Infrastructure as Linked Social, Ecological, and Technological Systems (SETS) to Address Lock-In and Improve Resilience

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Introduction and Background

Recent events like Hurricanes Harvey, Irma, and Maria highlight the limitations of traditional response mechanisms and have illustrated the major challenges that extreme weather events continue to pose to our infrastructure systems. Important (and often overlooked) exacerbating factors related to the threat that extreme events pose to our infrastructure systems include:

Lock-in - constraint of today's systems by past decisions, even in the context of changing conditions or the emergence of more effective alternatives, and

Path dependency – the idea that it is often very costly and difficult to alter an infrastructure system from its current trajectory

Lock-in and path dependency apply to physical infrastructure as well as institutional elements such as the way we design, operate, and protect our infrastructure. Thus, a critical aspect of enhancing the resilience of our infrastructure systems will be to address the lock-in and path dependency that have resulted in increasingly inflexible, rigid, and vulnerable physical and institutional systems.

This research uses a combination of literature review and conceptual framing to explore how the characterization of infrastructure as Social-Ecological-Technological Systems (SETS) – rather than traditional characterizations as purely technical or socio-technical systems – can help infrastructure managers more effectively understand:

i) the development and evolution of lock-in/path dependency over time

ii) the relationships and properties that emerge between S, E, and T domains

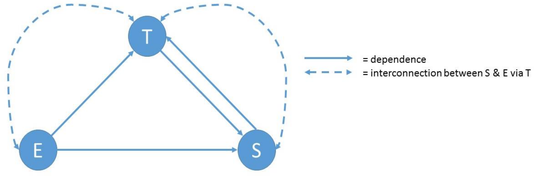
iii) expanded solution sets for addressing vulnerability, lock-in, and path dependence

SETS Elements of Infrastructure

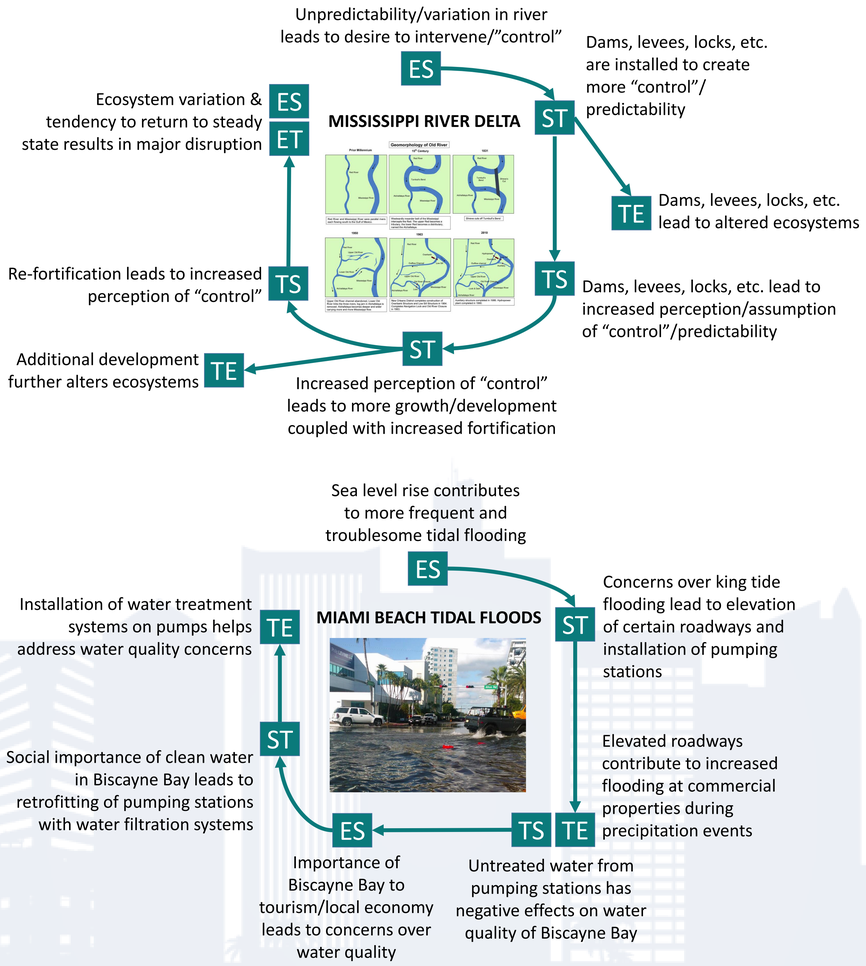
Social Components	Ecological Components	Technological Components
Operational Decisions	Atmospheric Emissions	Water Systems (treatment, supply, distribution)
Equity and Affordability	Water Pollution	Transportation Systems (roads, rails, canals, airports,, etc.)
Rules, Codes, & Regulations	Solid and Hazardous Wastes	Buildings (residential, commercial, industrial)
Financial Mechanisms	Radioactive Wastes	Industrial Systems (mines, manufacturing plants, etc.)
System Users	Natural Resource Consumption	Energy Systems (refineries, power plants, etc.)
System Operators	Biodiversity	Information Communication Technology Systems (cell towers, satellites, broadband)
Employment	Loss of Habitat	Planning Systems (Demand Forecasting, etc.)
Recreation Activities	Land Use Practices	Management Systems (Electrical dispatch, ITS; etc.)
Research and Development	Weather/Climate Effects	Sensing & Control Technology
Professional Groups		
Community Members/Groups		

