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G7 Transport Academic Workshop

Transport decision-making in an uncertain future

Charlene Rohr
Technical Principle, Futures and Foresight and Modelling, Mott MacDonald

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Politecnico di Milano, Bovisa Campus, Milan (Italy)

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The transport system is a complex system that is influenced by a number of external factors that are deeply uncertain.

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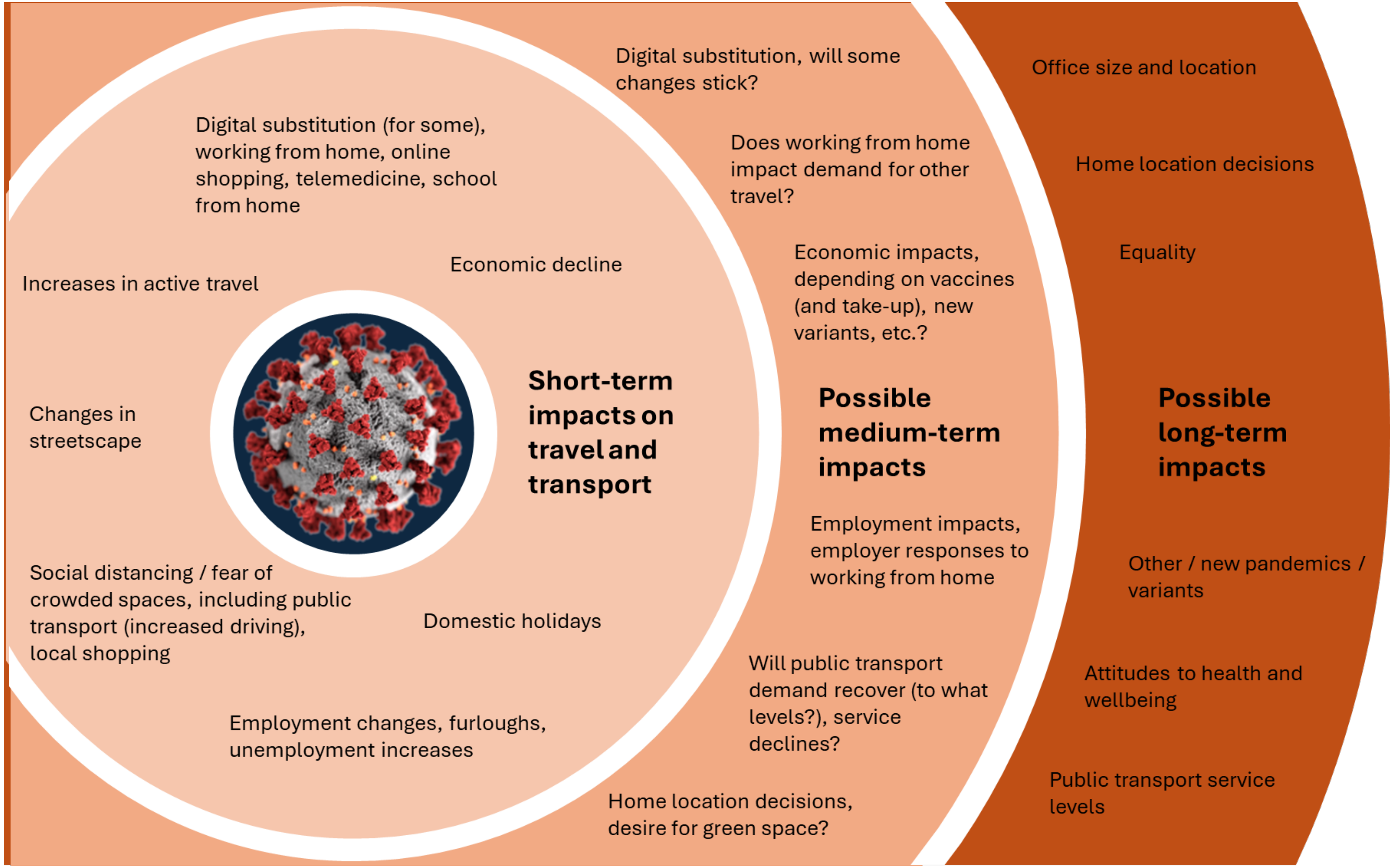


And there are many other uncertainties that may impact transport

And many of these uncertainties will have significant impacts on future travel supply and demand, e.g.

