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Infrastructure Resilience Matters

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PIIRS
Princeton Institute for International and Regional Studies

6th April 2017

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Infrastructure Resilience Matters

- Systemic Modelling of Infrastructure
- Infrastructure: Systems of Systems
- UK Progress and Prospects
- Exploring Interdependency: Enhancing Interactions
- Understanding Asset Criticality and Network Resilience
- TRaCCA: A Case Study
- Measuring Infrastructure Performance
- Managing the Mess

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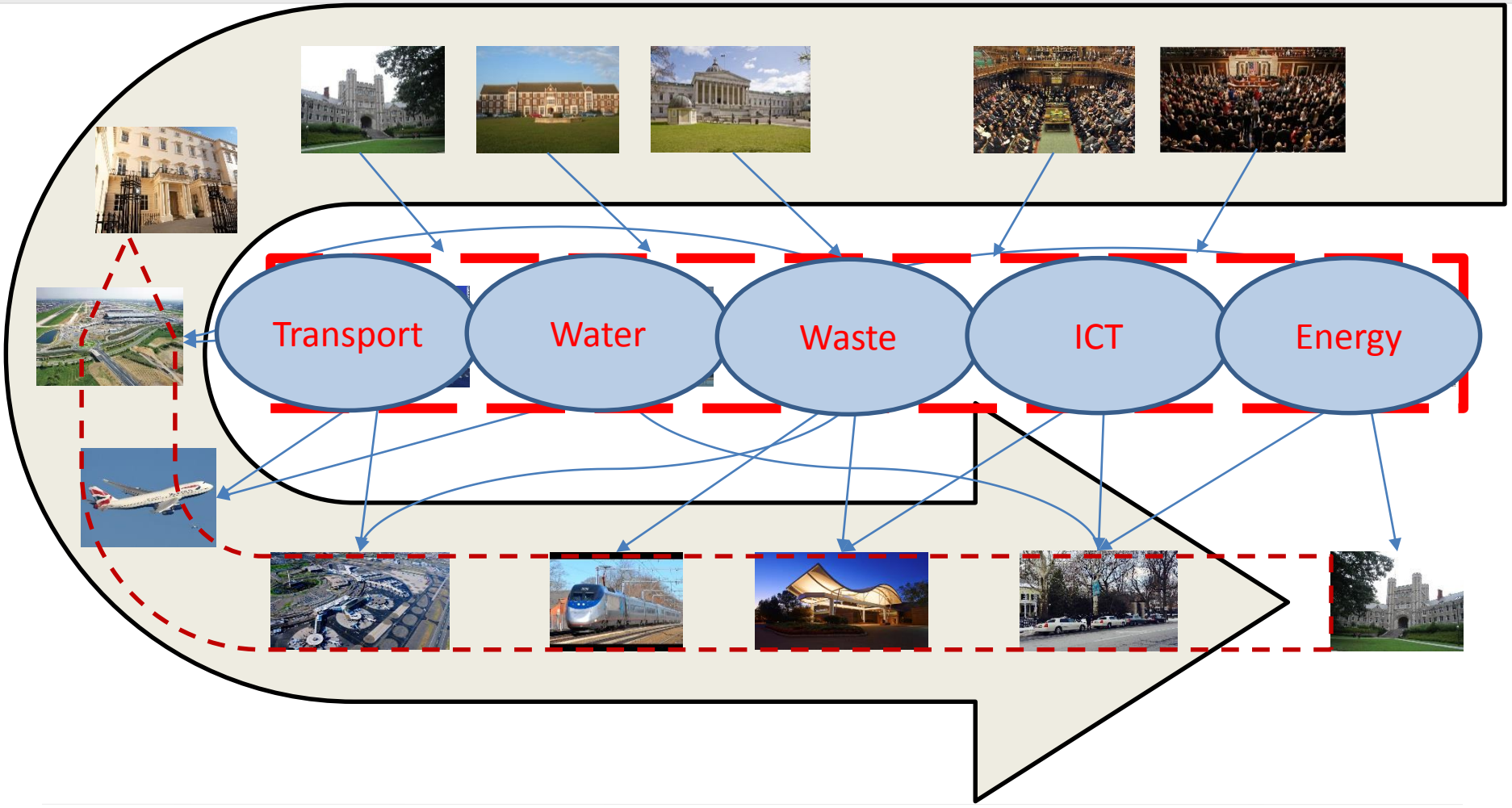
Infrastructure Resilience Matters



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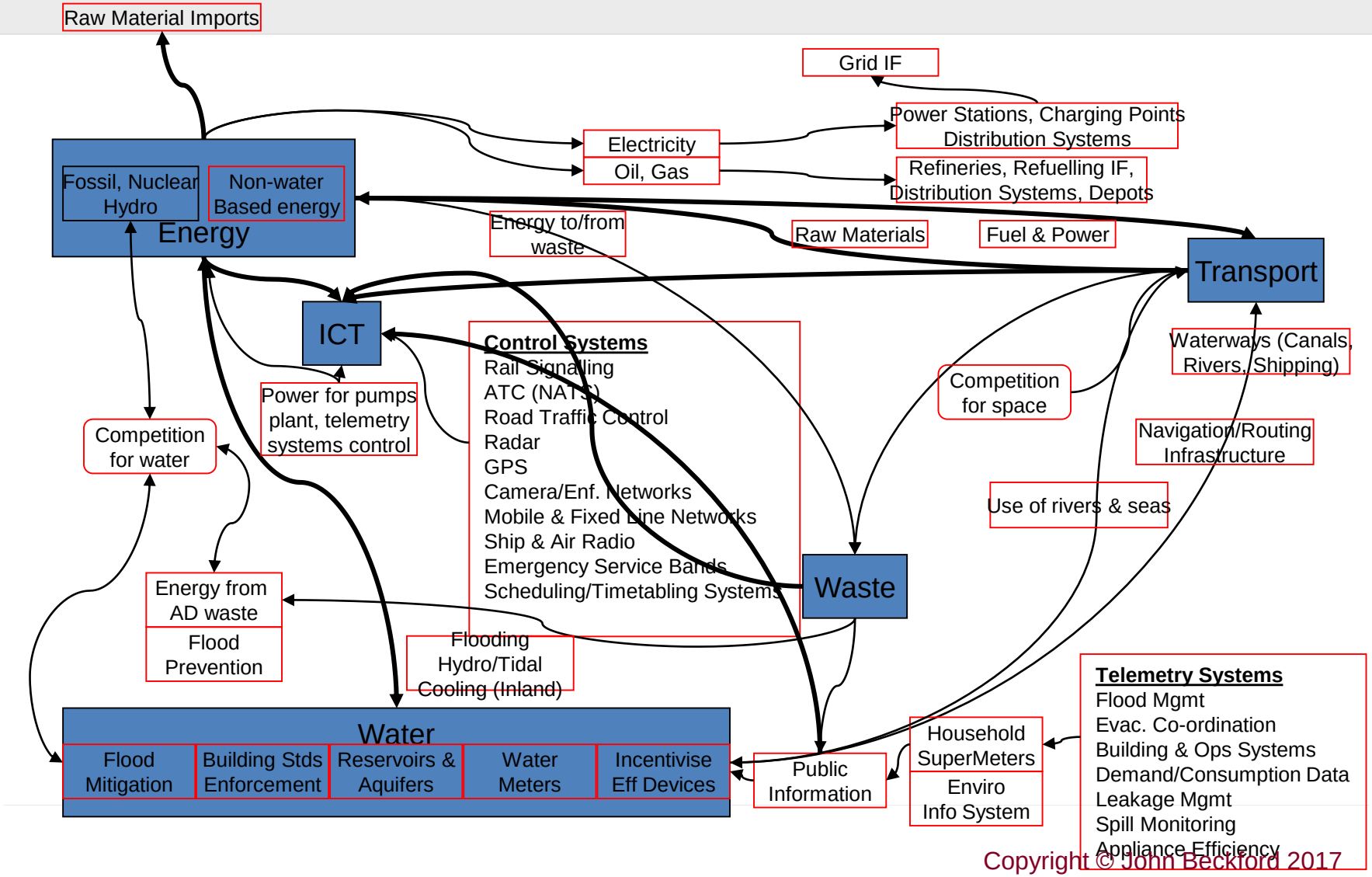
Systemic Modelling

Systemic Modelling

- "Is it possible to produce a systemic map of the infrastructure systems of the UK for Water, Waste, Transport, ICT and Energy?"
  - 2009 Professor Brian Collins

- We do not 'analyse' systems we 'synthesise' them
- Our need is to understand interaction and interdependency
  - "real improvement is only possible through enhancing the interactions"
  - Russ Ackoff, Wharton School in Creating the Corporate Future, Wiley, 1981

Systemic Modelling



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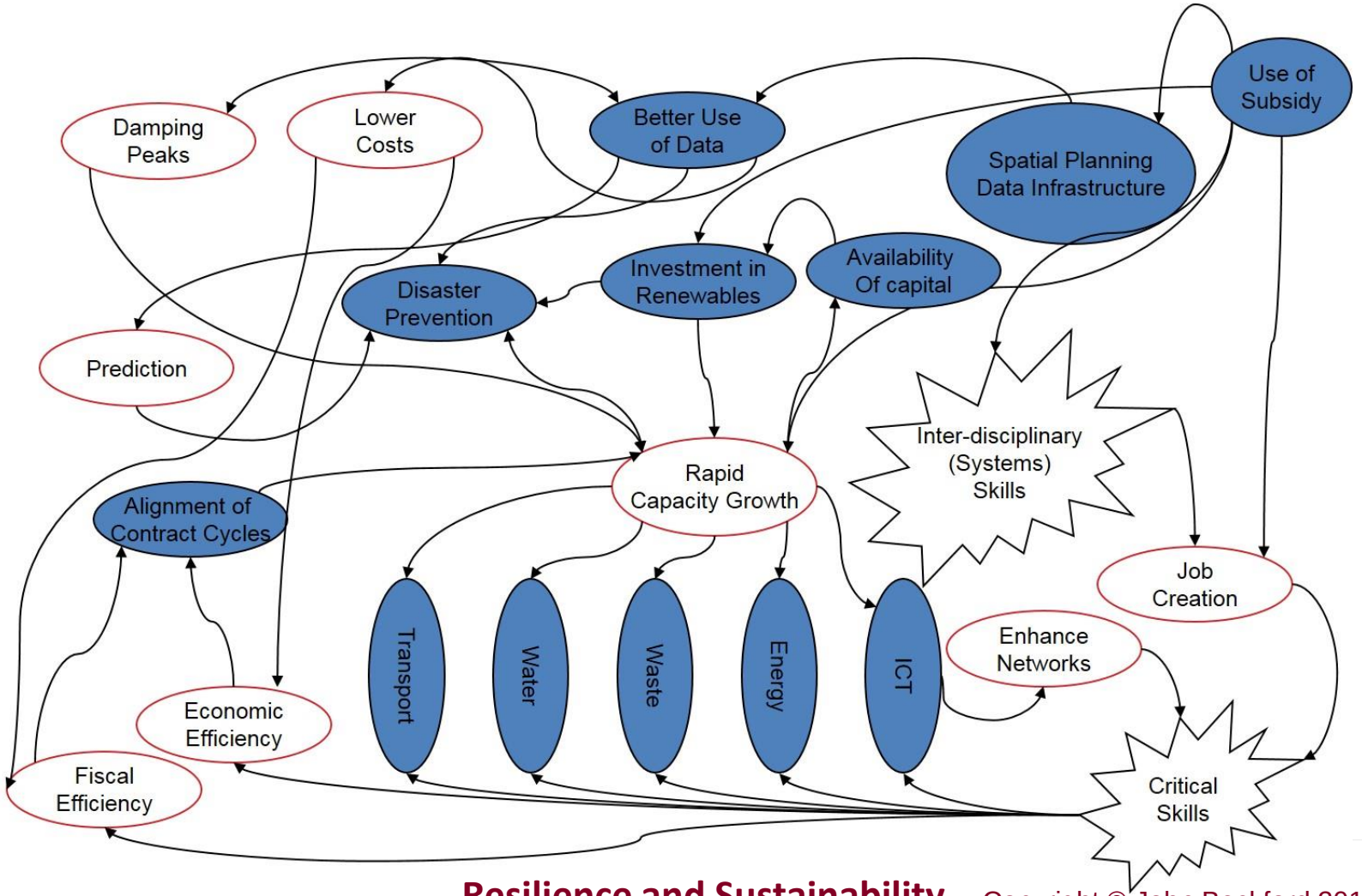

