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Engineer Research and Development Center

Risk and Resilience: Past and Future

Igor Linkov

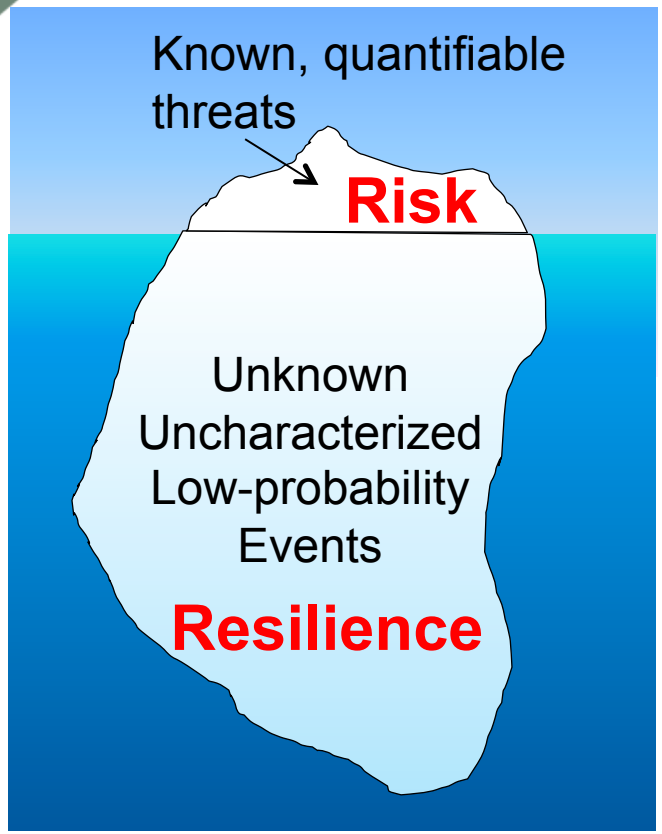
Igor.Linkov@usace.army.mil

Risk and Decision Science Focus Area Lead, USACE

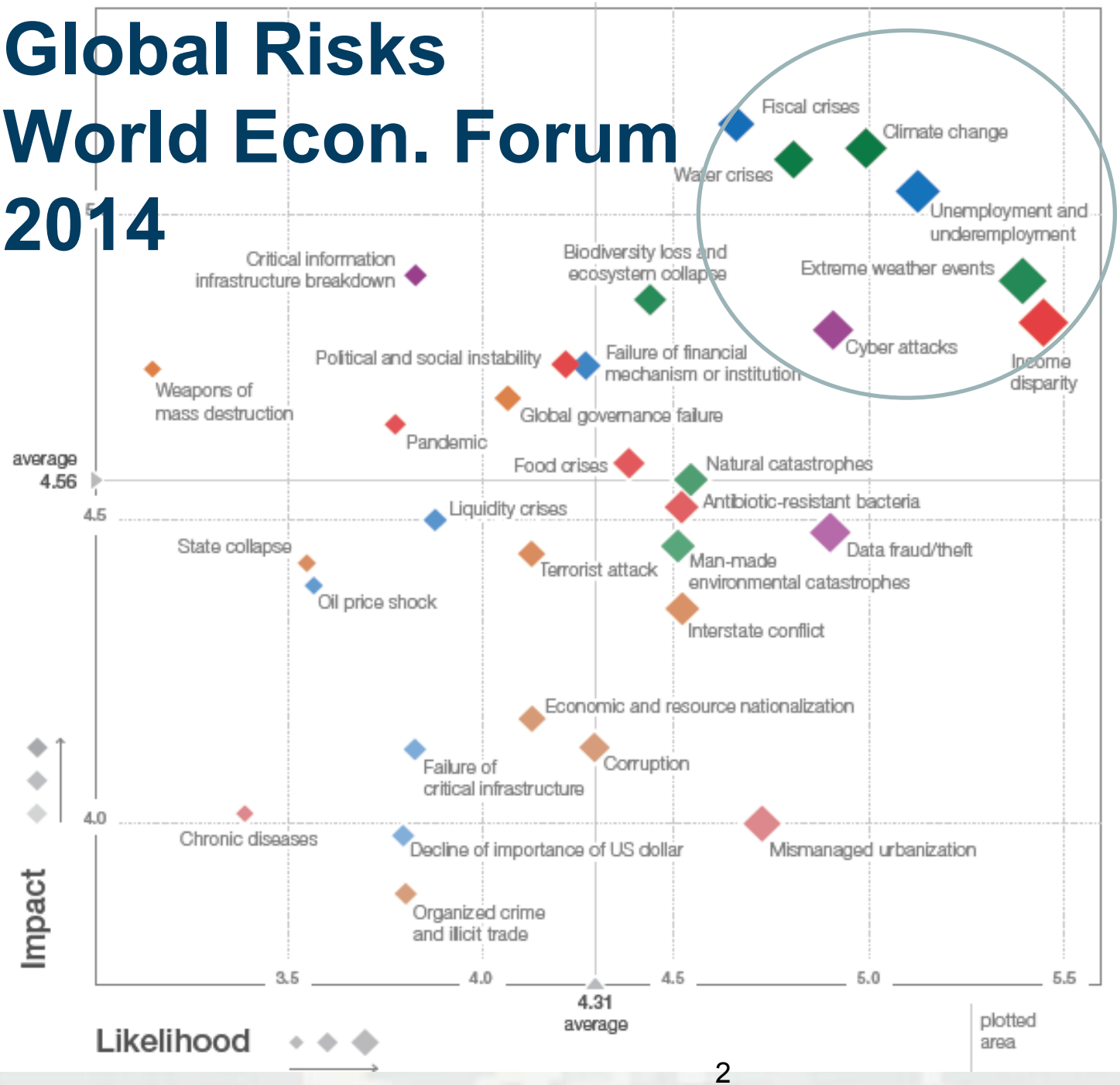
Adjunct Professor, CMU

Visiting Professor, Ca Foscari University of Venice, Italy

US Army Corps of Engineers®



Global Risks World Econ. Forum 2014



Emerging Global Risks

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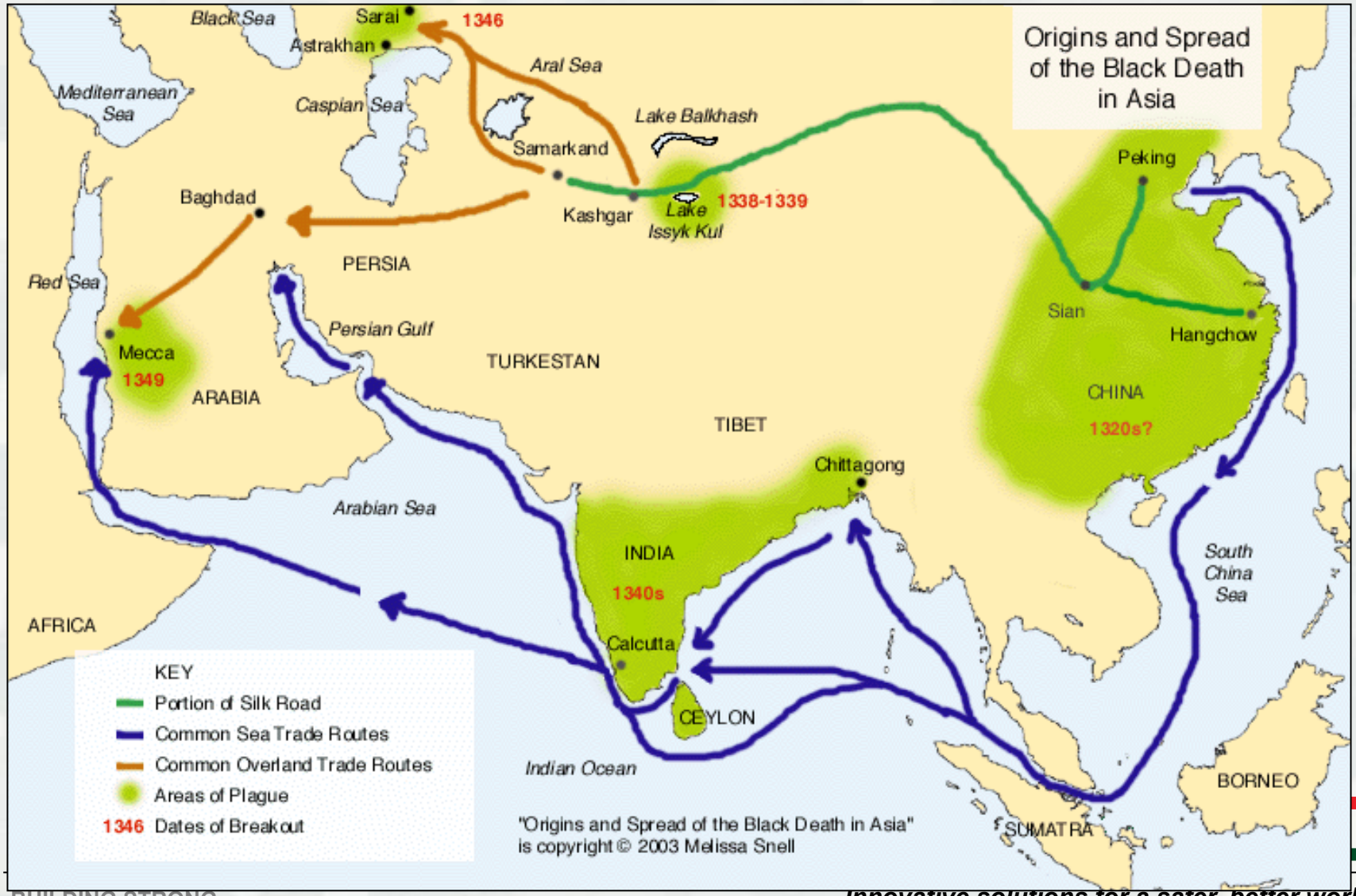
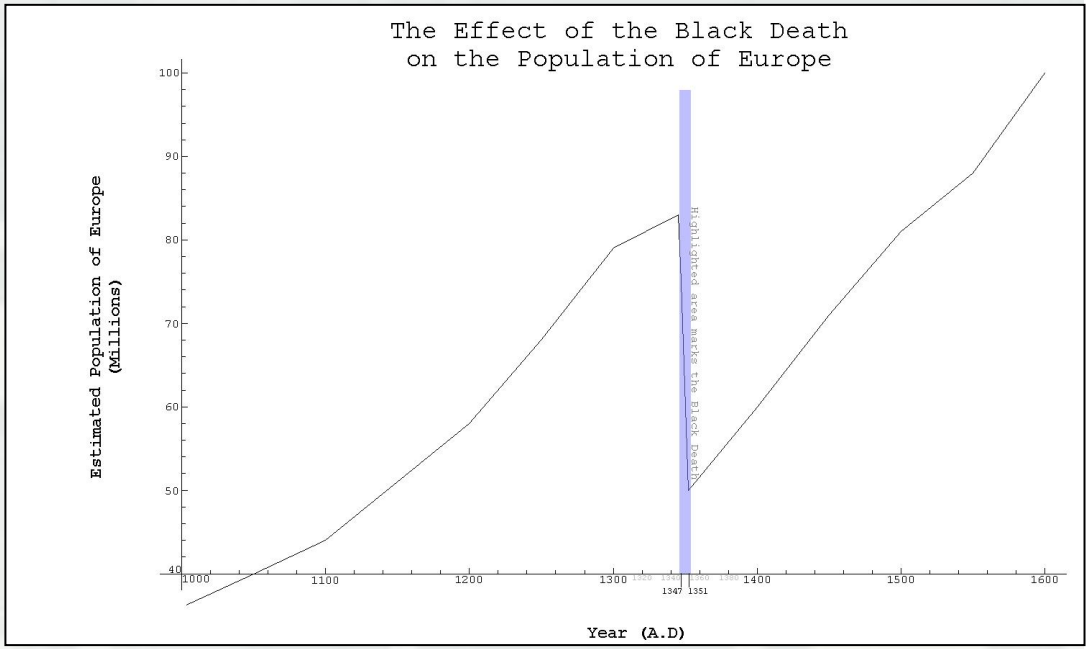
Global Risks Before: Plague



Plague in Europe

- In 1347 Italian merchants fled the plague-infected Black Sea ports and unwittingly spread the disease to the Mediterranean Basin

- By 1348, following trade routes, plague had sparked epidemics in most of western Europe
- Victims developed inflamed lymph nodes, most died within a few days of onset of symptoms
- Significant population decline, “Black Death”



Risk Assessment Formulation

What can happen (go wrong)?

How likely is it?

What are the consequences?