- Impacts of moving to electric (and autonomous) vehicles on cost of travel, comfort, car ownership …
- Impacts of working from home in terms of commuting, business travel, other travel and possibly on home location, business location and even car ownership
- Impacts of other new technologies, e.g. AI
- Impacts of climate change on the travel network, the structure of cities and on travel

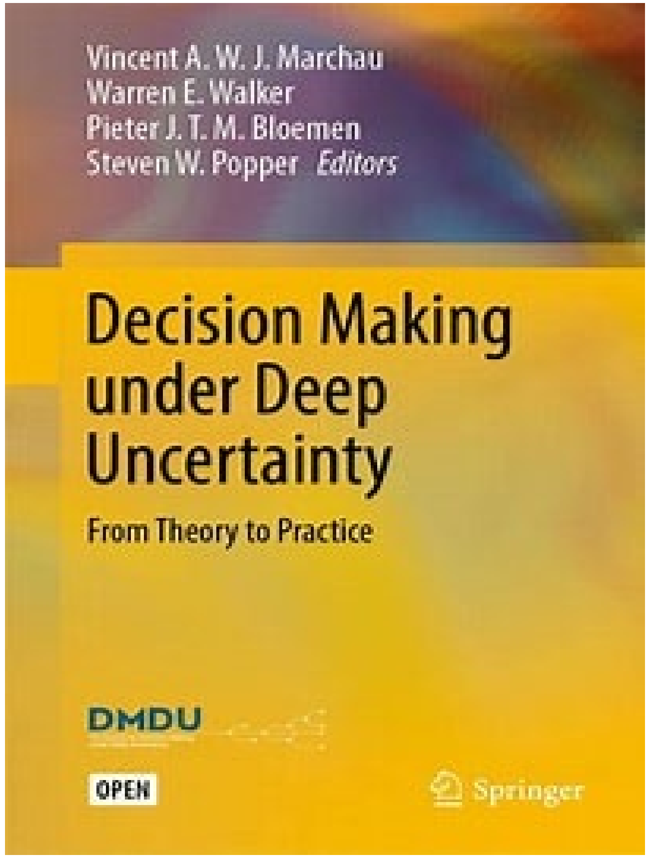
Many of these influences are not well represented in our transport models (or are inputs that have significant impacts on model predictions and outcomes).

Deep Uncertainty: A situation in which analysts do not know or cannot agree on (1) models that relate key forces that shape the future, (2) probability distributions of key variables and parameters in these models, and/or (3) the value of alternative outcomes.

Hallegatte S., Shah A., Lempert, R., Brown, C. & Gill, S. (2012) Investment Decision Making Under Deep Uncertainty: Application to Climate change. Policy Research Working Paper for the World Bank, Available at: World Bank Document

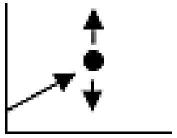
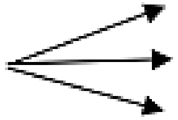
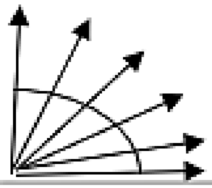
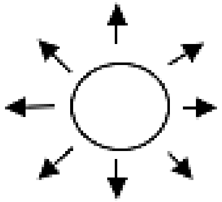
Uncertainty can be associated with different aspects of a system – all which apply to transport modelling and planning

- The world outside the system (referred to as the context ‘X’), e.g GDP growth, the cost of travel, take-up of new technologies and how they will impact transport supply, the cost of carbon and the global response to climate change.....
- The decision domain (the model system, referred to as ‘R’), e.g. changing travel behaviour, values of time (e.g. for AVs), future supply characteristics
- The outcomes from the system (the system outcomes ‘O’), e.g. the model predictions in terms of demand, carbon emissions, etc.
- The importance placed on the outcomes (with weights applied to outcomes ‘W’), codified in appraisal, e.g. value of travel time savings, value of carbon, safety outcomes, the impact of noise, health impacts, etc.