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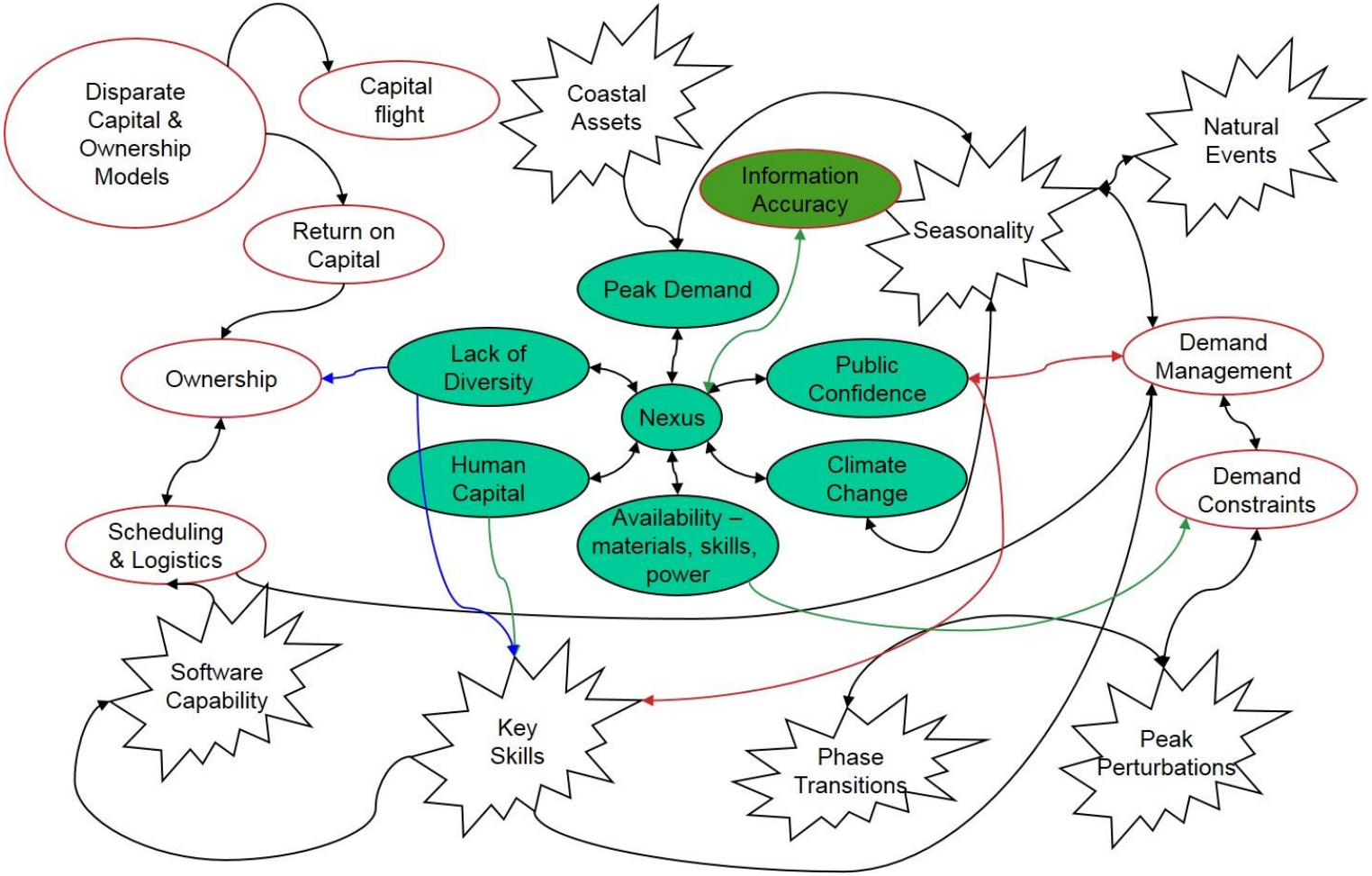

Risk and Failure Points

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Systemic Modelling

Systemic Modelling

- 3 levels of consideration
  - Energy and Transport needed four!
- Policy:
  - Ownership, Governance, Direction, Regulation, Constraints, Business and Funding Models,
- Infrastructure:
  - Supply and Delivery Systems, Owners, Business Systems,
- Demand:
  - Industrial, Commercial and Domestic
- 67 Interactions (at least)

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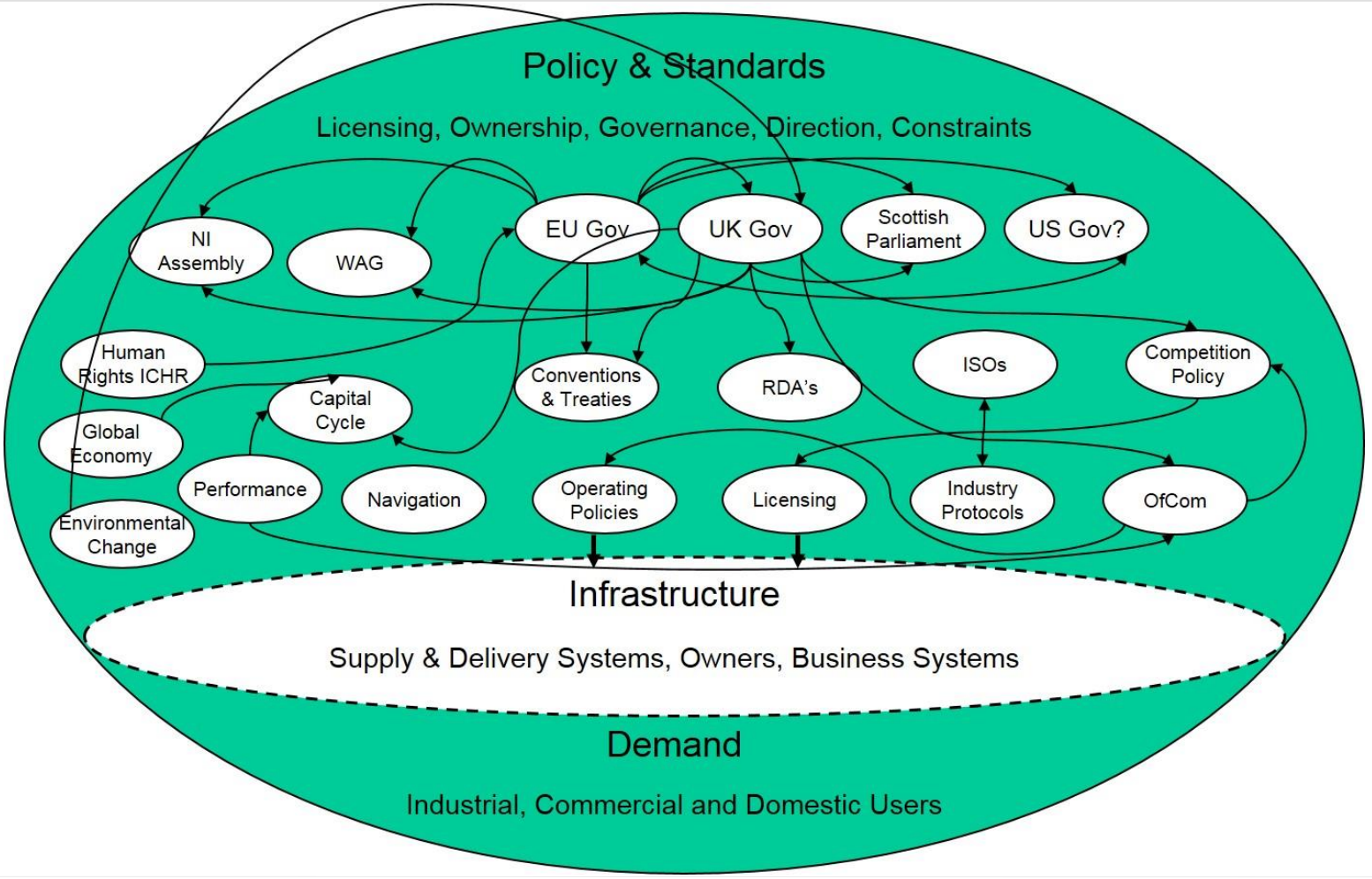
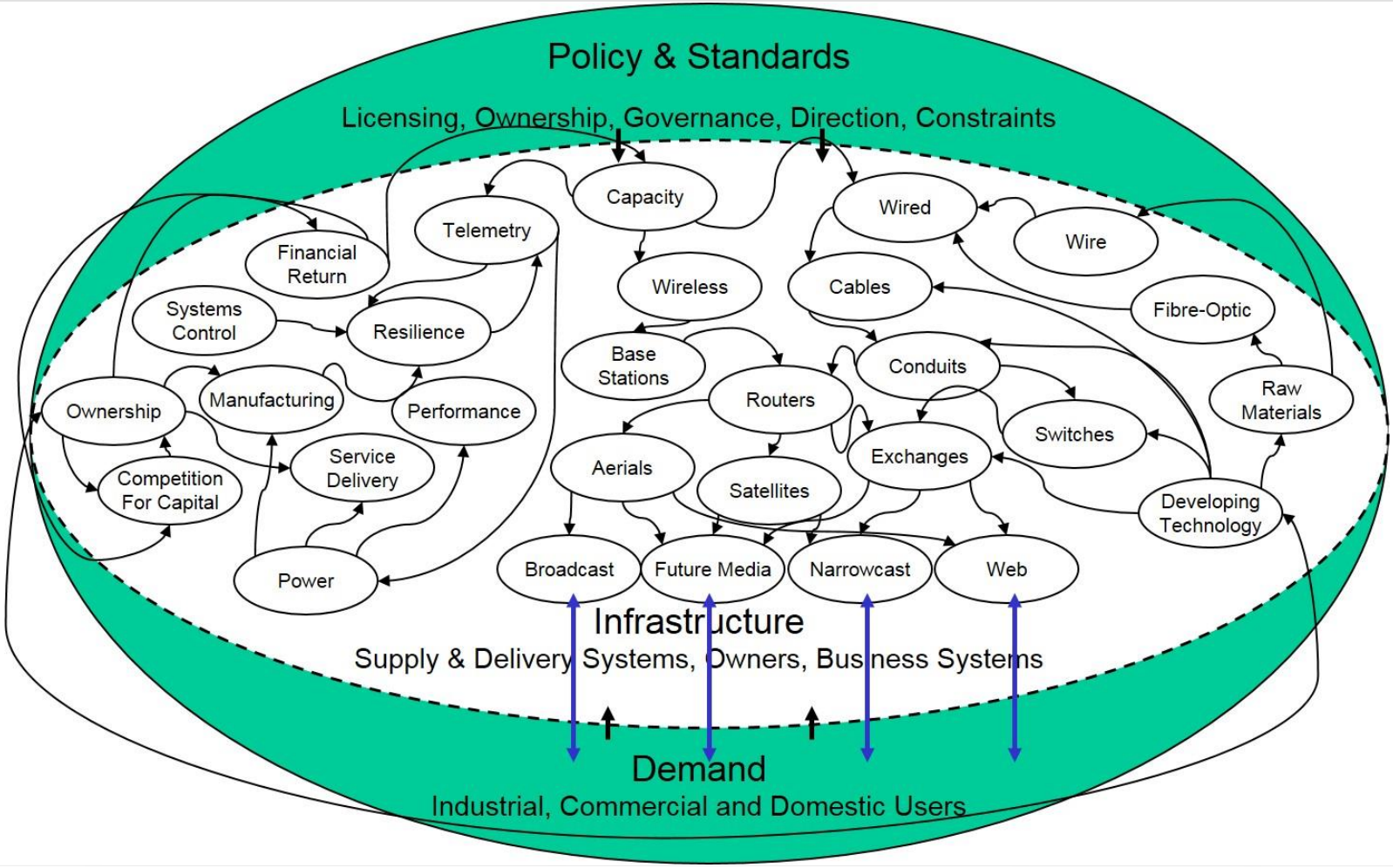
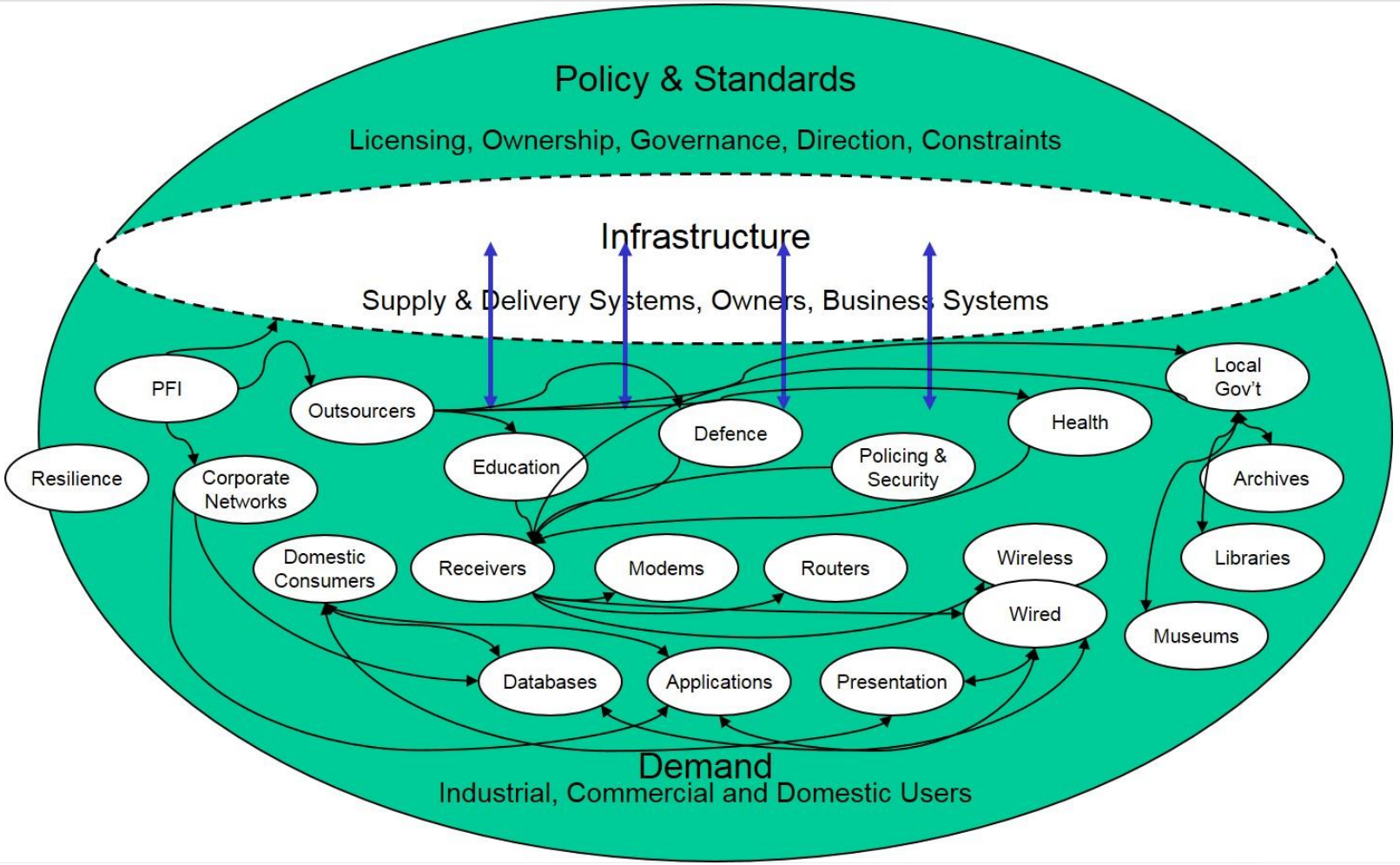
Systemic Modelling: ICT