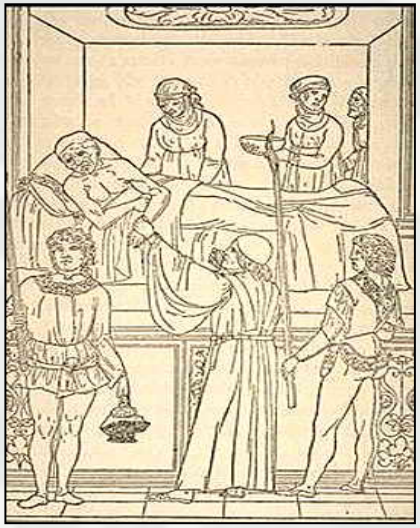
Plague Risk Assessment & Management (Venice, 1348)

Threat: God

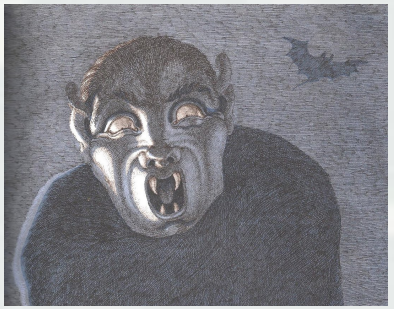
Management: Praying, Flagellants

Threat: Skin

Management: Metals

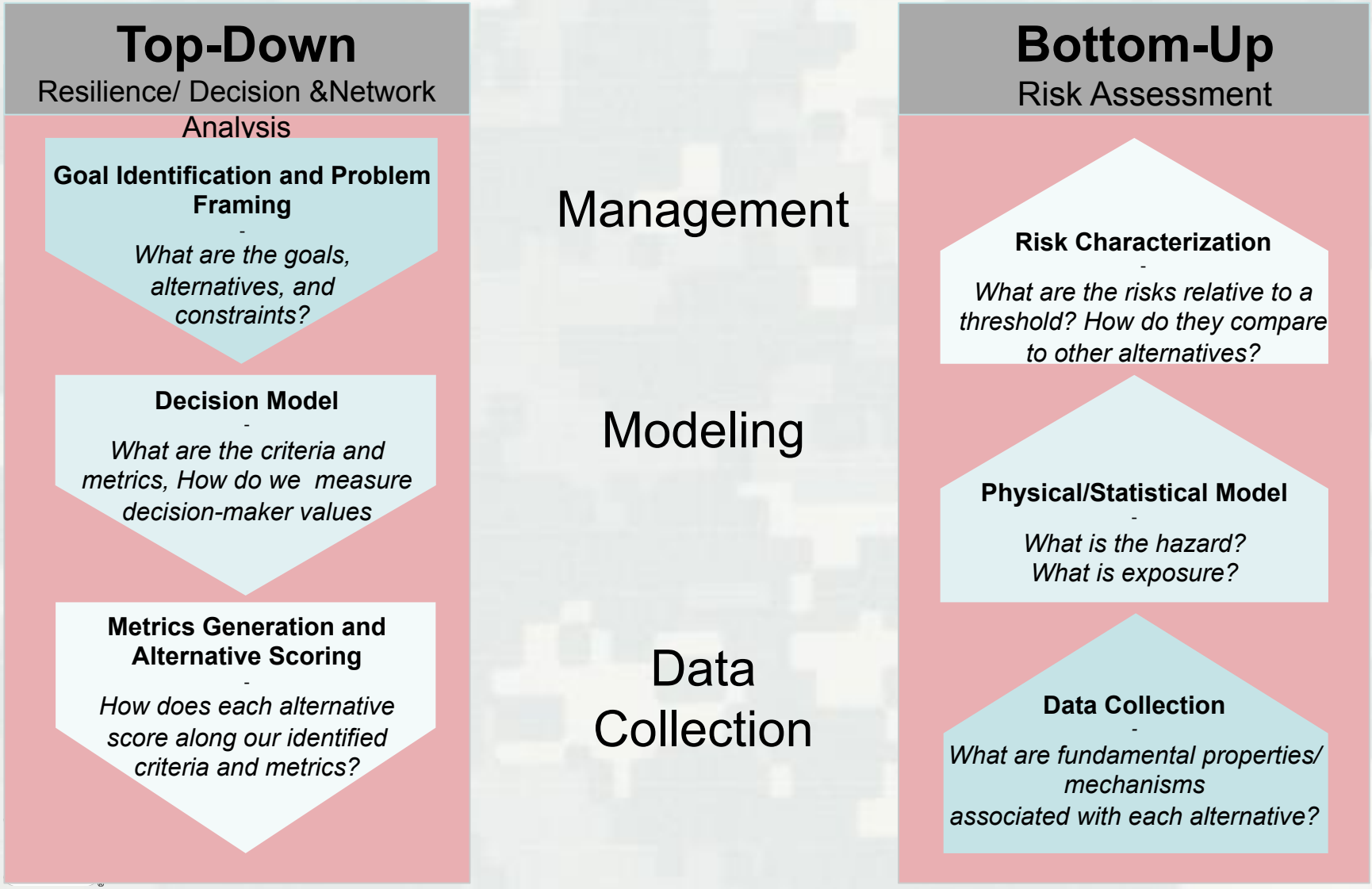


Threat: Vampire



Management: Brick in Mouth

Risk-Resilience Integration



Linkov et al., 2014

Outline

- From Physics to Social Science
  - Seeing the Wood Despite the Trees
  - Model Uncertainty and Choices Made by Modelers
  - Using our Brain to Develop Better Policy
- From Risk to Resilience
  - Risk
    - Conceptualization
    - Risk Assessment Case Studies
    - Problems with Risk-based Approaches
  - Resilience
    - Conceptualization
    - Resilience Matrix Approach and Jamaica Bay Case
    - Network Science Approach
- Discussion

Serendipity and Looking for an Edge

Physica B 185 (1993) 313–318
North-Holland

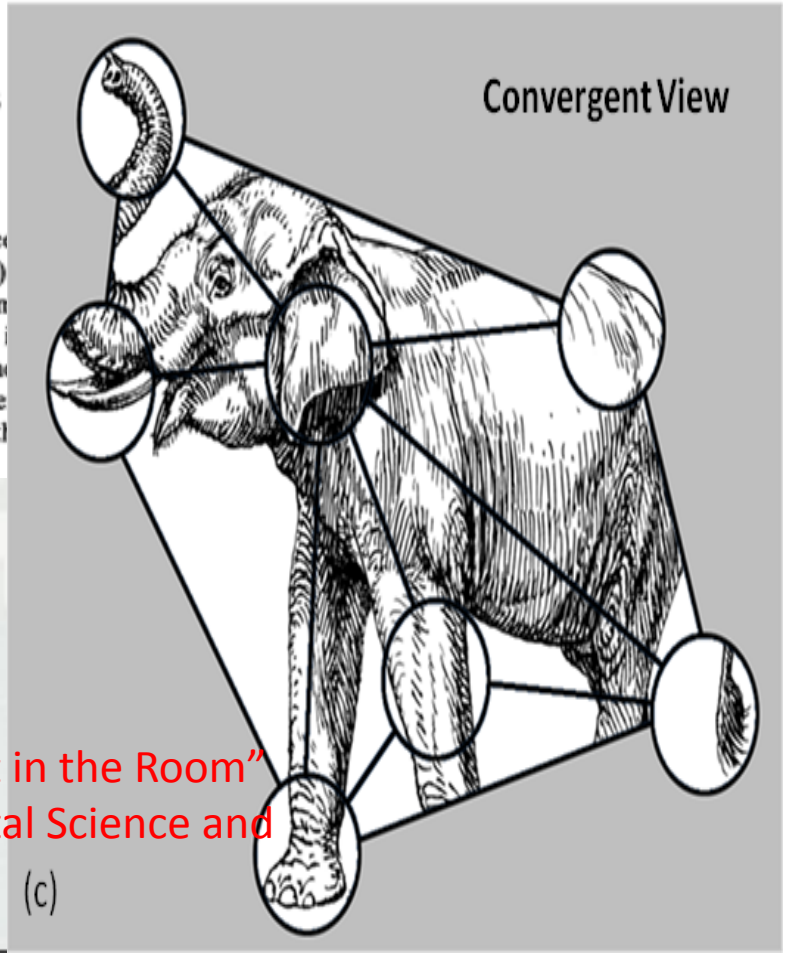
PHYSICA B

Exciton luminescence of compensated SiC–6H

V.V. Evstropov, I.Yu. Linkov, Ya.V. Morozenko and F.G. Pikus
A.F. Ioffe Physico-Technical Institute, St. Petersburg 194021, Russian Federation

Photoluminescence of compensated and uncompensated epitaxial SiC–6H layers has be
grown by container-free LPE and contained different concentrations of nitrogen (donor)
proposed that the high-temperature (500–900 K) photoluminescence (PL) of SiC–6H is n
tion of the free exciton. It is found that at high temperature, the shape of the exciton band
exciton band width are discussed. In closely compensated samples, there is a shift of th
lower energies. Exciton localization by the potential fluctuations is supposed. The free e
found to depend markedly on the Al concentration. A decay model of the exciton in t
compensated silicon carbide is proposed.

Edge



"Scientific Convergence:
Dealing with the Elephant in the Room"
Linkov et al., Environmental Science and Technology (in press)

Environmental Science & Technology

Viewpoint

pubs.acs.org/est

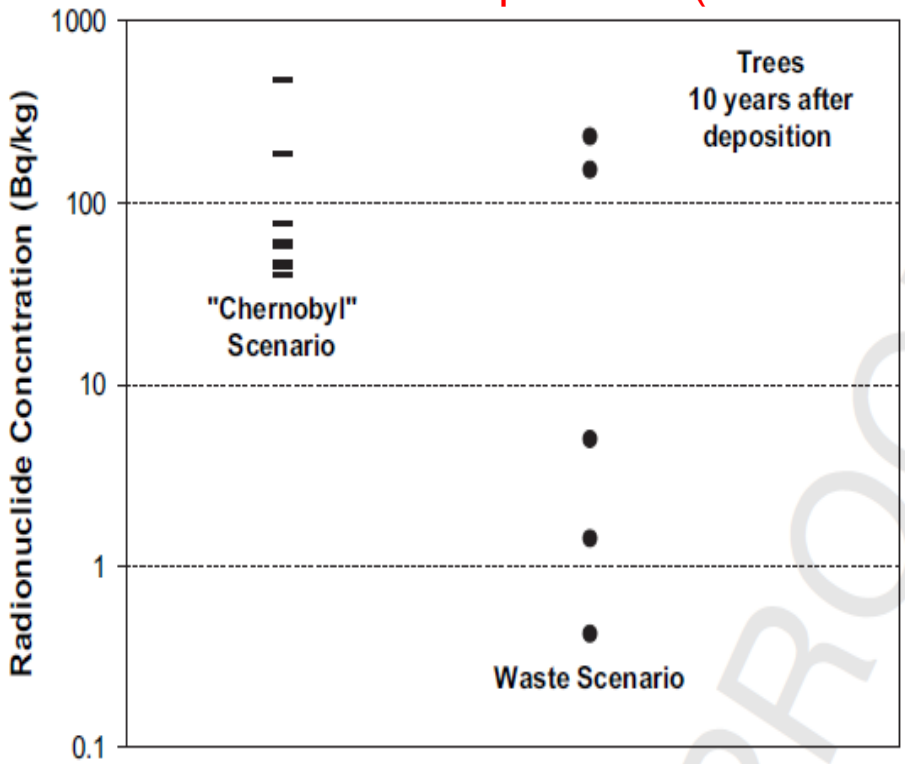
Forests in Japan (2012)

Radioactive Contamination of Natural Ecosystems: Seeing the Wood Despite the Trees

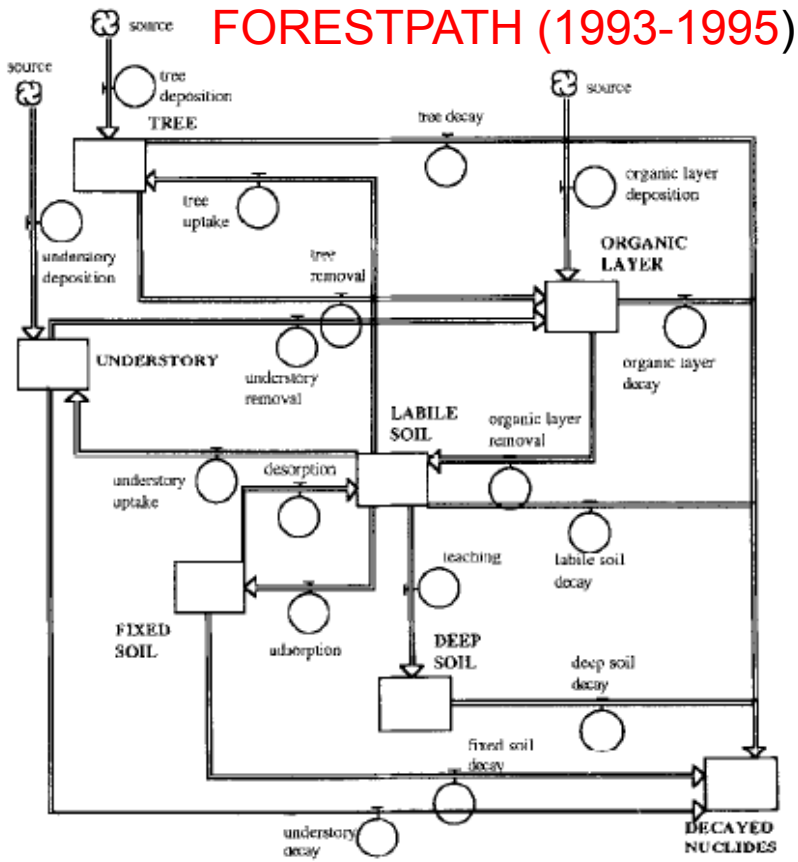
Shoji Hashimoto,*,† Igor Linkov,‡ George Shaw,§ and Shinji Kaneko†

I. Linkov, D. Burmistrov / J. Environ. Radioactivity ■■ (2005) ■■■–■■■

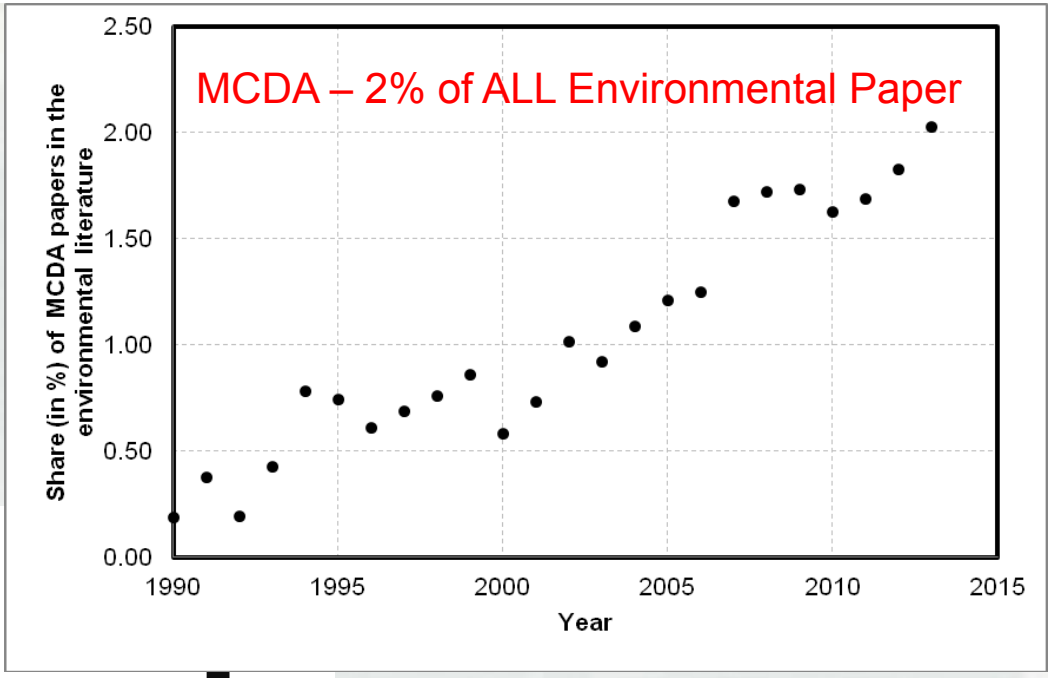
IAEA Model Intercomparisons (1997-2002)



