The Risk of Not Being Resilient

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

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Risk Assessment and Management

Risk = Threat × Vulnerability × 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.
Innovative solutions for a safer, better world

EMERGING THREATS

- Generated data about threats
- Increasing gap requires innovative management

CHALLENGE

- Further investment in risk will only yield marginal returns
- Governments and industry should value and encourage resilience thinking

COSTS OF BUYING DOWN RISK
Resilience Definitions

- Definition released by OECD Public Governance Committee:
  
  ▶ “...the ability to resist, absorb, recover from or successfully adapt to adversity or a change in conditions"

- Consistent with the National Academies of Science (NAS) definition of resilience:
  
  ▶ “...the ability to plan and prepare for, absorb, recover from, and adapt to adverse events”

- OECD directorates indicate that resilience needed to combat economic, social, and environmental risks on social systems
How Resilience can Help?

Water exclusion strategies: Building resistance

Water entry strategies: Building resilience

OECD’s Role

Provide guidance for unique considerations within each governance jurisdiction:

- What rules/regulations exist, and how do they capture the process and products of emerging risks?

- How do the unique political and institutional frameworks of a given jurisdiction affect emerging risk governance?

- Do these regulatory differences influence the perception of risk by local experts and regulators?

After Trump, Linkov et al 2016
Regulatory change is typically slow in most democracies, particularly in the case of emerging technologies.


US Army Engineer Research and Development Center

2500 Employees

Over 1000 engineers and scientists 28% PhDs; 43% MS degrees, $1.3B Budget Annually

Cold Regions Research Engineering Laboratory (Hanover, NH)
Risk and Decision Science Team (Boston, MA)
Topographic Engineering Center (Alexandria, VA)
Construction Engineering Research Laboratory (Champaign, IL)
Environmental Laboratory
Coastal & Hydraulics Laboratory
Geotechnical & Structures Laboratory
Information Technology Laboratory
Headquarters (Vicksburg, MS)
Global Trends and Military

**Globalization II**
- Developed Rules
- Mature Markets
- Narrowing Customer Base
- Security=Defense

**Globalization III**
- Emerging Rules
- Market Opportunities
- New Customer Base Emerging
- Security=All Else+Defense

**Industrial Age**
- Long Cycle Time
- Well Developed Tools/Processes
- Deliberate Planning
- Deconflicted Joint
- Tautrol Interoperability

**Information Age**
- Short Cycle Time
- New Competencies
- Adaptive Planning
- Integrated Joint
- Interdependent

Military Systems Doctrine as a Foundation for Resilience

Command and Control actions in 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: Political Importance and Challenge

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

Resilience Formulation

After Connelly et al., 2016
Component vs. System

Risk Assessment – Focus on Finding Weak Link:

Resilience -- Management at System Level

- Anticipate weak links and be ready to recover. *Ex: sand to close new inlets.*
- Provide diverse and redundant protection. *Ex: buried seawall AND beach/dune system.*
- Provide accessible information for rapid decision-making. *Ex: raised homes, evacuation routes.*
Critical Function – Stakeholder Engagement

- System has multiple functions, but not all of them are equally important
  - Stakeholder elicitation is required
  - Prioritization of project alternatives
  - Values, preferences
  - Public education