Systemic Modelling: ICT



Systemic Modelling: ICT



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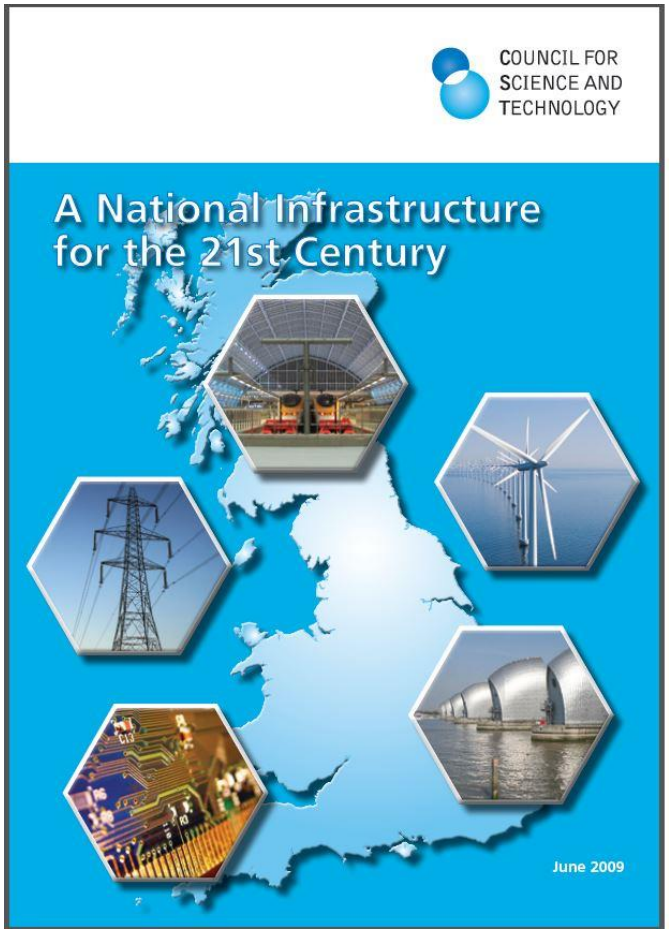
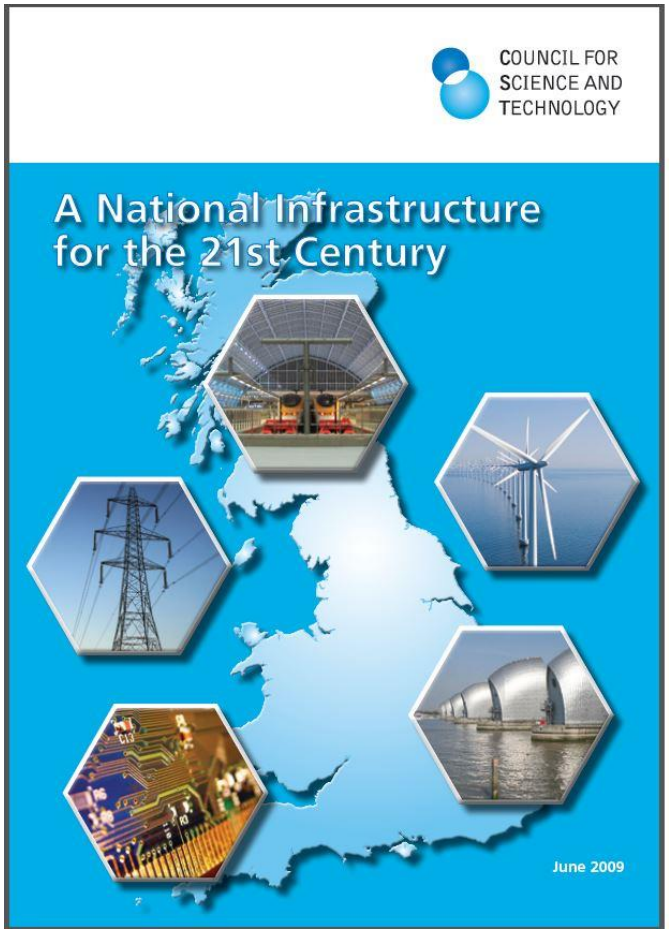
Progress and Prospects: A Network of Networks



- HM Treasury:
  - Engineering and Interdependency Expert Group
- National Infrastructure Plan
- National Infrastructure Commission
- Research: ICIF, iBuild, ITRC
- UKCRIC (2016)
  - (Initially) 14 Universities
  - National Laboratories
  - Co-ordination Hub
  - Knowledge Hub
  - Over £300m capital investment

Progress and Prospects: A Network of Networks



- So, what's the problem?

Progress and Prospects: A Network of Networks

- Exploiting capacity
  - Last 50 years we have been benefitting from historic investment
  - Nearing capacity we have to find different ways of managing
    - The old ways are no longer relevant or, perhaps, functional
    - There may be limits to sustainable growth
    - Increasing risk of systemic chaos in disruption with wider impacts

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Progress and Prospects: A Network of Networks

- Ageing Infrastructure
  - London Underground is 153 years old
  - London Sewers 1860-1875
  - Congestion, Beyond Design Capacity, Questionable Resilience
  - Potential for Systemic or Cascade Failure
    - Rooted in increasing and often unrecognised interdependence
      - Especially on ICT
  - Frequent Performance Challenges
    - 400 infrastructure impairments in November/December 2010
    - Grain Dryers in Northumbria reduce performance of ECML
    - Snow on slip road prevents food deliveries
    - Buses not running due to snow
    - £50k fine for pollution that devastated river

Progress and Prospects: A Network of Networks

He said it was 'not good enough' that the UK Government had still not devolved franchise powers to Wales, although this should have happened by May 2016.

The DfT has been approached by *Transport Network* for a response on the delay.

Ferries plied the Hudson River through the mist on Wednesday. Some commuters are turning to ferries amid the disruptions stemming from Monday's derailment.

MARK LENNIHAN/ASSOCIATED PRESS

Amtrak Under Fire Over Penn Derailments

By Kate King

New York-area commuter rail services Wednesday lashed out at Amtrak for its upkeep of rail lines in the northeast corridor two days after a derail- … major disruptions …

… Director Veronique "Ronnie" Hakim wrote that the "increasing frequency of these failures leaves the clear impression that Amtrak is not aggressively maintaining its tracks, switches and related equipment at Penn Station."

The MTA operates the Long Island Rail Road, which delivers an estimated 230,000 commuters … station each day.

… able," Mr. Santoro said.

Amtrak Chief Executive Charles "Wick" Moorman said the company is investigating and will take prompt action to address the cause of the recent derailments. Amtrak aims to restore regular service to Penn Station by Friday.

"We value our partnership with the commuter railroads and share the frustration these recent issues present to all of our customers," Mr. Moorman said in a statement.

One focus of the investigation into Monday's derailment is whether the rails may have become spaced too far apart, according to a person familiar with the matter.

"That's one of the things we're looking at, the width of the gauge," this person said, adding that it wasn't clear whether a switch or mechanical problem with the train contributed to the wreck. Track maintenance at the station is Amtrak's responsibility.

Mr. Santoro said NJ Transit verified that all of its railcars were up-to-date on required 180-day inspections at the … the derailment. "We feel that those railcars were in good shape," he said.

As the commuting nightmare resulting from Monday's train derailment stretched into a third day, lawmakers in New York and New Jersey … the disruption … the need for federal … jump-start a … Hudson River Rail … Local funding … essary permit … but construc… until the fe… agrees to … ect's firs… cost $1…

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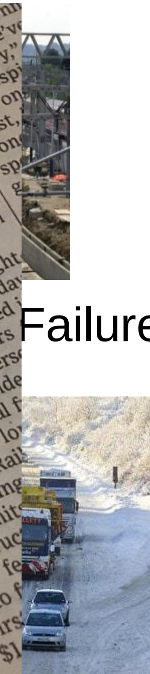
Failure



Traffic

Progress and Prospects: A Network of Networks

- UK Opportunities and Needs
  - NIC Pipeline of £500bn, 728 Projects and Programmes
    - Autumn Statement 2016
      - Autonomous Vehicles
      - Smart Grid
      - Renewable Energy Sources
      - Nuclear
      - HS2
      - Additional Runway Capacity
  - Climate Change Adaptation
- Context
  - Largely Private Ownership, Government Financial support
  - Economic and Safety Regulation

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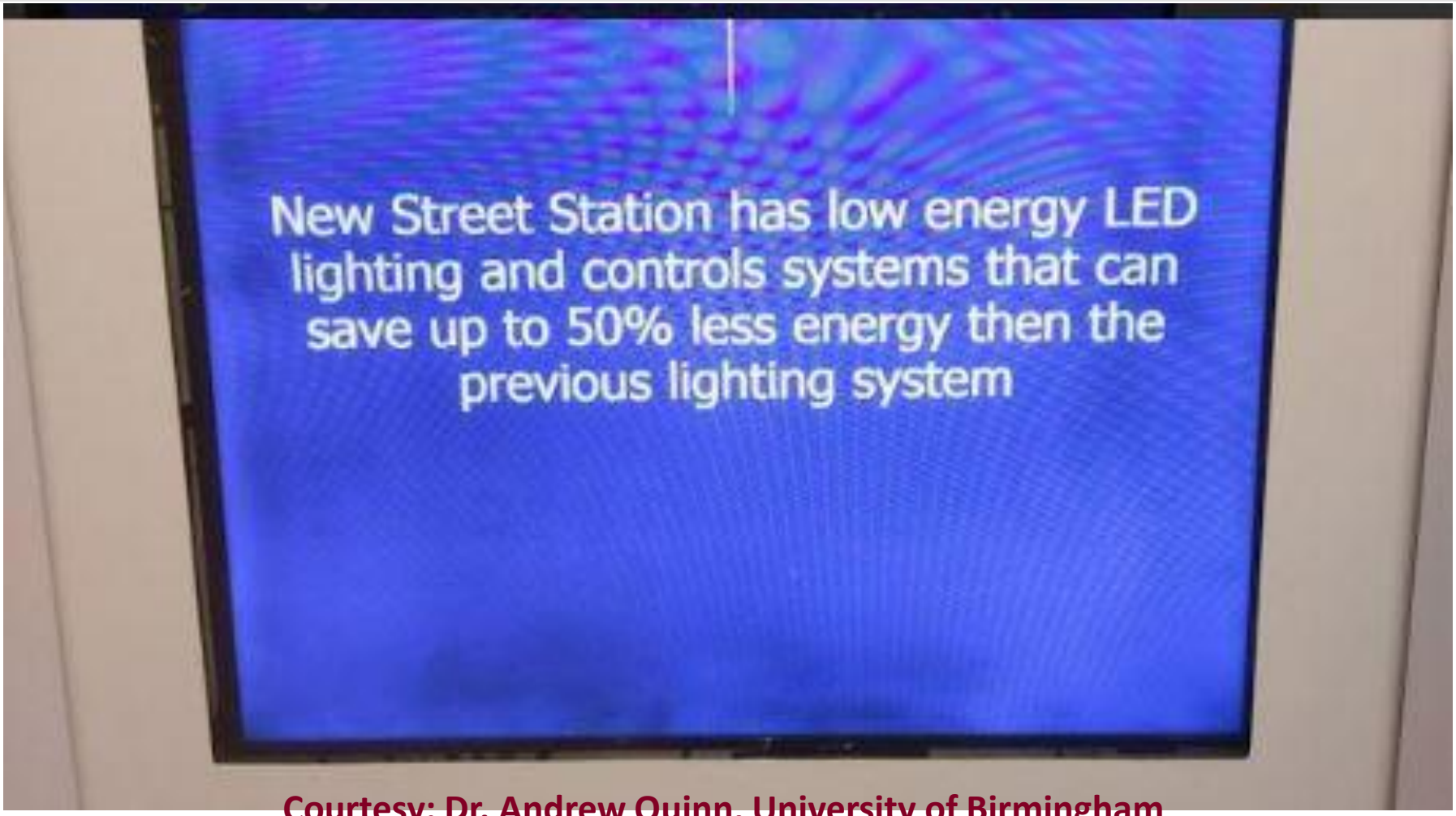


Courtesy: Dr. Andrew Quinn, University of Birmingham

Exploring Interdependency: "Enhancing Interactions"

- Dependency:
  - This depends on that
- Inter-dependency:
  - This depends on that and that depends on this
    - Geo-physical, Weather (short term), Climate (longer term)
    - Functional, inter-operability
    - Operational
    - Economic
- Value Generating – fulfilling purpose
- Value Enabling – supporting and conditioning value generation
- Systemic Interdependency - "A network of networks"

