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Applying Systems Thinking to Coastal Infrastructure Systems

David Pezza
Old Dominion University, dpezza@odu.edu

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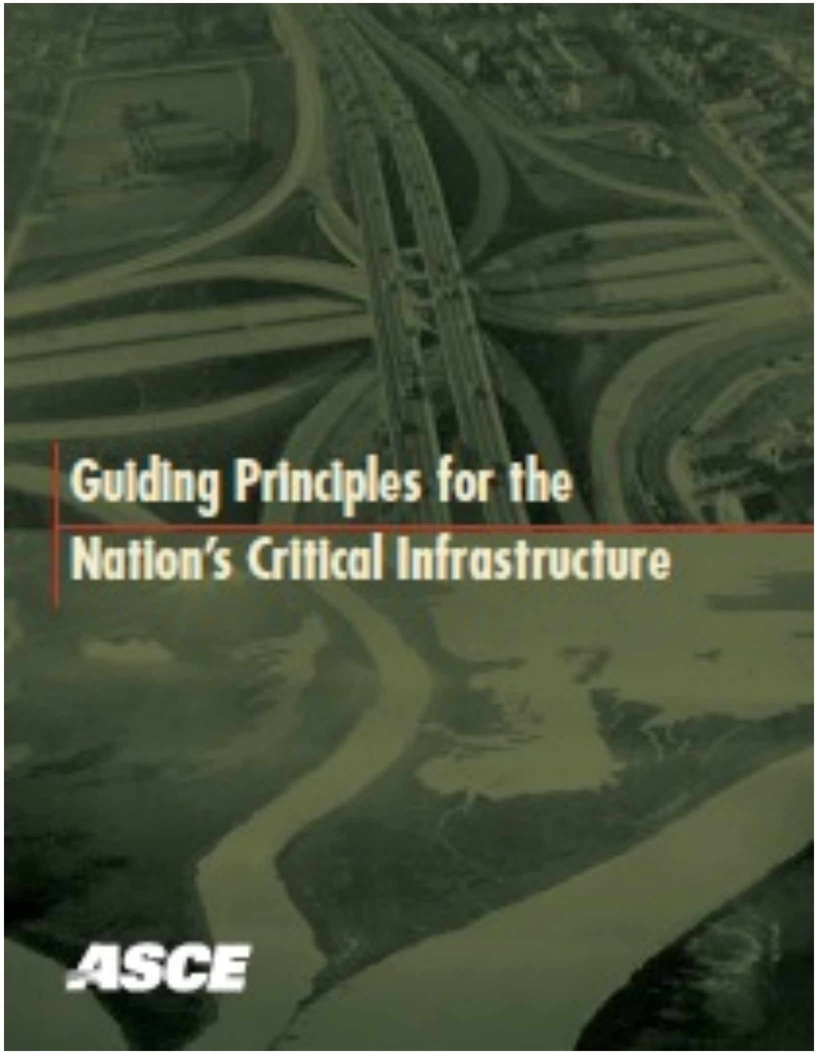
Applying Systems Thinking to Coastal Infrastructure Systems

David A. Pezza[1] and C. Ariel Pinto[1]

Objectives

- Explore how to represent the coast as system.
- How to apply systems thinking to coastal infrastructure.
- Offer a framework to employ an integrated systems approach.

Representing the Coast as a System



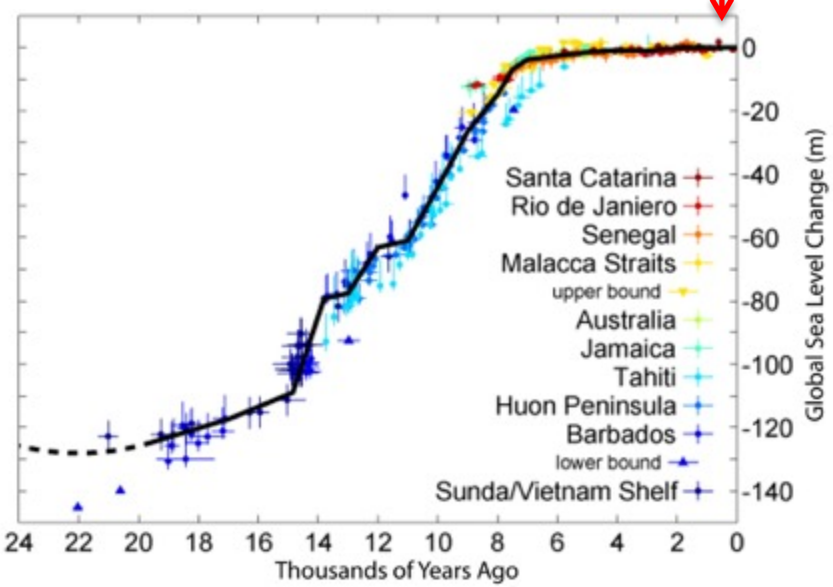
- Quantify, communicate, and manage risk
- Employ an integrated systems approach
- Exercise sound leadership, management, and stewardship in decision making processes, and
- Adapt critical infrastructure in response to dynamic conditions and practice.

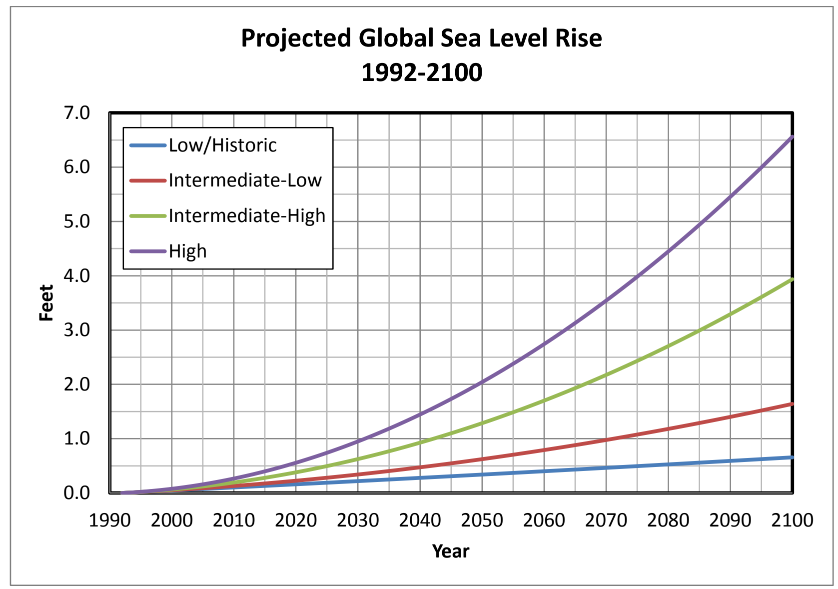
(ASCE, 2009, p.14)

Rising Seas

"It is change, continuing change, inevitable change, that is the dominant factor in society today. No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be." Sir Isaac Asimov, 1982 (p.29)

