SESSION II: Pop-Up Talks

Special presenter: **John G Rees**, NERC
1) **Dennis Konadu**, University of Cambridge
2) **Ian Temperton**, Ian Temperton Consulting
3) **Alexandra Collins**, Imperial College London
4) **Julien Harou**, University of Manchester
Specialist: **Liz Varga**

ATKINS cep UKERC
UK Energy Research Centre

Imperial College London
Grantham Institute
Climate Change and the Environment

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Decision-Making Under Risk & Uncertainty in Complex Infrastructure Systems

Imperial College London

Professor Liz Varga, liz.varga@cranfield.ac.uk

10th Feb 2016

Transforming knowledge into action

Energy, transport, water, waste and telecoms

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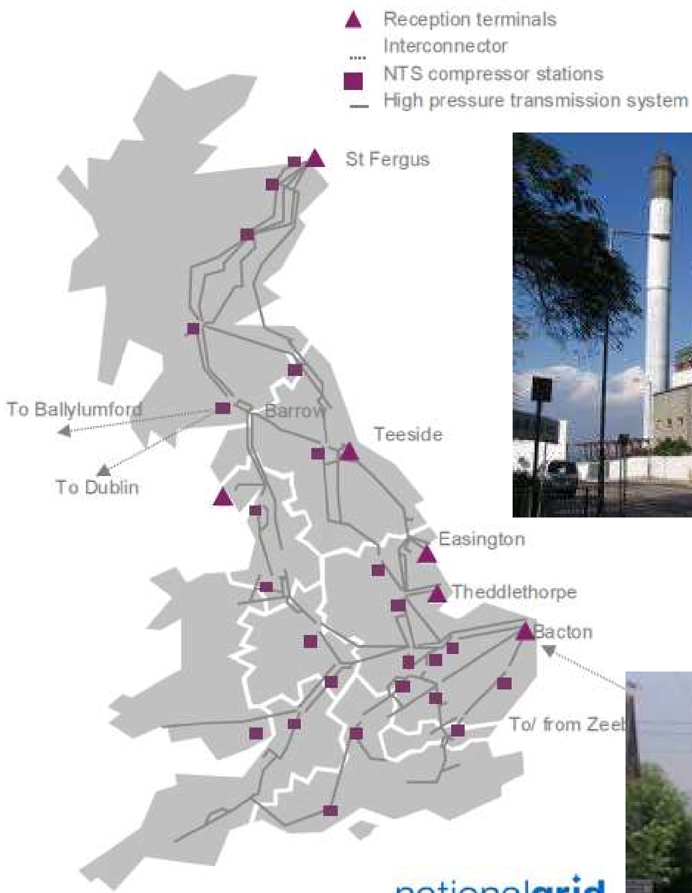

nationalgrid

Why complex?

- Networked and interacting
- Multi-scale and emergent
- Dynamic, adapting and evolving
- Involve people, so they are not deterministic