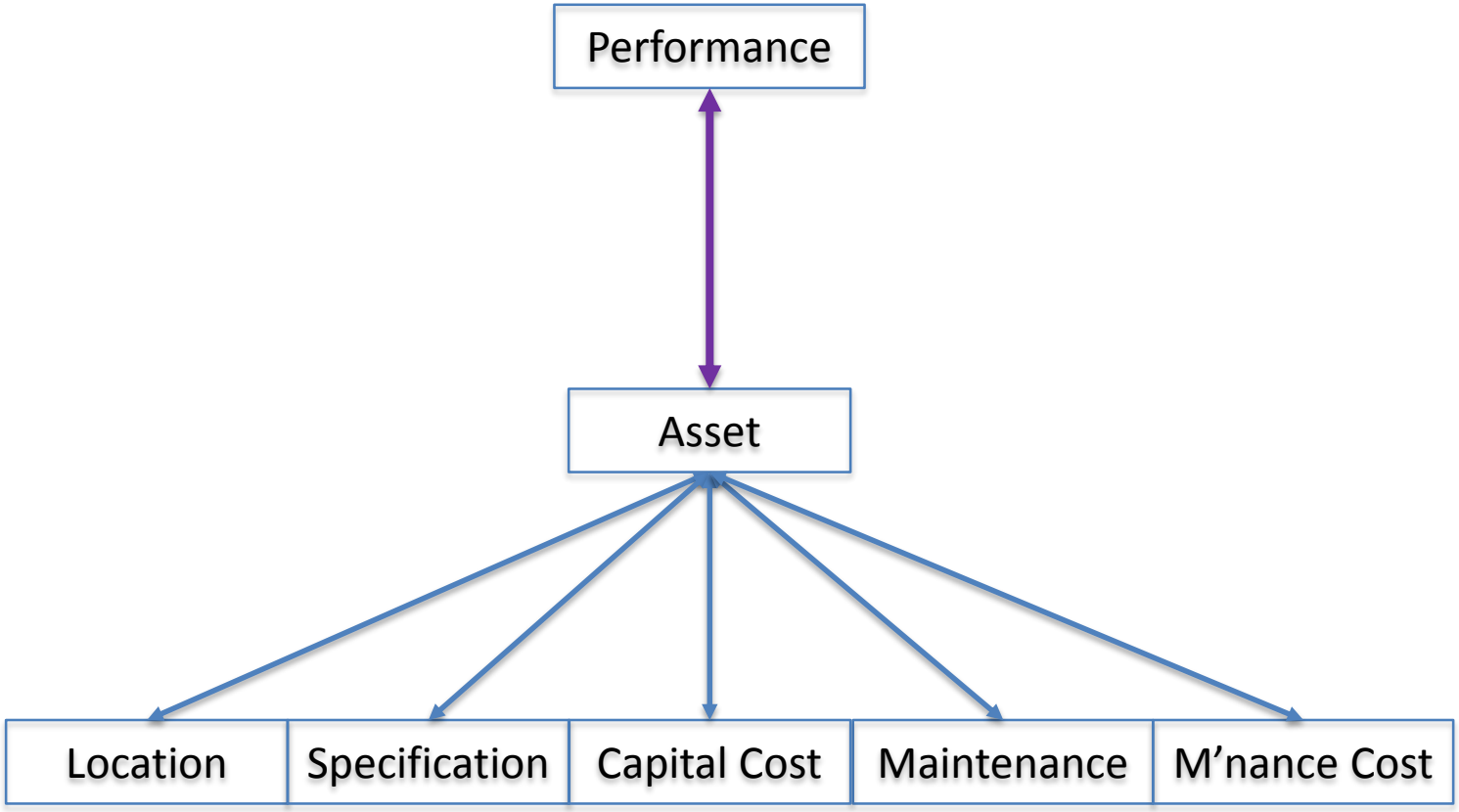
Exploring Interdependency: "Enhancing Interactions"

- Efficiency and effectiveness
  - Increases in short run efficiency can embed long term effectiveness risk
    - Use of remote monitoring and control
  - System availability is co-dependent
    - It all works or none of it works – but 'we' don't control it all
- Remember these:
  - 400 infrastructure impairments in November/December 2010
  - Grain Dryers in Northumbria reduce performance of ECML
  - Snow on slip road prevents food deliveries
  - Buses not running due to snow
  - £50k fine for pollution that devastated river
- Everyone driven by pursuit of short-run (financial) efficiency

Exploring Interdependency: “Enhancing Interactions”

Asset

Exploring Interdependency: "Enhancing Interactions"



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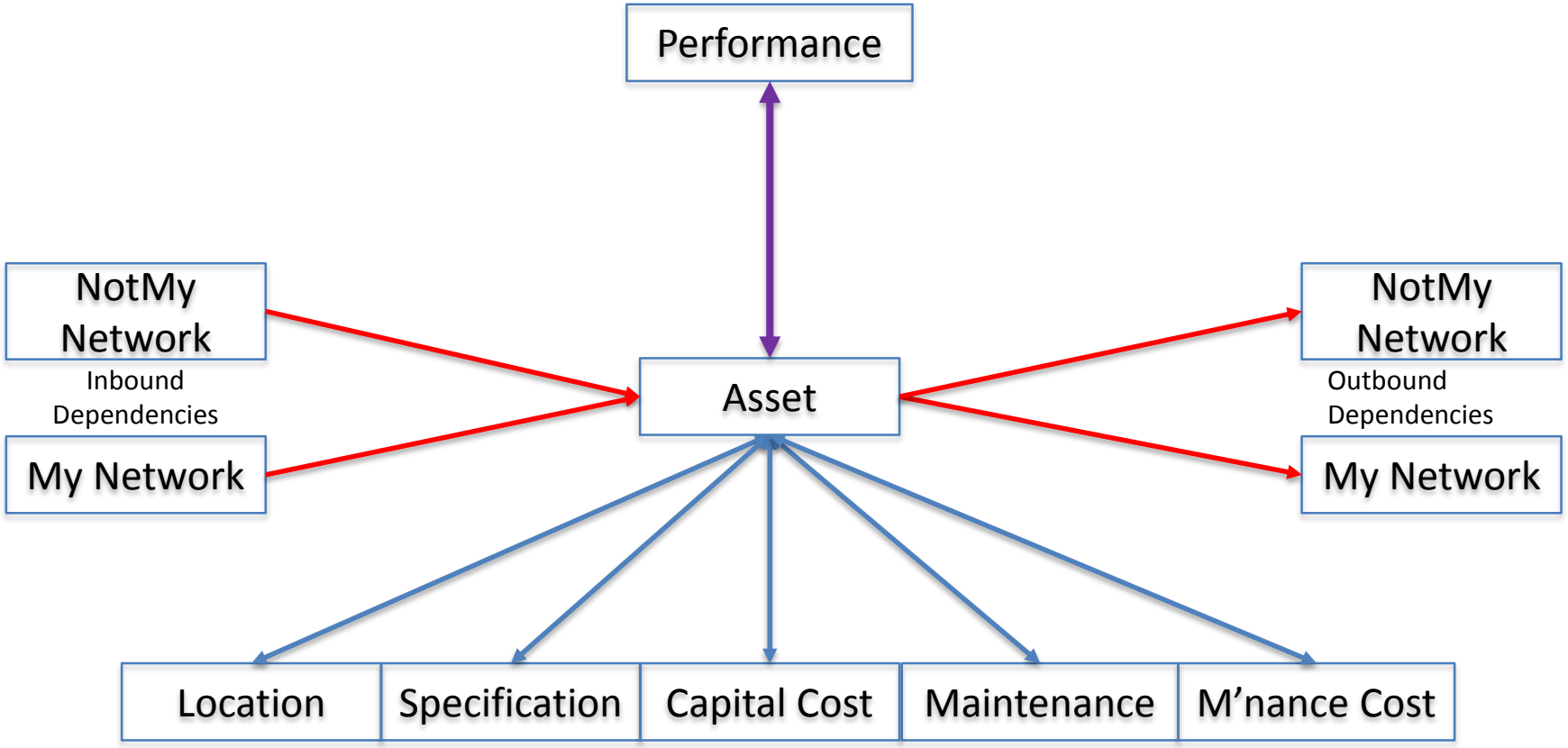

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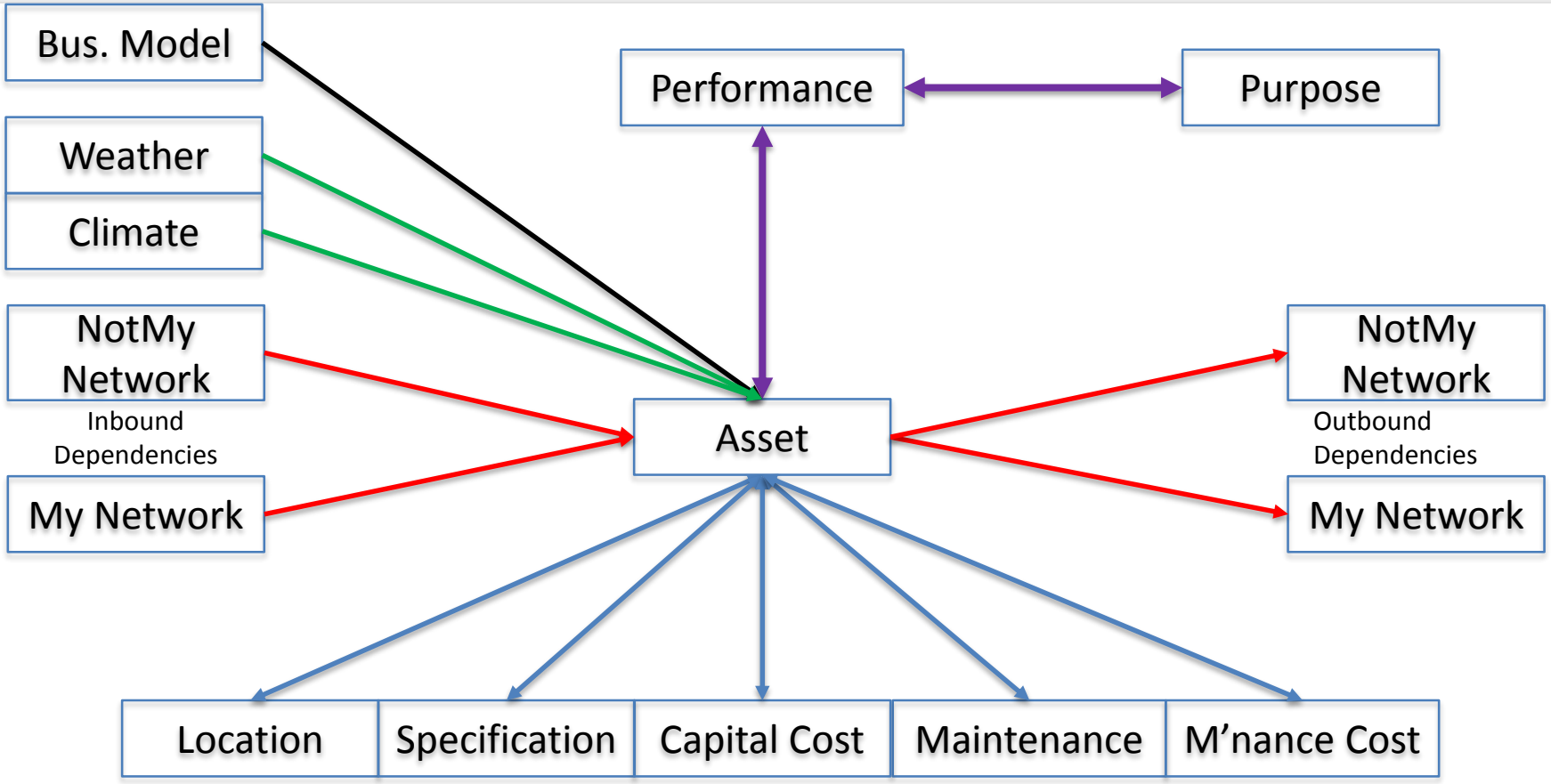

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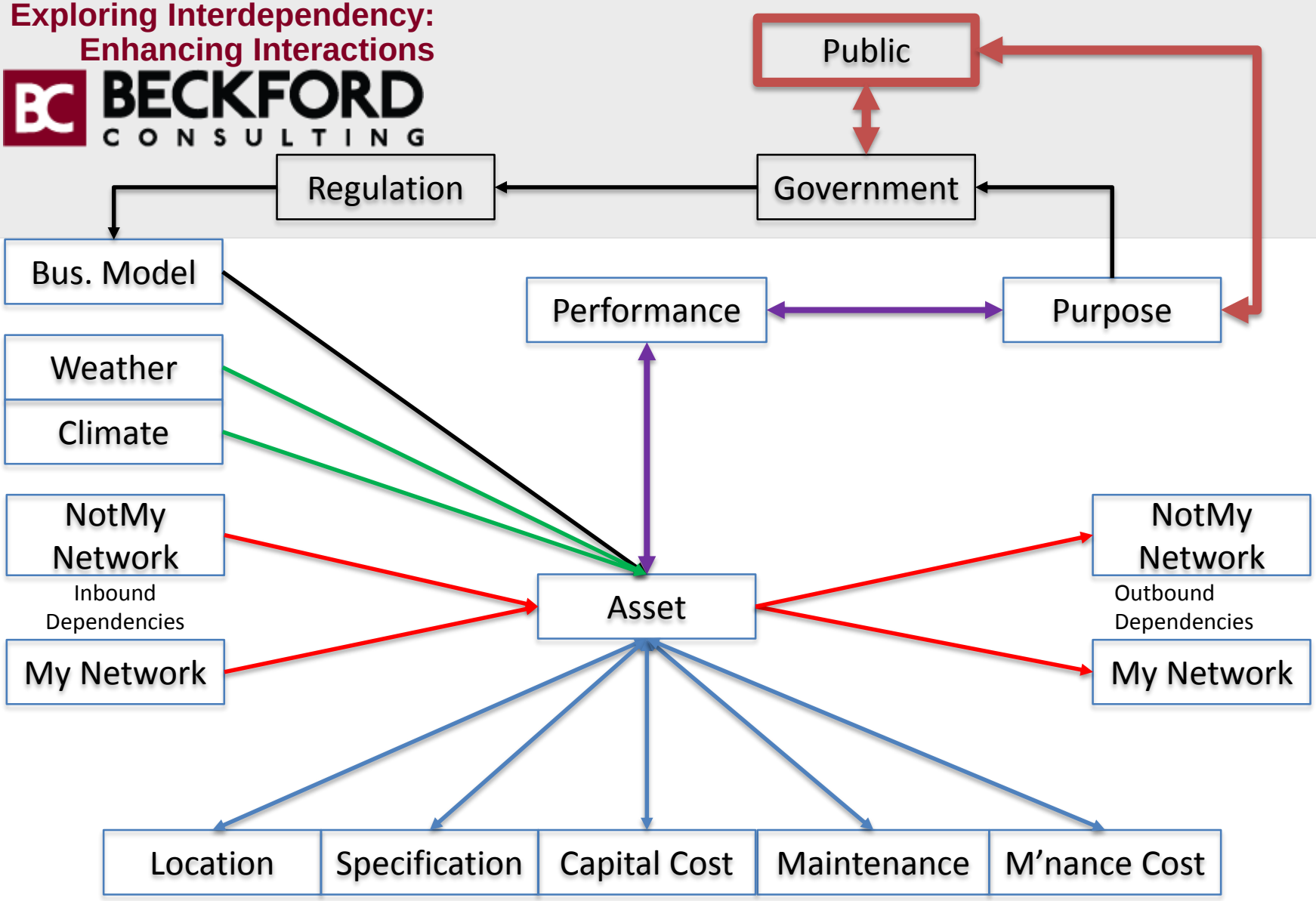