Founding of Jamestown



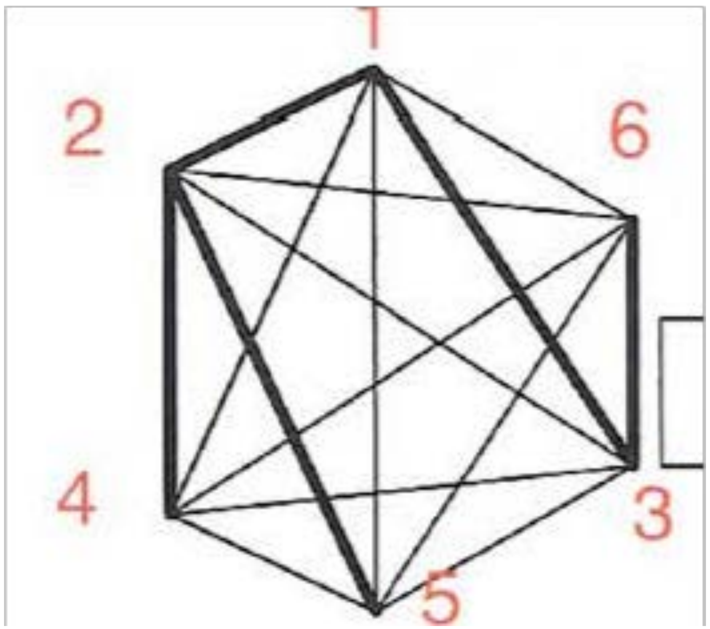


Plag (2014)

Representing an Integrated Coastal System

An Enterprise System

A Network

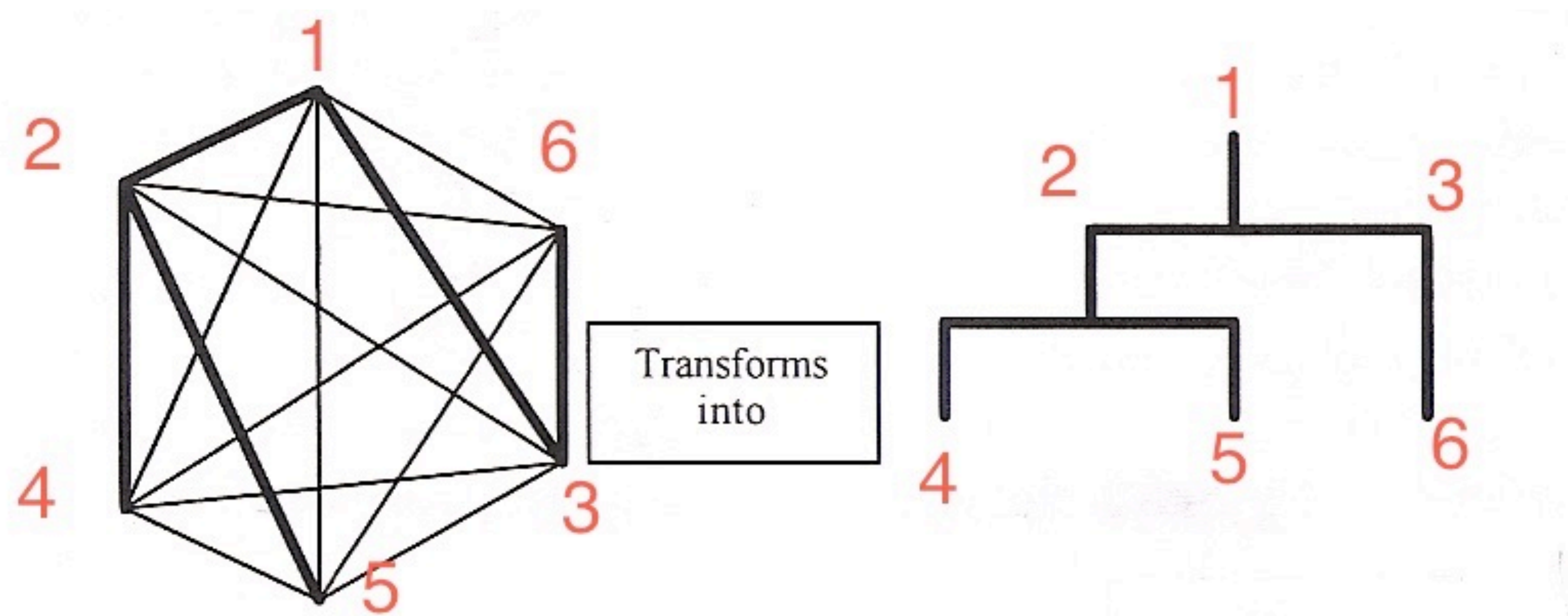


A network of interdependent people, processes and supporting technology not fully under control of any single entity (Mitre, 2007).

An Enterprise Systems Approach

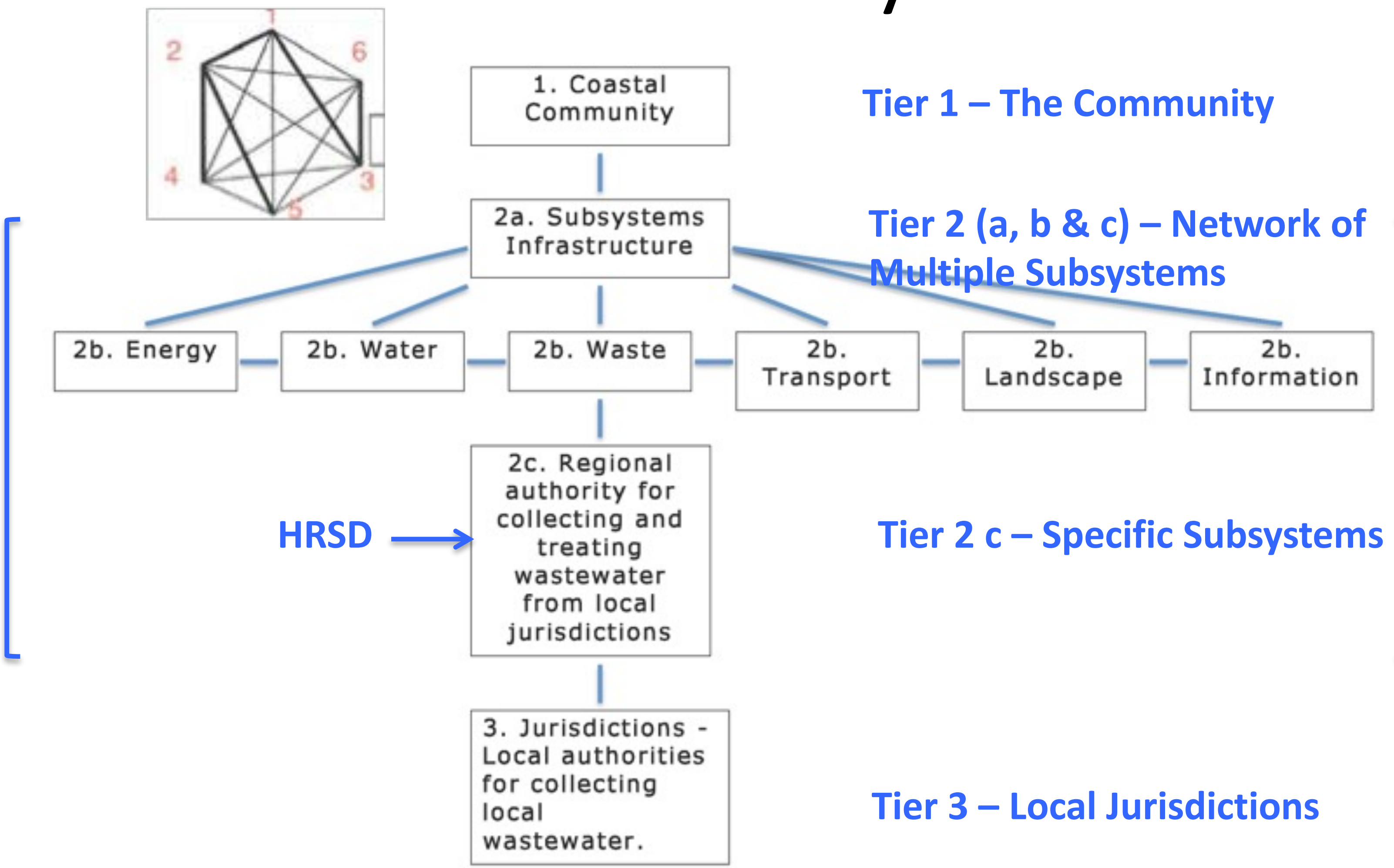
- It represents a democratic society where no single entity is in control.
- It is structured as a network where all points are linked.
- Its behavior is emergent, that is its properties are unknown in advance and only evident as the network interacts.
- Capable of adaptation to change