Marchau, V., Walker, W., Bloemen, P.T.M. & Popper, S.W. (2019). Introduction. In V. Marchau, W. Walker, P.T.M. Bloemen & S.W. Popper (Eds), Decision Making Under Deep Uncertainty: From Theory to Practice. Springer. Open Access available at: Decision Making under Deep Uncertainty | SpringerLink

Uncertainty implications for modelling and analysis

	Complete determinism	Level 1	Level 2	Level 3	Level 4 (deep uncertainty)		Total ignorance
					Level 4a	Level 4b	
Context (X)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
System model (R)		A single (deterministic) system model	A single (stochastic) system model	A few alternative system models	Many alternative system models	Unknown system model; know we don't know	
System outcomes (O)		A point estimate for each outcome	A confidence interval for each outcome	A limited range of outcomes	A wide range of outcomes	Unknown outcomes; know we don't know	
Weights (W)		A single set of weights	Several sets of weights, with a probability attached to each set	A limited range weights	A wide range of weights	Unknown weights; know we don't know	

Marchau et al, 2019

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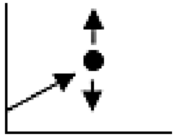
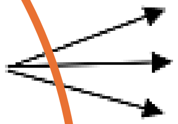
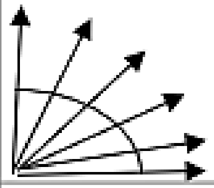
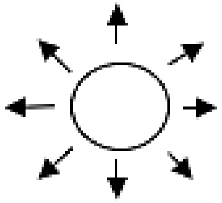
Context (X)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
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Marchau et al, 2019

Transport models largely adopt Level 1 or 2 approaches for dealing with uncertainty, i.e. models are deterministic or probabilistic, predict point estimates (rarely with confidence intervals), for a single future (with some sensitivity testing maybe). We generally assume the same behavioural mechanisms in future as today and use projections of key inputs derived from past trends. We also assume the same weights broadly apply in future, although we may change values of time as a result of income change predictions.

Uncertainty implications for modelling and analysis

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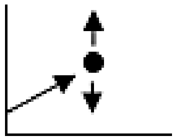
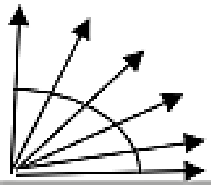
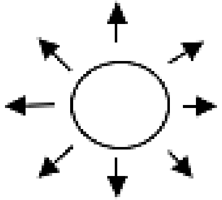
Context (X)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
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But we live in this world.......... There is substantial uncertainty in the exogenous inputs, we do not completely understand the system model or represent all interactions (e.g. supply responses, changes in attitudes or travel behaviour), assumptions about these will generate different system outcomes... and we may not agree on weights (now or in future).

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We need a different approach to planning in an environment of deep uncertainty: Decide and Provide

1. We must set out clearly what we are aiming for – our vision – and develop policies and investment pathways to get there.
2. We need to understand future risks and uncertainties and test our proposed policy and investment pathways across a wide range of possible future conditions.
3. We need to understand what things we need to do now to help shape the future in the direction we desire.
4. We also need to understand what policy actions may be required to mitigate against future risks we do not want to happen.
5. We need to monitor for future risk and uncertainties and review our plans.

We need to design and invest in policies and investments that are **robust across a range of futures**.

