Driving in the dark
As economists must do
Incorporating and assessing travel demand uncertainty in transport investment appraisals

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Risk versus Uncertainty

**Risk**

*KNOW probability distribution of future*

“*PREDICT and ACT*”

**Common within:**
- Insurance
- Funds management
- Bank dealings in financial instruments
- R&D corporates
- Oil companies

**Uncertainty**

*DO NOT KNOW probability distribution*

“*ANTICIPATE and ADAPT*”

**Common within:**
- Climate change
- Environment in general (flood risk, water supply)
- Telecommunications
- Defense

See Knight (1921), Guthrie (2011), Chades et al (2015)
More “uncertainty”

• Walker et al (2010) – clear (enough) future, probable alternatives, multiple plausible futures or future unknown (i.e. deep uncertainty)
• Chapman and Ward (2011) – ambiguity, inherent, event or systemic
• Kodukua and Papadesu (2006) – market-related v. project-specific
• Boardman (2011) – collective v. private

General observation: uncertainty can be many-faceted

References as above
Travel demand uncertainty

• 4-stage model
  • Trip generation, trip distribution, modal split and trip assignment

• Forecast errors due to:
  • Input data errors, parameter estimation and/or model specification

• Key uncertainties
  • Economic development (especially local development for short-term forecasts)
  • Local population growth
  • Technology and social effects on traffic demand
  • Mode share

• Treatment of uncertainty
  • Hubris – ongoing process of forecasting improvement
  • Humility – show uncertainty and reduce sensitivity of decisions to forecasts

Approaches to “uncertainty”

<table>
<thead>
<tr>
<th>“Standard” CBA</th>
<th>Apply risk-adjusted <strong>discount rate</strong> to expected cash flows, plus <strong>sensitivity</strong> testing</th>
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<tbody>
<tr>
<td><strong>Operations research</strong></td>
<td>Optimise amongst pathways, <strong>decision trees</strong></td>
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<tr>
<td><strong>Financial valuation (including ROA)</strong></td>
<td>Estimate value using <strong>probability distributions</strong>, using <strong>market pricing</strong> and taking advantage of <strong>portfolios</strong></td>
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<td><strong>Institutional</strong></td>
<td>Recognise value is inherent in ‘rights’ and see <strong>contracts as opportunities</strong> to exploit uncertainty</td>
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<td><strong>Risk management (including AM)</strong></td>
<td><strong>Process</strong> to understand, manage, communicate and monitor risk</td>
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<tr>
<td><strong>Better Business Case</strong></td>
<td>Align to strategy, analyse volatility, consider wide set of alternative actions, include risk in discount rate</td>
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What can be learnt from finance?

- Investors are risk averse and hence require an extra return for risk.
- Risk dampened by diversification (and hence focus is on portfolios).
- Current “fair value” equals discounted expected future returns.
- Real options show there is value in limiting unwanted outcomes.
- There is a general reliance on efficient market pricing.
- Risk is limited according to measures such as VaR e.g. limit risk to such that returns will be above a threshold, say, 99% of the time.
- Hedging does not necessarily match 1-to-1 with liabilities (e.g. pension liabilities hedged with equities).
- A premium is paid for liquidity (a form of adaptability).
Risk and Real options

• Right but not obligation to invest (divest) in a real asset
• Types: Defer, Abandon, Scale, Stage, Learn, Switch
• Involves: a risky future, irreversible decisions, sequential decisions
• Valuation based on probability distributions
  • By Black-Scholes, Binomial Lattice, Monte Carlo and/or Decision Tree
• Decisions now can create, retain or extinguish real options
• Real Options Analysis (ROA) can be on (a) valuation and/or (b) flexible decision making
  • This project puts emphasis on “(b) flexible decision making”
• Key aim: to harness uncertainty

Guthrie (2009), Kodukula and Papadesu (2006)
Key real options

• **Option written to others to expand**
  - Infrastructure investment undertaken
  - Property owners given increased value in option to develop – if demand and complementary investment is sufficient

• **Option to learn**
  - Major investment is delayed while learning activities undertaken
  - Investment scaled as uncertainty resolved (or at least thresholds reached)
Uncertainty and AM

• “Adaptive management (AM) is an iterative process of reducing uncertainty through time by learning by doing and monitoring”
• Typically deals with small number of unknowns
• Learning can be active or passive
• Entails:
  • Structuring uncertainty
  • Learning by doing
  • Sequential decisions
  • Decisions taken to create flexibility
  • Typically adapting to triggers
• E.g. a self-learning dyke
• Key aim: to reduce uncertainty

Focus on quantitative approach? AADT, stochastic properties and ROA

• E.g. the AADT of the Auckland Harbour Bridge
  • Require known & stable probability distribution of AADT (at least) to use ROA