Integrated, interdependent Complex Infrastructure Systems

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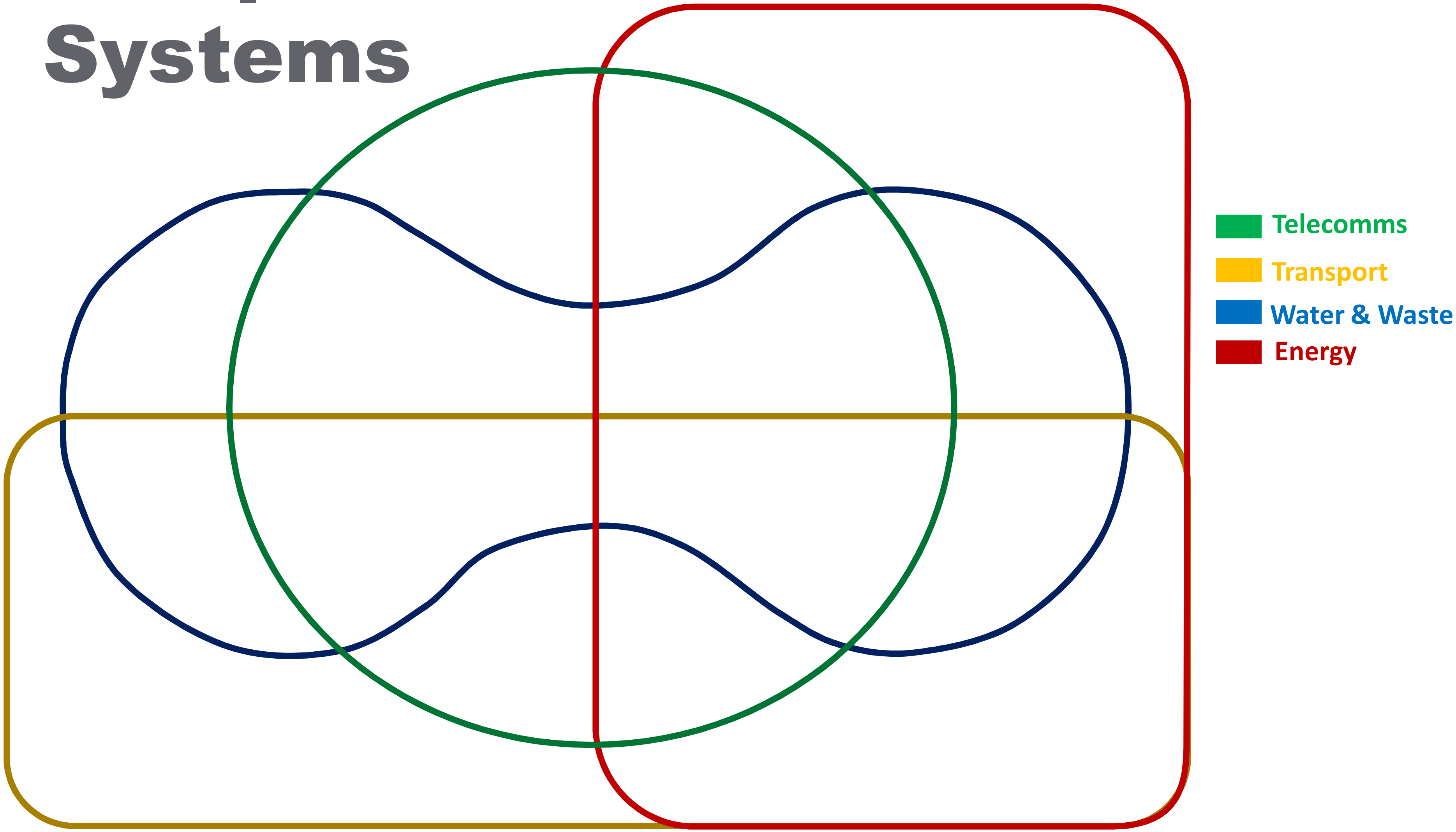
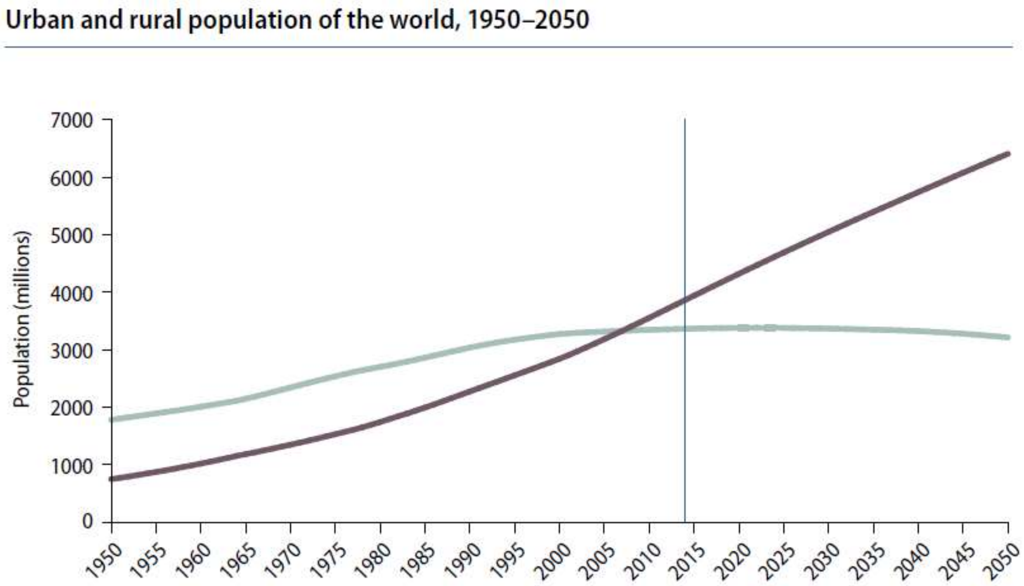


Futures

- Population growth
  - Pressure to build on flood plains
- Urbanization/ densification
  - Pressure to share existing capacity



United Nations. World Urbanization Prospective: 2014 Revision, New York, 2014.

