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Cost-benefit analysis

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Three BIVEC-GIBET lectures

Today:

- CBA and its role in transport decision making

February 17, Brussels:

- Congestion pricing – design, effects, attitudes and politics

May 28, Eindhoven:

- Trends in travel behaviour – mobility, urbanization, lifestyles, and the peak car hypothesis

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Disposition

- CBA – Why and how
- Are results robust?
- Does CBA matter?
- Cost overruns and benefit shortfalls
- Methodological problems and pitfalls
  - Timetables
  - Wider economic impacts – when consumer surplus is not enough
  - Long term effects – land use and urban development
- Other applications than investments
  - Congestion charges
  - Toll interoperability directive

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Weighing benefits against costs

- Humans are bad decision makers in complex situations
- 5 important deficiencies
- We tend to
  - **generalize** from scarce evidence – use anecdotes as proof
  - **simplify** problems by focusing on one dimension
  - use wishful thinking – **optimism** bias
  - misjudge **orders of magnitude**
  - form immediate intuitive opinions, and then **look for supporting evidence**, disregarding counterevidence

- Need a structure to summarize and overview
  - Activate ”system 2” (slow, deliberate) rather than ”system 1” (fast, emotional)

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Cost-benefit analysis – a structure to summarize costs and benefits

	millions per year
Shorter travel times	+600
Higher travel costs	-100
Fewer accidents	+150
Increased CO2 emissions	-70
Less health emissions	+20
Cost of public funds	-150
Maintenance costs	-20
Investments costs	-350
NET BENEFIT	**+80**

+ Forces honesty and structure
+ Help to consider all aspects
+ Help to see relative magnitudes
+ Compare different investments and policies consistently

- Relative effect valuations not uncontroversial
- May hide redistributions
- Certain effects may be missing or badly estimated

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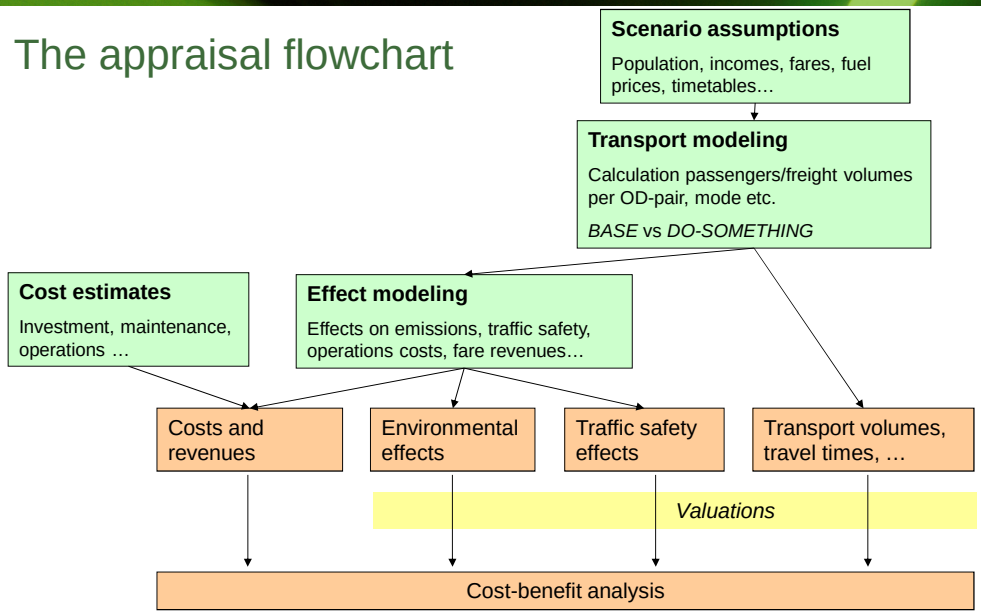
The appraisal flowchart



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Effects (typically) included in a transport CBA