Figure 1 Transformation from Network to Hierarchy



Lawson, 2005

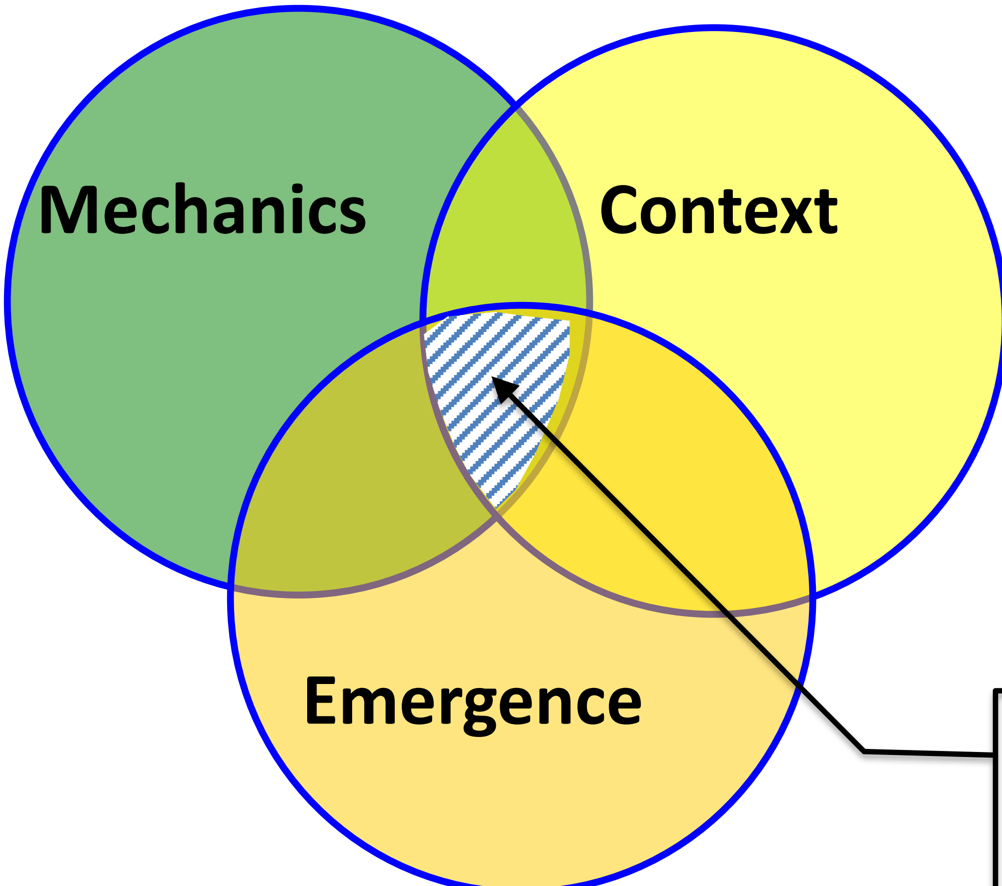
Figure 2 Hierarchical Structure of Local Infrastructure Systems



Pezza and Pinto (2018)

ISI, 2014, ENVISIONTM

Systems Thinking

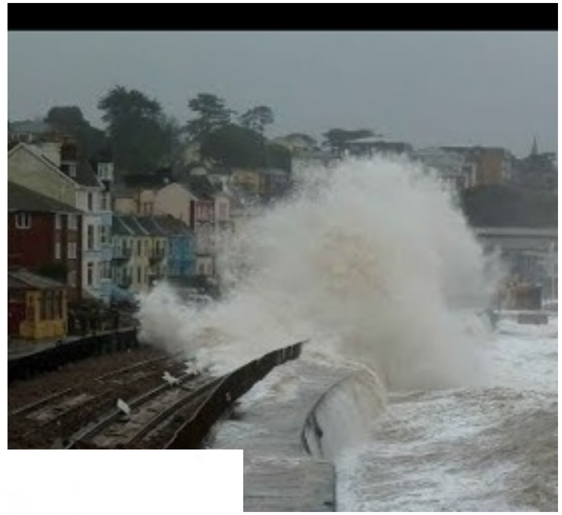


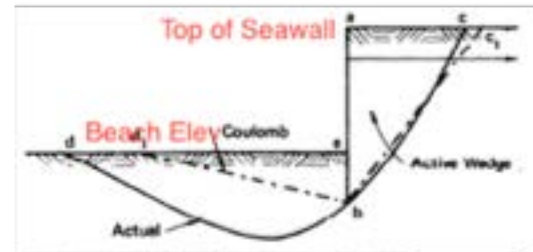
- **Mechanics** – Traditional Modeling (quantitative)
- **Context** – Non-traditional Modeling (qualitative)
- **Emergence** – Design for extreme uncertainty, interrelationships, influence and paradigm shifts

The Dilemma – a predicament that defies a satisfactory solution.