FORESTPATH (1993-1995)



Perspectives on Modeling



Linkov and Keisler (2014)

Reliance on empirical data

Rarely used methods

Used in most environmental areas

- Decision maker - Value
- Bayesian Expert - subjective
- Statistical– data
- Mechanistic - model

Judgment

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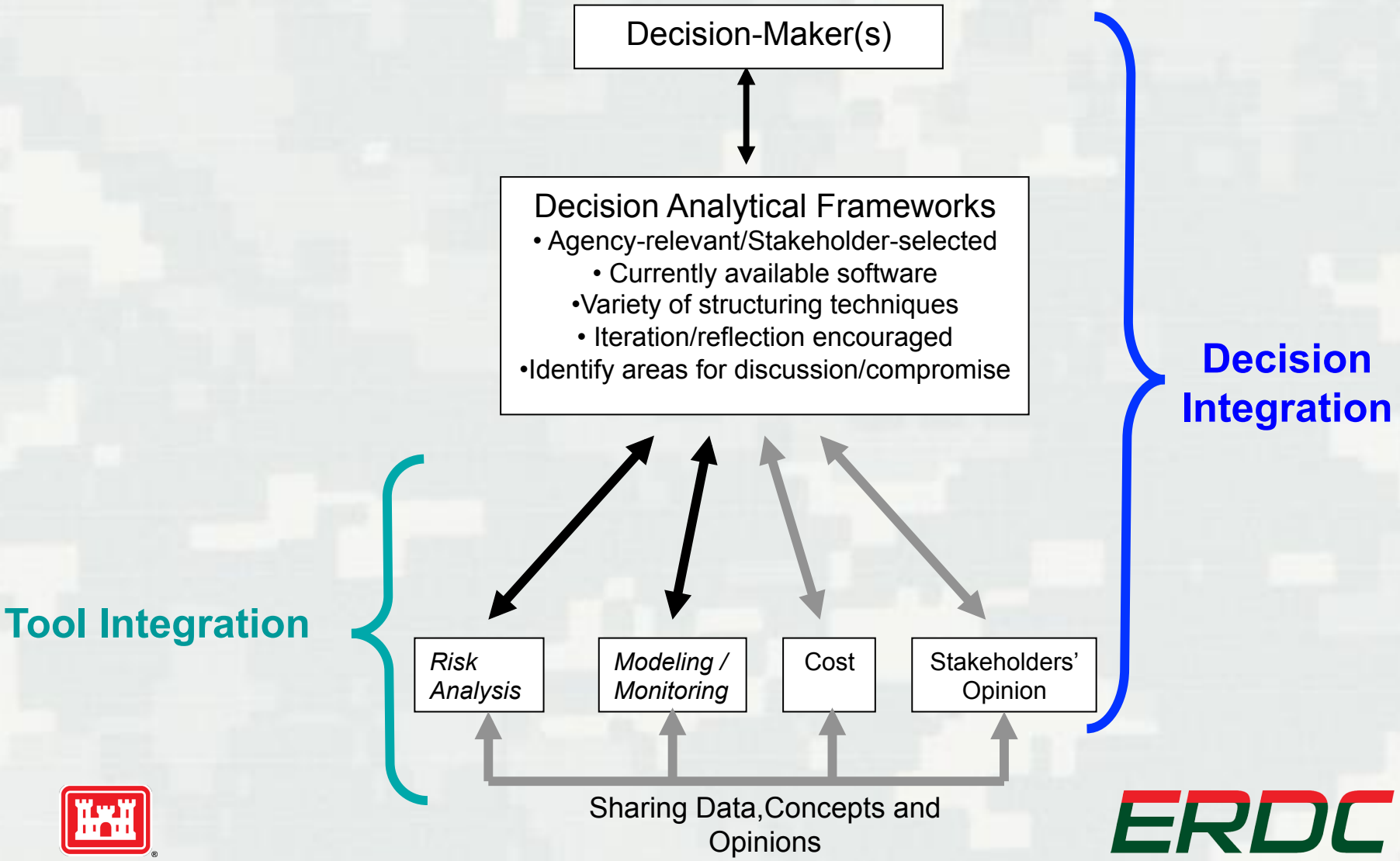
Decision Analysis



Mental Modeling

Risk Analysis, Vol. 32, No. 3, 2012

Perspective

Using Our Brains to Develop Better Policy

Igor Linkov,[1,*] Susan Cormier,[2] Joshua Gold,[3] F. Kyle Satterstrom,[4]

Risk Analysis, Vol. 32, No. 8, 2012

DOI: 10.1111/j.1539-6924.2012.01832.x

Flood Risk Management: US Army Corps of Engineers and Layperson Perceptions

Matthew Wood,[1] Daniel Kovacs,[2] Ann Bostrom,[3] Todd Bridges,[1] and Igor Linkov[1,*]

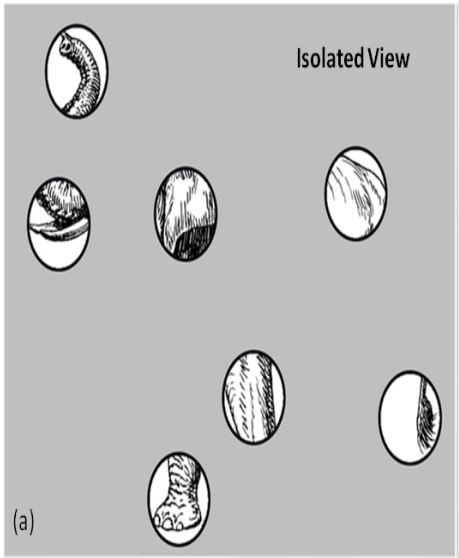
Environ Syst Decis
DOI 10.1007/s10669-013-9461-6

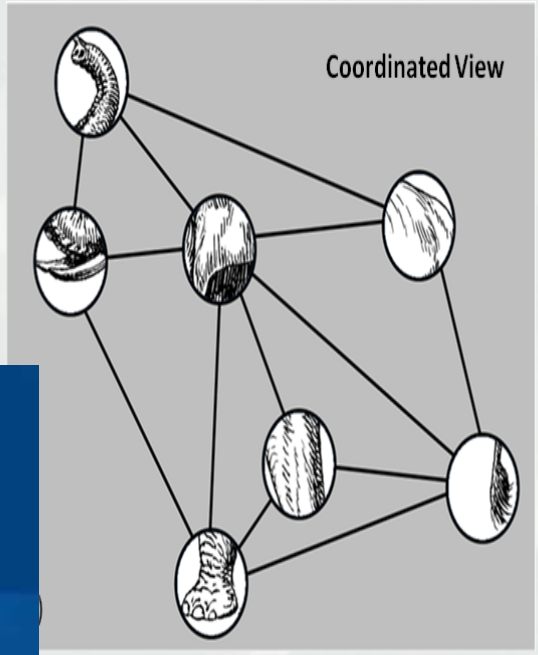
Climate change risk management: a Mental Modeling application

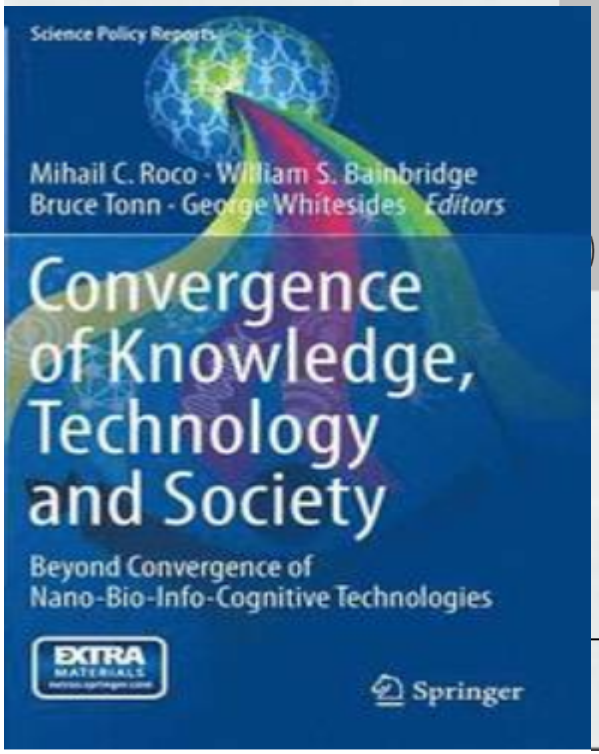
Todd S. Bridges · Daniel Kovacs · Matthew D. Wood · Kelsie Baker · Gordon Butte · Sarah Thorne · Igor Linkov

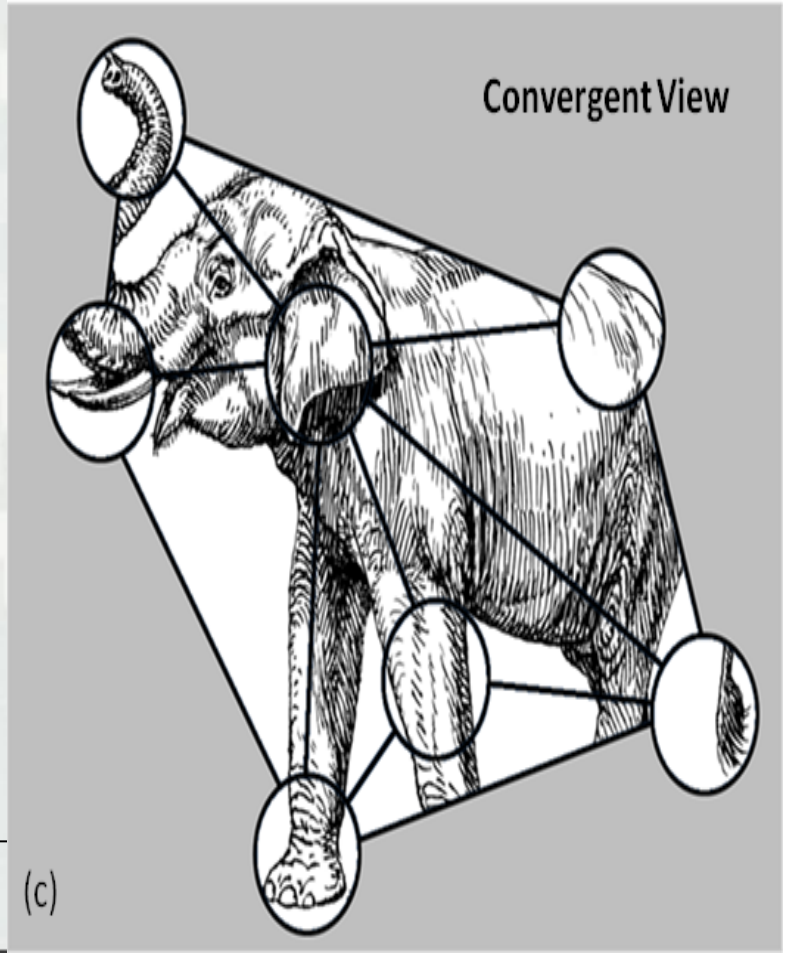
Linkov and Kelsler (2014)

Scientific Convergence: Dealing with the Elephant in the Room









Risk Management Challenges

- $Risk = Threat \times Vulnerability \times Consequence$

- Requires specific knowledge and quantification of all three components
- No temporal component
- Modern system complexity and threat uncertainty make risk management difficult and expensive.

SET EDITION: U.S. | INTERNATIONAL | MÉXICO | ARABIC

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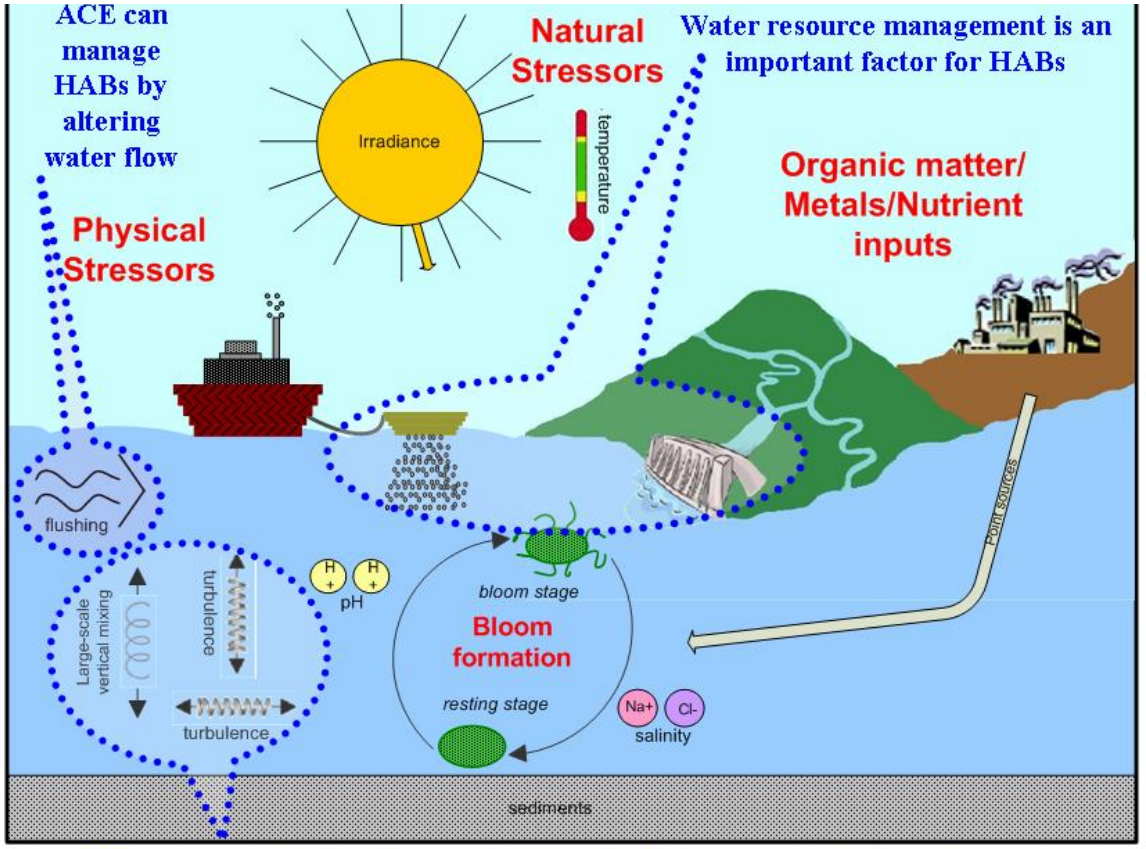
400,000 in Toledo, Ohio, water scare await test results

By **Susanna Capelouto** and **Mark Morgenstein**, CNN

updated 9:15 PM EDT, Sun August 3, 2014

Algal Blooms

Hazard?
Exposure?
Effects?