- User benefits – consumer surplus for persons and freight traffic
  - *This "trickles down" as economic growth, land values etc*
- Producer surplus for public transport operators
- Investment and maintenance costs
- Emissions – health-related and carbon
- Traffic safety (deaths, injuries, material damage)
- Public costs and revenues
- Marginal cost of public funds

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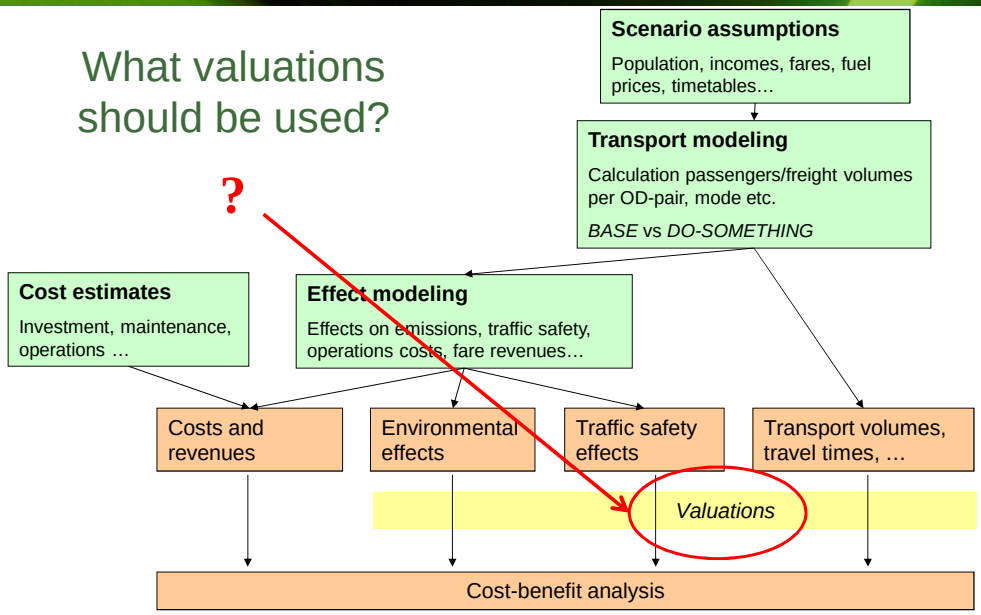
What valuations should be used?



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Which valuations should be used?

- CBA: Citizens' own valuations
  - Works like market prices e.g. when time is traded for wage or housing location
  - Decision makers may have different valuations! (used in multi-criteria analysis)
- Revealed from behaviour (or stated choices)
  - E.g. choices between fast/expensive vs slow/cheap
  - Value of emissions and safety more uncertain
- Average valuations are almost always used
  - Income effects usually removed
  - In practice, most other heterogeneity removed too (too much?)
- Exception: carbon valuation
  - Several logics in use – generally some (indirect) political choice