SETS as a Lens to Identify the Evolution of Vulnerabilities

- As complexity and interconnectedness increase, S, E, and T systems increasingly cannot be decoupled from one another
- Ecological and social systems continually interact with and influence each other via technological systems
  - T' systems are often the mechanism by which social systems affect ecological systems via pollution, resource consumption and land use
  - 'T' systems are often mechanisms that enhance services provided by ecological systems (to social systems) (e.g., water purification & delivery)
  - 'T' systems are often the primary mechanism for 'protecting' social systems from ecological 'disservices' (e.g., air conditioning, dams, etc.)
  - At varying times and scales, each of the SETS domains has 'agency' and exerts influence on the other systems



- Applying these principles to historical case studies helps illuminate how lock-in, vulnerability, and other unintended consequences develop and evolve



Beyond Technologically-Focused Resilience Strategies

- A SETS lens to infrastructure can also help open the design and decision space to more than just technologically-focused resilience strategies
- Incorporation of SETS strategies – as opposed to 'T' or 'S-T' strategies – can add flexibility and agility to the system

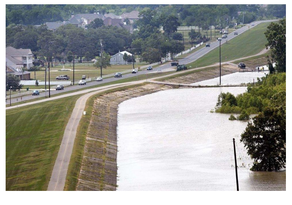
'Traditional' Strategy Vs. **'SETS' Strategy**

Los Angeles River

Vs.

Indian Bend Wash

Mississippi River Levees



Vs.

Netherlands 'Room for the River'

Conclusions and Discussion

- Typical adaptation strategies that are highly techno-centric and/or risk-based are likely to result in unwanted trade-offs, unintended consequences, and under addressed vulnerabilities
- Lock-in and path dependency appear to be some of the most troublesome and underappreciated of these trade-offs and unintended consequences
- One reason for under-appreciation and under-recognition of maladaptive lock-in and path dependency is that infrastructure is often not thought of as more than technical/socio-technical systems
- A SETS lens to infrastructure shows promise for addressing these issues by:
  - Aiding in the identification (and possible prevention) of lock-in, path dependency, and vulnerabilities that evolve over time
  - Illuminating resilience options that may not traditionally be considered – possibly increasing flexibility, agility, and ultimately adaptive capacity of infrastructure systems

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