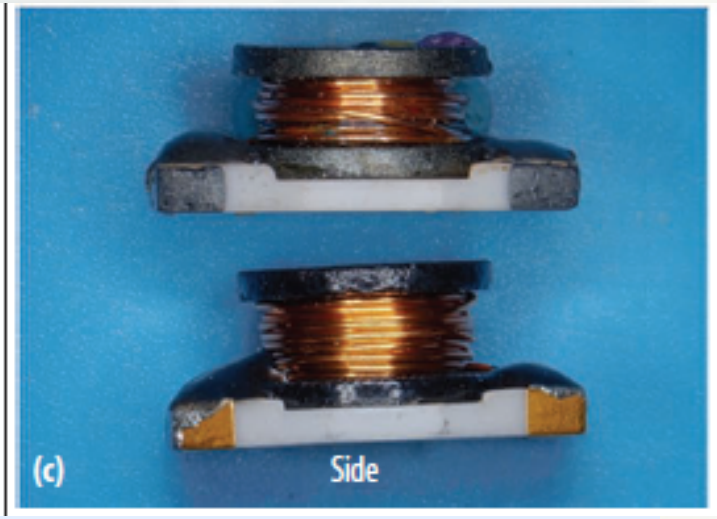
ACE can generate turbulence and mixing by altering water intake regimes and decreasing HABs.

Linkov et al., 2007

BUILDING STRONG®

Cybersecurity Risks

Hazard? Exposure? Effects?



From: Springer [SpringerAlerts@springeronline.com]
To: Linkov, Igor ERD
Cc:
Subject: [EXTERNAL] Your modified SpringerAlerts profile

Dear SpringerAlerts Subscriber,

We have received your changes to your personal profile for SpringerAlerts. To access the overview page of your profile directly please log in at springer.com/alertprofile
<http://www.springer.com/alert/urltracking.do?id=L4356358Mfd9c46

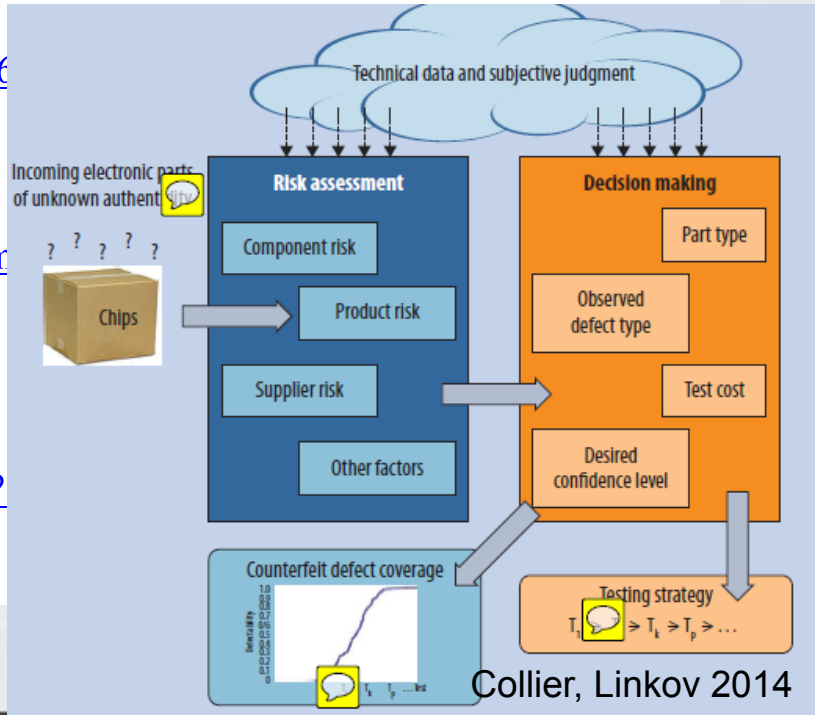
Changes to Your Journal Alerts

<http://www.springer.com/cda/content/image/cda_displayim

Added alerts

<http://www.springer.com/cda/content/image/cda_displayimage.jpg?

Journal of Zhejiang University SCIENCE A



Collier, Linkov 2014

Ebola in the USA?

Hazard?
Exposure?
Effects?

Michael McAuliff Become a fan

mike.mcauliff@huffingtonpost.com

Ebola Hearing Details Real Risks Of Deadly Disease Hitting U.S.

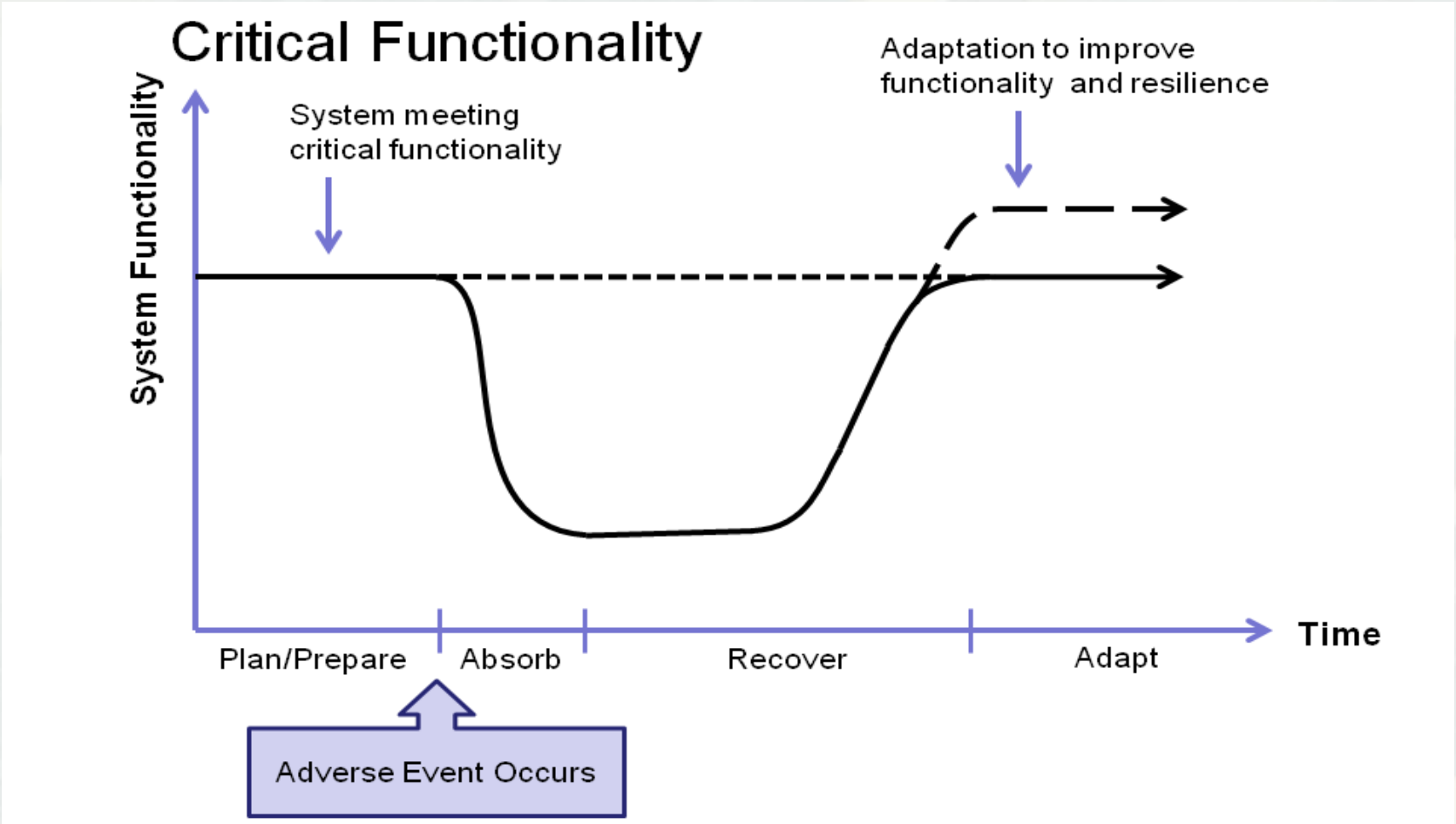
Posted: 08/07/2014 4:54 pm EDT | Updated: 08/07/2014 5:59 pm EDT