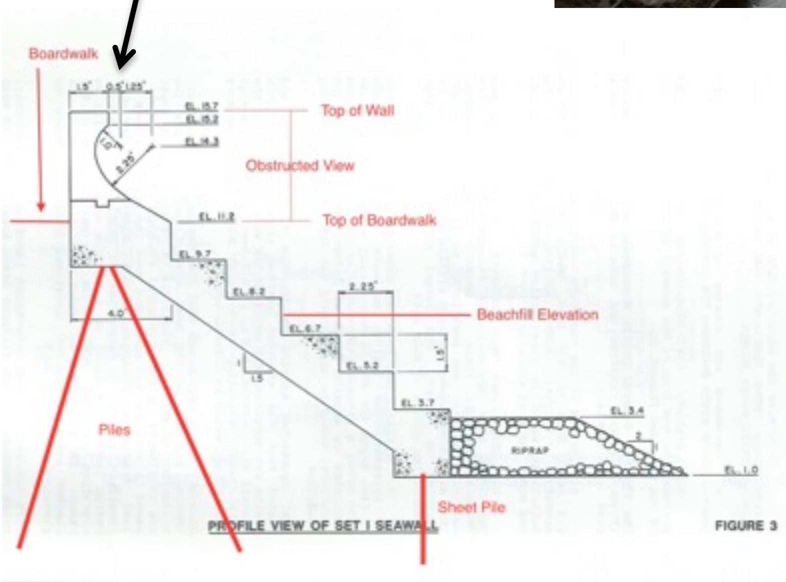
Keating, Slide 400 (2014)-modified

An Example of a Dilemma





4 foot height blocked view



The best technical solution to a design may very well not be the best overall solution (Allen et al., 2004)

Table 1 The Nature of a Problem Situation

Attribute	Traditional Problem	Unique Problem
Problem Type	**Complicated**	**Complex**
Quantifiable	Yes	Not Easily
Structure	Understood	Emergent
Approach	Evident	Not Evident
Definition	Clear	Ambiguous
Environment	More Static	More Dynamic and Turbulent
Boundaries	Defined	Ambiguous

Keating, Peterson & Rabadi, (2003)

Complicated Systems

- Complicated systems can have many pieces, where each component is understood in isolation and the whole can be reassembled from its parts such as many mechanical systems.
- These pieces work as one system to accomplish its function, but one key defect can stop the function.
- Also, complicated technical systems lack the ability to adapt. Such systems require redundant or backup components to mitigate failure.

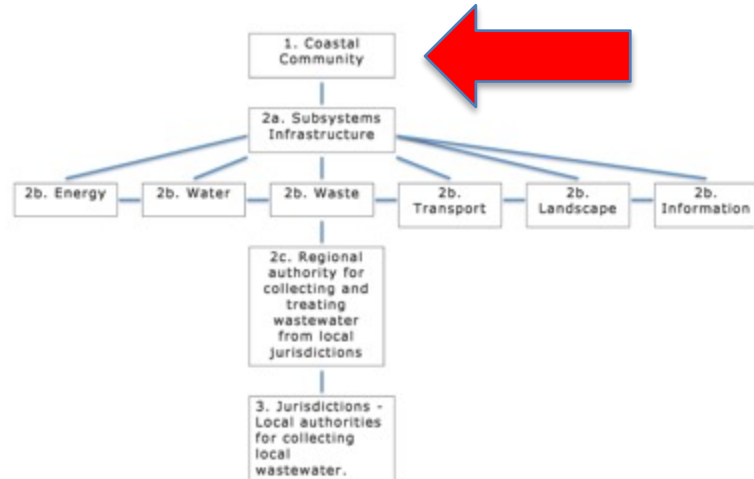
(Ottino, 2004)

Complex Systems

- Situations where human participation or judgment is a key component, reductionist methods can misrepresent the problem domain.
- The human aspect introduces relationships between stakeholders as well as complexities not easily represented by hard systems methodologies.
- These kinds of problems require decision makers to account for both the technical factors and the needs of stakeholders to achieve sustainable results.

(Kirk, 1995)

Stakeholders' Worldview
Frame the Nature of the Problem



It is important for stakeholders to have a Common worldview.

It is at Tier 1 in Figure 2, the level of governance, where agreements are made to bring together the resources needed to Adapt to rapid change.

Types of Errors

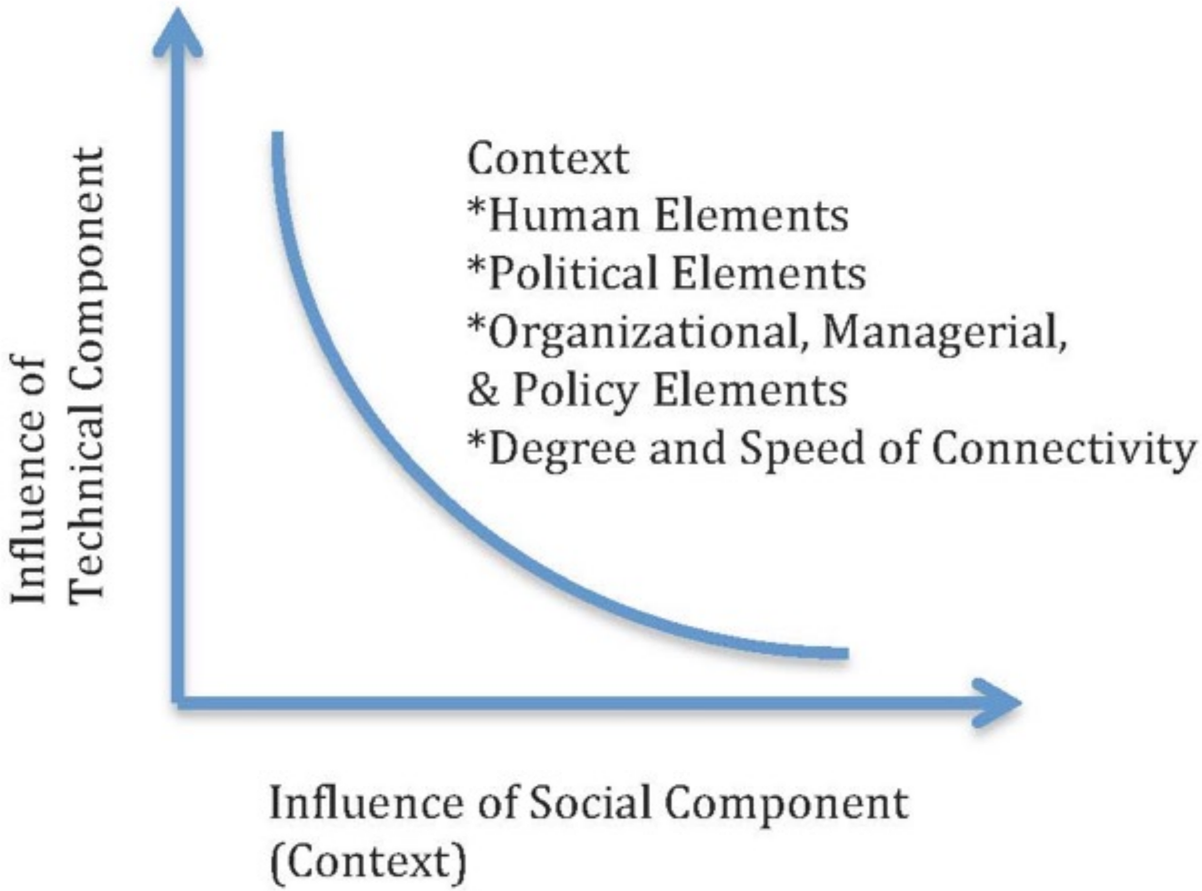
A Type III error is solving the wrong problem precisely in the most efficient way possible. This is often caused by having the wrong stakeholders involved or letting biases shape the problem definition.

A Type IV error is engaging in “muddled” thinking that is typically caused by a philosophical mismatch among stakeholders such that agreement is unlikely and movement to resolution is highly improbable.