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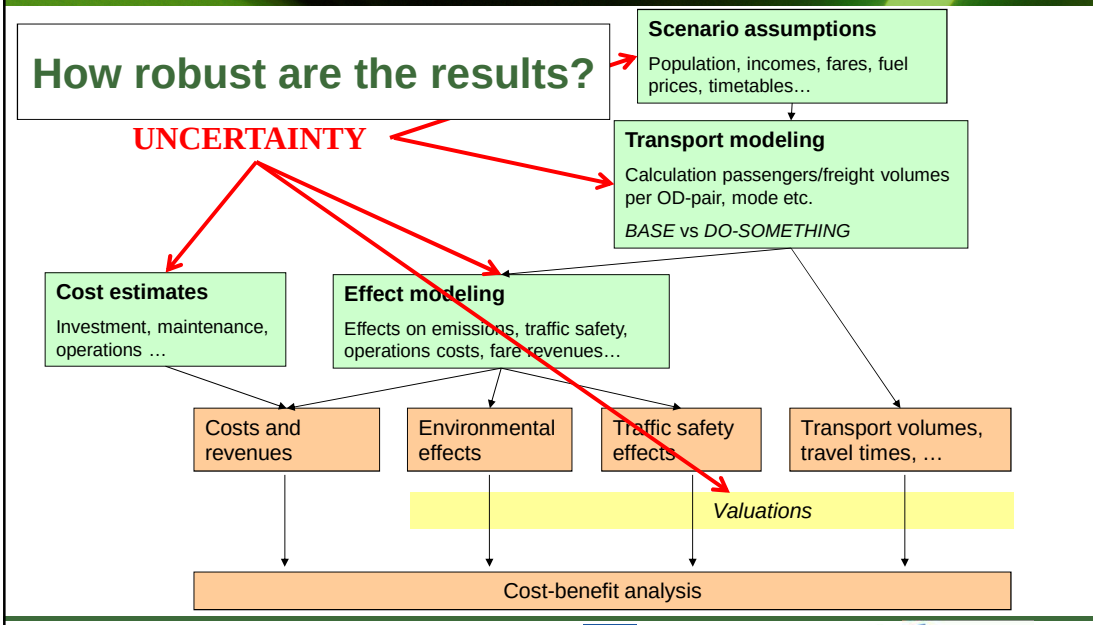

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How robust are CBA results to uncertainties?

Börjesson, M., Eliasson, J., Lundberg, M. (2014) Is CBA ranking of transport investments robust? *Journal of Transport Economics and Policy* 48(2), 189-204.

Eliasson, J. and Fosgerau, M. (2013) Cost overruns and demand shortfalls: deception or selection? *Transportation Research B* 57, 105-113.

Thuresson D. and Eliasson, J. (2015) The sensitivity of CBA to uncertainties. PhD thesis, Working paper.

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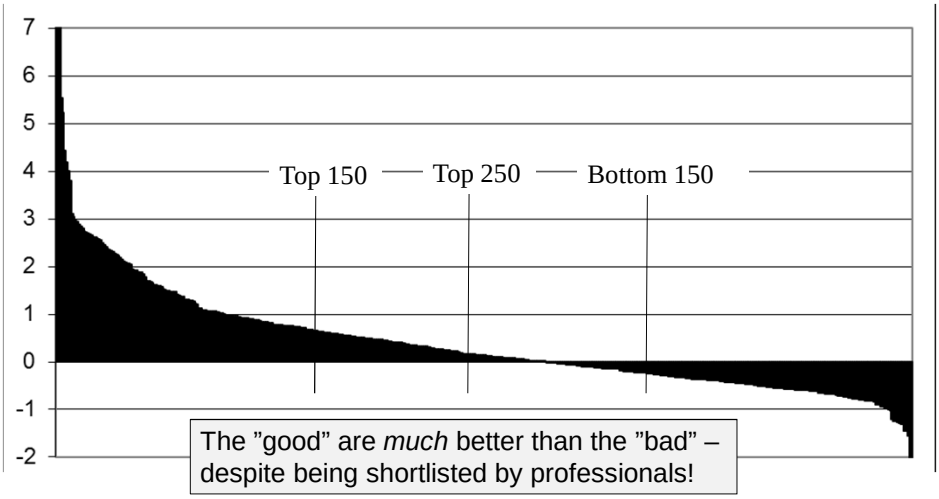
Ranking of ~500 suggested investments wrt. net B/C ratio



The ”good” are *much* better than the ”bad” – despite being shortlisted by professionals!

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The effect of relative valuations

	Freight benefits +100%	Safety benefits +100%	Emission benefits +100%	Person travel time benefits +100%	New values of time (diff. wrt mode, purpose)
Changes in Top 150	14	22	5	11	5
Changes in Top 250	13	27	5	21	5
Changes in Bottom 150	9	18	4	15	4
Rail investm. (originally 21)	24	17	23	17	21

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Uncertainties in scenario assumptions

- The future is uncertain – so how meaningful are CBA results?

