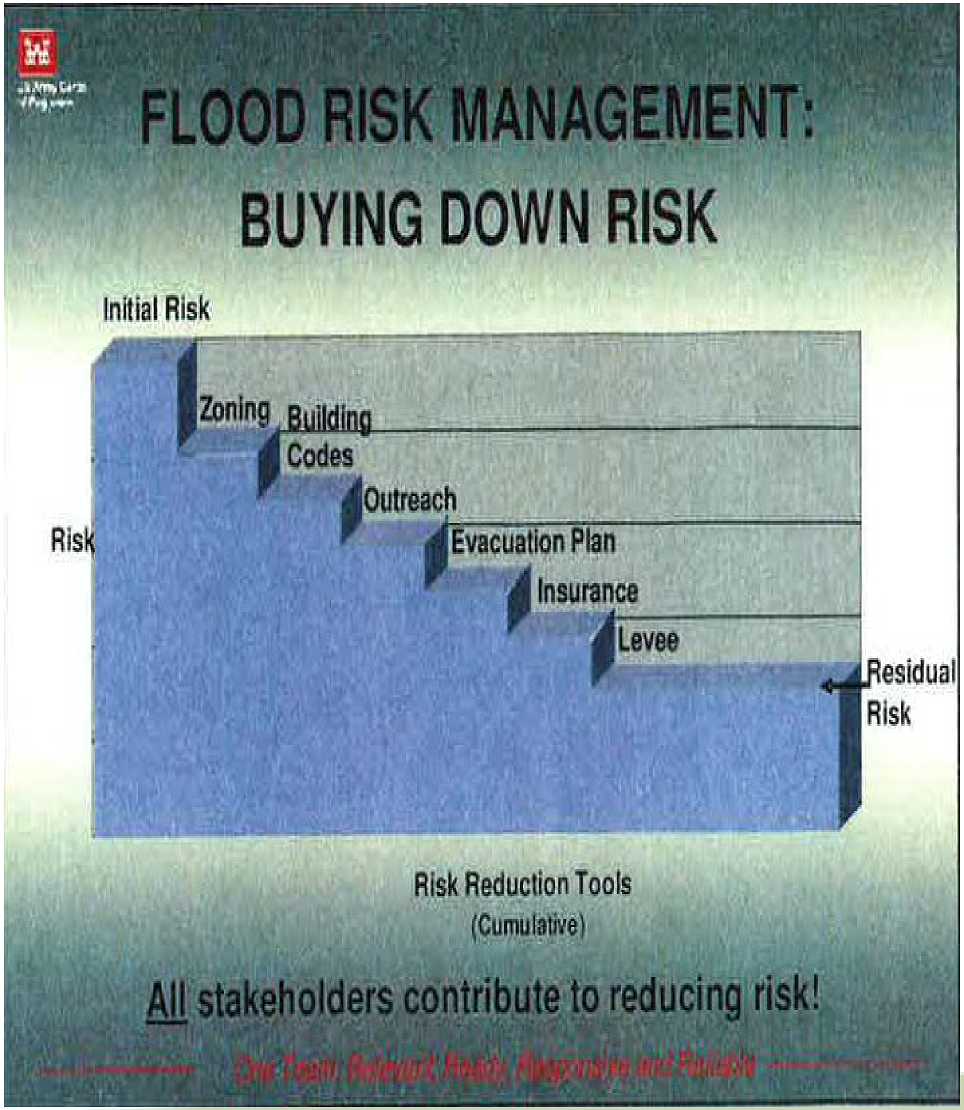
- *Protection* for vulnerable infrastructure assets; (proved effective in reducing damages from Superstorm Sandy);
- *Accommodation f*or high-rise buildings);
- *Strategic Retreat* for residential assets.