(World Economic Forum 2011, Keating, 2008)

Systems Analysis

Figure 3
Influence of Social Component



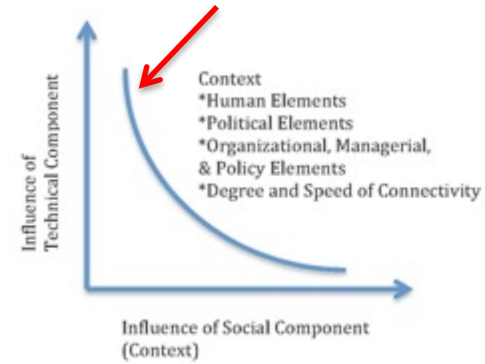
Pezza and Pinto (2018) & Keating (2014)

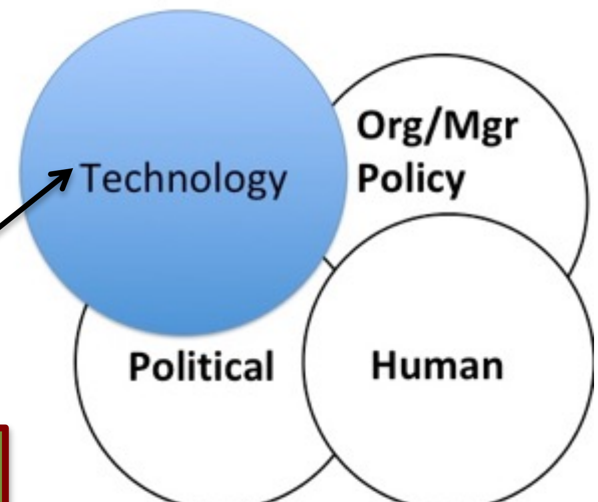
Hard Systems Thinking

Table 1 Nature of a Problem

Attribute	Traditional Prob
Problem Type	Complicated
Quantitative	Yes
Structure	Understood
Approach	Evident
Definition	Clear
Environment	More Static
Boundaries	Defined

Technical Problem





Keating (2014)

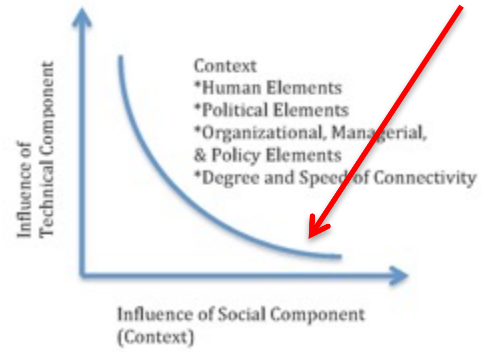
Optimized Solutions

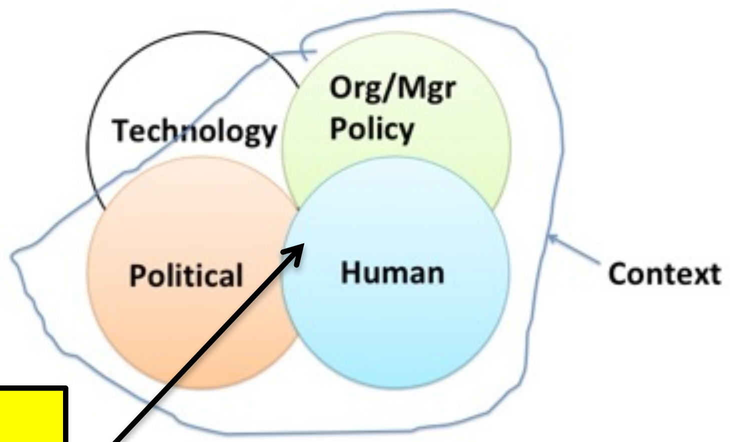
Soft Systems Thinking

Table 1 Nature of a Problem

Attribute	**Unique Problem**
Problem Type	Complex
Quantitative	Not Easily
Structure	Emergent
Approach	Not Evident
Definition	Ambiguous
Environment	More Dynamic & Turbulent
Boundaries	Ambiguous

Socio-Technical Problem





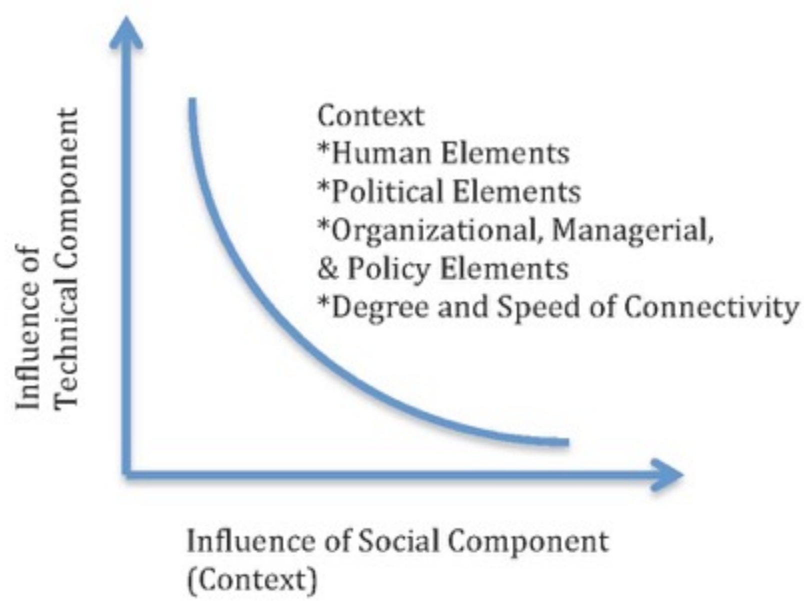
Keating (2014)

Satisficing Solution – an acceptable solution, while not optimal, it is good enough.

The Conundrum – How do you judge?