- Future oil price? *Test doubling it*
- Technical development of cars? *Test no plug-in hybrids*
- Future car ownership? *Test trend increase instead of 7% less*
- Strong policy measures for reducing carbon emissions? *Test "do nothing" scenario*

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Effects of different scenario assumptions

	Higher oil price	Slower technological development	Higher car ownership	No carbon reduction measures
Changes in Top 150	2	1	2	3
Changes in Top 250	2	1	1	2
Changes in bottom 150	1	0	2	3

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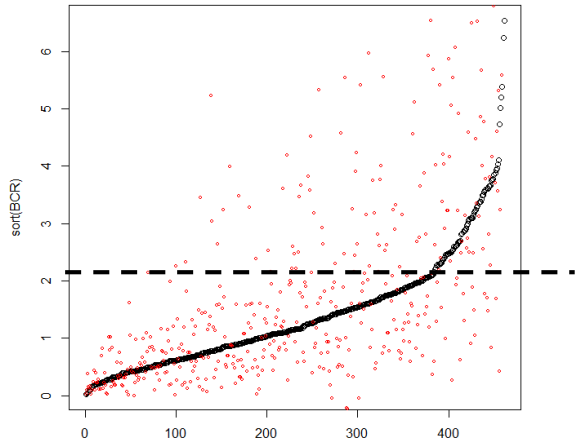
General uncertainty in costs and total benefits

Real benefit/cost ratio (BCR)

Estimated benefit/cost ratio (BCR')



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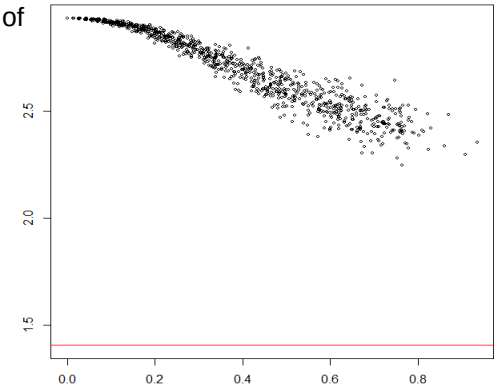
CBA remains good criterion despite uncertainties

Mean BCR of selection



Average BCR of all candidates

Relative stddev of BCR' ⟶

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Does CBA matter?

Eliasson, J. and Lundberg, M. (2012) Do cost-benefit analyses influence transport investment decisions? Experiences from the Swedish Transport Investment Plan 2010-2021. *Transport Reviews* 32(1), 29-48.

Eliasson, J., Börjesson, M., Odeck, J., Welde, M. (2014) Does benefit/cost-efficiency influence transport investment decisions? CTS Working paper 2014:6.

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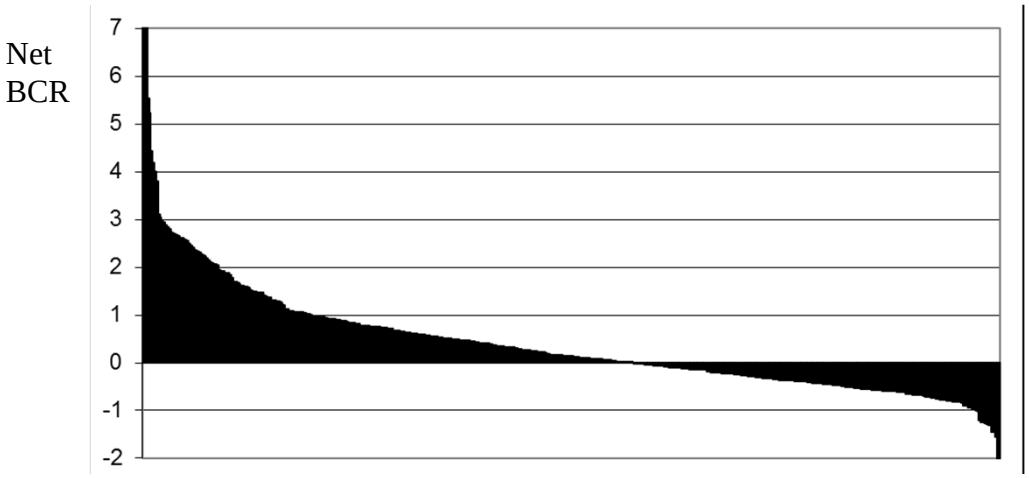
Selection of investments by Swedish and Norwegian politicians and planners