Predict and Provide vs Decide and Provide

Predict and provide

Predict the future and develop a policy plan to meet future needs

1. Run your model for future years to predict future travel demand and conditions
2. Identify problems and challenges
3. Identify policies or interventions to solve predicted challenges
4. Appraise polices and/or interventions to identify optimal solutions

Decide and Provide

Decide where you want to get to and make a robust plan to get there

1. Specify your vision and measures of success
2. Develop plausible future scenarios about how the world may play out (because of factors outside your control)
3. Test your policy strategy to reach your vision across these different scenarios.
4. Choose options that are robust across a range of scenarios, rather than are optimal in one.

Models are needed in both approaches – but in “Predict and Provide” you are making your plans on model predictions and in “Decide and Provide” you are using your model to **stress test your plans**.

The use of scenarios is a key part of a Decide and Provide approach

The benefits of exploratory scenarios

- (Exploratory) scenarios are constructed to reflect key future uncertainties – and interactions between these
- Developing scenarios helps planners and policymakers think about future uncertainties
  - Challenges that may negatively impact on the success of their plans (and mitigation strategies to minimise these)
  - Opportunities that may increase the success of plans (and shaping strategies to encourage these)
- They are used to develop and test policy and investment plans, leading to more robust plans
- Scenarios are being used more and more in the UK to test robustness of investments and policy plans
  - The UK DfT has published a set of Common Analytical Scenarios (CAS) to be used to appraise transport policy and investment decisions

... but there are also challenges.....

- Assumptions around what are key uncertainties, e.g. travel cost, and the range of values they may take in future, may be wrong
  - We may underestimate the impact of these
- We may limit the number of uncertainties considered in scenarios
- There is a tendency to stay close to evolutionary (discontinuity-averse) business as usual situations, which can limit their effectiveness

"All founder on the same shoals: an inability to grapple with the long-term's multiplicity of plausible futures"

Steven Popper, RAND Corporation (2009)

Lyons, G., Rohr, C., Smith, A., Rothnie, A. and Curry, A. (2021). Scenario planning for transport practitioners. *Transportation Research Interdisciplinary Perspectives*, 11, 100438.

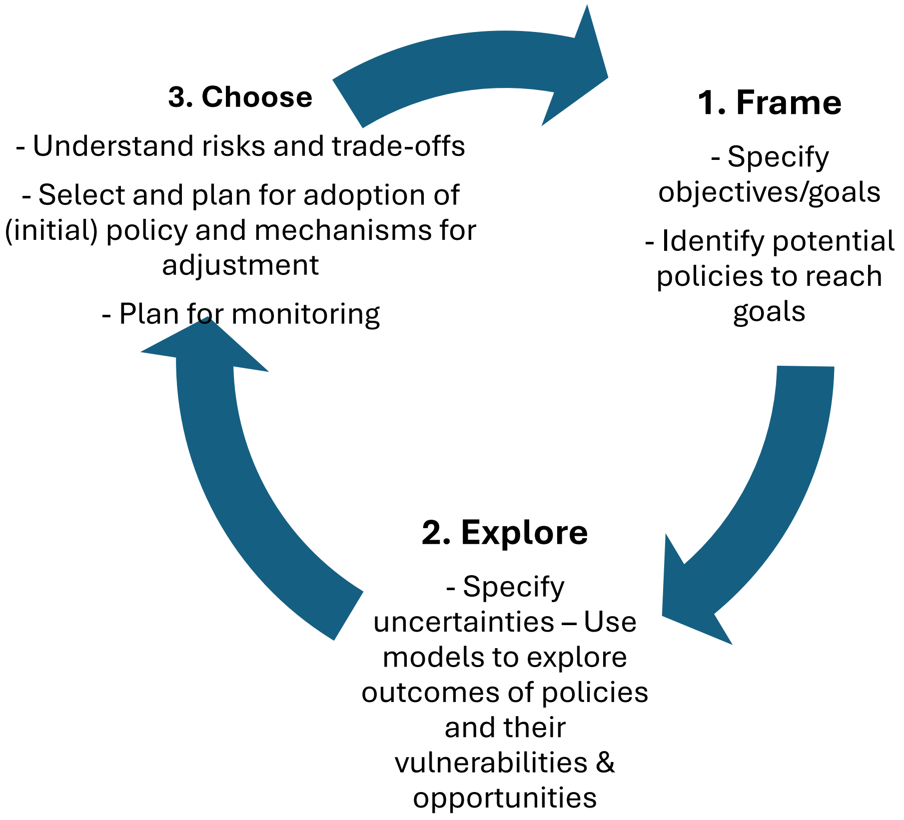
For more info on DfT CAS see: TAG uncertainty toolkit (publishing.service.gov.uk)

