

DYNAMIC RESILIENCE PLANNING FOR INTERDEPENDENT ECONOMIC SYSTEMS

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Why Resilience

If we cannot control the **volatile tides of change**, we can learn to build better boats. We can design—and redesign organizations, institutions, and systems to better absorb disruption, operate under a wider variety of conditions, and shift more fluidly from one circumstance to the next.

[Zolli and Healy 2012]



HM Government

Climate Resilient Infrastructure: Preparing for a Changing Climate





Interdependent Infrastructures





Resilience: background

- The notion of resilience has a strong history in several fields
 - Ecology, social sciences, civil engineering
- But lots of conflict in developing an agreed definition and resilience framework
- In particular a resilience framework for interdependent systems is missing



Relevance of this work

- Build a quantifiable resilience framework
- A resilience paradigm from engineering with an economic interdependency model
- Provide a means to valuate preparedness strategies



Defining Economic Resilience

Ability exhibited by systems that allows them to recover productivity

- In a desired time
- And/or with an acceptable cost

[Pant et al. 2012, 2014]



Resilience is planned for in advance of a disruptive event through preparedness policies and investments.

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Dynamic inoperability IO model

For *n* interdependent sectors

$\mathbf{q}(t+1) = [\mathbf{I} - \mathbf{K}^* (\mathbf{I} - \mathbf{A}^*)]\mathbf{q}(t) + \mathbf{K}^* \mathbf{c}^*(t)$





Resilience definitions: through model

- Measuring dynamic resilience with inoperability
 - Performance metrics that quantify the interdependent resilience from inoperability





Engineering Resilience definitions

- Dynamic resilience
 - Ability to resist the initial impact
 - Ability to recover in **desired time**





Interdependent resilience planning

Ultimately, the 4-tuple of $({f F},{f q}^m, au,{f K}^*)$ provide a means to describe interdependent economic resilience and generate planning strategies

[Pant et al. 2014]





Multiple external shocks

Different values for the 4-tuple $(\mathbf{F}, \mathbf{q}_h^m, \tau_h, \mathbf{K}_h^*)$ can describe planning options after each shock event at h = 0, 1, ...



[Pant et al. 2013]

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A dynamic feed-back control problem that sets the model parameters

- setting resilience targets
- controlling interdependence planning

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Model application



Port of Catoosa: Oklahoma

Dock commodity operations





Inland waterway network





Commodity flows and disruptions

Commodity queuing model at port and dynamic commodity flow along network





Targeted Recovery





PANT R & BARKER K. 2014. Dynamic resilience planning for Interdependent Economic systems

 τ = Time to recovery

Chart showing degree of investment in inventory of Primary Metals into other sectors for recovery AL-EA

eci university of oxford	F 1				Resilier	nce deper	ndence	of port
Kesillence	FOr	Port	Sect	ors	sectors	on other	sector	for 5 day
Oil and gas extrac	ction				stabiliz	ation from	disrupt	tion
Construc	tion	• • • • • • • • • •	••••••	•	•	•	•	•
Food and beverage prod	lucts · · 69.6%		· · · · · · · · · · ·					
Textile mills and textile product	mills	•••••				🗨		
Wood prod	ucts · · · · · 🔴 · ·					🛑		
Petroleum and coal prod	ucts	81.2%						· · · · · · · · · · · ·
Chemical produ	ucts		• 55.9% • •					
Plastics and rubber prod	ucts							
Mineral prod	ucts			· 71.5% · ·				
Primary me	tals				30.2%	27.3%	28.1%	· · · · · · · · · · · ·
Fabricated metal prod	ucts · · · · · · •				👅			🌰
Machin	ery 🔹	•••••	• • • • • • • • •	•		🗮		
Electrical equipm	nent 🔸 🔸		🔶		🌰	🛑		🌰
Motor vehicles, bodies and tra	ilers •	•	•••••••••••••••••••••••••••••••••••••••	•			•••••	
Other transportation equipn	nent · · · · · •					👝		🌰
Furniture and related prod	lucts 🛛 🖕	•	• • • • • • • • •	•				
Miscellaneous manufactu	iring · · · · 🔶 · ·		🔶		🌒	🔴		
Wholesale tra	ade 🛛 🖕	•	• • • • • • • • • •	•				
Retail tra	ade							
Truck transporta	tion · · · · · · ·	• • • • • • • • • • • • • • • • • • • •		• • • • • • • • • •				
Administrative and support service	vices 🔒 🔒							
Computer systems design and related serv	vices 🛛 🖕	•	•	•				
Fc	ood and beverage oducts	Petroleum and coal products	Chemical products	Mineral products	Primary metals	Fabricated metal products	Machinery	Miscellaneous manufacturing



Scope for Future development



- Integrating network dynamics with economic dynamics
- Long term risk, resilience and adaptation analysis





Thanks for the attention Questions?

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