Patient tested in California for possible Ebola exposure

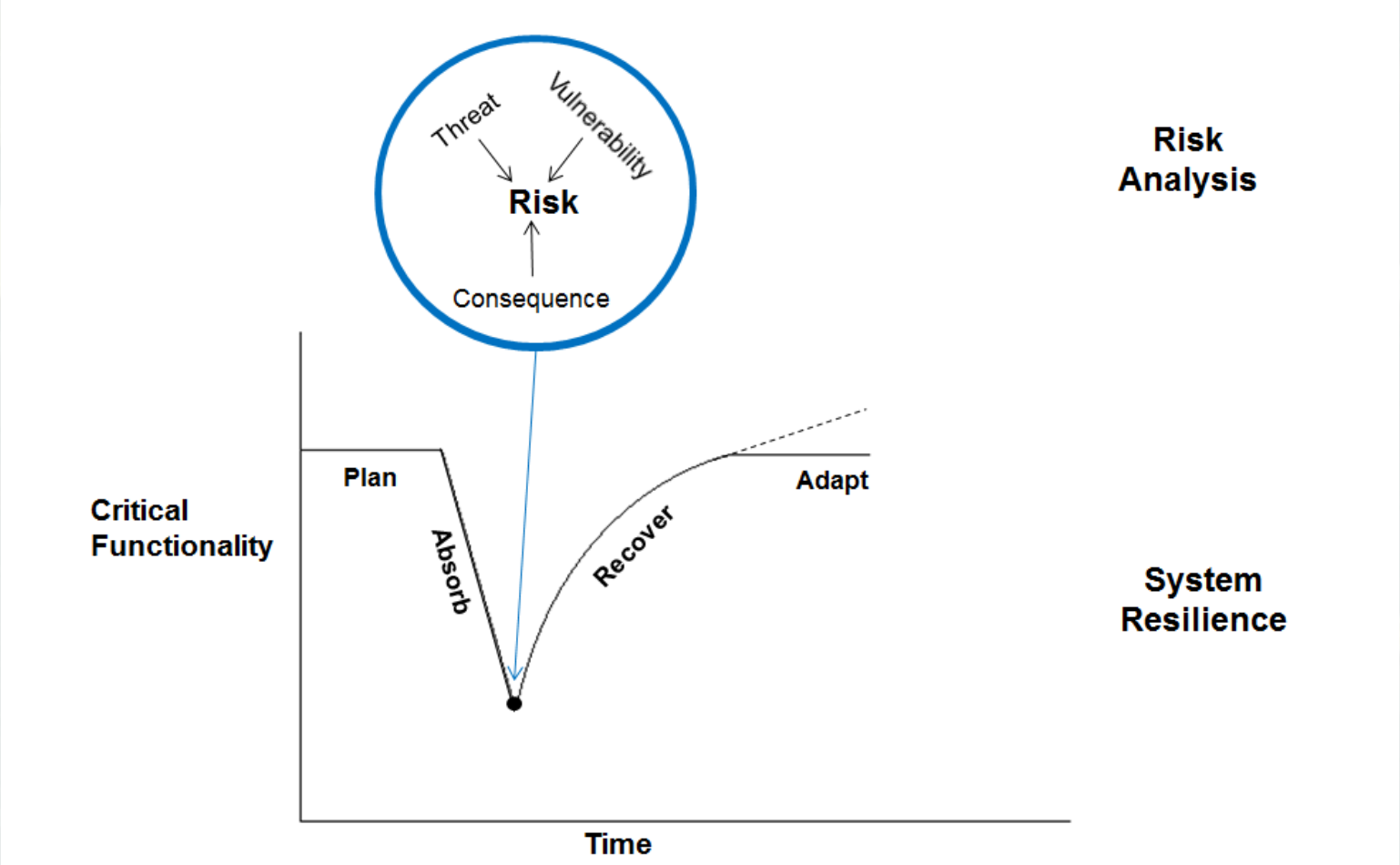
By **Laura Ly**, CNN

updated 6:53 AM EDT, Wed August 20, 2014

mrΣsilience tricks

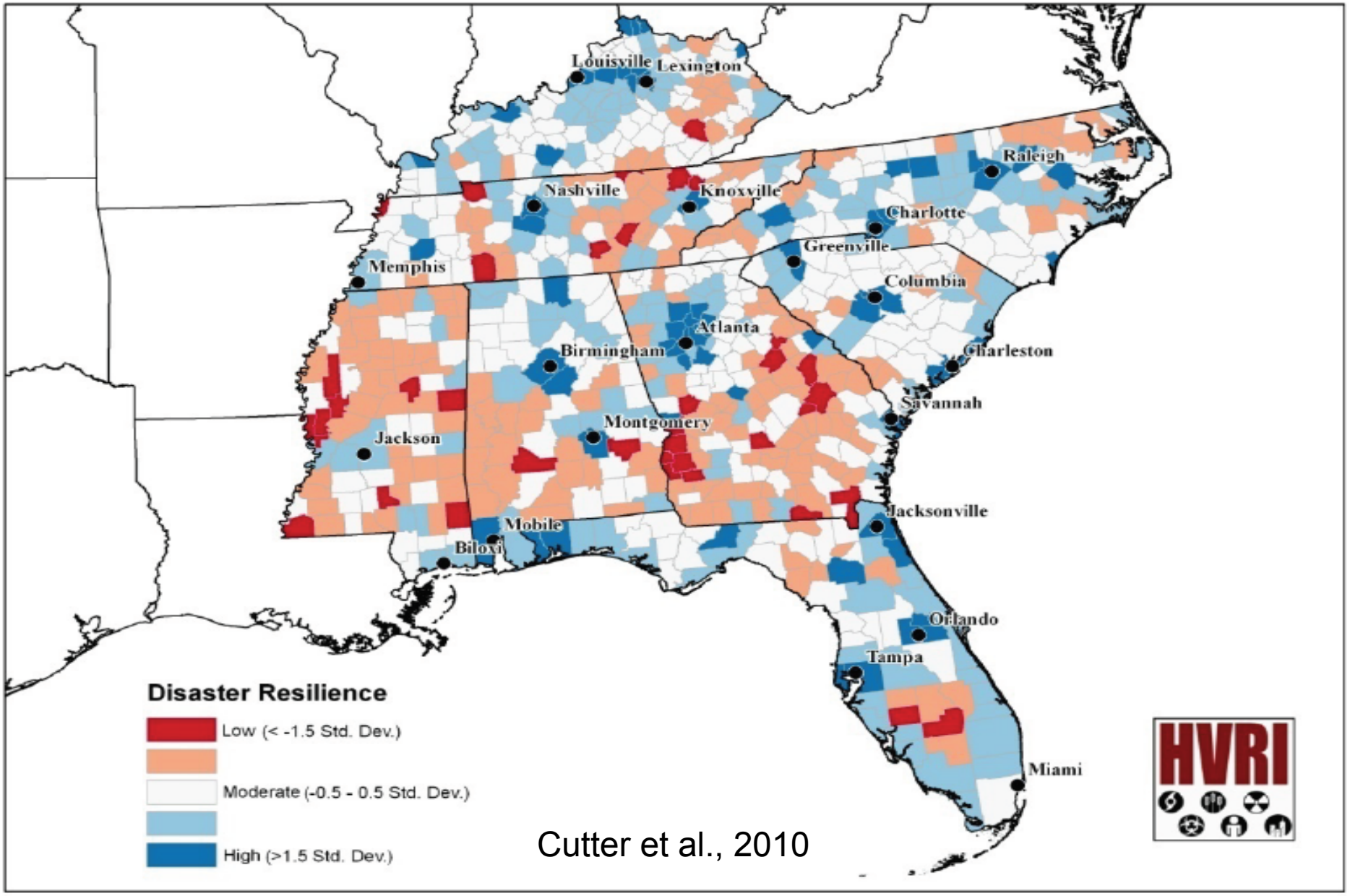


Risk Assessment is one part of Resilience

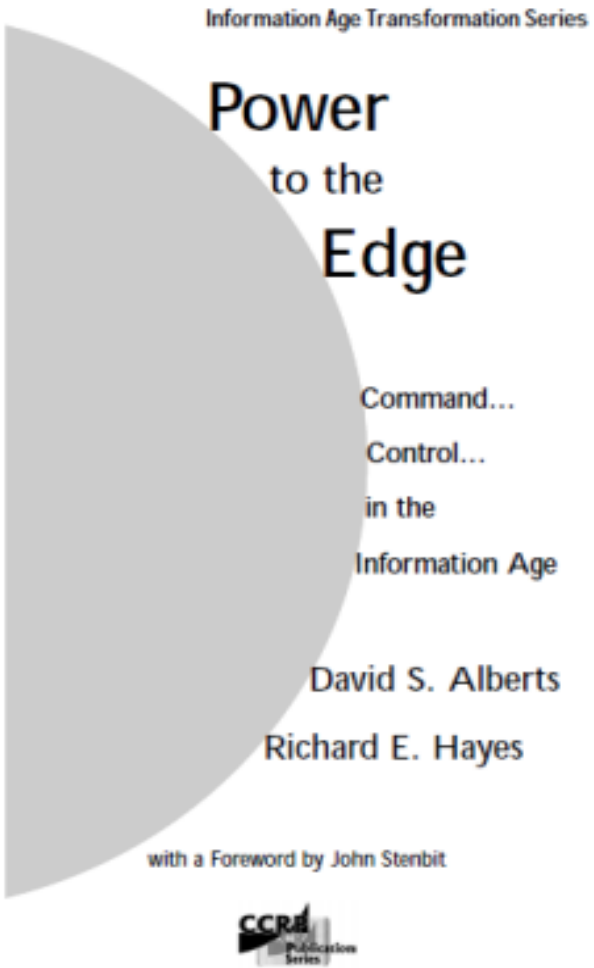


After Linkov et al, Nature Climate Change 2014

Resilience Quantification – Background



Cutter et al., 2010



Learning from Military

A highly networked system is governed by *domains of warfare* that organize system components and establish a basis for measurement.

Physical: system performance in space and time.

Information: creation, manipulation and sharing information.

Cognitive: translating, sharing, and acting upon information to enable system management.

Social: interaction, collaboration and self-synchronization between individuals and entities.

Resilience: Matrix Approach

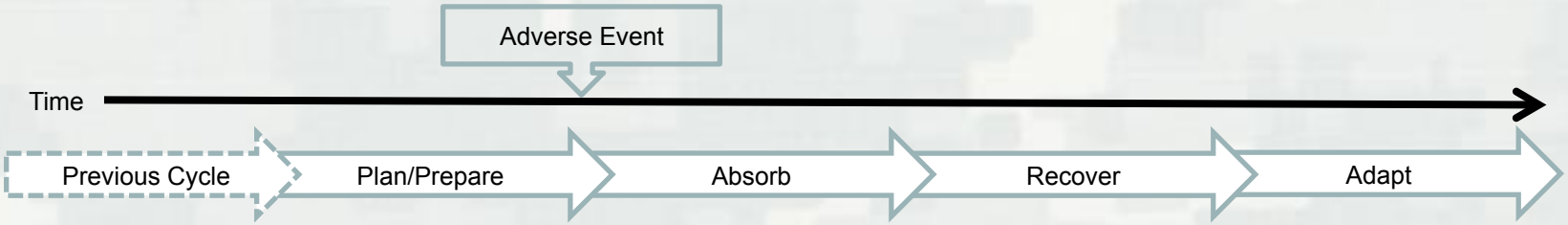
Resilience Matrix:

Analyze the functionality of each **domain** of the system across each **stage** of the event timeline

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

- Uses general metrics for measuring relative system resilience
- Different from vulnerability assessment – threats unknown
- Useful for identifying weak areas and prioritizing investment to improve overall resilience

General Form of Resilience Matrix



	Plan/Prepare	Absorb	Recover	Adapt
Physical	• State and capability of equipment and personnel, network structure	• Event recognition and system performance to maintain function	• System changes to recover previous functionality	• Changes to improve system resilience
Information	• Data preparation, presentation, analysis, and storage	• Real-time assessment of functionality, anticipation of cascading losses and event closure	• Data use to track recovery progress and anticipate recovery scenarios	• Creation and improvement of data storage and use protocols
Cognitive	• System design and operation decisions, with anticipation of adverse events	• Contingency protocols and proactive event management	• Recovery decision-making and communication	• Design of new system configurations, objectives, and decision criteria
Social	• Social network, social capital, institutional and cultural norms, and training	• Resourceful and accessible personnel and social institutions for event response	• Teamwork and knowledge sharing to enhance system recovery	• Addition of or changes to institutions, policies, training programs, and culture

From Linkov et al, Env. Sci. & Tech 2013

Assessment using Decision Analysis

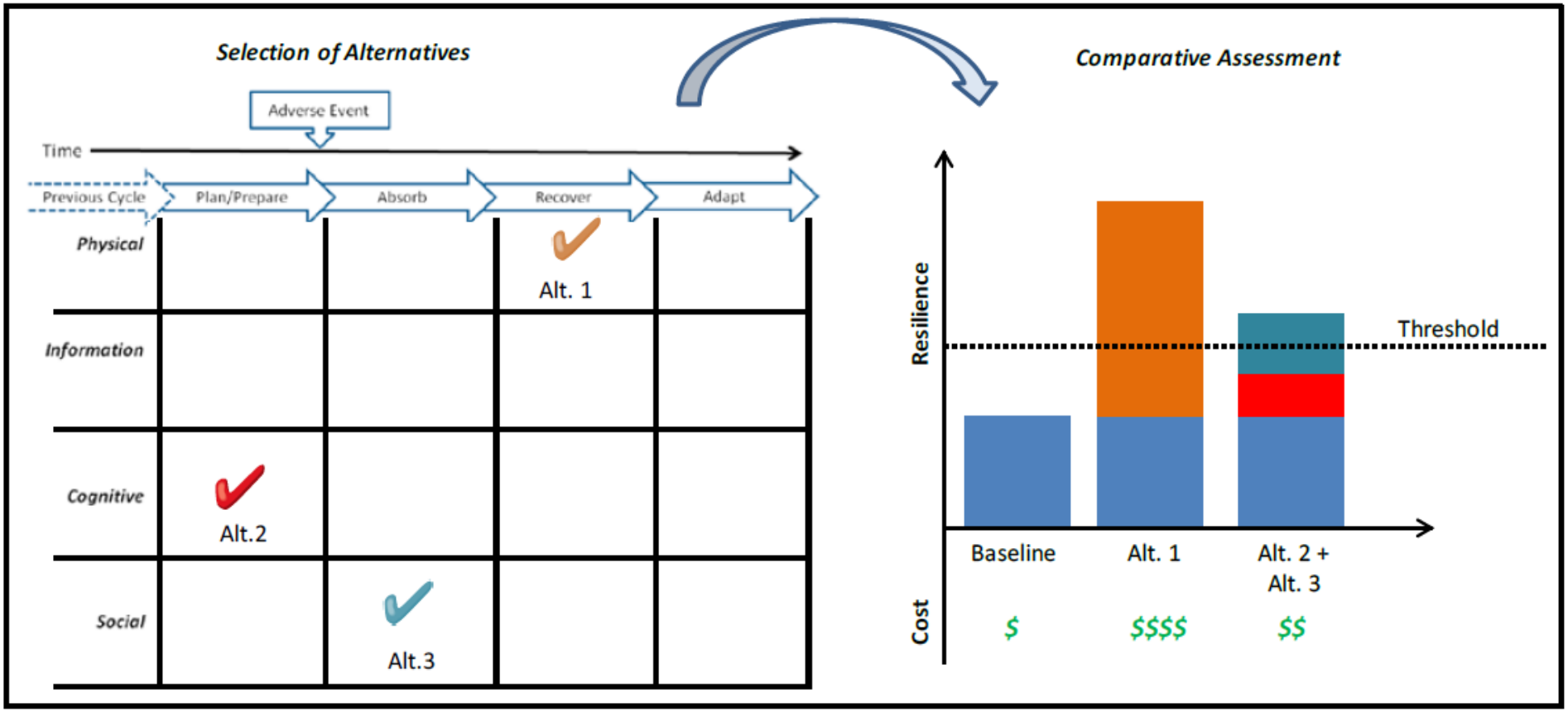


Figure 5: Comparative Assessment of Resilience-Enhancing Alternatives

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

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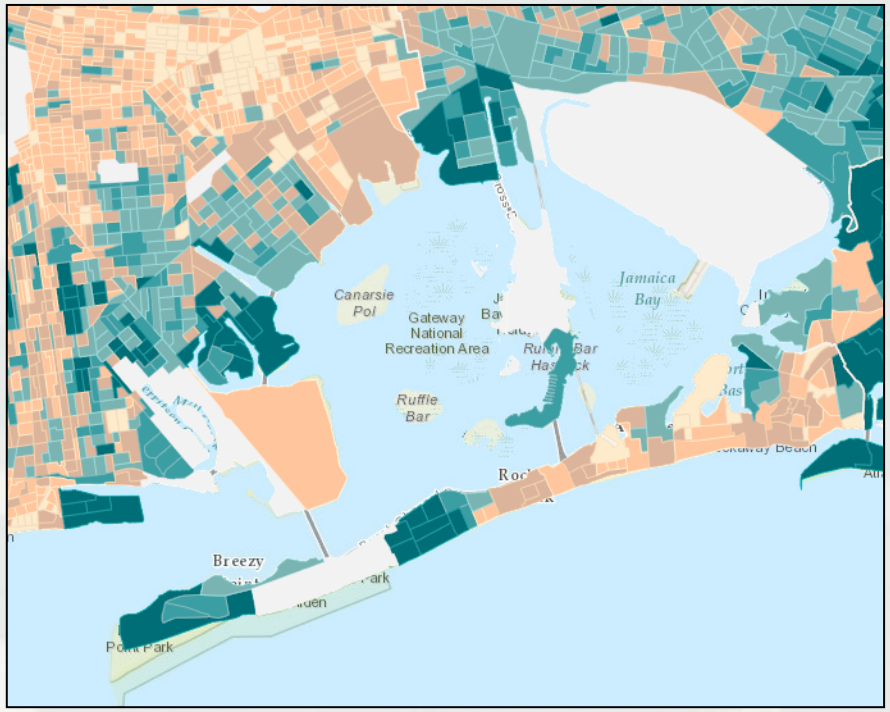
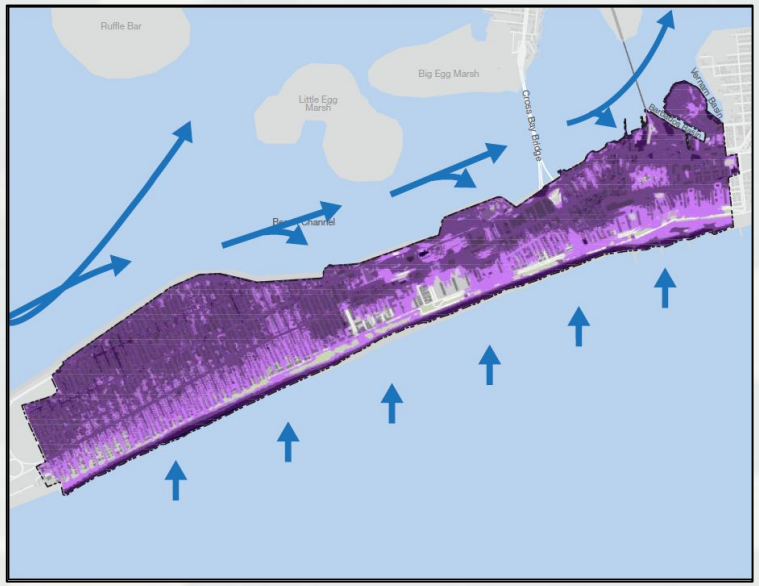
Resilience Matrix: Jamaica Bay Case Study