Decision Making Under Deep Uncertainty (DMDU) methods aim to get round these challenges

Robust Decision Making (RDM) is one DMDU method

- Incorporates scenario thinking, robust decision criteria, stress testing, the use of exploratory models, visualisation and high-powered computing

- Exploratory modelling is a key part of the process
  - Used to systematically explore consequences of uncertainties on policy decisions across a range of outcomes using 'what if' scenario thinking
  - Can stress test policy plans over a much larger set of future conditions
  - Systematic analysis of outcomes helps decisionmakers understand under what conditions policies work and when they do not (and what trade-offs may be needed)
  - May mean that you need to go back to drawing board for policy strategy development



Robust Decision Making: Key steps

So, what's stopping us from using DMDU methods in transport.... a discussion of challenges and opportunities from DMDU Society Panel (October, 2023)

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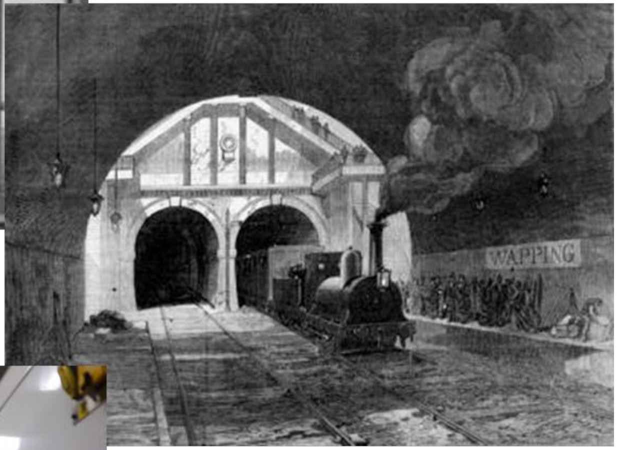
Moving to “adaptive” policy plans in transport?

Robust plans work well across a range of future conditions and are often **adaptive**.

- “Adaptive policy pathways” are sequences of actions that can be implemented progressively depending on how the future unfolds as knowledge develops.
    - Order matters…. what we do shapes how the future unfolds
        - Do our models (and appraisal) adequately account for such shaping effects?
    - We also need to define ‘trigger points’ for action
- Can we build in adaptability in big capital investment projects? Or are smaller investments more adaptable?
- Are multiple strategies more robust, e.g. multi-pronged approach for decarbonisation:
    - **Avoid**, travel less, digital substitution, 15-minute cities
    - **Shift**, high quality public transport, road user charging, land-use / transport planning
    - **Improve**, switch to zero emission vehicles

Infrastructure best if it can adapt (even if we don’t realise it at the time).

Thames Tunnel: Built between 1825-1843, originally for horse-drawn carriages (although mostly used by pedestrians).



In 1860 was converted into a railway tunnel for the East London Line, later absorbed into the London Underground.

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Do we need faster-running models for DMDU analysis?

Travel demand models are a key part of the process of how we plan. They are a treasure trove of complex understanding of travel demand.

But we should not fool ourselves that our models can predict the future.