• Stochastic properties of AADT on AHB
  • Series showed break circa 2008 when modelled using GDP, petrol prices
  • Model in 2006 implied 2015 AADT 6.6% above actual outcome

• Applying risk concepts to AHB
  • If apply random walk to AADT and assume high threshold then rational to delay (but could also actively learn instead of passively waiting)
  • Full ROA would require mapping AADT to asset values and then the estimation of certainty-equivalents for expected asset values (not undertaken)

• Inference: emphasis required here on process rather than valuation per se
## Recommended process

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<tr>
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<th>FRAME</th>
<th>MODEL</th>
<th>EVALUATE</th>
<th>THEN DECIDE</th>
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<tbody>
<tr>
<td>1</td>
<td>Define the issue</td>
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<td>2</td>
<td>Estimate the status quo and business and usual (BAU) scenario</td>
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<td>3</td>
<td>Identify key drivers of uncertainty</td>
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<td>4</td>
<td>Create short-list of alternative investment opportunities</td>
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<td>5</td>
<td>Draw decision tree for each alternative</td>
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<td>6</td>
<td>Probe uncertainties</td>
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<td>7</td>
<td>Crudely estimate indicative payoffs</td>
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<td>8</td>
<td>Establish threshold(s) that favour one alternative over another</td>
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Multiple influences
Case I. Auckland Northern Busway (SH1)
Historical example, involves High Occupancy Vehicles (HOV)

• Uncertainties:
  • PT demand north to/from CBD
  • Total traffic flow north to/from CBD
    • Employment & Work locations (likewise tertiary education)
    • Population & Resident locations
  • Future network requirements
    • Additional Harbour Crossing (AWHC)
    • Rail on north shore

• Options:
  • To switch
  • To learn and expand
  • Future-proofing

Highlight: Option to switch
• Example of ‘insurance’ or ‘protecting the downside’
• In this case allow use of HOV
• Akin to distribution of outcomes being no longer symmetrical
  • i.e. average BCR is higher

Informed by various pre- and post-busway reports
Tree for ‘learning’

Case Study
Auckland Northern Busway

Learnings:
• Project did involve real options
• Including endogenous learning
• Decision tree was insightful
• Crude estimates of real option values possible (but not essential)
• Real option approach helped structure uncertainty
Case II. Kaimai Ranges (SH29)
Hypothetical, involves Ports of Auckland (POA), Tauranga (POT)

• Uncertainties
  • Mix of POA/POT expansion
  • Hamilton inland port
  • General local economic development

• Options:
  • To expand

Highlight: Option to expand (for others)
• Example of ‘transformational infrastructure’
• In this case, expansion near POT and non-port expansion near POA
• White elephant a possibility
  • Implies seek option to switch
  • Or defer until ALARP
• Also many instances when only ‘modest’ benefits likely
  • Suggests twofold BCR
  • Base BCR and With-Option BCR
Kaimai Ranges

Learnings:
• Again decision tree was insightful
• Emphasised importance of attention to
  a) Probability of ‘prosperity’ scenario
     • And how to improve this probability
  b) Outcome if ‘prosperity’ scenario did not emerge
     • And how to improve the BCR of these other scenarios
Tree for ‘prosperity’

Case Study

TreeAge, PrecisionTree
Case III. Auckland Light Rail
An “on-the-table” example, involves Public Transport (PT)

• Uncertainties
  • Traffic implications of technology
  • Uptake of PT
  • Tolerance of PT in Queen Street
  • Bus tunnel requirement in CBD
  • Development around Dominion Rd
  • Effect of current/mooted changes (e.g. Waterview, congestion charges)

• Options
  • To delay and learn (and then expand or abandon)
  • To switch
  • To future-proof

Highlight: Option to delay and learn
• Example of ‘buying time’ and ‘building ramps’
• In this case, potentially use buses to learn PT uptake
• Reduces white elephant possibility
• Enables resolution of multiple uncertainties while leaving option for LRT or BRT open
• i.e. an adaptive solution
Auckland Light Rail

Learnings:

• Many real options potentially exist

• Highlights importance of
  • Interdependencies
  • Adaptive abilities
More on option to delay

- Key component of adaptive management
- Delay until uncertainty removed
  - Either resolved passively
  - Or by active investment
- Major advantage of delay is avoidance of large unnecessary investment
- But also disadvantage potentially of running cost of delay (e.g. congestion)
- Not required to resolve uncertainty completely but just sufficiently to be able to make decision
  - “Switching value” = the threshold where the investor decision would change
Concluding comments
“Insights not simply numbers”

• Important to understand whether unknowns are ‘risk’ or ‘uncertain’
• Risk enables valuation
• Uncertainty shifts the focus to ‘process’
  • Although process is also useful when addressing risk
• Process required on big projects is to consider options and adaptiveness
• Process suggested fits within current BBC and CBA approaches
  • By emphasising exploration of alternatives and scenarios