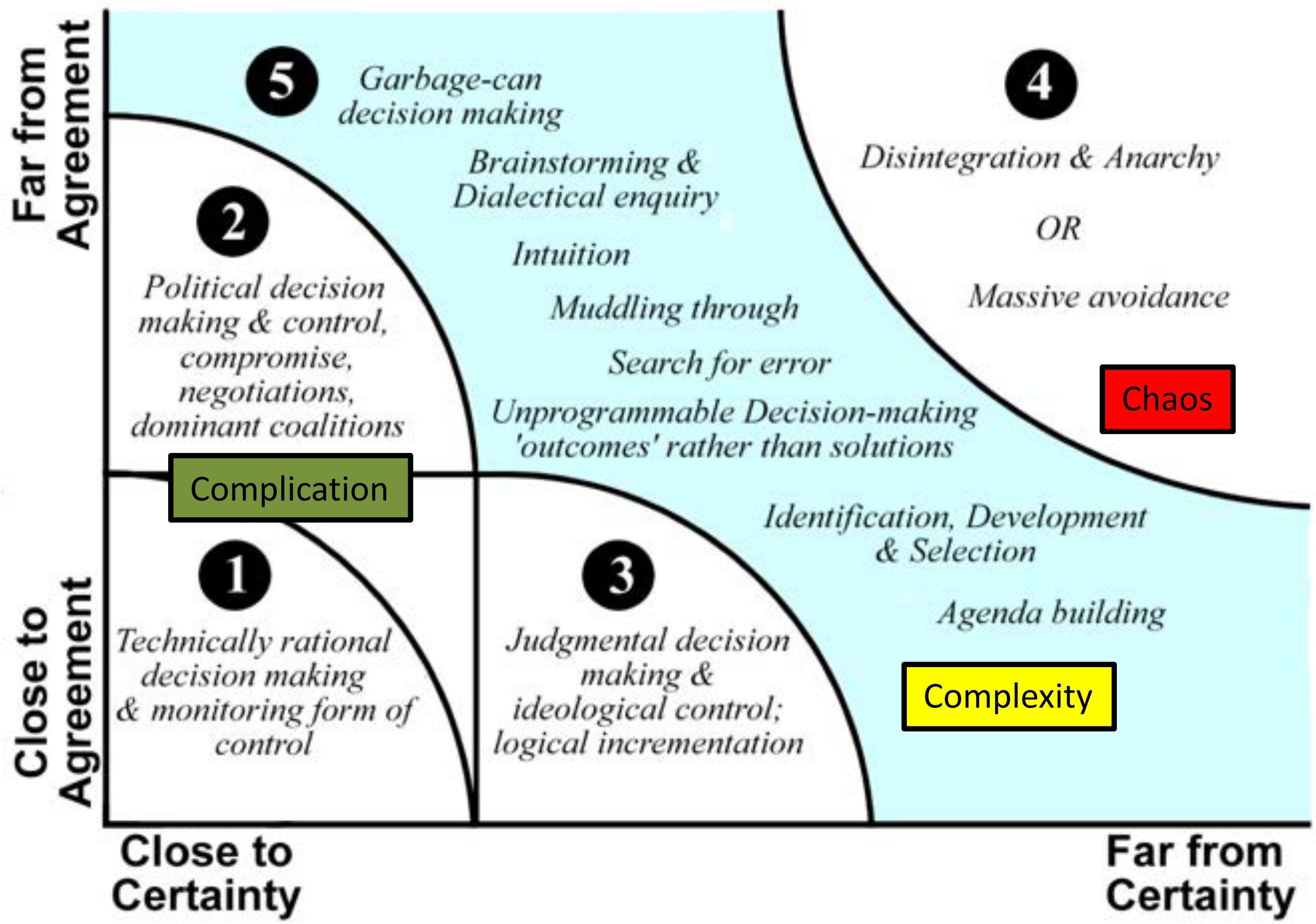
- Optimization most compatible with complicated engineering solutions

- Satisficing solution is more compatible with complex engineering solutions.



Complexity Theory

Stacey's Zones of Complexity



Stacey (2011)

Figure 4 The Zones of Complexity

Agreement vs Certainty

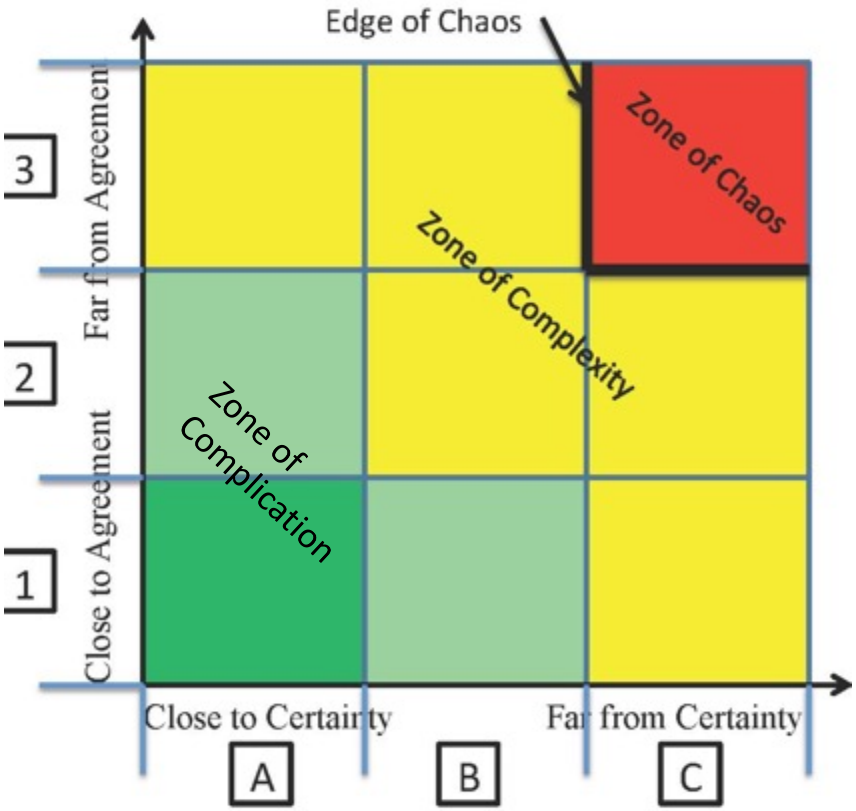


Table 2 Constructed Scale

A: Can predict the potential hazard with a degree of confidence

B: Can only represent the potential hazards with planning scenarios.

C: Unable to represent the potential hazards in any scientifically based format.

1. There is an agreed upon solution(s), schedule and the financial capacity to implement resiliency.
2. There is an alignment of Federal, State and local jurisdictions in the form of a signed partnership agreement.
3. There is no regional or state representation with authority that can serve as sponsor with Federal government.

Systems Methodology
Ackoff's Interactive Planning

- The interactive planning objective "is directed at creating the future.
- It is based on the belief that an organization's future depends at least as much on what it does between now and then, as on what is done to it.
- Therefore, this type of planning consists of the design of a desirable present and the selection or invention of ways of approximating it as closely as possible. It creates its future by continuously closing the gap between where it is at any moment of time to where it would most like to be.

Approach has three underlying principles

- Participation – The stakeholders must lead the process and not leave it to outside experts.
- Continuity – Stakeholders should plan for emergence, i.e., unanticipated changes characteristic of complex problems only evident as the problems unfold.
- Holism – Stakeholders should plan across and down the hierarchical tiers to seek agreement in the worldview to avoid Type IV error.

(Ackoff, 2001)