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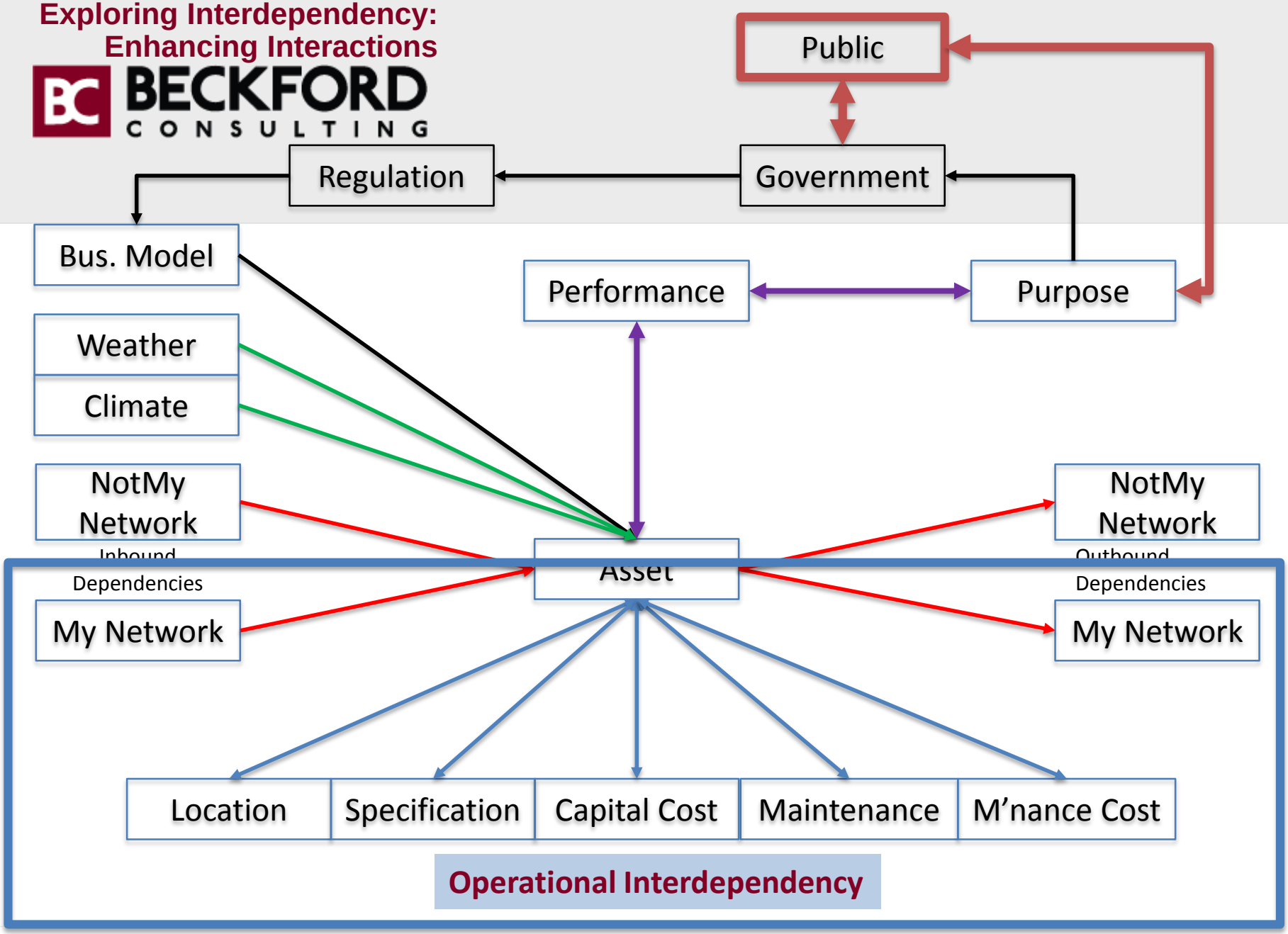

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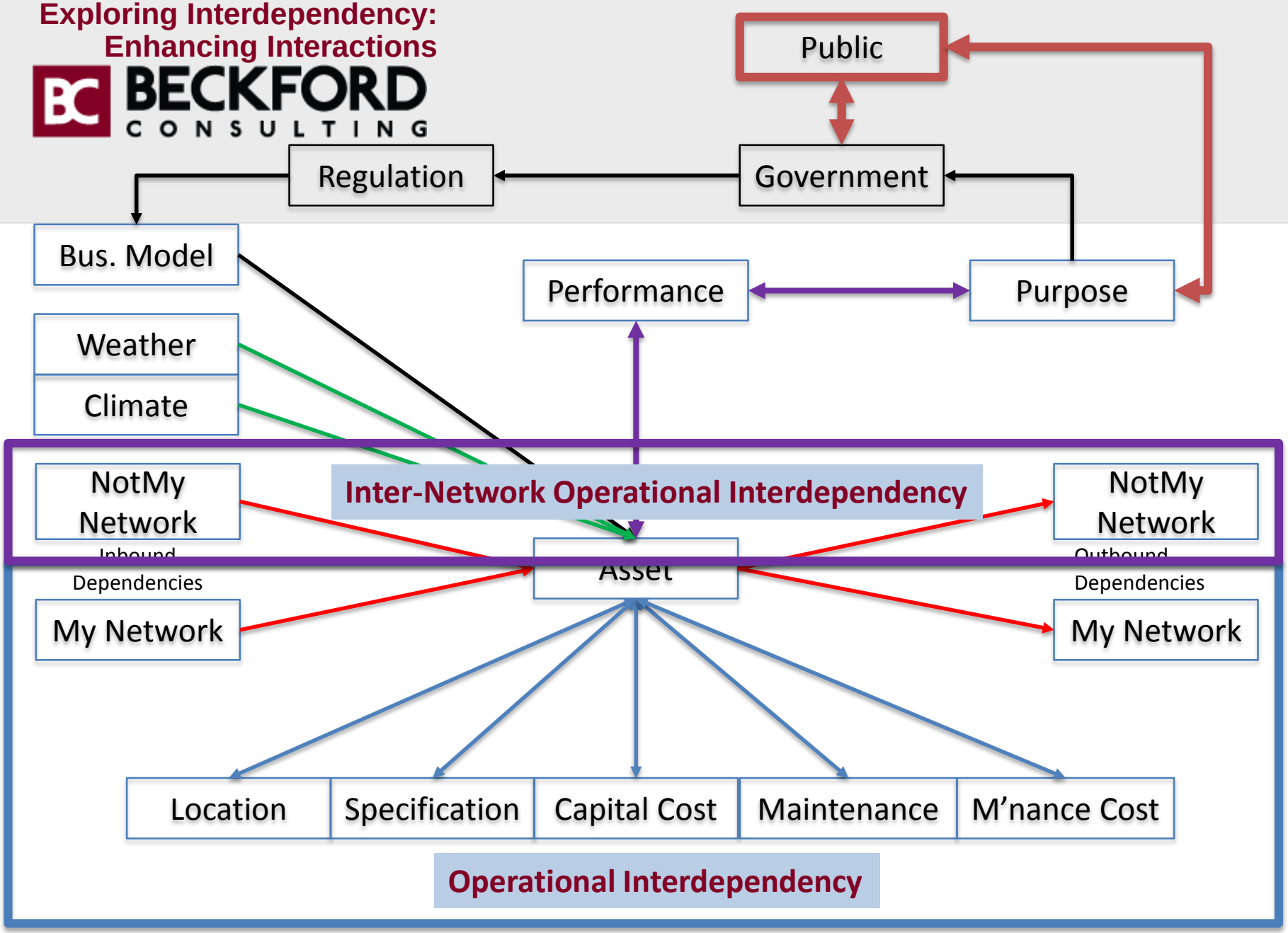

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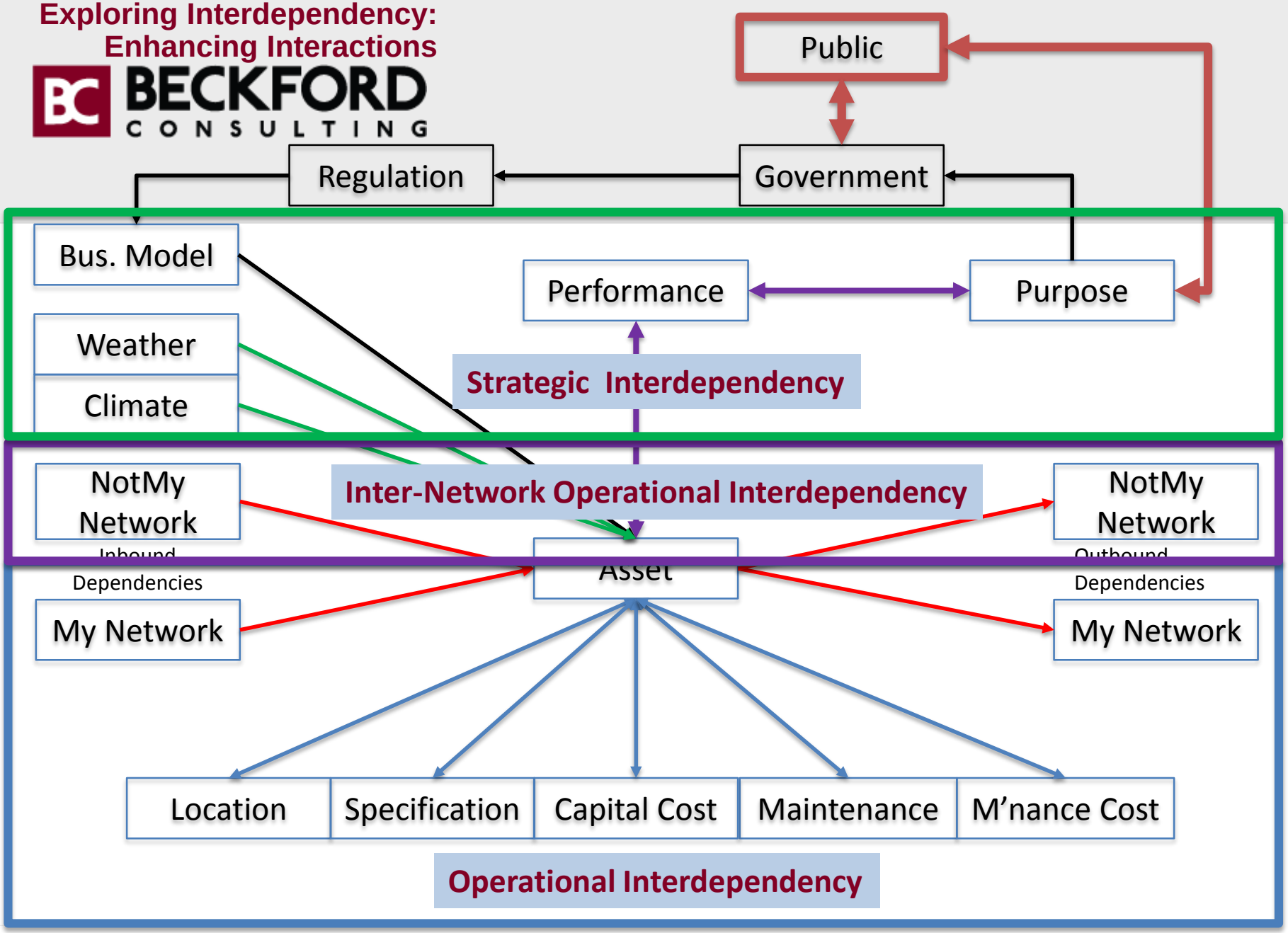