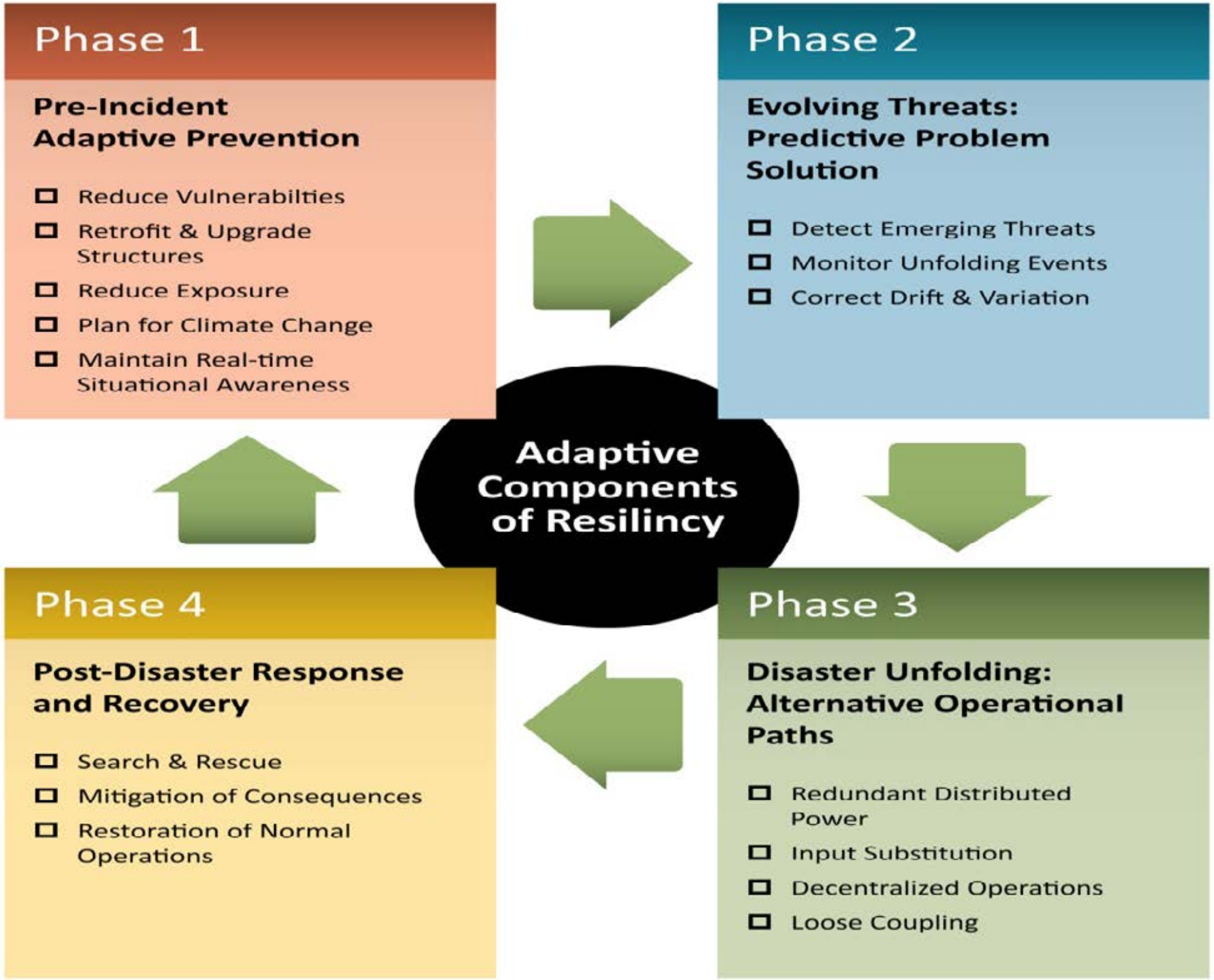
Adaptation as "Buying Down Risks"

The USACE systematic process for flood risk reduction may have reduced flooding damages by $140 Billion by:

- Calculating the difference in the magnitude of the estimated costs of *Initial Risk* and the *Residual Risk* by quantifying the cumulative impact of implementing all engineering and structural measures;
- However, the USACE does not routinely estimate the size of the "*residual risk*", nor does it attempt to measure the "Levee Effect";



Adaptation - A Proactive Approach to Reducing Risks and Enhancing Infrastructure Resilience



Graphic Source: The Volpe National Transportation Systems Center

Catalyzing More Effective Approaches to Quantifying the Costs and Benefits of Adaptation Strategies

We have three key takeaways on climate-change adaptation research:

1. Our track record in quantifying the costs and benefits of specific adaptation improvements at the regional scale is not very long. Our current infrastructure condition models do not go beyond identifying the baseline costs of the "state of good repair" or identify vulnerabilities.
2. Field data from pilot tests designed to quantify the costs and benefits of adaptation will generate dual benefits: Help address the Federal Flood Risk Management Standard and the OMB guidelines for *Making a Business Case* for major public infrastructure investments; and bridge the gap in the application of scientific data by linking them to the regional decision-makers.
3. Costs of damage protection are likely to be far higher in the future since climate-change risks accelerate along non-linear and "*scale-free*" paths. Efforts to quantify the costs and benefits of preventive action will help bend the cost curve by showing how costs grow the longer we wait.