A Framework for Systems Thinking

Figure 4

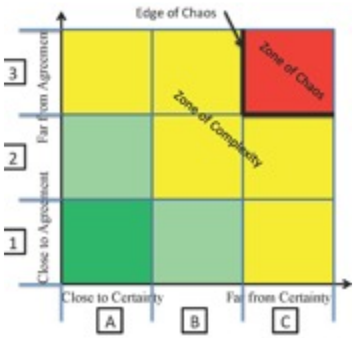
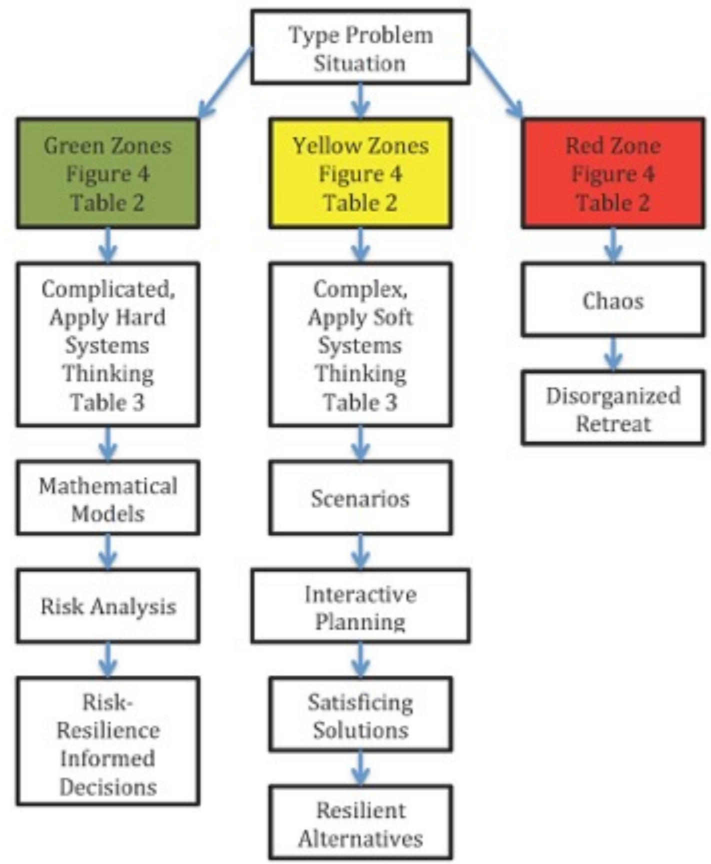


Table 3 Classification of System

Table 3. Classification of Systems.

Characteristic	Green Simple system Apply hard system thinking	Yellow Complex system Apply soft systems thinking
Stacey's zones	Dark green, a hard systems approach. Light green, a hybrid approach to address uncertainties.	Yellow or red, a soft systems approach.
Number of elements	Small	Large
Interactions between elements	Few	Many
Predetermined attributes	Yes	No
Interaction organization	Highly organized	Loosely organized
Laws governing behavior	Well defined; deterministic or stochastic methods	Undefined; emergence behavior
System evolution over time	Not evolve	Evolves
Subsystems pursue own goals	No	Yes (purposeful)
System affected by behavioral influences	No	Yes
Predominantly closed or open to the environment	Largely closed	Largely open
Predictable	Yes	No
Method of analysis	Risk-resilience-informed decisions	Interactive planning
Type decision	Risk-resilience-informed decisions	Satisficing solutions

Figure 5 Systems Methodology Flow Chart



Example 1 Socio-Technical Problem

Figure 2

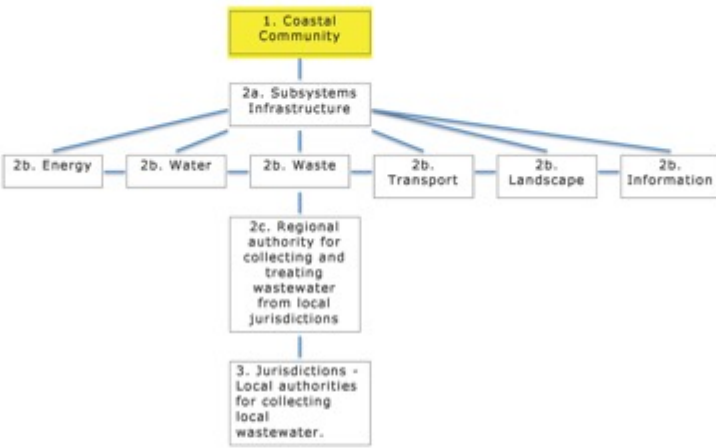


Figure 4

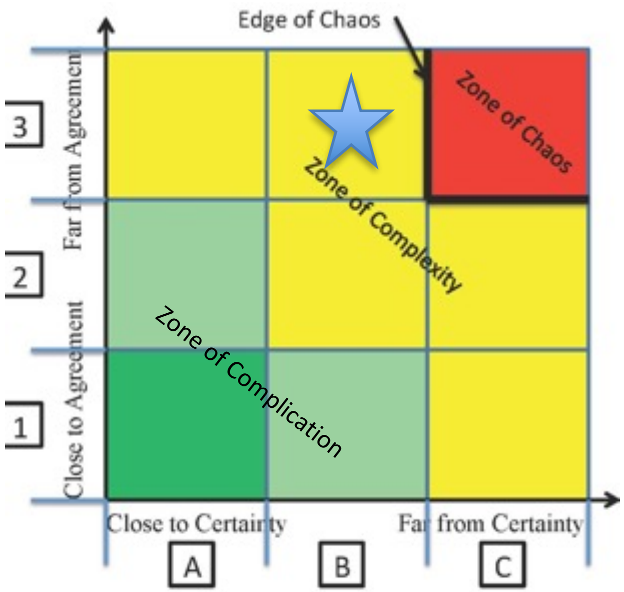
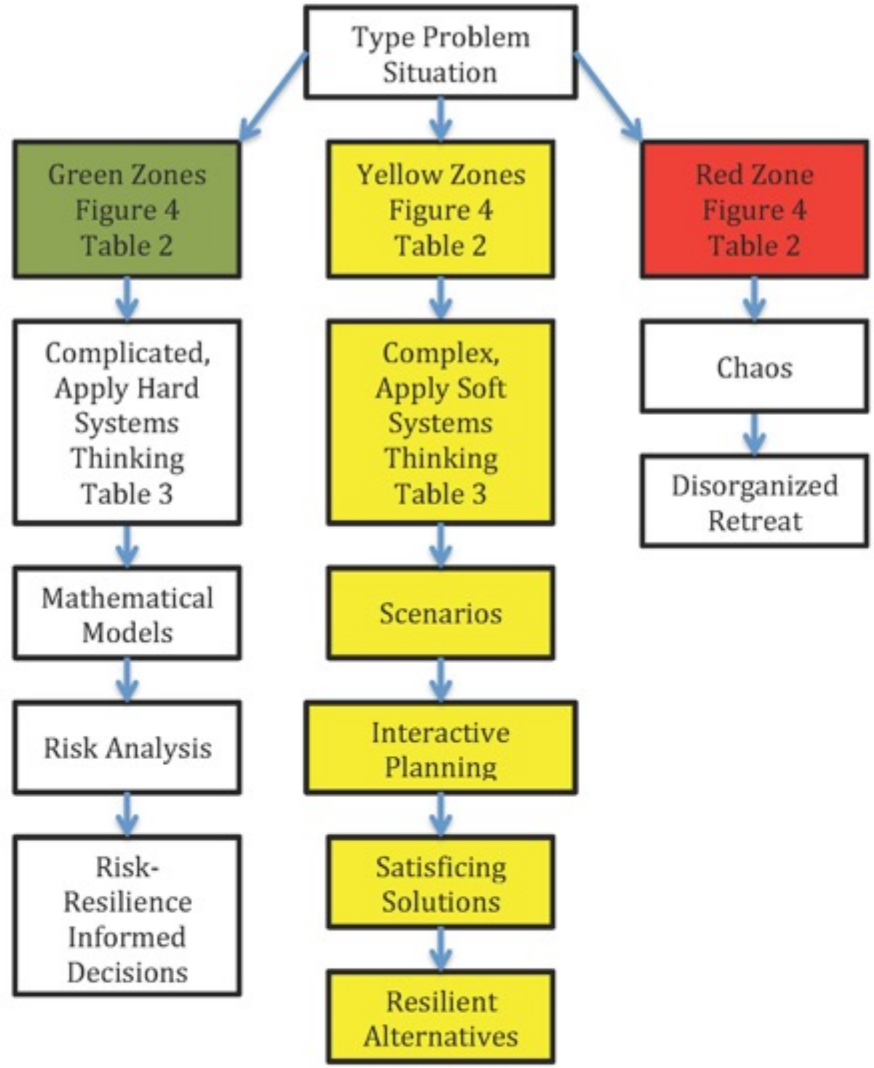
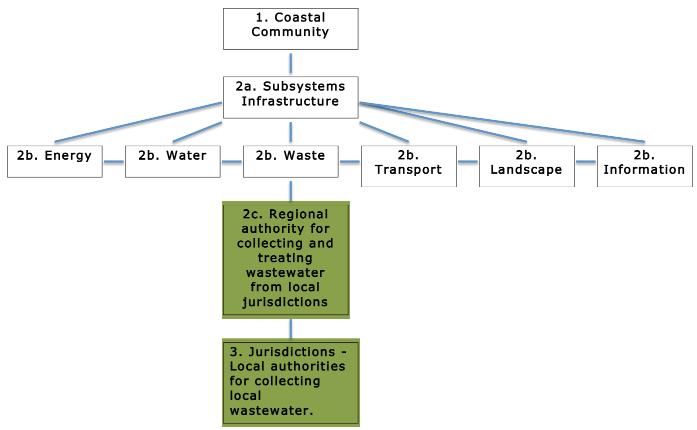