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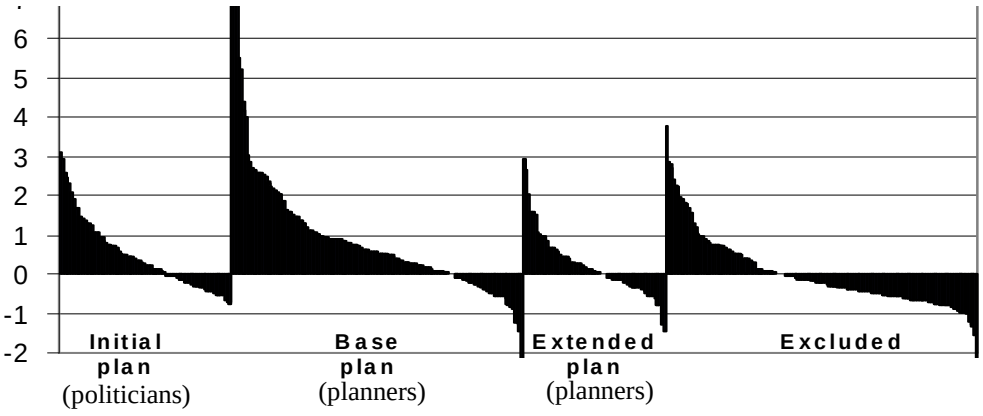
Swedish selection



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What variables influence investment selection?

Selection probability = β_1*BCR + β_2*size + β_3*acc./safety + … + ε

Statistically measurable influence

”everything else”

Separate estimations for Swe and Norw govt and civil servants
Many variables were tested

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Project selection likelihood (binary logit)

(only 95% sign. variables)

	Norway		Sweden	
	Govt.	***Adm.***	***Govt.***	***Adm.***
NBIR⁺ small	-	-	-	0.7
NBIR⁺ large	-	-	-	1.2
NBIR>0 small	-	-	1.5	0.4
NBIR>0 large	-	-	-	0.9
Size: log(cost)	-	-	1.2	-
Safety/acc.	-	-	-0.09	-

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Evidence of regional lobbying

Larger support for Govt. in a region increases selection probability

- Or is it regional policy? Priority to rural areas in Norway, cities in Sweden

	Norway						Sweden					
	Govt.				Adm.		Govt.		Adm.			
	Model 1		Model 2						Model 1		Model 2	
Variable	Par.	*t-stat*	Par.	*t-stat*	Par.	*t-stat*	Par.	*t-stat*	Par.	*t-stat*	Par.	*t-stat*
Log(vote)	0.694	2.2	*0.298*	*0.8*	0.136	*0.4*	0.928	*0.8*	2.312	2.6	-0.172	-0.1
City			*Ns*	-							0.732	2.1
Rural			*0.994*	*2.1*							-0.931	-2.3
NBIR small									0.466	3.2	0.429	2.9
NBIR large									1.285	3.9	1.247	3.7

