Motu

Building Bridges: Treating a New Transport Link As a Real Option

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Arthur Grimes

arthur.grimes@motu.org.nz www.motu.org.nz

Purpose

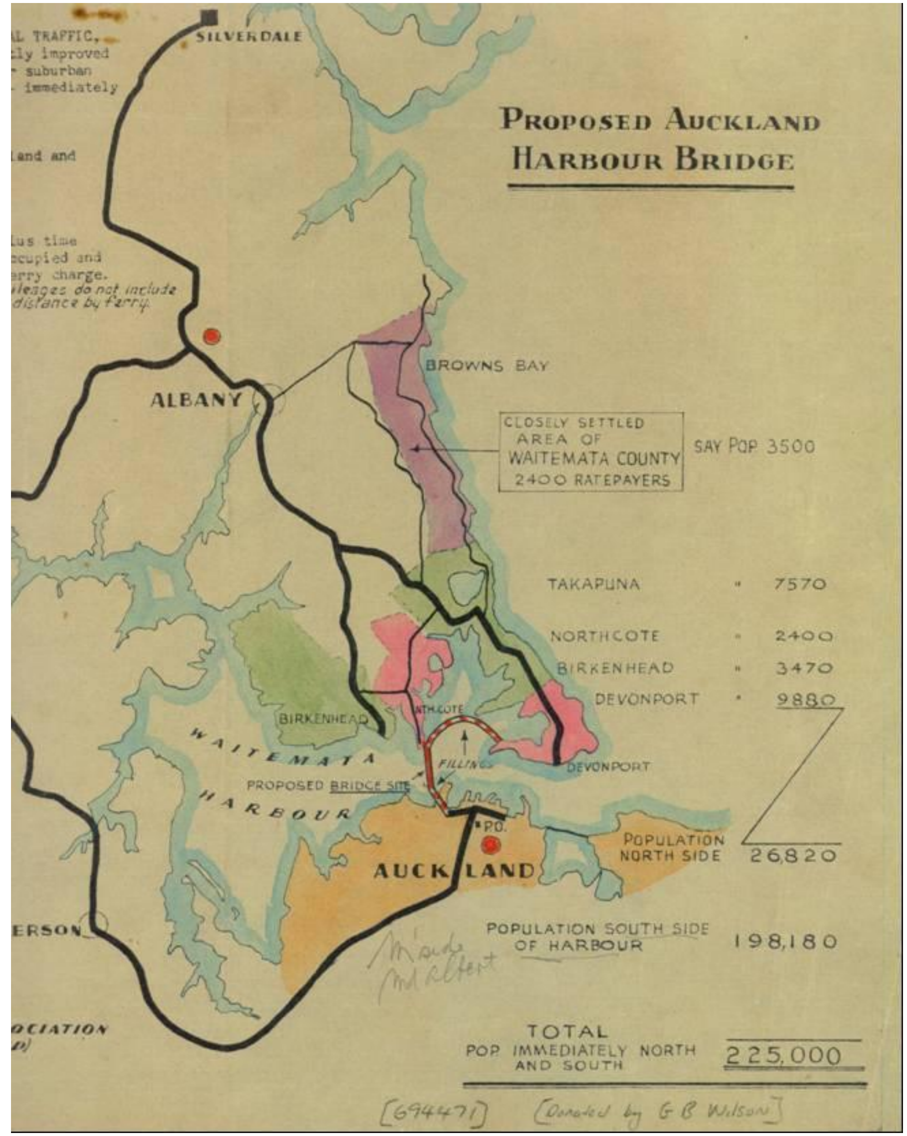
- Cost Benefit Analysis (CBA) commonly used to evaluate transport projects ex ante
- Includes:
  - Travel time cost savings
  - Vehicle operating cost savings
  - Accident cost savings
  - Seal extension benefits
  - Driver frustration reduction benefits
  - Vehicle emission reduction benefits
- Generally deterministic or certainty equivalents

Uncertainty Complications

- CBA inappropriate for 2 cases of uncertainty:
  1. When timing of project is flexible
     $\Rightarrow$ investment may be sub-optimal when BCR>1 (DCF>0)
  2. When multiple project stages are involved & investors learn about next stage(s) after 1st stage is built
     $\Rightarrow$ investment may be optimal when BCR<1 (DCF<0)
- In 2nd case, initial investor may be public & subsequent investors may be private
- In each case supplement CBA with real options analysis

Example: Auckland Harbour Bridge

- CBD on southern shore of Waitemata Harbour
- Only 1 km to northern shore
- Long way around the harbour
- Only 26,820 people on "north side" in late 1940s
- Royal Commission of Enquiry in 1946 to investigate if bridge should be built



Royal Commission of Enquiry: 1946

- The Commission: *was very conservative in its estimates of traffic build-up & population growth on the North Shore …*

  A truly accurate estimate was difficult because a bridge itself would be the biggest incentive for population growth on the North Shore but no one could be certain how much of an incentive.