Figure 5



Example 2 Technical Problem

Figure 2



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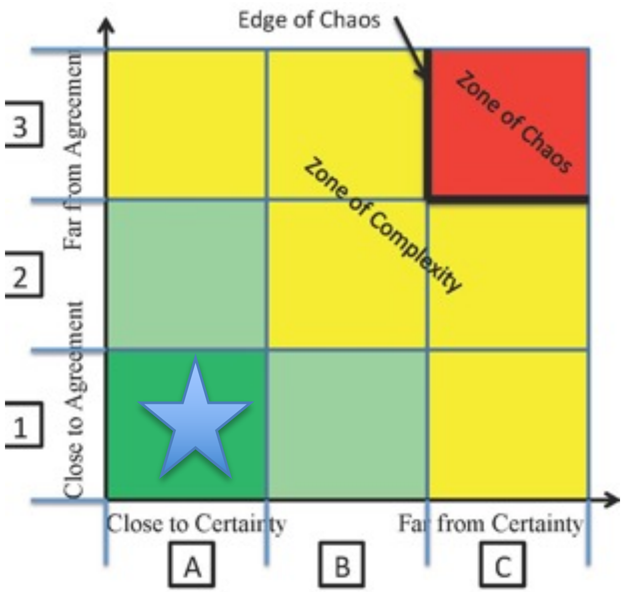
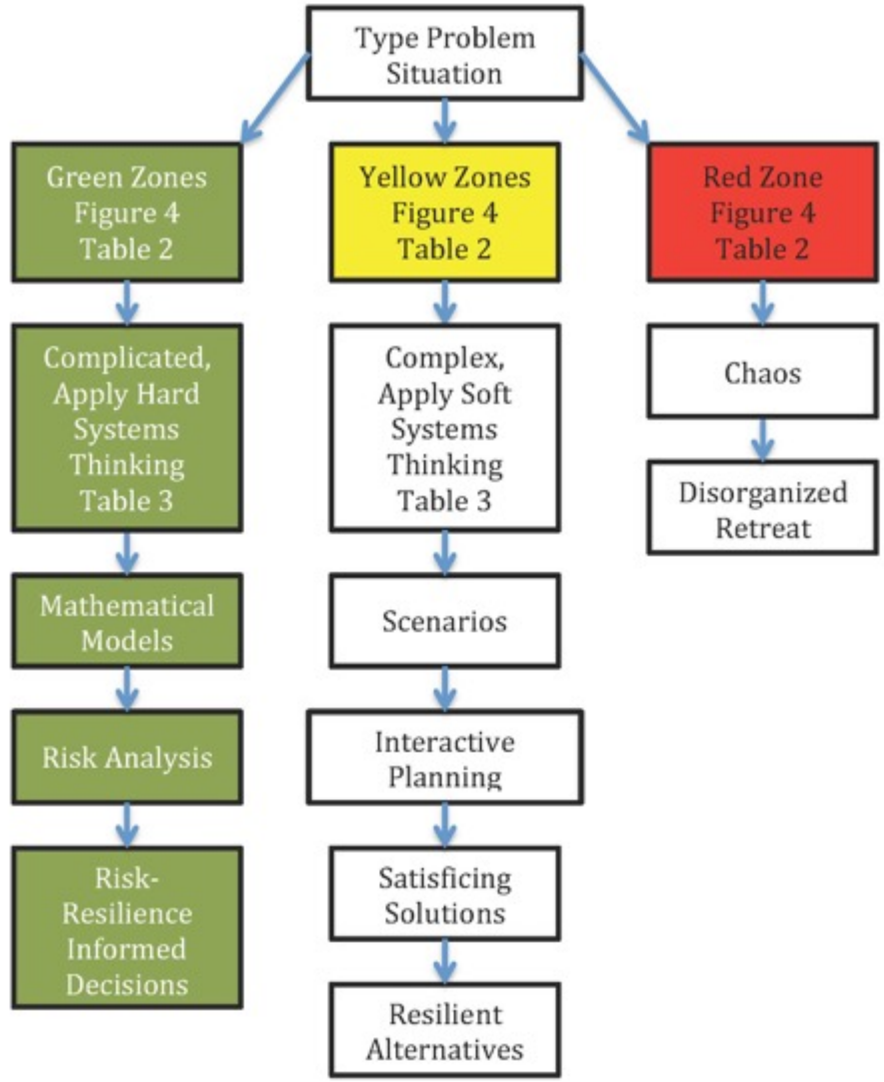


Figure 5



On-Going Projects

- Recent storms has help the City of VA Beach accept a worldview.
- Boston shifted from brute resistance to some forms of retreat; making room for flooding.
- New York City Big U, is it still struggling with a worldview? (28 to 33 minutes in video).

https://www.pbs.org/video/sinking-cities-new-york-twghqw/

Conclusions

- Simplified Process
- Disciplined way of structured thinking
- A graph to aid in determining hard or soft thinking
- A kind of thinking to plan capital improvement investments compatible with an uncertain future.
- A way to map the future to assess if moving toward resolution or toward chaos.

"For every complex problem there is an answer that is clear, simple and wrong." H. L. Mencken

McChrystal, General Stanley, USA (Retired), 2015. **Team of Teams, New Rules of Engagement for a Complex World**, Portfolio/Penguin, New York, NY. ISBN 978-1-59184-748-9

Q & A

WIZARD OF ID
by Hart, Mastroianni and Parker
WE ARE NEVER GOING TO SOLVE THIS EQUATION
I GOT THIS
X = ?
THAT'S NOT EVEN CLOSE TO THE RIGHT ANSWER
TRUE, BUT THOSE GRAPHICS WERE PRETTY COOL, YEAH?
X = 27