- More than $82,000
- $68,001 to $82,000
- $53,001 to $68,000
- $39,001 to $53,000 (US median: $50,157)
- $24,001 to $39,000
- $24,000 or less
- No households



Superstorm Sandy Flood Depths

- < 3 ft
- 3-6 ft
- 6-12 ft
- >12 ft
- Wave Action & Water Movement

Project Evaluation

- Baseline assessment can be used to evaluate proposed projects

	Prepare	Absorb	Recover	Adapt
Physical	71	16	60	10
Information	63	45	21	18
Cognitive	90	49	38	27
Social	82	54	12	52

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Project 1

	Prepare	Absorb	Recover	Adapt
Physical	+10	+18	+9	+32
Information	+8		+17	
Cognitive				
Social				

	Prepare	Absorb	Recover	Adapt
Physical	81	34	69	42
Information	71	45	38	18
Cognitive	90	49	38	27
Social	82	54	12	52

51

Project 2

	Prepare	Absorb	Recover	Adapt
Physical				
Information		+5	+15	+22
Cognitive				
Social	+3		+12	+21

	Prepare	Absorb	Recover	Adapt
Physical	71	6	60	10
Information	63	50	36	40
Cognitive	90	49	38	27
Social	85	54	24	73

47

*Projects may have (+) or (-) in other matricies

Network Science

We quantify resilience by using network science approach by considering the different domains as interdependent multiplex networks.

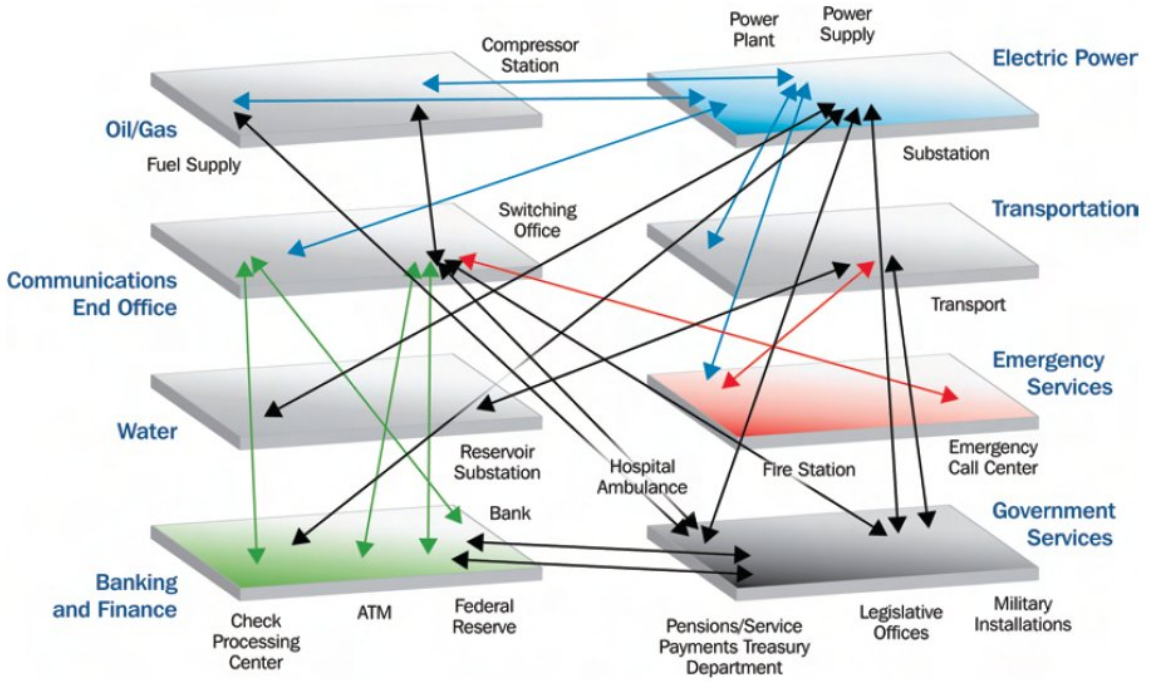
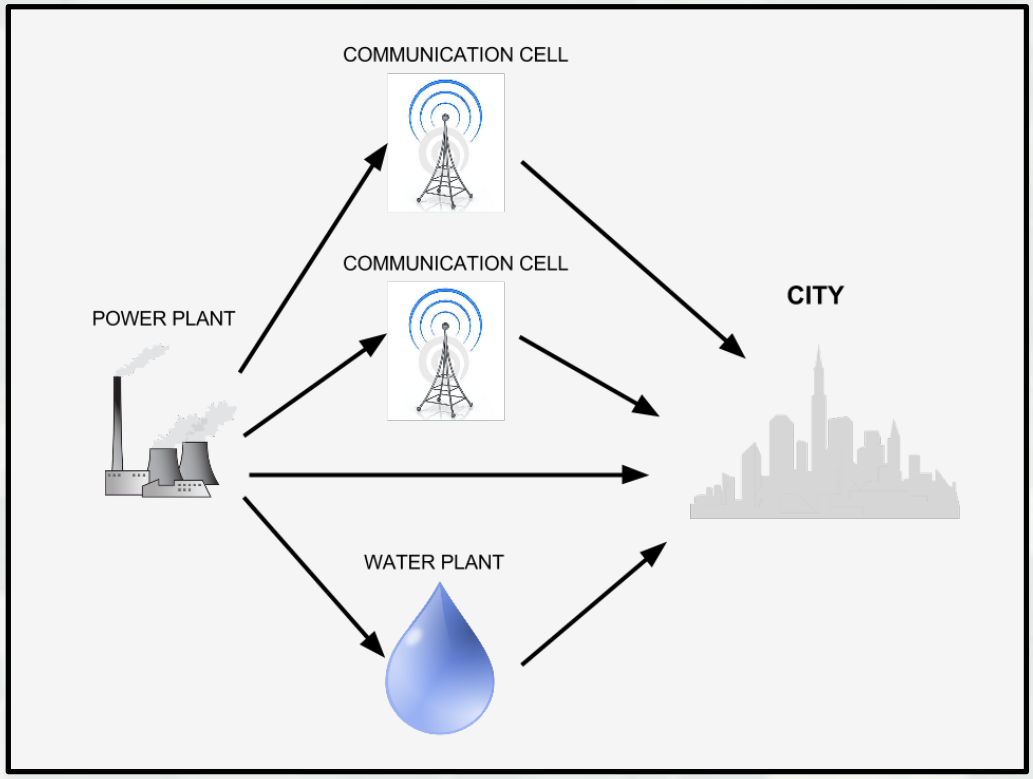


FIGURE 3.1 Connections and interdependencies across the economy. Schematic showing the interconnected infrastructures and their qualitative dependencies and interdependencies. SOURCE: Department of Homeland Security, National Infrastructure Protection Plan, available at http://www.dhs.gov/xprevprot/programs/editorial_0827.shtm.

Resilience and Network Science

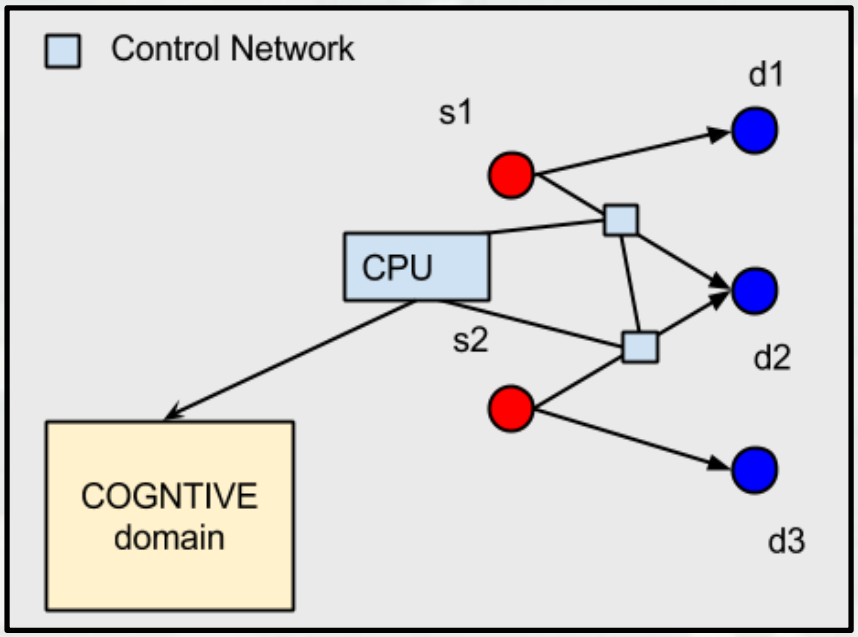


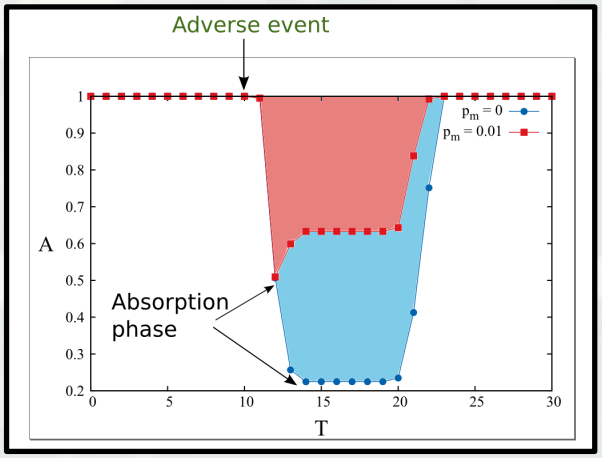
A simple illustration of the model, in which a city depends on Power, Mobile Communication and Water services, the latter of which are in turn dependent on Electrical power.

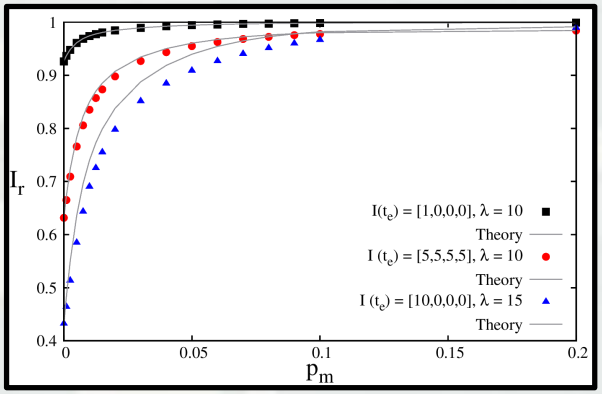
Here:

- **Power Plant**: supplier
- **City**: demander
- **Cell, Water**: both suppliers and demanders