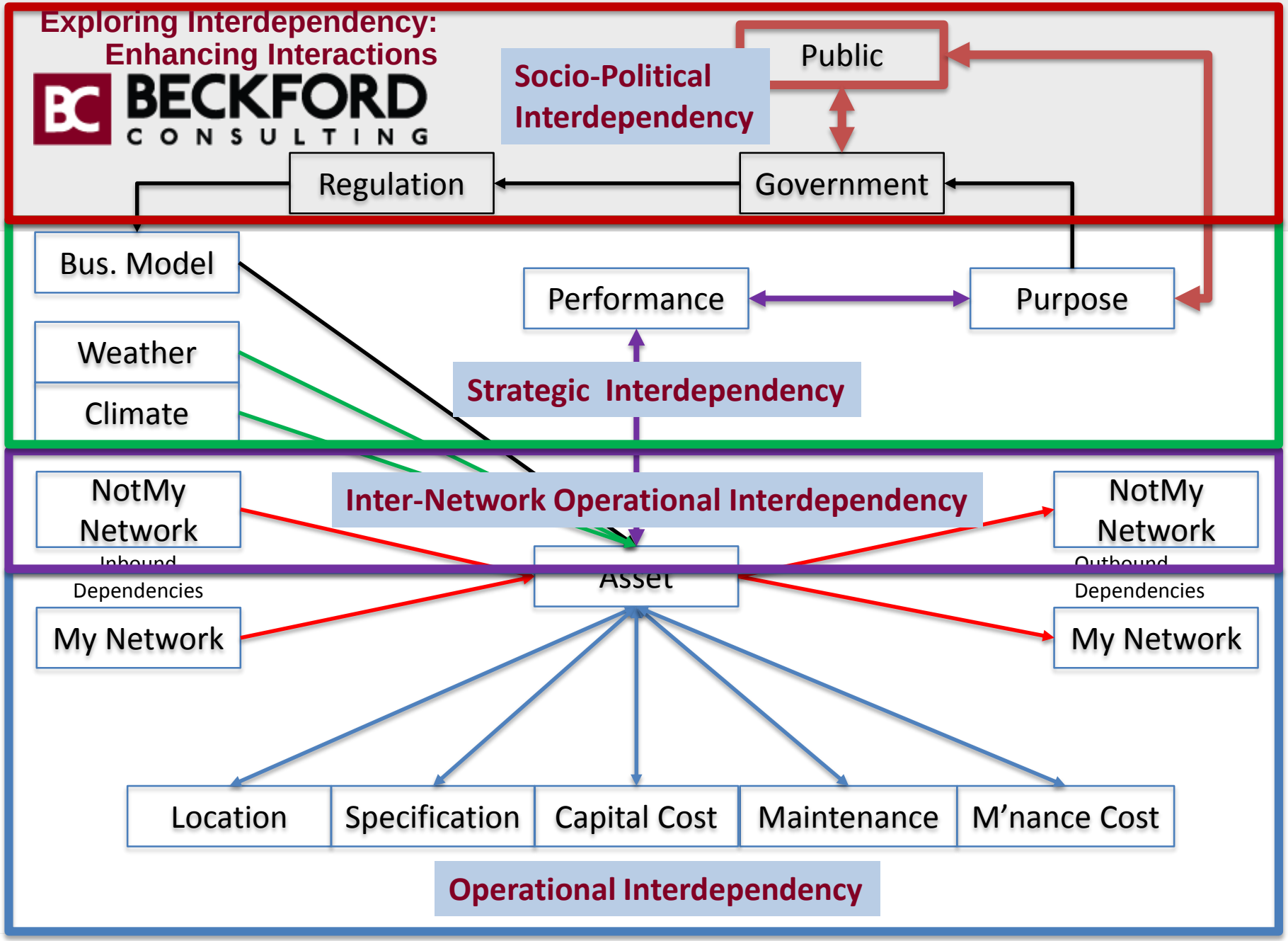

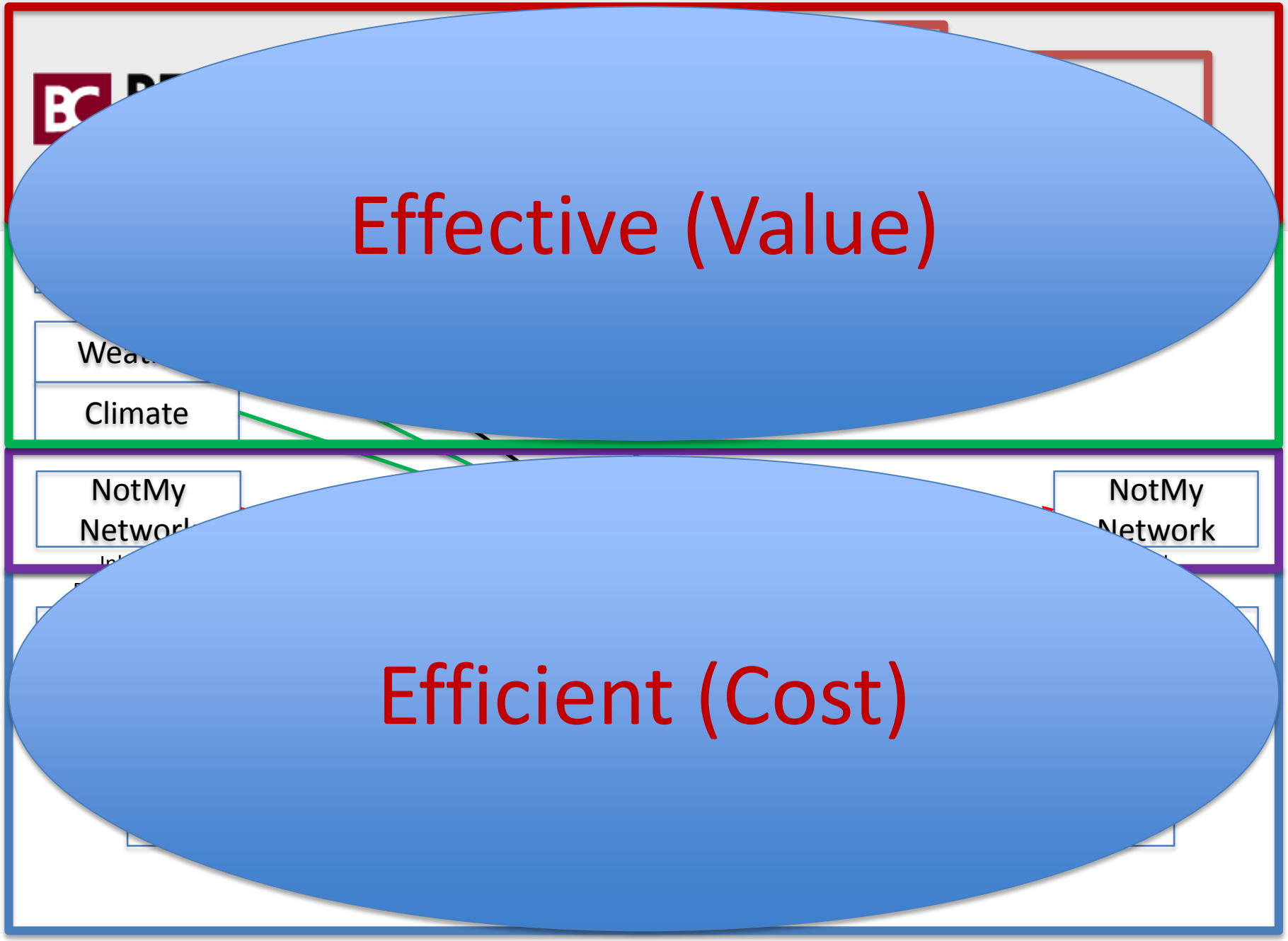

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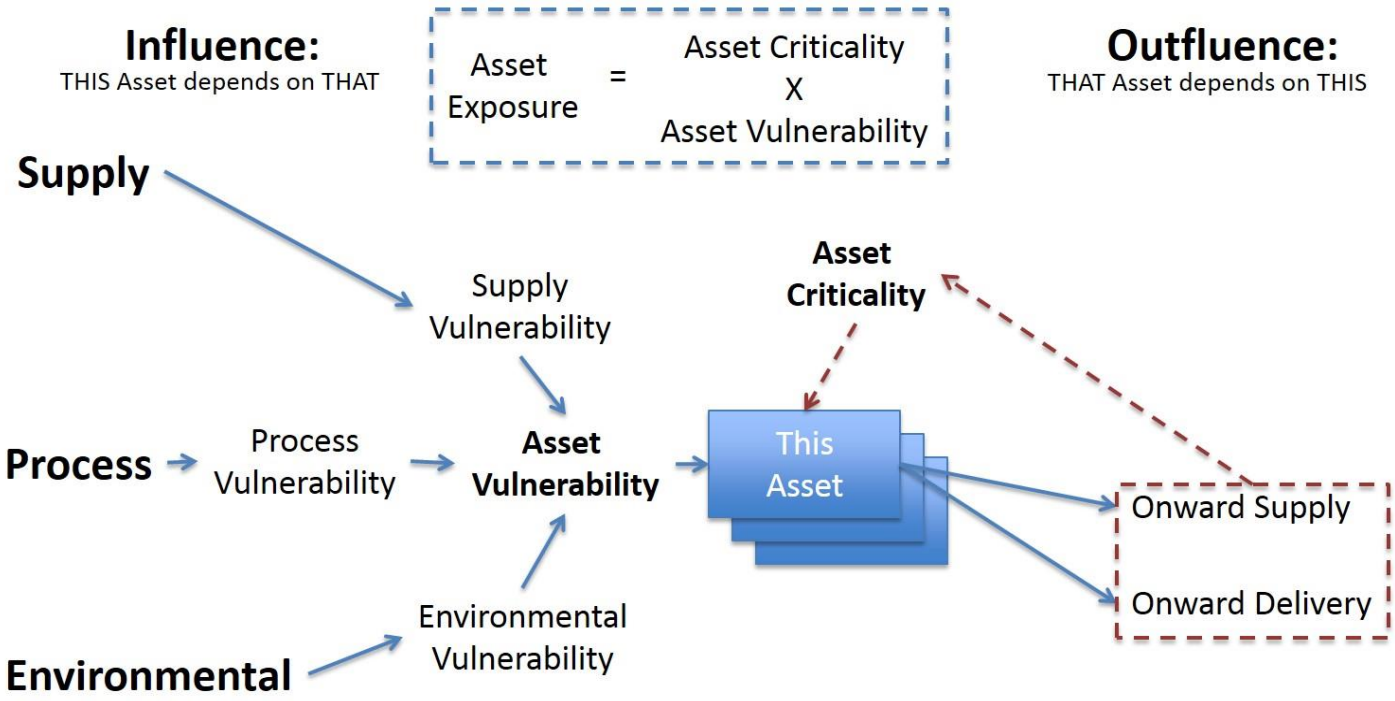
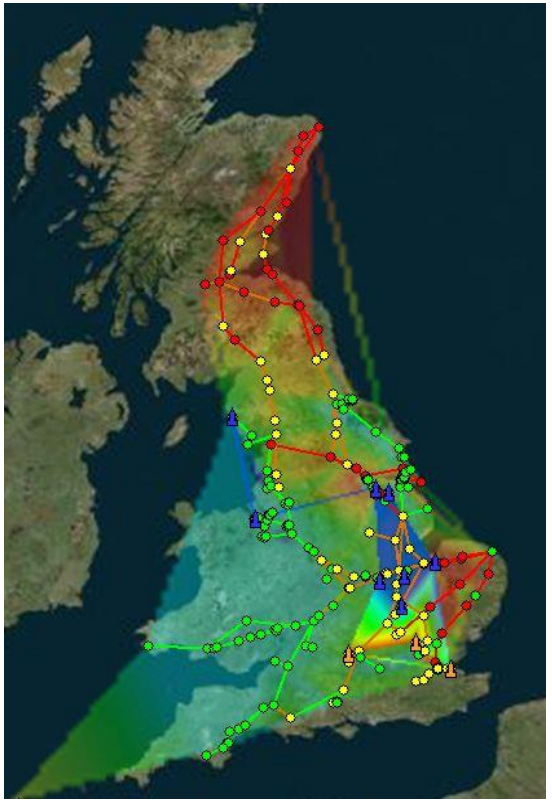
Asset Criticality and Network Resilience



Asset Criticality = Σ (Onward Asset Dependence X Onward Asset Criticality)
Supply Criticality = Asset Criticality X Supply Vulnerability
Process Criticality = Asset Criticality X Process Vulnerability
Environmental Criticality = Asset Criticality X Environmental Vulnerability
Asset Vulnerability = Max of Supply/Maintenance/Environmental Vulnerability

Asset Criticality and Network Resilience

- Consider UK Infrastructure as a ‘network of networks’:
  - model the interdependencies
  - model how failure propagates across
    - individual networks (e.g. gas, electricity)
    - multiple networks (e.g. gas AND electricity)
  - represent the results graphically
  - identify affected populations
    - develop a vulnerability and/or criticality index for:
      - the individual assets
      - the networks
- Understand where
  - our system is vulnerable to failure
  - to take mitigating action to deliver greatest social benefit
  - investment will best increase resilience



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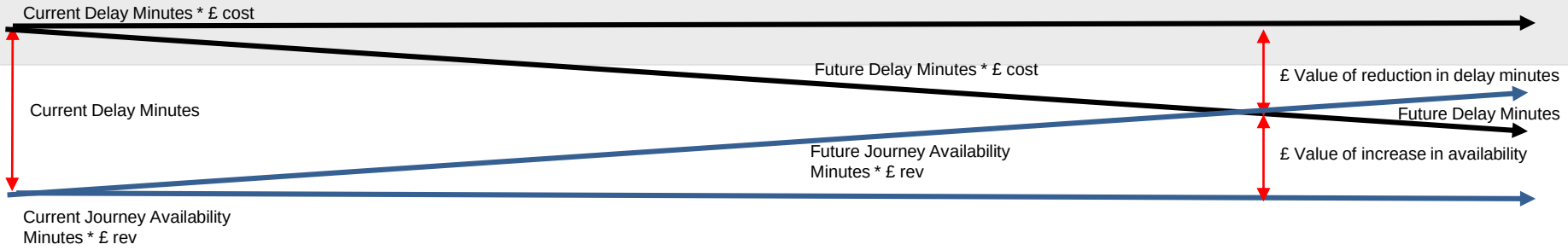
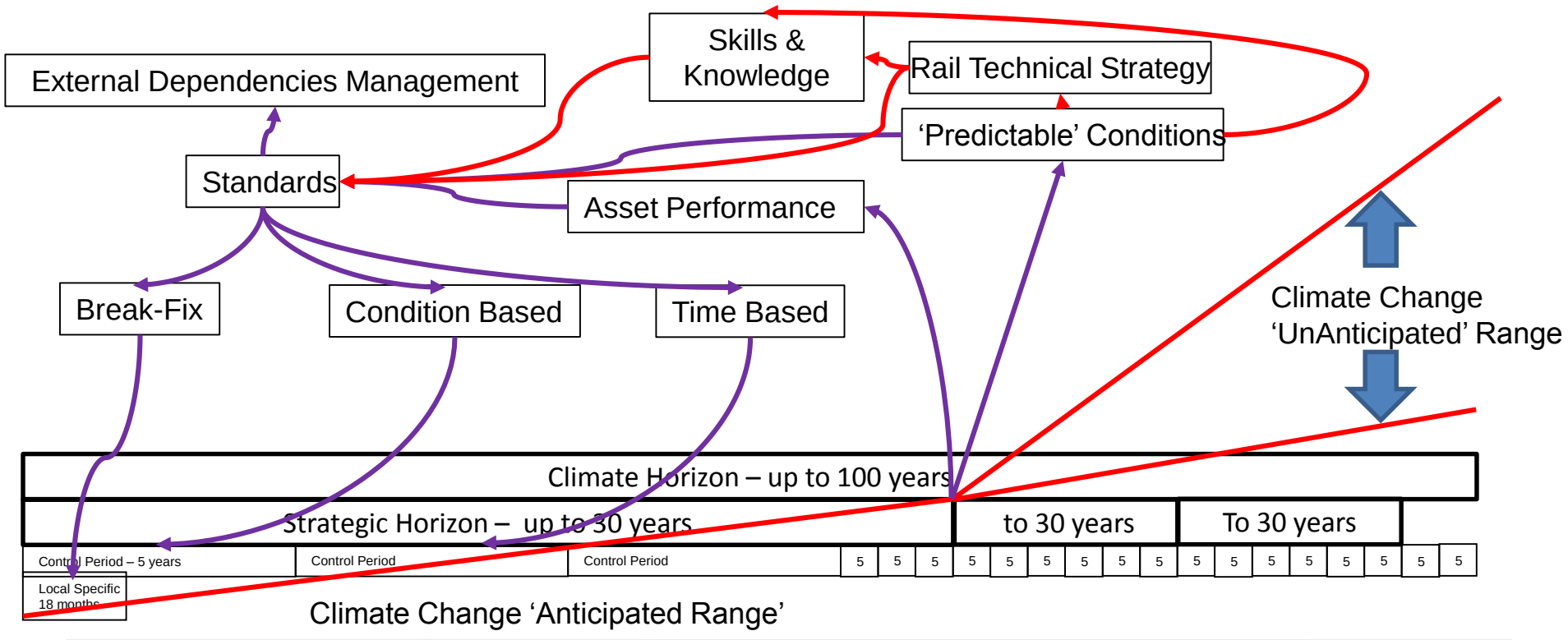
TRaCCA: A Case Study