- Govt approved 4-lane bridge in 1953; opened 1959

(Source: Encyclopedia of New Zealand)

Harbour Bridge Outcomes

- Traffic flows vastly exceeded forecasts:
  - 5 million in 1961
  - 15 million in 1970
  - 32 million by 1985
- North Shore population exploded:
  - 309,000 by 2006
  - cf 27,000 pre-bridge
  - i.e. over 10-fold increase
  - cf 2.4-fold for NZ in total
- 4 extra lanes added in 1964

Northern Motorway Extension

- Extended by 18 km starting in early 1990s
- Pop within 3 km of new exit ↑ 57% over 15 yrs
  - and by 80% at end of motorway
  - cf 21% for rest of North Shore (38% for Auckland)
- Employment within 3 km of new exit ↑ 67%
  - and by 120% at end of motorway
  - cf 34% for rest of North Shore (55% for Auckland)

Northern Motorway: Overall Benefits

- Using relative land value changes to evaluate benefits, BCR at least 6.3
- Ex post benefits measured using land values over twice ex ante benefits
- Implies real option value (embedded in land value) may equal sum of all other calculated CBA benefits

Transport Infrastructure "Failures"

- Many transport link failures
  - NZ's Bridge to Nowhere
  - Canada's 19th century canals & railroads (Belich: *Replenishing the Earth*)

- But options are not always exercised
  - Even when bought optimally
  - So an ex post 'failure' does not <u>necessarily</u> imply ex ante sub-optimal decision-making

Classic result: Option Value of Waiting

- Assume 3 periods (t=0,1,2)
- Each period can have good or bad news (prob: bad=p)
- Can invest at t=0 or t=1; payoffs in t=2 (and t=1)
- BCR at t=0 is say 1.2 ($\Rightarrow$ invest given standard CBA)
- At t=1, BCR may be either 1.5 or 0.9 (p=0.5)

$\Rightarrow$ WAIT until t=1 to decide on investment

I.e. do not invest at t=0 despite BCR>1

Different result: <u>Multi-Stage Investment</u>

- Large-scale transport investments are multi-stage:
  - Public project in t=0
  - Potential private (& public) investments in t=1, …
- Main payoffs come later (e.g. t=2)
- Private sector invests if and only if:
  - Public has already invested in large project at t=0; <u>AND</u>
  - Profitable to do so when viewed at t=1
    - i.e. good news at t=0

Parameters and terminology

- Assume p=0.5
- Real discount rate = 0.04
- State shown by no. of bad news events (i) prior to t

- Payoffs, Y(i,t), in t depend on state, i
  - (payoffs decrease as i increases)

Payoff Matrices: Multi-Stage Project

Cost of public investment (t=0) = 1

Undiscounted Payoffs Y(i,t) if Private does not invest

	t (period)		
i	0	1	2
0	-1	2	1
1		0	-1
2			-5

Undiscounted Payoffs Y(i,t) if Private does invest

Cost of private investment (t=1) = 1

	t (period)		
i	0	1	2
0	-1	1	25
1		-1	-5
2			-12

DCF Analysis

- If public invests and private does not:
  - Then ΣDCF (at t=0) = -1.43

    $= -1 + (0.5*2+0.5*0)*1.04^{-1} + (0.25*1 - 0.5*1 - 0.25*5)*1.04^{-2}$

- If both public and private invest:
  - Then ΣDCF (at t=0) = -0.31

- Both BCR<1:

  - CBA concludes <u>do not build </u>the public project

Option Value

- BUT: private decision only occurs:
  - After public investment occurs; AND:
  - After news at t=0 is revealed

- To analyse how this changes the analysis, form value functions at each node

- Value function is value of being at that point in the decision tree at t given existing i

E.g. where private invests:

$V(0,1) = 1 + (0.5*25-0.5*5)/1.04 = 10.62$

Value Functions: Multi-Stage Project

If i=0 at t=1 benefit is 10.62 if invests and is 2.00 if does not invest – so invests

If i=1 at t=1 benefit is -9.17 if invests and is -2.88 if does not invest – does not invest