Approach to Quantifying Resilience





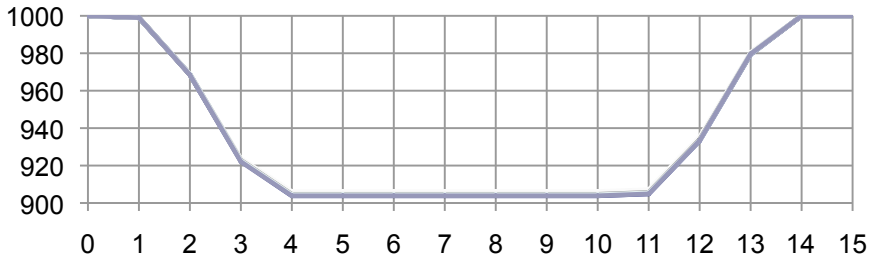


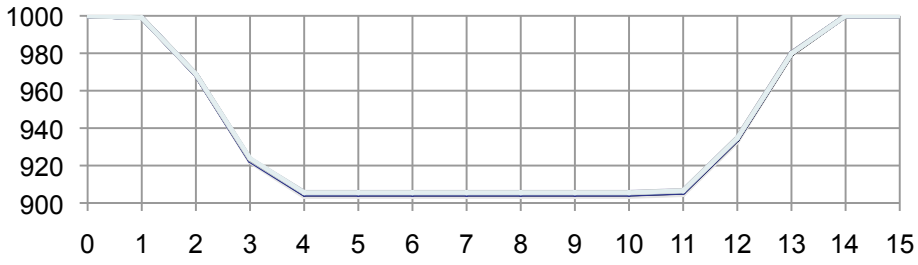
Preliminary Results

Instant switching

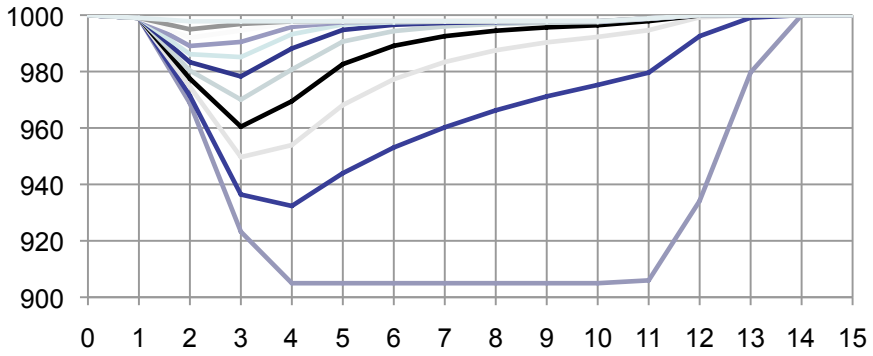
Next step switching

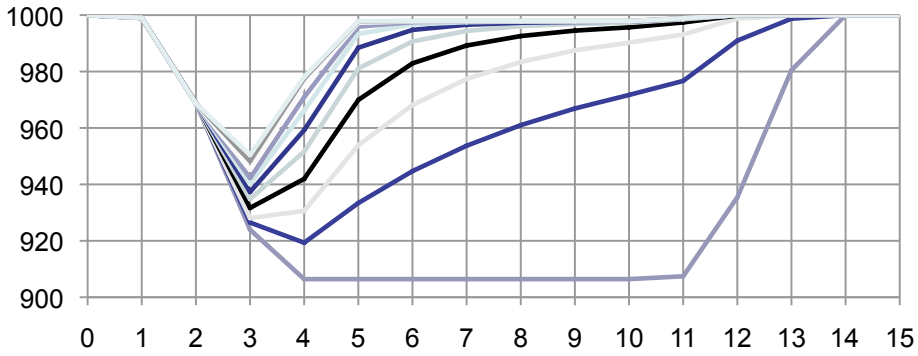
No additional links: $P_{multiple = 0}$





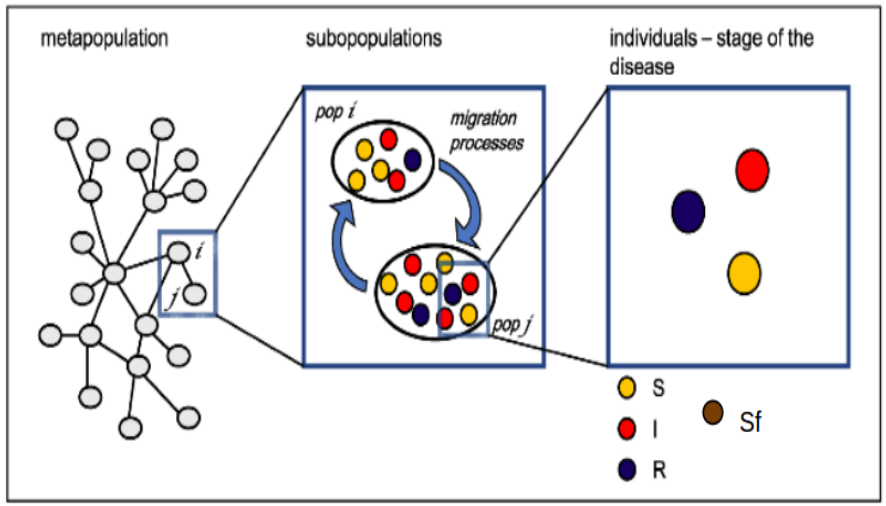
Additional links enabled: $P_{multiple = 0.1}$





Resilience and Epidemic Spread

The resilience is defined as a competition process between commuters and disease spreading in a metapopulation system.



Three Behavioral Disease models

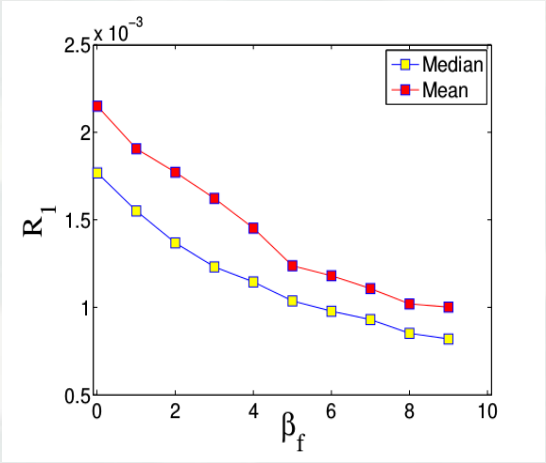
1. Local Information

2. Global Information

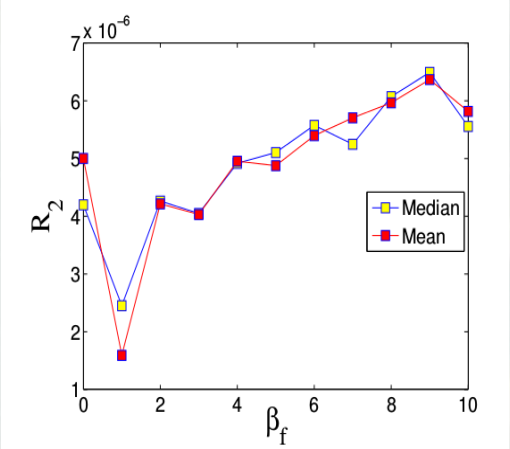
3. Local, belief-based spread of the fear of the disease

Preliminary Results

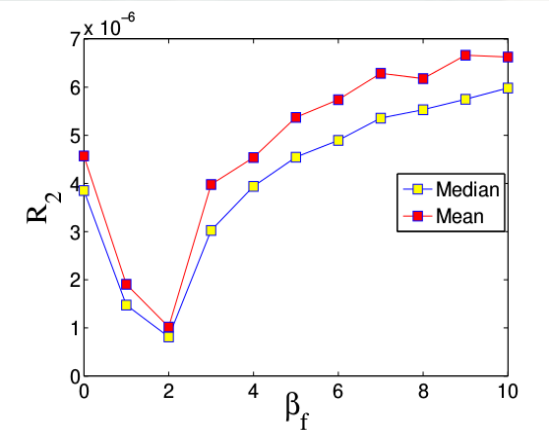
MODEL 1



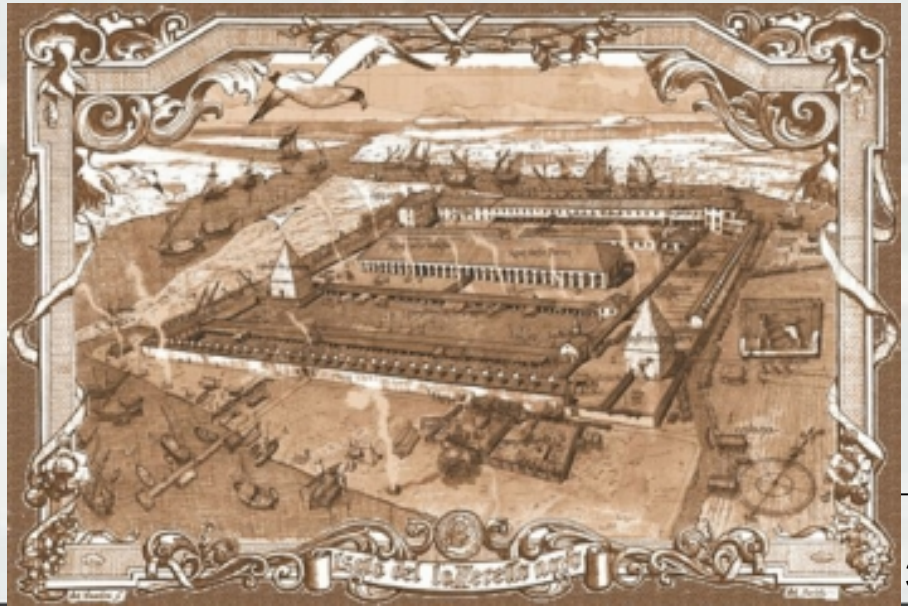
MODEL 2



MODEL 3

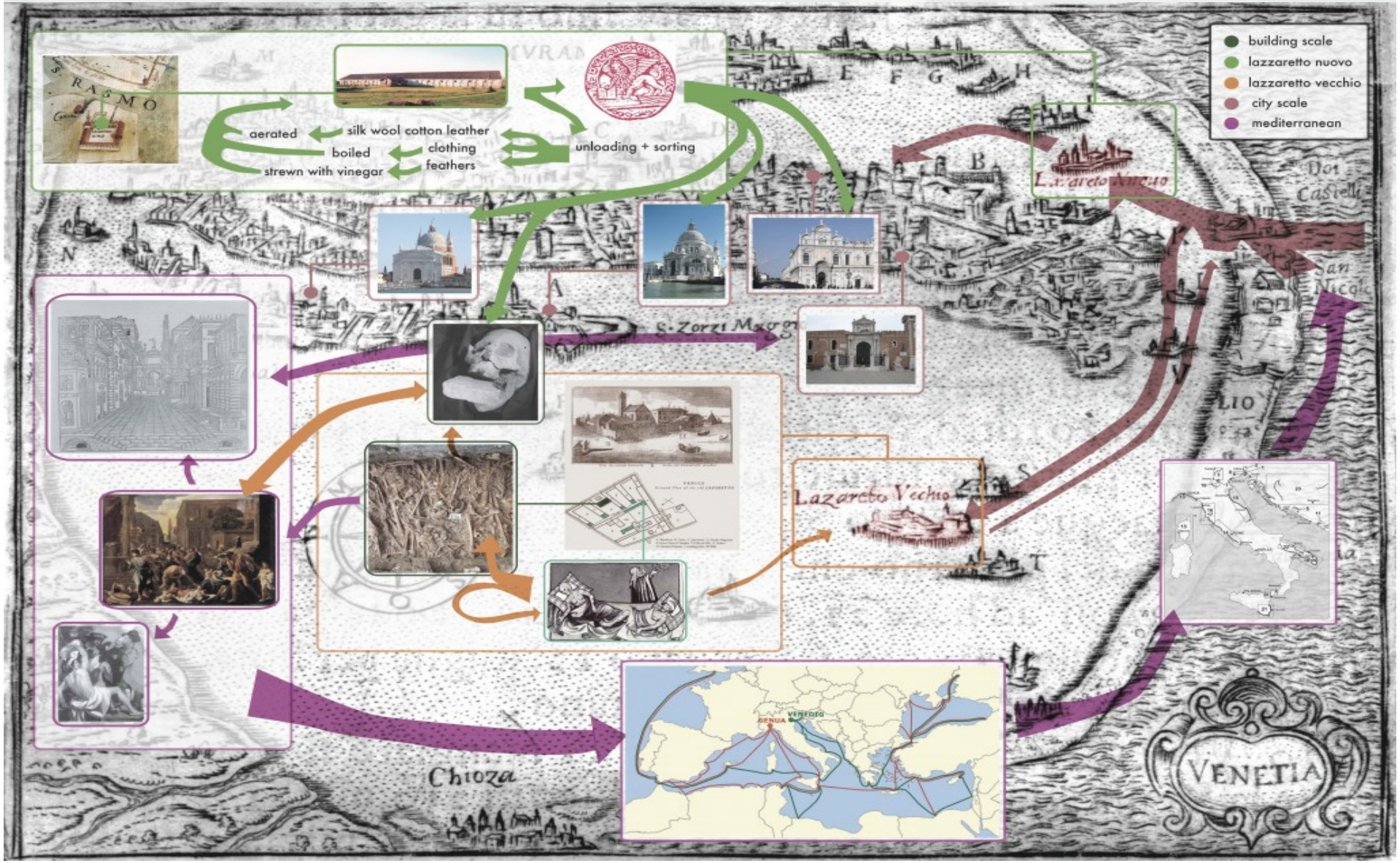


Resilience in Venice?



What Happened in Venice?

Linkov et al., 2014



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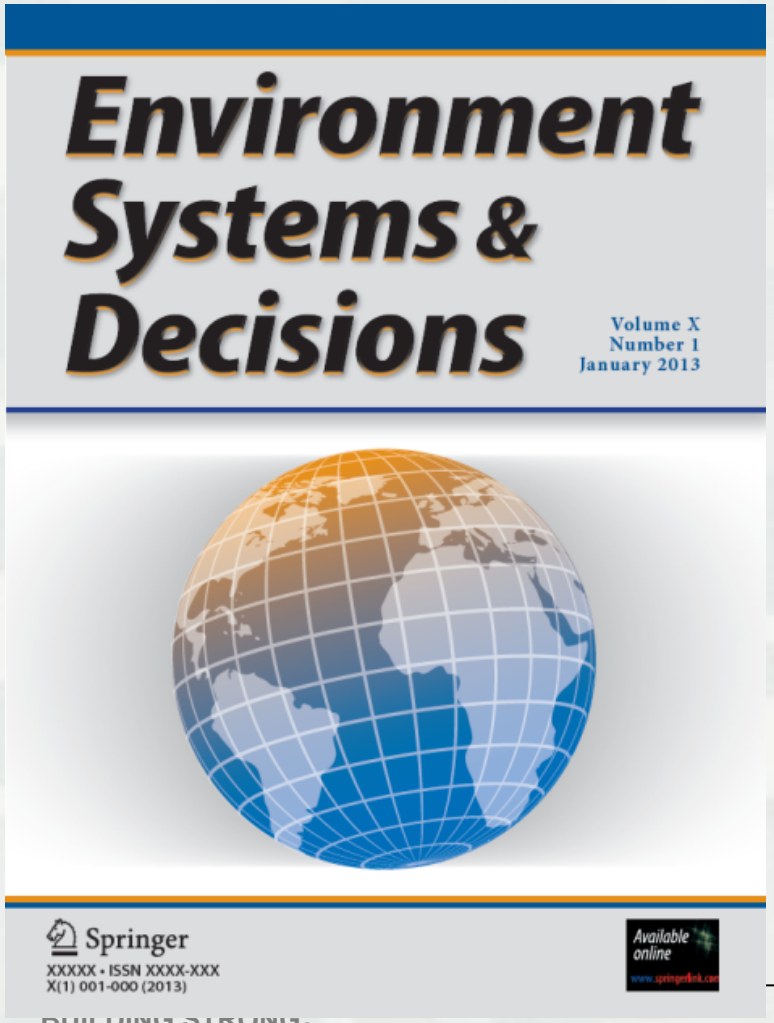
Call for Papers: Springer's Environment, Systems and Decisions



ESD provides a catalyst for research and innovation in cross-disciplinary and trans-disciplinary methods of decision analysis, systems analysis, risk assessment, risk management, risk communication, policy analysis, environmental analysis, economic analysis, engineering, and the social sciences.

