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
Decision-Making Under Risk & Uncertainty in Complex Infrastructure Systems
Imperial College London
Professor Liz Varga, liz.varga@cranfield.ac.uk
10th Feb 2016
Energy, transport, water, waste and telecoms
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
Futures

- Population growth
  - Pressure to build on flood plains
- Urbanization/densification
  - Pressure to share existing capacity
- Regulation, legislation
  - Pressure to control carbon, nitrates, air quality,...

Technological discontinuities and creative destruction

- 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.

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 \textbf{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 \textbf{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 (RAUI) matrix

Decision-Making (DM)

- 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).
- Simon (1959) recognized game theory had a role in processes of concept formation.

Durmagambetov, 2015, SLR
Decision-Making choices

- 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
## Typology for uncertainty

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

Continuum quantified risk and qualified uncertainty

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

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Qualitative</th>
<th>Mixed</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Descriptive techniques</strong></td>
<td>• Word count</td>
<td>• Integrated data display</td>
<td>• Frequency count</td>
</tr>
<tr>
<td>describe data by</td>
<td>• Cognitive mapping</td>
<td></td>
<td>• Correlation</td>
</tr>
<tr>
<td>categorisation or</td>
<td>• Thick description</td>
<td></td>
<td>• Cluster analysis</td>
</tr>
<tr>
<td>interpretation</td>
<td>• Content analysis</td>
<td></td>
<td>• Measures of central</td>
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<td></td>
<td>• Theoretical Coding</td>
<td></td>
<td>tendency and dispersion</td>
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<td></td>
<td>• Grounded Coding</td>
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<td>• Principal components</td>
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<tr>
<td></td>
<td>• Taxonomic analysis</td>
<td></td>
<td>analysis</td>
</tr>
<tr>
<td><strong>Comparative techniques</strong></td>
<td>• Multi repertory grids</td>
<td>• Data transformation</td>
<td>• Mann-Whitney ‘U’ test</td>
</tr>
<tr>
<td>compare two or more data sets</td>
<td>• Analytic induction</td>
<td>• Cross-Over analysis</td>
<td>• t-tests</td>
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<tr>
<td></td>
<td>• Inter-rater analysis</td>
<td>• Data consolidation</td>
<td>• ANOVA</td>
</tr>
<tr>
<td></td>
<td>• Concordancing</td>
<td>• Results synthesis</td>
<td>• ANCOVA (covariance)</td>
</tr>
<tr>
<td><strong>Prescriptive techniques</strong></td>
<td>• Induction</td>
<td>• Pattern Matching</td>
<td>• Regression</td>
</tr>
<tr>
<td>explain the data and</td>
<td>• Theory building</td>
<td></td>
<td>• Path analysis</td>
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<tr>
<td>attempt to predict</td>
<td>• Abductive inference</td>
<td></td>
<td>• Genetic algorithms</td>
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<tr>
<td>future patterns</td>
<td>• Framework development, e.g. BCG</td>
<td></td>
<td>• Modeling</td>
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<tr>
<td></td>
<td>Matrix</td>
<td></td>
<td>• Simulation</td>
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<tr>
<td></td>
<td>• Qualitative models, e.g. Porter’s 5</td>
<td></td>
<td>• Network Analysis</td>
</tr>
<tr>
<td></td>
<td>forces</td>
<td></td>
<td>• Data mining</td>
</tr>
</tbody>
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Varga, 2016
Modeling

“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

- **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)*
Thank you

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