- Regulation, legislation
  - Pressure to control carbon, nitrates, air quality,...

Technological discontinuities and creative destruction

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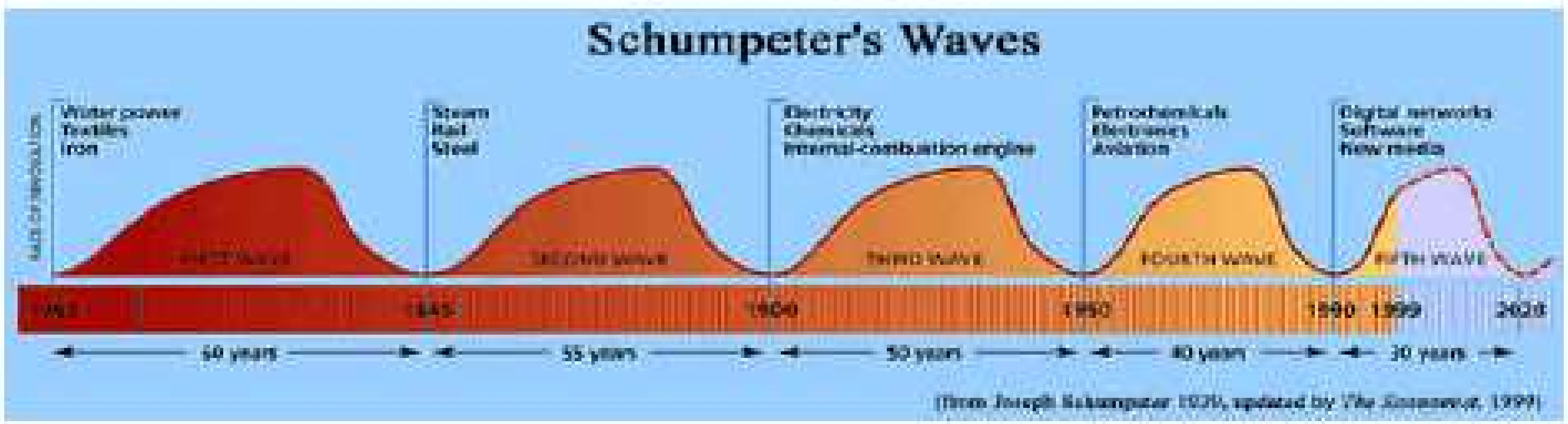
- Firms innovate and create the technological trajectories in the environment, co-evolving with the environment in which they operate.
- The success of individual firms will be related to the compatibility of the firm to the technological trajectory of the extant paradigm.

Tushman, M. L. and Anderson, P. (1986), "Technological Discontinuities and Organizational Environments", *Administrative Science Quarterly*, vol. 31, no. 3, pp. 439-465