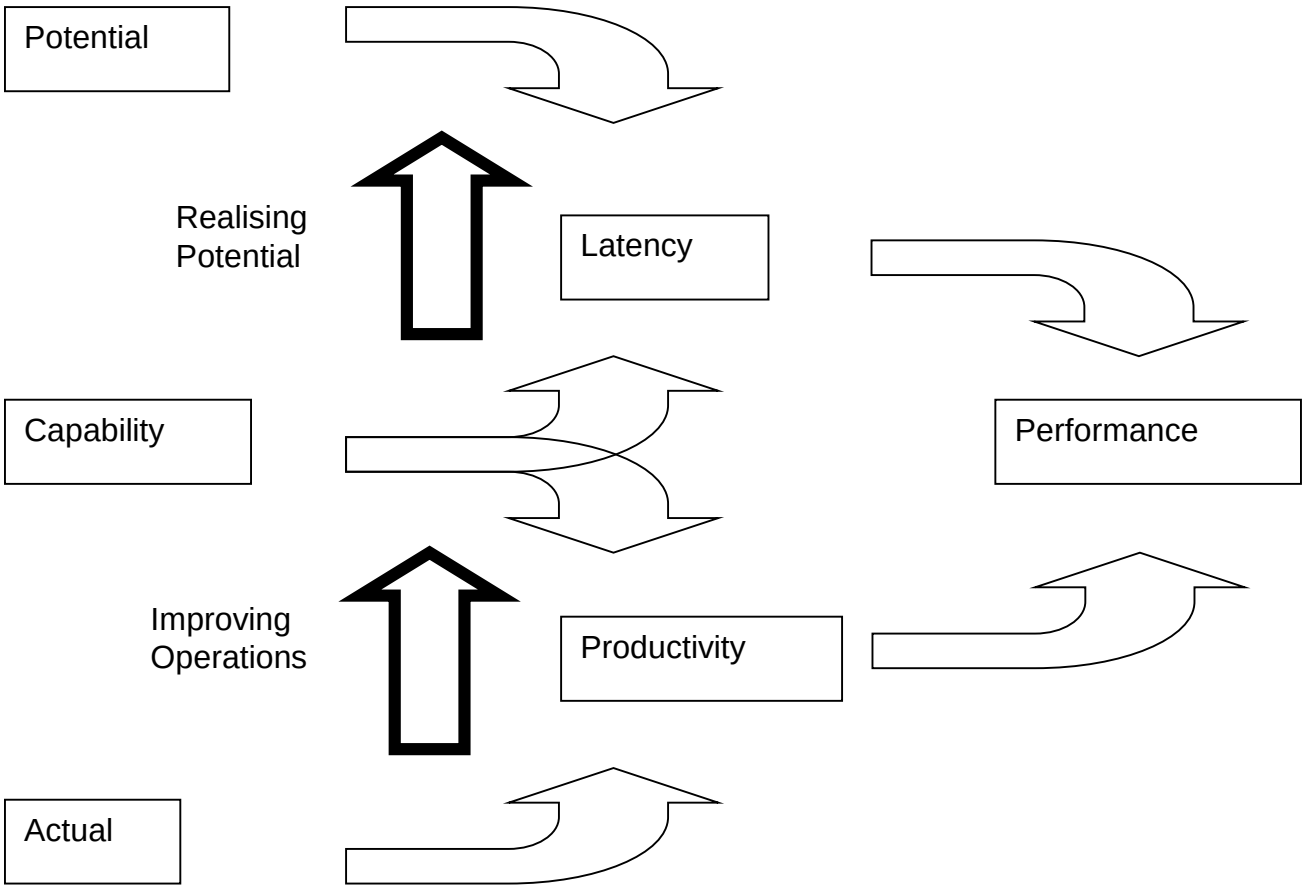
Infrastructure Availability + Service Availability = Journey Availability (proxy = delay minutes)

TRaCCA: A Case Study





Measuring Infrastructure Performance



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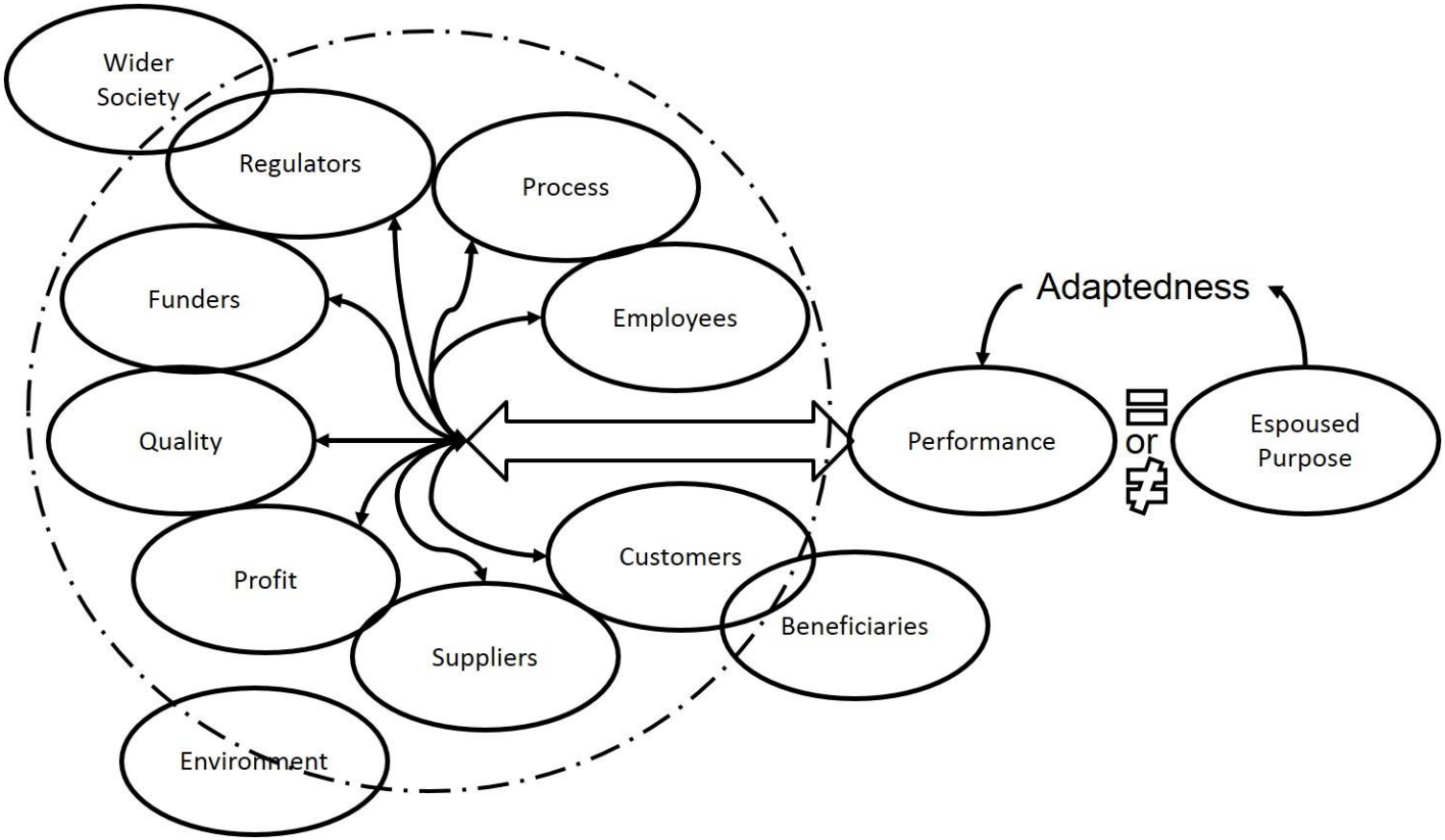

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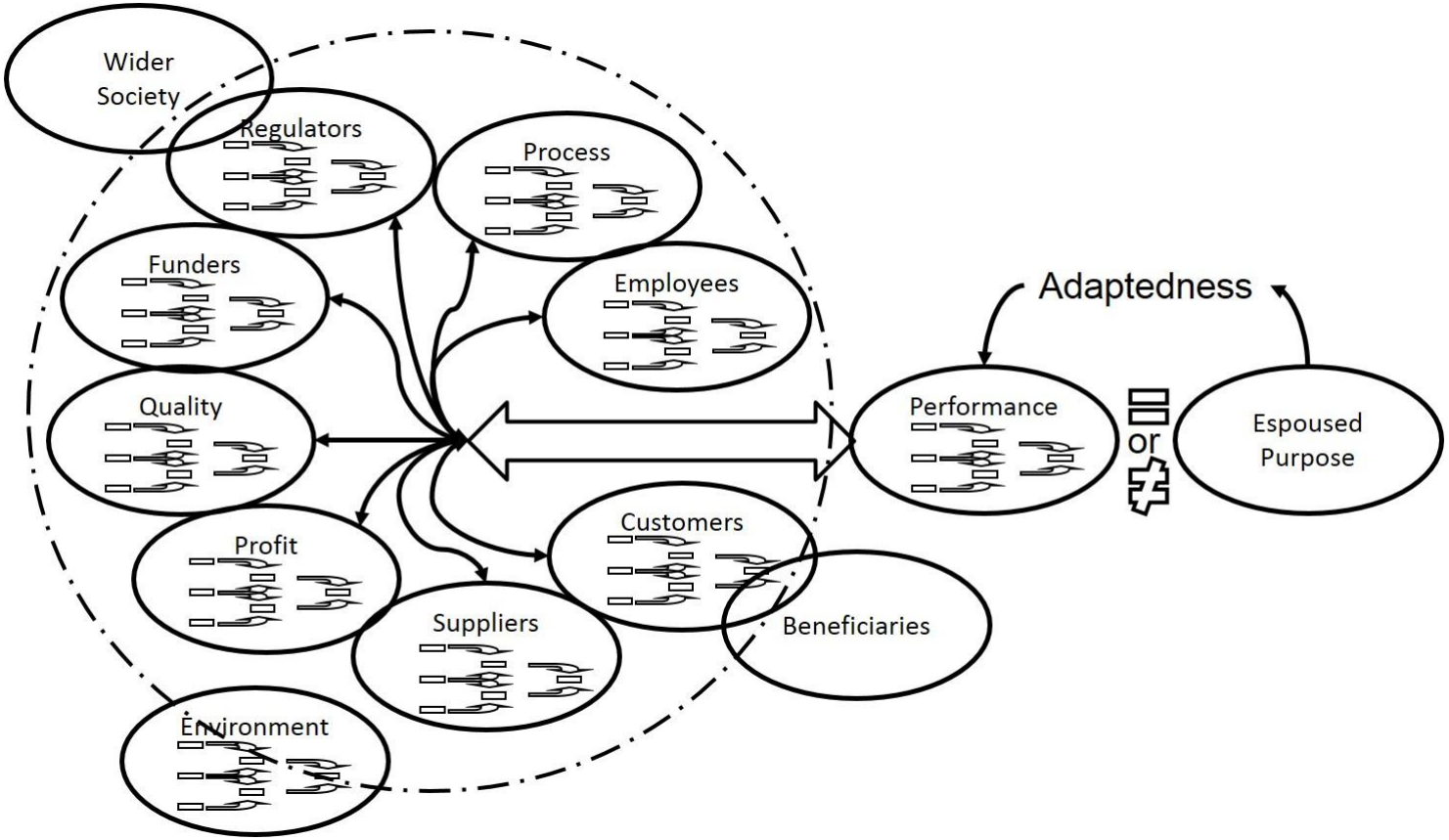

