Managing Resilience and Sustainability of Interconnected, Interdependent, and Interactive Critical Infrastructure Systems

The California Sacramento Delta Region
The Sacramento Delta is an Infrastructure ‘Chokepoint’ for California
California's Sacramento Delta

- Supplies water to more than 22 million Californians, industry and agriculture
- Water supply supports $400 billion state economy
- Home for more than 400,000 people
- Habitat for 500 species
- Highways, pipelines, power distribution, railroads, and deep water ports
An Interdisciplinary Collaboration

- Economics
- Law
- Public Health
- Engineering
- Architecture & City Planning
- Management

University of Colorado at Boulder
Center for Catastrophic Risk Management

University of California Berkeley
Center for Catastrophic Risk Management
<table>
<thead>
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<th>Name</th>
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<td>Research Team Members</td>
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Develop and validate advanced Risk Assessment & Management (RAM) approaches to help improve the Resilience and Sustainability of the Delta’s Interconnected, Interdependent, Interactive Critical Infrastructure Systems (I^3CISs)
Categories of Uncertainties resulting in Risks

- Intrinsic
  - Inherent Variability
  - Analytical Models

- Extrinsic
  - Human Performance
  - Information Development
Analyzing Risks: Pfs (likelihoods of failure) \& Cfs (consequences of failure)

\[ Pf = Pf_{\text{Intrinsic}} + Pf_{\text{Extrinsic}} \]

\[ Cf = Cf_{\text{Intrinsic}} + Cf_{\text{Extrinsic}} \]

Not included in conventional engineering risk analyses
Resilience - time to regain Functionality

meaningful metrics for ‘decision makers’?
Sustainability - Ability to maintain functions

Sustainable

Not Sustainable

meaningful metrics for ‘decision makers’?
Research Risk Assessment & Management (RAM) approaches and strategies

- **PROACTIVE**
  - to prepare

- **INTERACTIVE**
  - to respond

- **REACTIVE**
  - to recover

- Increase detection & correction
- Reduce likelihoods
- Reduce consequences
Technology Delivery System: TDS

Inputs

TECHNOLOGY

Nature

Outputs

Public

Industrial Enterprise

Government
Outcomes:

A manual of practice for RAM of $I^3$CISs
Outcomes:

An interdisciplinary curriculum for Infrastructure Engineering of I³CISs
Research Project Tasks

2009

• Group formation
• System definition & analyses
• QMAS & SYRAS developments
• GIS #1
• Key stakeholder identification
Define & Characterize
**System, Performance Attributes & Failures**
- Operators, Organizations, Environments
- Hardware, Structures, Procedures, Interfaces

**QMAS**
- Audit team, Audit training, Audit scheduling
- Screening assessments, Factors of Concern
- Gradings, Consequences of 'Failure', Remediations

**SYRAS**
- Normal rates of malfunctions, Performance Shaping Factors
- Probabilities of proper Detection, Analysis, Correction
- Probabilities of Failure for all System Components, Correlations

**Operator ‘domain experts’ evaluations elicitation processes:**
- Failure Scenarios
- Performance Shaping Factors
- Factors of Concern
- Mitigations

**Probabilistic risk analysis, Management options, Implementation monitoring**
2009

• I³CISs operator discussions
• Studio Course #1 - GIS
• Workshops & conferences
• WWW sites development
• Sherman Island pilot project - 1
2010

RAM methods & guidelines development
I^3CISs operator discussions
Sherman Island pilot project - 2
GIS #2
Studio Course #2 - Law
TDS implementation
2011
Multiple chokepoints project - 1
I³CISs operator discussions
RAM guidelines validations
GIS #3
Studio Course #3 - Engineering
TDS implementation

2012
Multiple chokepoints project - 2
I³CISs operator discussions
RAM guidelines documentation
GIS #4
TDS implementation
A new approach to risk: The implications of E3

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Abstract: The fundamental thesis of this paper is that the science and technology of complex systems, whether technical or non-technical in their operation, or modeling of complex systems usually involves variables and processes, typically with feedback and organizational and methodological loops that avoid committing errors of the type commonly seen in technical systems. This paper presents a methodology for developing new technologies, systems, and processes to improve the performance of complex systems, using a combination of traditional and emerging technologies, such as artificial intelligence, machine learning, and data analytics. The methodology is illustrated through case studies in water resources, environmental engineering, and public policy.

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Keywords: risk analysis; human factor; information systems; environment; organizations

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2009 Research Outcomes

Adaptation Planning and Climate Impact Assessments: Learning From NEPA

by Daniel A. Farber

Daniel A. Farber is the Shi-Sen Professor of Law and Chair of the Energy and Resources Program at the University of California, Berkeley.

Abstract: Given that the earth’s warming is already causing significant and growing economic and human losses around the globe, we must act sooner rather than later. The NEPA process, which provides for meaningful public participation in decisions that may have harmful environmental impacts, is an essential part of the solution.

Balancing the Risks: Choosing Climate Alternatives

CR Payne

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Abstract: Very aggressive reductions in greenhouse gas emissions are needed over the next ten years to avoid a “planet on fire.” Current state, national and international policy assumes that carbon sequestration, hydro, nuclear power, ocean fertilization, atmospheric aerosols and other such technologies, which heretofore have been considered too novel or too dangerous to use, will have to be deployed at large scale, globally. Moving forward with promising technologies that might preserve us from the consequences of global warming will be difficult because they also pose potential hazards, promise uncertain benefits, and in some cases are already burdened with restrictive legislation and poor public image. The lack of a rational process of risk assessment and public decision making is likely to lead to a poor long-term outcome.

Abstract: A test decision can be made based on whatever information we have now, and indeed a decision will have to be made after all, the decision to maintain the status quo is still a decision. And scientific work is liable to be upset or modified by advancing knowledge. That does not confer upon us the freedom to ignore the knowledge we already have, or to postpone the action that it appears to demand at a given time.

1. Background: Defining the Problem

Very aggressive reductions in greenhouse gas emissions are needed over the next ten years to avoid a “planet on fire.” A great challenge for policymakers today is to introduce low carbon technologies on a fast-track without sacrificing environmental and human health or equity. Democratic, environmental and human rights principles require processes that weigh a range of values and expert opinion.

It is now believed that global average temperature increase must be held to no more than 2°C above pre-industrial levels to avoid widespread, intolerable impacts on human well-being. The
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