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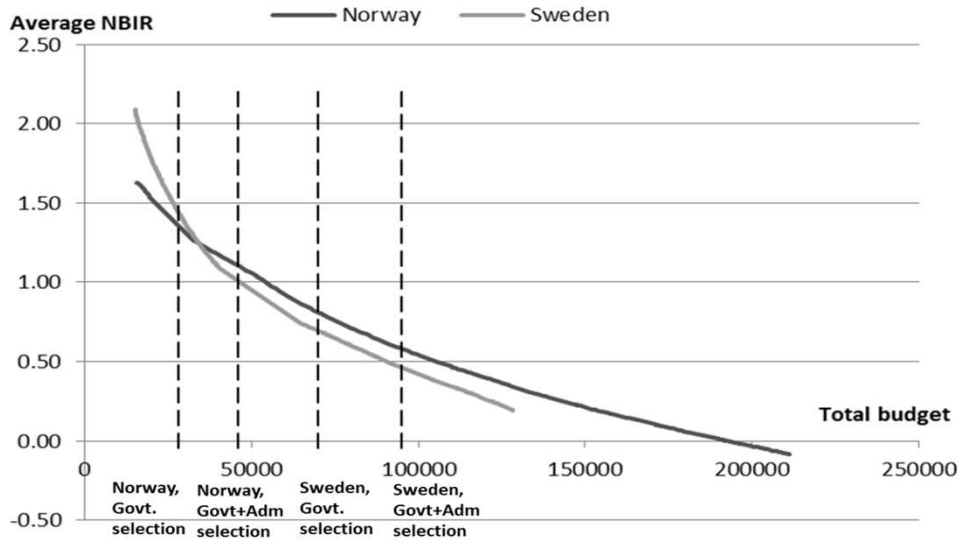
”Trickle-down efficiency” in Sweden and Norway



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Conclusions

- CBA matters less than official rhetoric indicates
- May matter sometimes…
  - Competition between agencies? Regions?
- Evidence of vote-seeking or political lobbying
- Even professionals seem to be unable to filter out low value-for-money suggestions without help from CBA
- If cost-efficiency does not matter, bad candidates stay on the shortlist

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Optimism bias

Welde & Odeck (2014) Cost increases in the front-end of Norwegian road projects, working paper

Eliasson, J. and Fosgerau, M. (2013) Cost overruns and demand shortfalls: deception or selection? *Transportation Research B* 57, 105-113.

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Investments tend to be more expensive and give lower benefits than expected

(from Lundberg, Jenpanitsub, Pyddoke 2011)

Source (country)	Number and type	Cost deviation
UMTA 1990 (USA)	10 transit projects	+52%
Riksrev (Sweden)	7 rail, 8 road	+17%, +86%
OPAGA (USA)	3969 projects	+7%
Odeck (Norway)	620 roads	+8%
Lee (South Korea)	16 rail, 138 roads	+48%, +11%
Singh (India)	122 rail, 157 road	+95%, +16%
Nat. Audit Office (Sweden)	28 rail, 35 road	+55%, +12%

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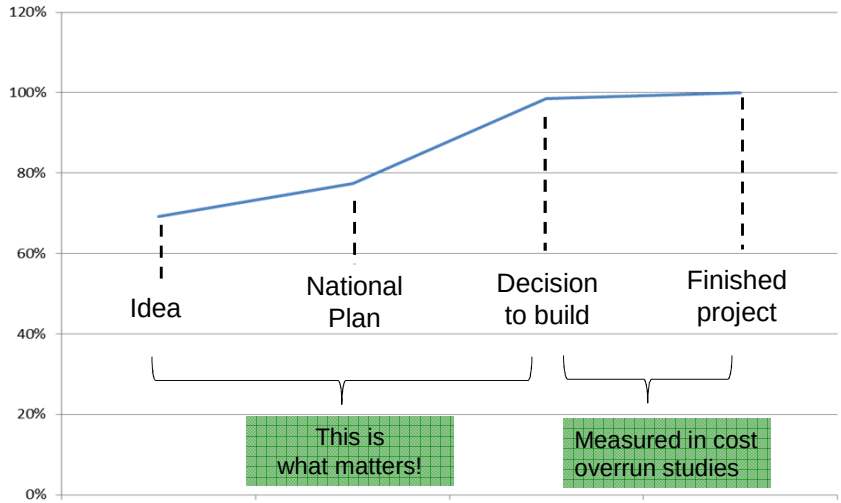
Most of cost increases occur in initial stages