The Society for Risk Analysis invites you to join us to the

World Congress on Risk 2015 in Singapore

–

Risk Analysis for Sustainable Innovation.

Save the Date:

July 19-23, 2015

Call for Participation: SRA World Congress on Risk IV

In 2003, the International Society for Risk Analysis (SRA) launched a series of World Congresses on Risk, in partnership with other scientific societies, professional organizations, governments, corporations, and foundations. SRA hosted the first World Congress on Risk in Brussels, Belgium, in 2003, and has held two subsequent World Congresses since that time.

SRA will hold the fourth in the series of World Congresses on Risk from the 19th to 23rd of July 2015 in Singapore. The theme of the World Congress on Risk 2015 is: "Risk Analysis for Sustainable Innovation." By selecting this theme, SRA hopes to focus attention on risks of importance to global development with specific attention to the experiences of developing countries, in such domains as:

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Risk and Resilience: Political Importance and Challenge

The White House

Office of the Press Secretary

For Immediate Release Oct

Presidential Proclamation -- Critical Infrastructure Security and Resilience Month, 2013

CRITICAL INFRASTRUCTURE SECURITY AND RESILIENCE MONTH, 2013

- - - - - - -

BY THE PRESIDENT OF THE UNITED STATES OF AMERICA

A PROCLAMATION

Over the last few decades, our Nation has grown increasingly dependent on critical infrastructure, the backbone of our national and economic security. America's critical infrastructure is complex and diverse, combining systems in both cyberspace and the physical world -- from power plants, bridges, and interstates to Federal buildings and the massive electrical grids that power our Nation. During Critical Infrastructure Security and Resilience Month, we resolve to remain vigilant against foreign and domestic threats, and work together to further secure our vital assets, systems, and networks.

Executive Order:

"resilience" means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

Jamaica Bay Demonstration

Goal

- Quantitative, comprehensive assessment of community resilience to inform project prioritization efforts.

Motivation

- Provide context to traditional risk-based engineering

NY Rising, Jamaica Bay Communities	743 pgs
NYC Special Initiative for Rebuilding and Resilience	34 pgs
Building Resiliency Task Force	42 pgs
Structure of Coastal Resilience, Jamaica Bay	52 pgs
2100 Commission	206 pgs

Outline

1. Define System and Threats
2. Identify Critical Functions of the System
3. Performance Indicators
4. Performance Scores
5. Prioritize Efforts
6. Critical Function Weights
7. Project Evaluation

1. System and Threats

System

Jamaica Bay Wildlife Refuge
and Surrounding Communities

Threats

Coastal storms (hurricanes,
tropical storms, nor'easters)

Corps Missions:
coastal protection, ecological restoration

2. Identify Critical Functions

- Identify critical functions of the communities:
  - Transportation
  - Sanitation
  - Access to Food and Water
  - Housing/Shelter
  - Support Commerce
  - Recreation/Community
  - Electrical Power
  - Health Services
- Identify critical functions of the bay:
  - Wildlife Habitat
  - Recreation/Education

3. Performance Indicators

- Experts identify indicators of performance for each cell of the matrix for each critical function.
- Based on resilience properties:
  - Redundancy
  - Flexibility
  - Modularity
  - Robustness
  - Resourcefulness
  - Distributed
  - etc.

Housing

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

Transportation

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

Wildlife Habitat

	Prepare	Absorb	Recover	Adapt
Physical				
Information				
Cognitive				
Social				

4. Performance Scores

- Identify specific metrics (qualitative or quantitative) or proxies for the capability of the system to perform in each cell of the matrix.
- Examples:

	Raw Value	Normalized Score
Participation in Notify NYC Alert System:	48%	7.5
Existing dunes/berms:	8’	6
Access to debris removal equipment:	med-low	2

5. Prioritize Efforts

- Use matrix form to identify weaknesses in resilience.
- Ex:

Transportation Resilience

	Prepare	Absorb	Recover	Adapt
Physical	90%	81%	62%	10%
Information	80%	19%	23%	75%
Cognitive	68%	95%	22%	40%
Social	76%	88%	92%	34%

(Hypothetical Values)

6. Critical Function Weights

- The matrix approach is broadly applicable but can be tailored to specific management goals.

Ex: USACE is budgeted/mandated to protect people and property and support ecosystem health. Therefore, apply weights to critical functions:

Housing	30%
Transportation	20%
Wildlife Habitat	20%
Recreation	10%
Electrical Power	10%
Health Services	10% …

7. Project Evaluation

Baseline Resilience Score used to…

- Compare mutually exclusive projects
- Develop portfolio of projects
- Identify system gaps not addressed by any projects

… but full matrix provides best information to guide resilience management.

Risk (or Consequence) Quantification

Benchmarks – Reflection of "Acceptable" Risk

$$HQ = \frac{MediaConcentration}{Benchmark}$$

Hazard Quotient (Threat-Specific)

$$HI = \sum_i HQ_i$$

Hazard Index (Cumulative)

No benchmarks for Emerging Threats!

Traditional Risk Assessment

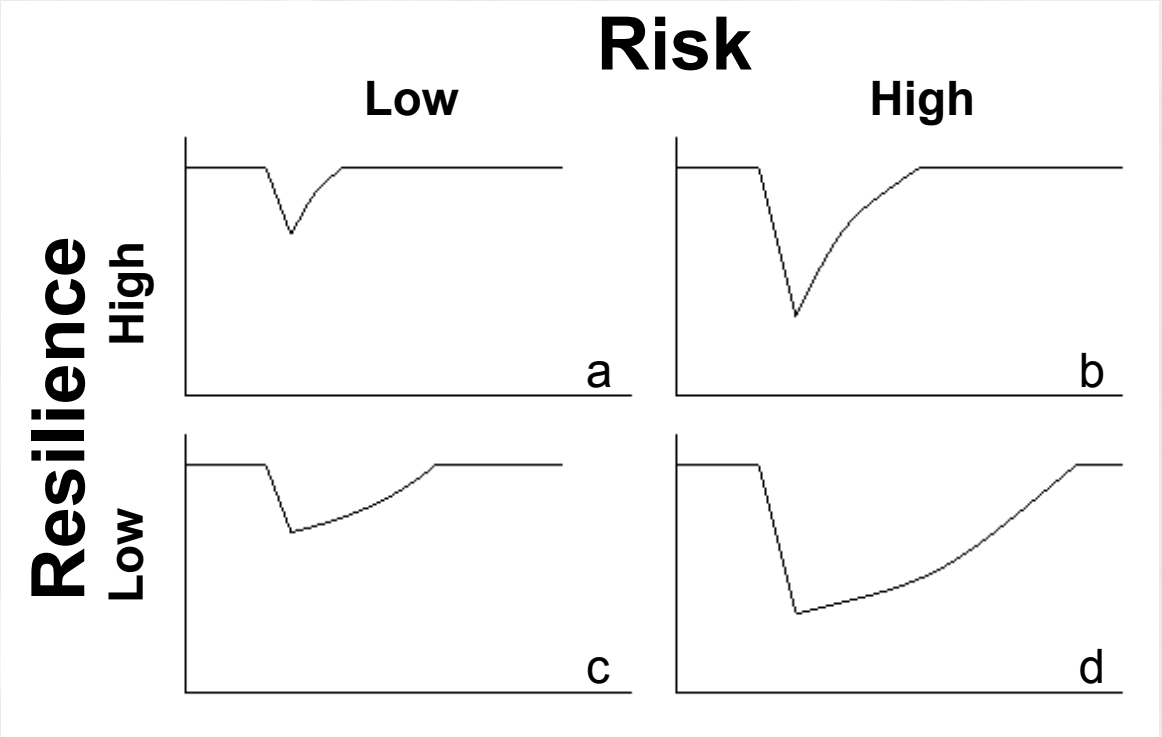
- **Example: Drinking contaminated water**
- **RA Goal: Will exposure to a contaminant cause adverse health effects?**
- **Quantification of Hazard and Exposure (or Threat and Vulnerability) based on data (often limited and imprecise) regarding toxic effects of materials on people and animals**
- **State-of-the-science hazard and exposure assessment is not very far advanced**
  - **Two general bodies of data**
    - **Toxicity studies in animals**
    - **Epidemiologic studies in humans**
    - **Exposure Scenarios**
  - **Uncertainties can be tremendously large**

Risk Management Challenges

- $Risk = Threat \times Vulnerability \times Consequence$

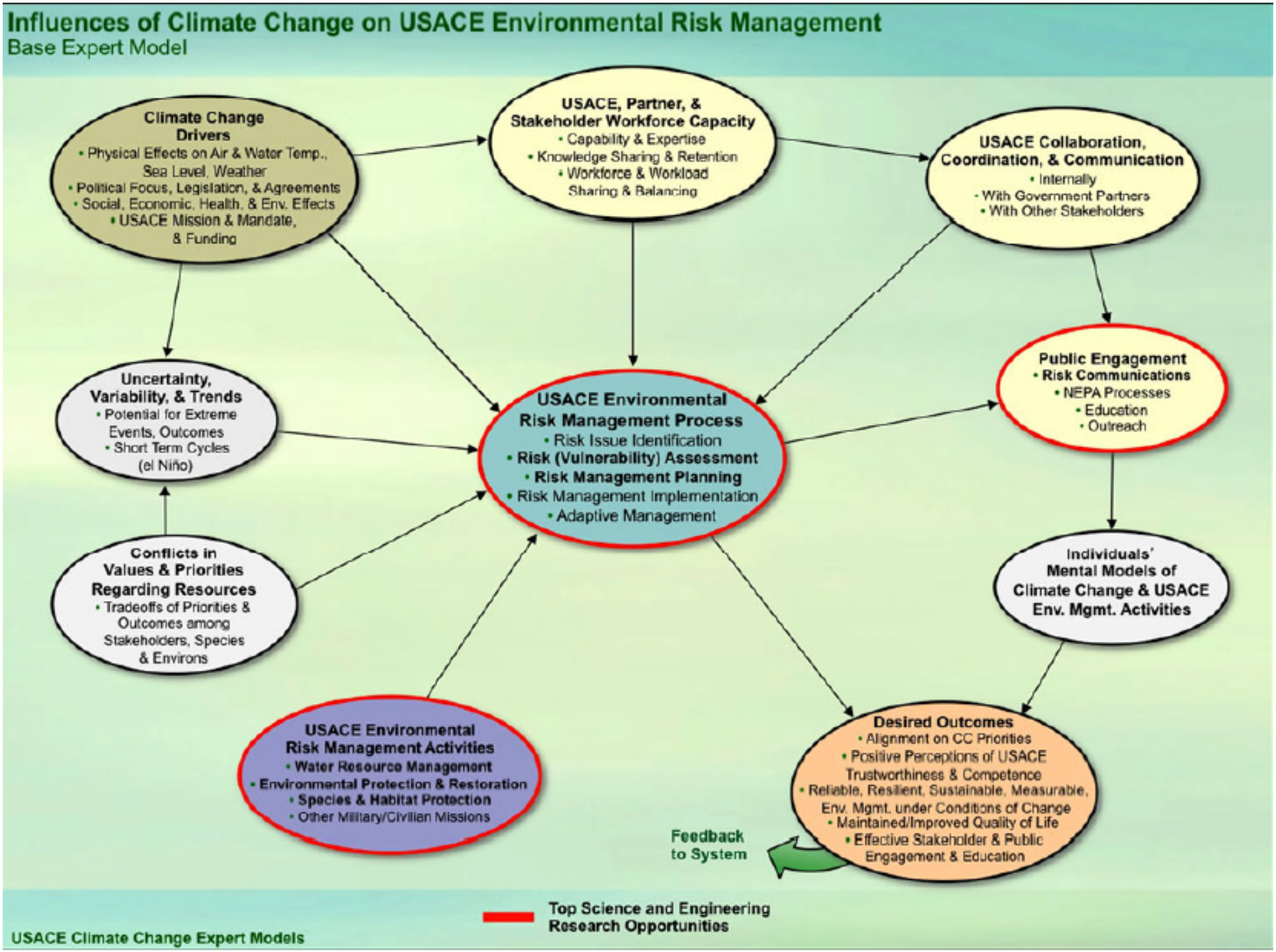
- Requires specific knowledge and quantification of all three components
- No temporal component
- Modern system complexity and threat uncertainty make risk management difficult and expensive.

Importance of Recovery



Traditional risk management focuses on planning and reducing vulnerabilities. Resilience management puts additional emphasis on speeding recovery and facilitating adaptation.

After Linkov et al, Nature Climate Change 2014


Influences of Climate Change on USACE Environmental Risk Management
Base Expert Model
Climate Change Drivers
• Physical Effects on Air & Water Temp., Sea Level, Weather
• Political Focus, Legislation, & Agreements
• Social, Economic, Health, & Env. Effects
• USACE Mission & Mandate, & Funding
USACE, Partner, & Stakeholder Workforce Capacity
• Capability & Expertise
• Knowledge Sharing & Retention
• Workforce & Workload Sharing & Balancing
USACE Collaboration, Coordination, & Communication
• Internally
• With Government Partners
• With Other Stakeholders
Uncertainty, Variability, & Trends
• Potential for Extreme Events, Outcomes
• Short Term Cycles (el Niño)
USACE Environmental Risk Management Process
• Risk Issue Identification
• Risk (Vulnerability) Assessment
• Risk Management Planning
• Risk Management Implementation
• Adaptive Management
Public Engagement
• Risk Communications
• NEPA Processes
• Education
• Outreach
Conflicts in Values & Priorities Regarding Resources
• Tradeoffs of Priorities & Outcomes among Stakeholders, Species & Environs
Individuals' Mental Models of Climate Change & USACE Env. Mgmt. Activities
USACE Environmental Risk Management Activities
• Water Resource Management
• Environmental Protection & Restoration
• Species & Habitat Protection
• Other Military/Civilian Missions
Desired Outcomes
• Alignment on CC Priorities
• Positive Perceptions of USACE Trustworthiness & Competence
• Reliable, Resilient, Sustainable, Measurable, Env. Mgmt. under Conditions of Change
• Maintained/Improved Quality of Life
• Effective Stakeholder & Public Engagement & Education
Feedback to System
Top Science and Engineering Research Opportunities
USACE Climate Change Expert Models