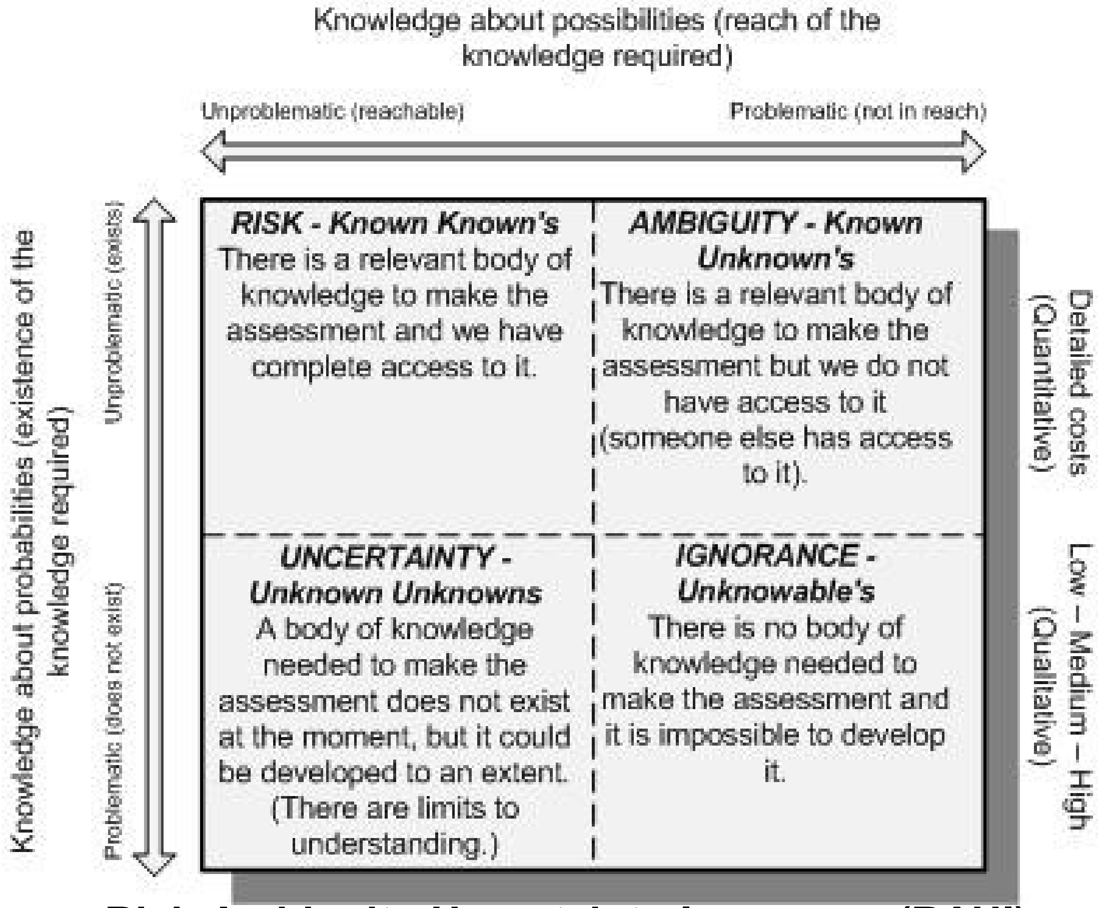


Risk vs uncertainty

- Knight was among the first to differentiate risk and uncertainty in his classic work[1]
- Risk deals with situations and events to which **we can assign probabilities** of their future states
- Uncertainty deals with situations where we can't; it is a much trickier concept and a problem occurs when the idea of risk is overstretched to the extent that **uncertainty becomes synonym for risk**, known as the "delusion of control" explaining the hubris among some policymakers.

[1] Knight (1921) Risk, Uncertainty and Profit, Houston Mifflin.

Risk, Ambiguity, Uncertainty, Ignorance



Risk-Ambiguity-Uncertainty-Ignorance (RAUI) matrix

Grubic et al (2013) Future utility services' (un)knowns framework: Knowledge existence and knowledge reach. *Futures* (Based on Snowden and Boone, 2007 and Stirling, 2010)

Decision-Making (DM)

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- Buchanan and O'Connell (2006) trace back the general history of DM and development of managerial DM concepts such as the **economic theory of risk and uncertainty by Knight** (1921) and organizational DM from the **theory of cooperation** by Barnard (1938).
- Köksalan et al (2013) examine **utility theory** from the work of Edgeworth (1881), contribution of Frisch (1926) with his **theory of ordinal and cardinal utility** and the **theory of subjective expected utility and probability** by Ramsey (1926) and De Finetti (1937).
- Raiffa (1968) wrote a report on utilities with **multi-attribute alternatives** within RAND. Multi-attribute analysis was further elaborated by Keeney and Raiffa (1976) who formulated **multi-attribute utility theory** (MAUT). Prior to MAUT significant contributions to **MCDM** include the efficient vectors and contributions to multiple objective mathematical programming (Koopmans, 1951), the goal programming (Charnes et al, 1955), the outranking methods within the ELECTRE-project (Bernard, 1968), and the concept of **multiple objective optimization** (Cohon, 1978).
- Saaty (1977, 1996) developed **Analytic Hierarchy Process and Analytical Network Process** decision making methods which treat decision making structures as hierarchies and interdependent networks.
- Simon (1959) recognized **game theory** had a role in processes of concept formation.