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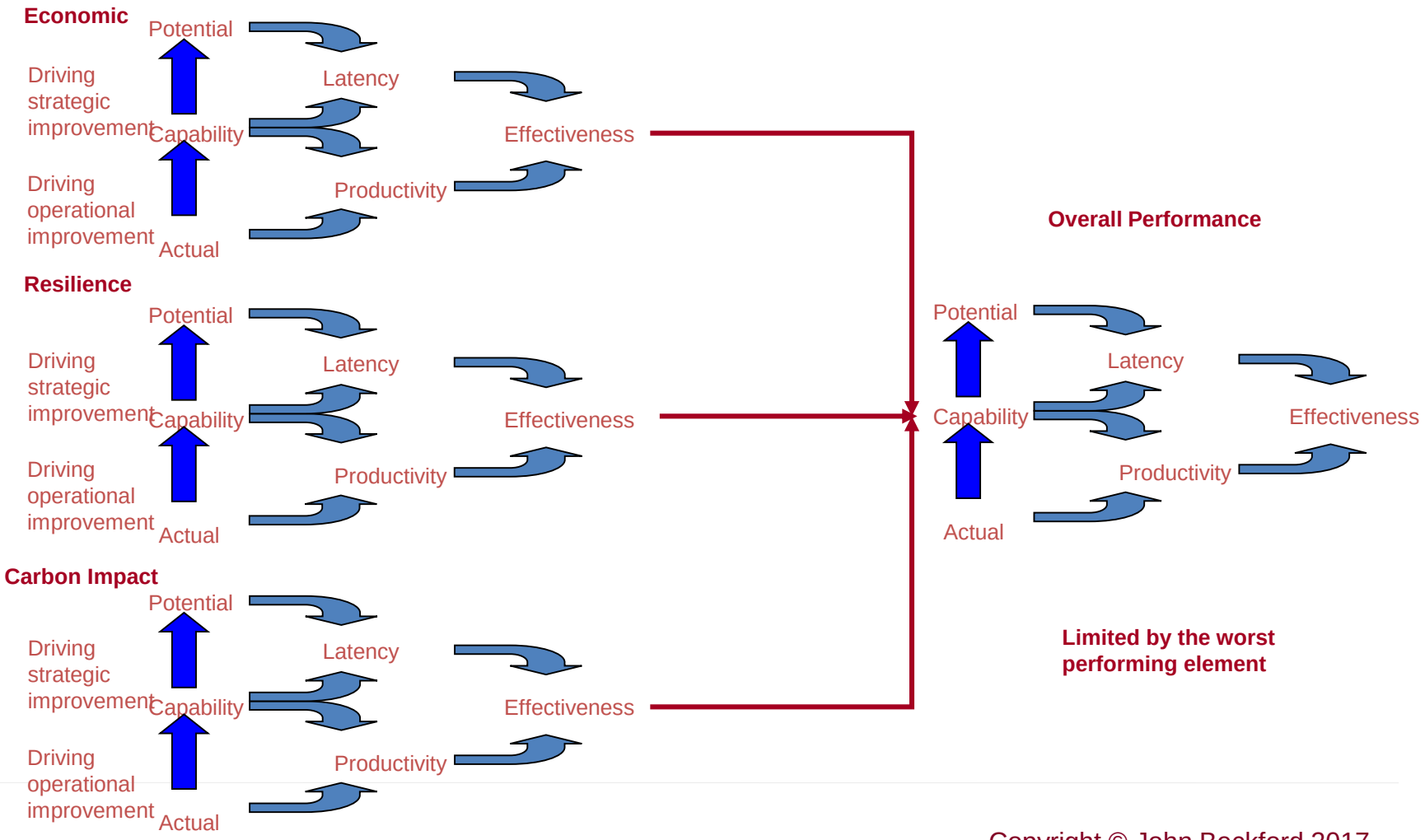

Measuring Infrastructure Performance

1st Cycle						Performance			2nd Cycle					Performance			3rd Cycle					Performance	
Standard Position						System			Stage One: Single Dependency Loss					System			Stage Two: Multi-Dependency Loss					System	
						Capability	136							Capability	94							Capability	79	
NOTE:	Critical Dependencies					**Performance**	**0.69**							**Performance**	**0.58**							**Performance**	**0.49**
NOTE:	White Boxes					Actual	94							Actual	79							Actual	67
This	**Depends on**								**Depends on**								**Depends on**						
	Waste	Water	Energy	Tport	ICT	**Waste**			Waste	Water	Energy	Tport	ICT	**Waste**			Waste	Water	Energy	Tport	ICT	**Waste**	
Waste		2	6	10	6	Capability	24			1	3	5	3	Capability	24			1	2	4	2	Capability	24
						Performance	**0.50**							Performance	**0.38**							Performance	**0.25**
Actual		1	3	5	3	Actual	12			1	2	4	2	Actual	9			0	1	3	2	Actual	6
						Water								**Water**								**Water**	
Water	6		12	10	2	Capability	30		6		12	5	2	Capability	30		5		8	4	2	Capability	30
						Performance	**0.83**							Performance	**0.63**							Performance	**0.53**
Actual	6		12	5	2	Actual	25		5		8	4	2	Actual	19		5		8	2	1	Actual	16
						Energy								**Energy**								**Energy**	
Energy	8	4		6	2	Capability	20		3	2		6	1	Capability	20		3	2		6	1	Capability	20
						Performance	**0.60**							Performance	**0.60**							Performance	**0.40**
Actual	3	2		6	1	Actual	12		3	2		6	1	Actual	12		2	2		3	1	Actual	8
						Transport								**Transport**								**Transport**	
Transport	8	10	8		6	Capability	32		4	8	7		5	Capability	32		3	7	6		4	Capability	32
						Performance	**0.75**							Performance	**0.63**							Performance	**0.63**
Actual	4	8	7		5	Actual	24		3	7	6		4	Actual	20		3	7	6		4	Actual	20
						ICT								**ICT**								**ICT**	
ICT	10	6	4	10		Capability	30		5	5	3	8		Capability	30		5	5	3	6		Capability	30
						Performance	**0.70**							Performance	**0.63**							Performance	**0.57**
Actual	5	5	3	8		Actual	21		5	5	3	6		Actual	19		4	4	3	6		Actual	17

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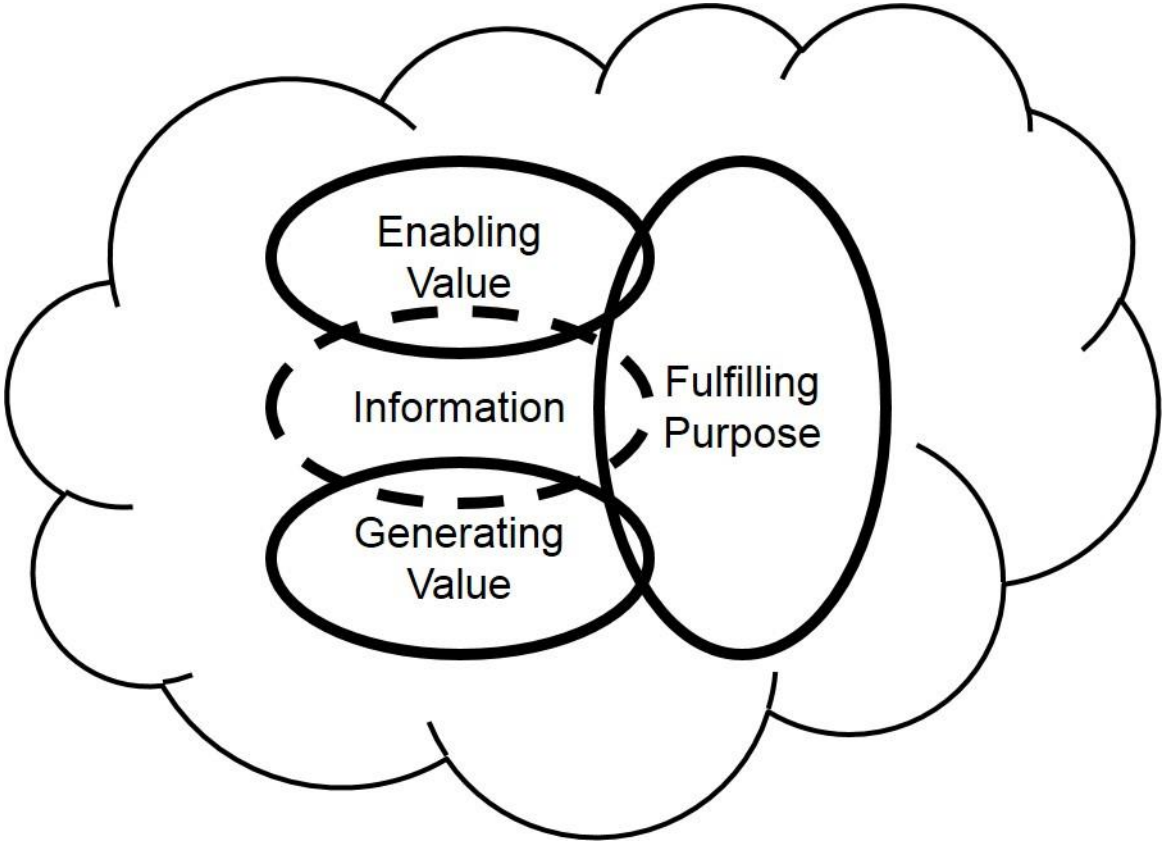
Managing the Mess



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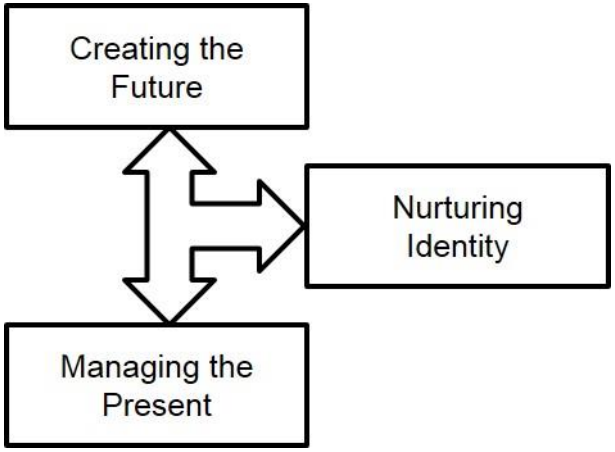

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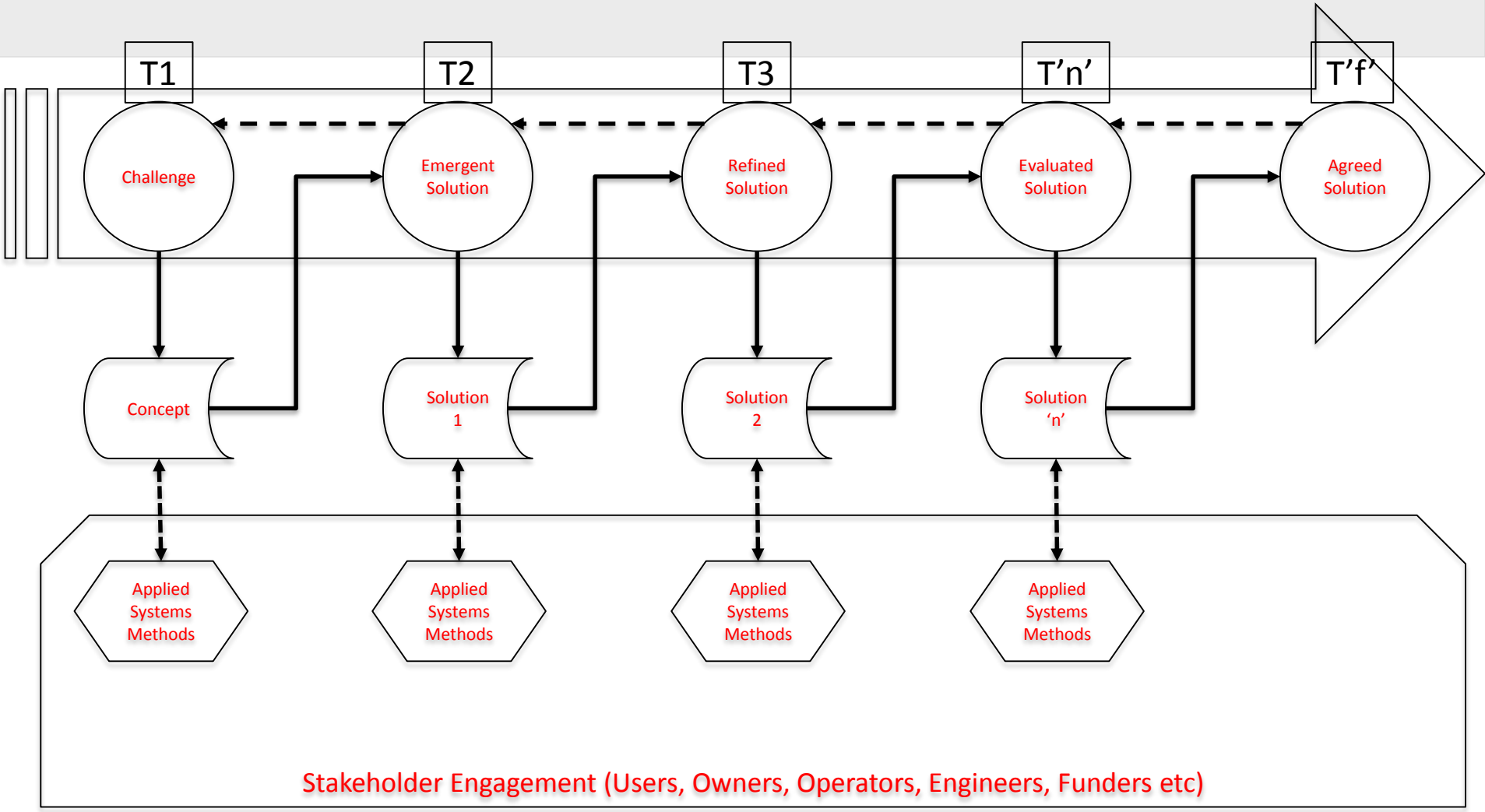

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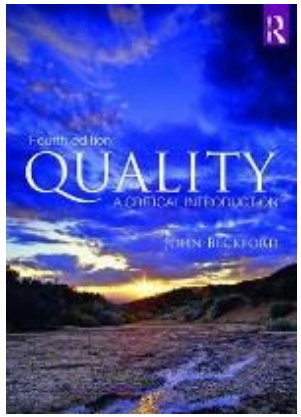

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