With p=0.5, value (at t=0) = 2.72 >0

= -1 + (0.5*10.62-0.5*2.88)/1.04

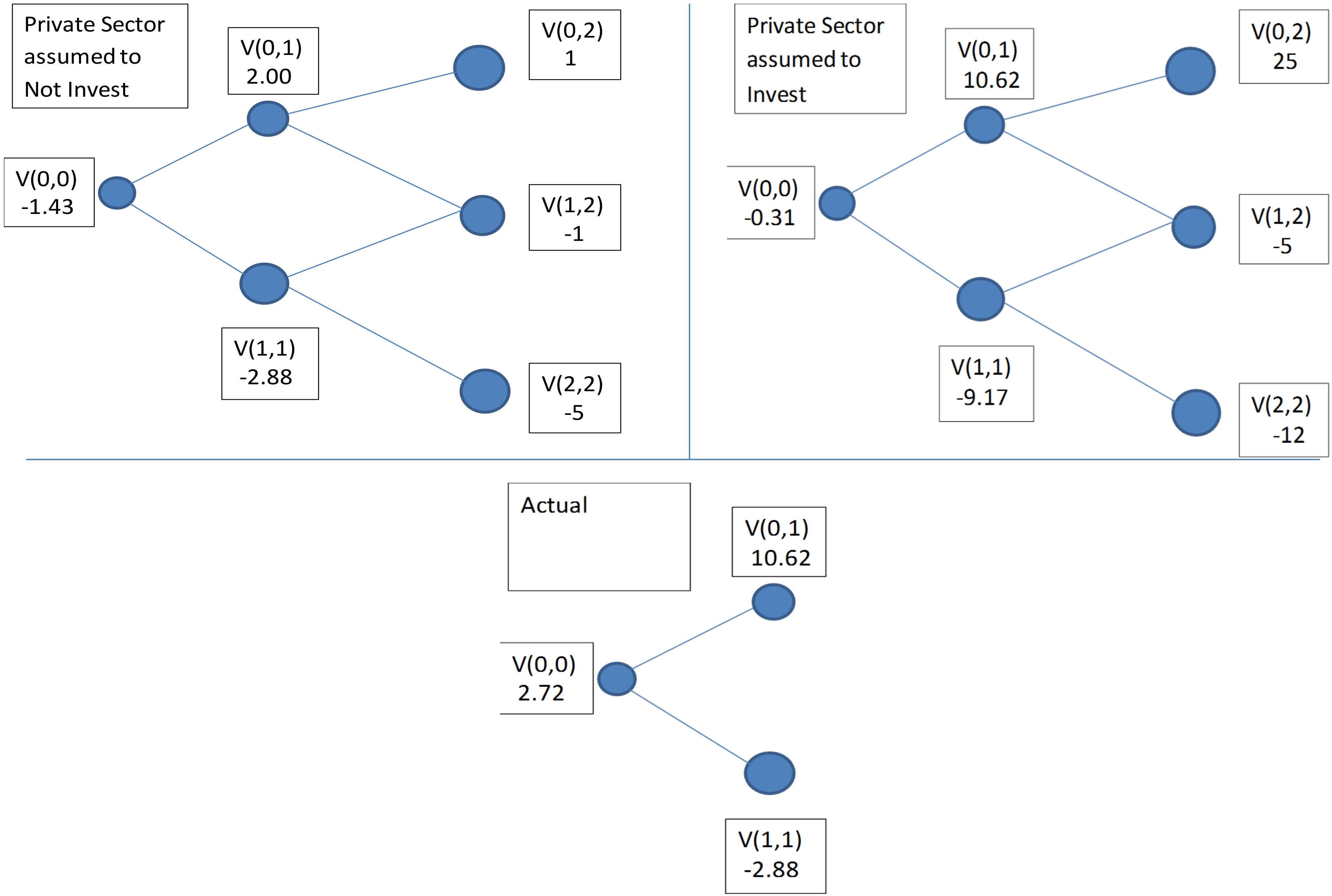
So project should go ahead

Value Function if Private does <u>not</u> invest

	t (period)		
i	0	1	2
0	-1.43	2.00	1
1		**<u>-2.88</u>**	-1
2			-5

Value Function if Private does <u>invest</u>

	t (period)		
i	0	1	2
0	-0.31	**<u>10.62</u>**	25
1		-9.17	-5
2			-12


Private Sector assumed to Not Invest
V(0,0) -1.43
V(0,1) 2.00
V(1,1) -2.88
V(0,2) 1
V(1,2) -1
V(2,2) -5
Private Sector assumed to Invest
V(0,0) -0.31
V(0,1) 10.62
V(1,1) -9.17
V(0,2) 25
V(1,2) -5
V(2,2) -12
Actual
V(0,0) 2.72
V(0,1) 10.62
V(1,1) -2.88

Option Gained through Investment

- The positive V(0,0) at t=0 implies the public should invest in the inital project despite:
  - $\Sigma DCF < 0$ (BCR < 1) in CBA (based on prior assumption that either private investors invest or do not invest)

- The public investment creates a valuable option for the private sector to exercise (or not) at t=1 that is not valued in conventional CBA

Final remarks

- Two counter-balancing forces relative to CBA:
  - Uncertainty creates option value for waiting; BUT:
  - Multi-stage investments create option value at 1st stage
- Both need to be included (plus usual CBA criteria)
- A project may fail despite being ex ante optimal
  - WARNING: Not all failures were optimally chosen!
- Analysis applicable to game-changing investments
  - Especially where land use may change dramatically