Durmagambetov, 2015, SLR

Decision-Making choices

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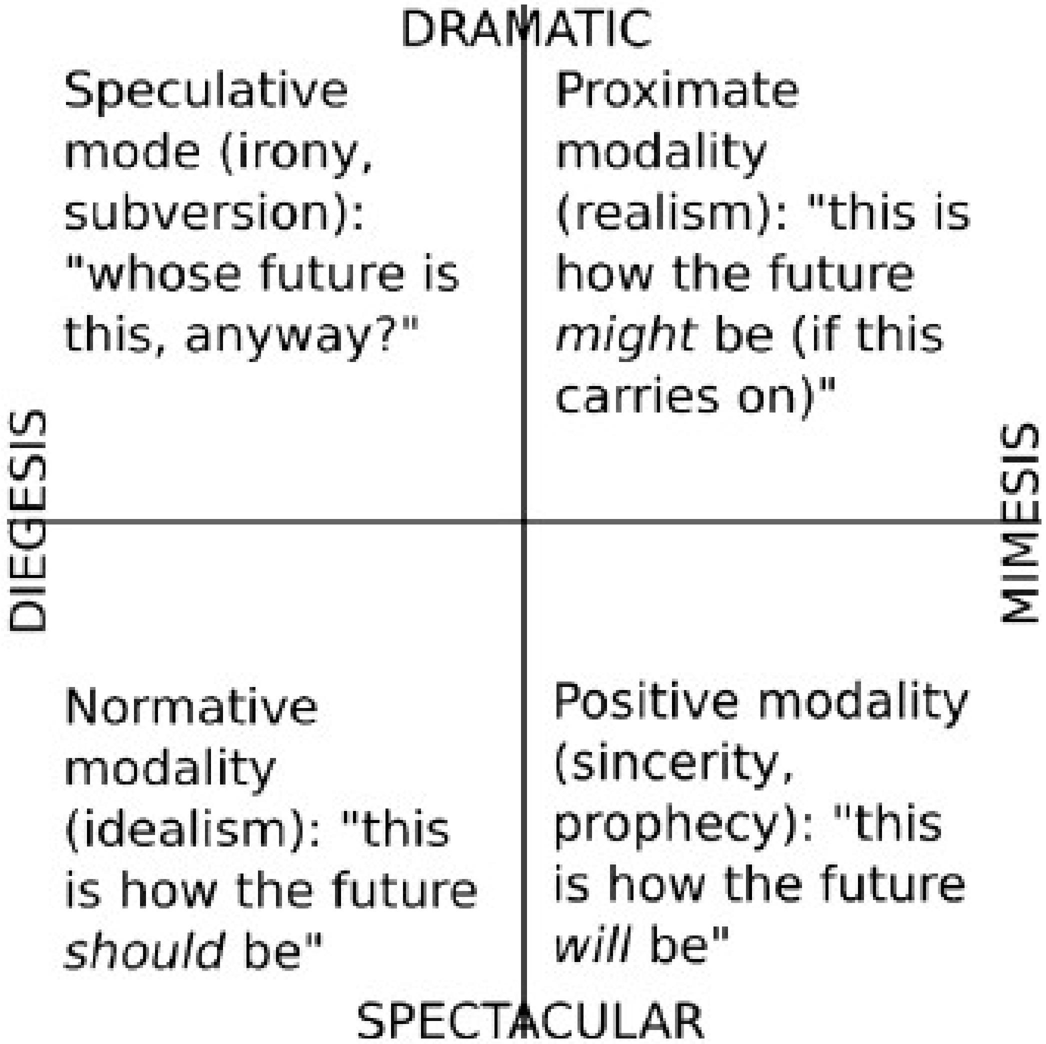
- By whom? (CEO, regulator, cabinet, …)
- Why? (cost avoidance, competitiveness, prevention, …
- About what?
  - Capital investment/renewal, maintenance
  - CAPEX, OPEX, TOTEX
- At what scale? Where?
- For whose benefit and at whose cost?
- When?
- Why not (paralysis)?