Risk and Resilience: Thresholds

After Linkov et al, Nature Climate Change 2014
Importance of Recovery

From Linkov et al, Nature Climate Change 2014

Quantifying Resilience - Resilience Matrix

System Domains

Disruptive Event Stages

Scale

Home Neighborhood Town County Region State Country
### General Form of Resilience Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Absorb</th>
<th>Recover</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Cycle</td>
<td>State and capability of equipment and personnel, network structure</td>
<td>Event recognition and system performance to maintain function</td>
<td>System changes to recover previous functionality</td>
</tr>
<tr>
<td>Plan/Prepare</td>
<td>Data preparation, presentation, analysis, and storage</td>
<td>Real-time assessment of functionality, anticipation of cascading losses and event closure</td>
<td>Data use to track recovery progress and anticipate recovery scenarios</td>
</tr>
<tr>
<td>Absorb</td>
<td>System design and operation decisions, with anticipation of adverse events</td>
<td>Contingency protocols and proactive event management</td>
<td>Recovery decision-making and communication</td>
</tr>
<tr>
<td>Recover</td>
<td>Social network, social capital, institutional and cultural norms, and training</td>
<td>Resourceful and accessible personnel and social institutions for event response</td>
<td>Teamwork and knowledge sharing to enhance system recovery</td>
</tr>
</tbody>
</table>

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

### Resilience at OECD

<table>
<thead>
<tr>
<th>OECD Directorate</th>
<th>Document</th>
<th>Plan</th>
<th>Absorb</th>
<th>Recover</th>
<th>Adapt</th>
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<tbody>
<tr>
<td>ITF</td>
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<td>ED</td>
<td>ENV/EPOC/WPCD(2016a)</td>
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<td>IEA</td>
<td>OECD/IEA, 2015</td>
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<td>DCD-DAC/R3(2016a)#R1</td>
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<td>OECD (2016b)</td>
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<td>OECD (2015)</td>
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<td>DGT5</td>
<td>COM/EC/CP/WP1-DGTLA/WP1 (2017)</td>
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<td>DGT6</td>
<td>OECD (2011)</td>
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<td></td>
<td>OECD (2014a)</td>
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<td>GOV/RDPC/URR(2016)</td>
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**OECD Directorates Resiliency Involvement.** OECD directorate publications denoted as they discuss the four stages of resilience “directly” vs. “indirectly,” or not at all.
### Discussion of Quantitative Approaches

<table>
<thead>
<tr>
<th>OECD Directorate</th>
<th>OECD Directorate Publications</th>
<th>Quantitative Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITF</td>
<td>(Lo, 2017)</td>
<td>Maritime Safety Analysis</td>
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<tr>
<td>EDS</td>
<td>ENV/DP/OC/NCPED (2018b)</td>
<td>Vagunility, Associated Economic Analysis, Cost-Benefit Analysis, Climate Risk, Informatin, Ties</td>
</tr>
<tr>
<td>ESCA</td>
<td>OECD (2015a)</td>
<td>Climate Change, Resilience, Assessments, Climate Scenarios</td>
</tr>
<tr>
<td>DSI</td>
<td>OECD (2015b)</td>
<td>Risk Assessment</td>
</tr>
<tr>
<td>DAC-DOAC</td>
<td>DAC-DOAC-ED (2016b) B/EDI</td>
<td>Risk Assessment</td>
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<td>OECD (2014b)</td>
<td>Risk Assessment</td>
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**OECD Resilience Quantitative Approaches.** Examples of resilience-based quantitative analyses discussed among OECD directorate publications.

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### Application of Resilience in OECD

- The emerging science of resilience has not been adequately featured in the body of work delivered by OECD
  - For many documents, a focus on Planning and Absorbing Risk, with less attention paid to system Recovery and Adaptation

- While the OECD directorates agree that resilience should be considered in systems development, OECD directorates focus heavily on resilience planning and preparation
  - Emphasis on other resilience features including system threat absorption, recovery, and adaptation are less prevalent
Resilience Matrix: OECD Divisions vs. US Agencies

OECD Directorate vs. US Agency resilience actions “directly” addressed (relative to NAS definition) in physical, information, and social domains. OECD publications discuss resilience within social domain while US agencies discuss resilience heavily within infrastructure domain.

Recommendations and Way Forward

- A normalized and operationalized definition of resilience within the OECD is useful to build adequate quantitative measures across directorates
1. Assessment using Decision Analysis

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

Pilot Study in Jamaica Bay, NY
Test two analyses to calculate present-day resilience:

- **Tier 1**: Resilience Matrix, screening
- **Tier 2**: Integrated Risk/Resilience Assessment using Bayesian probabilistic analyses; appropriate for design

POC: Julie Rosati, ERDC, CHL
How it works: Project Evaluation

- Baseline assessment can be used to evaluate proposed projects.