They can, however, help us understand the potential impacts of policies across a range of futures. And help us identify those policies that work well across a range of futures (and the conditions in which those policies may fail).

So they are a key part of our analysis toolkit for planning.

But to really stress test future plans our models need to evolve. We may need faster-running and maybe less precise models to support the thinking and planning that needs to happen over the longer term.

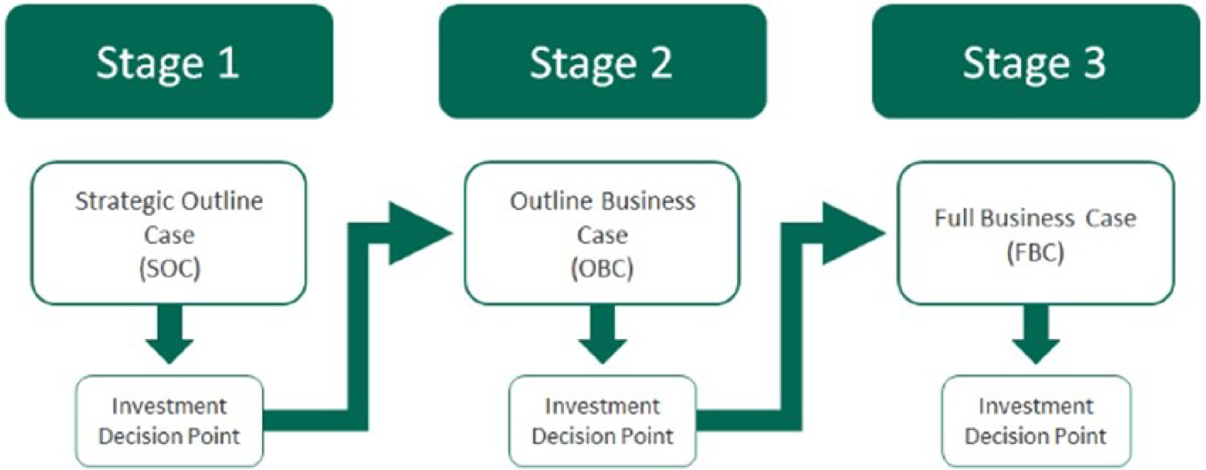
What modelling elements and what degree of precision are needed for modelling and testing long-term policy and investments plans?

Are CBA requirements stifling use of DMDU methods?

In many countries, cost-benefit analysis (CBA) is a key part of the decision-making process for making the case for policy and investments.

- Does CBA adequately cover the range of outcomes we need to consider in future planning?
  - Can we 'quantify' all outcomes of interest? Accessibility? Safety? Carbon? Quality of life? Equality? Resilience?
- Should appraisal processes test outcomes with different weights?
  - Assumptions around values of carbon? Discount rates?
- Would more approximate fast-running models fulfil appraisal requirements?
  - Do we need a multi-tiered approach (as in the UK), with different modelling and assessment requirements for different stages of policy development?
- Are CBA principles consistent with DMDU approaches, e.g. maximising utility vs minimising maximum regret? Testing policy pathways?

UK Department for Transport Business Case Assessment



Stage 1: Define the strategic case, including, defining measures of success, assessing long-list of options and identifying short-list of viable options

Stage 2: Detailed assessment of shortlisted options to find the "optimum" solution

Stage 3: Formal review, confirms conclusions, recommendations to Ministers.

We need to develop DMDU tools and skills in transport

DMDU analysis tools:

- Fast-running policy models
- EMA workbench, for performing exploratory modelling and analysis (TU Delft)
- TMIP/EMAT (USA)

Sharing findings / early wins:

- SACOG 2016 study (USA)

Opportunities to bring together policymakers, researchers and practitioners around decision making under uncertainty

- DMDU society – The Society for Decision Making under Deep Uncertainty (DMDU Society – The Society for Decision Making Under Deep Uncertainty)

Academic / practitioner collaboration research programmes

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