Futures - scenarios



Raven and Elahi (2015), Shaping of futures outputs, *Futures*

Futures - extrapolation

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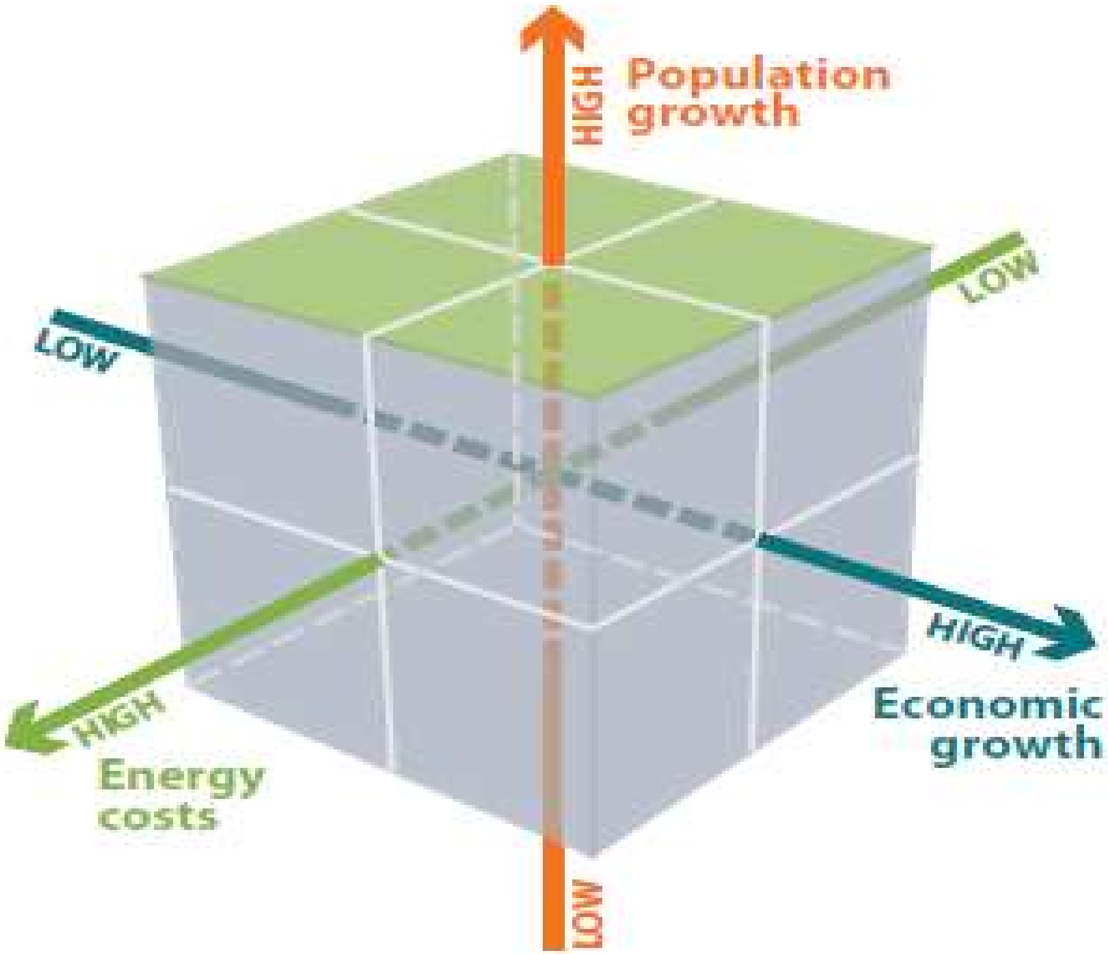

http://www.itrc.org.uk/wordpress/wp-content/FTA/ITRC-FTA-Executive-summary.pdf p7

Typology for uncertainty

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Category	Definition
Accuracy/error	difference between observation and reality
Precision	exactness of measurement
Completeness	extent to which info is comprehensive
Consistency	extent to which info components agree
Lineage	conduit through which info passed
Currency/timing	temporal gaps between occurrence, info collection & use
Credibility	reliability of info source
Subjectivity	amount of interpretation or judgment included
Interrelatedness	source independence from other information

Thomson et al, A typology for visualizing uncertainty (2005)