<table>
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<tr>
<th>Prepare</th>
<th>Absorb</th>
<th>Recover</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>71</td>
<td>98</td>
<td>60</td>
</tr>
<tr>
<td>Information</td>
<td>83</td>
<td>45</td>
<td>21</td>
</tr>
<tr>
<td>Cognitive</td>
<td>96</td>
<td>49</td>
<td>26</td>
</tr>
<tr>
<td>Social</td>
<td>82</td>
<td>54</td>
<td>12</td>
</tr>
</tbody>
</table>

*Projects may have (+) or (-) in other matrices.*

Problems with Metrics-Based Approaches

- Measuring for emerging threats remains difficult: the gap between measures and increased vulnerabilities can be hard to close.

- Many measurement programs utilize data that does not contribute to informing decisions or changing behavior.

*Not everything that counts can be counted, and not everything that can be counted counts.*

Albert Einstein
2. Future: Network Science

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

- **Physical domain**
- **Information domain**
- **Social and cognitive domains**

**Why Network Science Approach?**

- Most of the complex systems can be modeled as interconnected networks – as soon as a system is represented as a network it becomes a mathematical object
- Network representation allows better analysis of interplay between individual components comprising the system
- Better visualization
Network-based Resilience Theory?

- System's critical functionality \( (K) \)
- Network topology: nodes \( (N) \) and links \( (L) \)
- Network adaptive algorithms \( (C) \) defining how nodes' (links') properties and parameters change with time
- A set of possible damages stakeholders want the network to be resilient against \( (E) \)

\[
R = f (N, L, C, E)
\]

Transportation Networks – DC
Resilience Quantification

- Based on NAS Definition
- Widely Applicable

\[ R = \frac{S_{\text{active}}}{S_{\text{active}} + S_{\text{inactive}}} \]

Efficiency vs. Resilience

\[ R^2: 0.794; \text{Pearson:} 0.839; \text{Spearman:} 0.825 \]
OECD’s Role

Provide guidance for unique considerations within each governance jurisdiction:

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Do these regulatory differences influence the perception of risk by local experts and regulators?

After Trump, Linkov et al 2016

Comparative Assessment of Risk and Resilience Culture

Cross-comparison of Regulatory Risk Culture of Three Cases

After Trump et al 2017
Risk-Resilience Integration

Top-Down
Decision Analysis/Social Science

- Goal Identification and Problem Framing
  - What are the goals, alternatives, and constraints?

- Decision Model
  - What are the criteria and metrics, how do we measure decision-maker values?

- Metrics Generation and Alternative Scoring
  - How does each alternative score along our identified criteria and metrics?

Bottom-Up
Risk Assessment/Physical Science

- Risk Characterization
  - What are the risks relative to a threshold? How do they compare to other alternatives?

- Physical/Statistical Model
  - What is the hazard? What is exposure?

- Data Collection
  - What are fundamental properties/mechanisms associated with each alternative?

Modeling

- Data Collection
  - What are fundamental properties/mechanisms associated with each alternative?

Management

- Risk-Resilience Integration
  - Linkov et al., 2014

Future: Evolution of Approaches for Flood Risk Management

- Manage resilience?
  - Not all problems need to be solved
  - Systems approach & integration of communities is the key

- Live with floods
  - Individuals and small communities adapt to nature’s rhythm

- Use the floodplain
  - Permanent floodplain is utilized for flood production
  - Permanent communities develop in the floodplain

- Control floods
  - Large scale structural approaches are implemented through organized governance

- Reduce flood damages
  - Recognition that engineering alone has limitations
  - Efforts to increase the resilience of communities should be directed toward real solutions

- Manage risk
  - Non-engineering problems are equal
  - Risk management is an effective and efficient method to build needed limited investment

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END
References


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