Continuum quantified risk and qualified uncertainty

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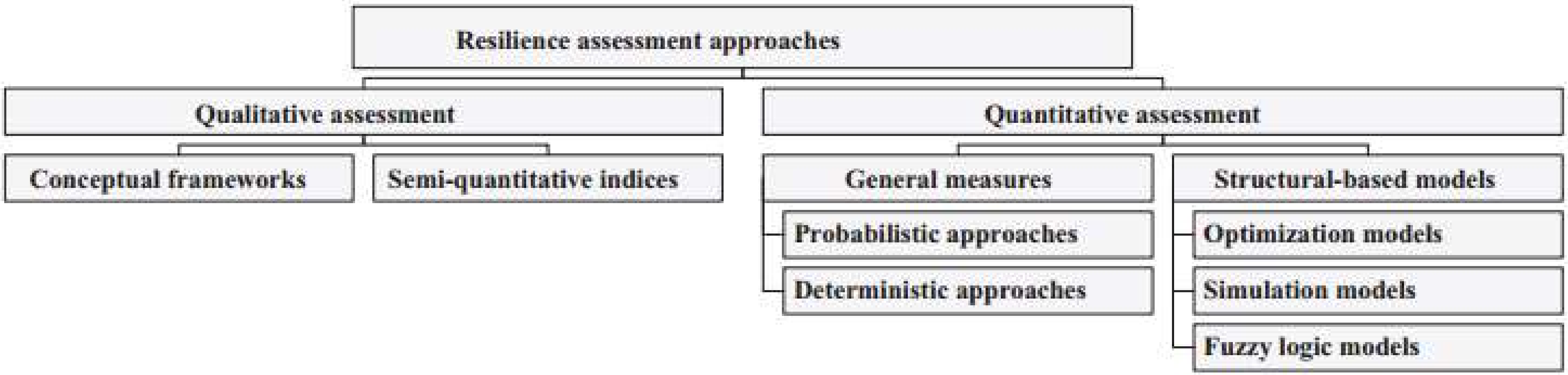
- Example 1: CCRA – high confidence
  - Multiple sources of evidence that contain similar results
  - Based on robust techniques
  - Data used is of a high quality
  - Evidence has been peer reviewed
  - Published relatively recently.

Qualitative and quantitative methods

- Example 2: Resilience Assessment



Modeling and evaluating system resilience (Hosseini et al, 2016, p51)

Mixed methods

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Techniques	Qualitative	Mixed	Quantitative
Descriptive techniques describe data by categorisation or interpretation	• Word count • Cognitive mapping • Thick description • Content analysis • Theoretical Coding • Grounded Coding • Taxonomic analysis	• Integrated data display	• Frequency count • Correlation • Cluster analysis • Measures of central tendency and dispersion • Principal components analysis
Comparative techniques compare two or more data sets	• Multi repertory grids • Analytic induction • Inter-rater analysis • Concordancing	• Data transformation • Cross-Over analysis • Data consolidation • Results synthesis • Pattern Matching	• Mann-Whitney 'U' test • t-tests • ANOVA • ANCOVA (co-variance)
Prescriptive techniques explain the data and attempt to predict future patterns	• Induction • Theory building • Abductive inference • Framework development, e.g. BCG Matrix • Qualitative models, e.g. Porter's 5 forces		• Regression • Path analysis • Genetic algorithms • Modeling • Simulation • Network Analysis • Data mining

Varga, 2016

Modeling

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- “A common method for making sense of a system which **cannot be easily or safely experimented** upon is to create a computational model of the system.”

  Bale, Varga, Foxon, 2015

- A computational model in which “a system is modeled as a collection of **autonomous decision-making** entities called agents”

  Bonabeau, 2014

Inter-disciplinary investigations

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- Decision making **for innovation**
  - Co-creation, user innovation **(EU-Innovate)**
  - Scale, replication, … **(Stepping Up)**
  - Storage: solving the intermittency problem **(Cryohub)**
- Decision making **for new business models**
  - Multi-utility service companies **(MUSCOs)**
  - Interdependence infrastructure systems **(ICIF)**
- Decision making **for efficiency**
  - Big Data, IOT: sensors, actuators, algorithms **(ABACUS)**
  - Matching energy supply with demand **(E-SIDES)**
- Decision making **for governance**
  - With public policy **(CECAN)**
  - For engineering resilience **(ENCORE)**

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Thank you

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