(Welde & Odeck 2014)



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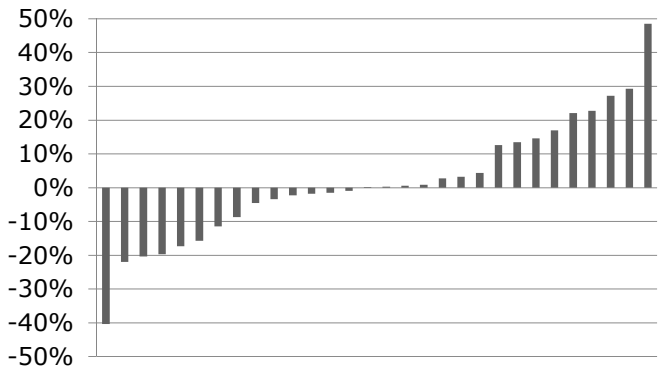
Good news first: cost underruns are as common as overruns



PCO - Decision to build, $n = 30$

- Mean overrun: 2%
- Median: 0%
- St.dev.: 18%
- 50% of projects with final costs within +/- 10% of estimates

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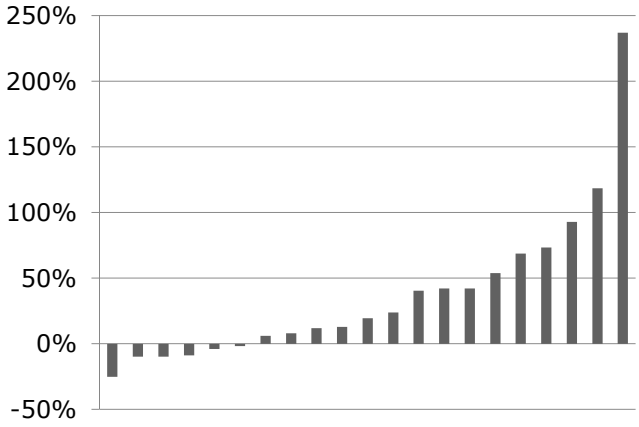
But costs are generally underestimated in the front-end



PCO – National transport plan, $n = 21$

- Mean overrun: 38%
- Median: 19%
- St.dev.: 58%
- 57% of projects with final costs within +/- 25% of estimates

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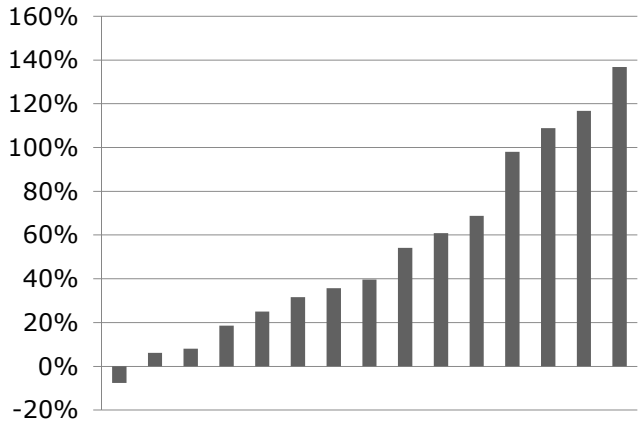
And the first (official) estimates are almost always too low



PCO – First project description, $n = 15$

- Mean overrun: 53%
- Median: 40%
- St.dev.: 43%
- 47% of projects with final costs within +/- 40% of estimates

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Why?

Possible reasons:

- Incompetence – bad transport models, incompetent engineers
- Insufficient management and control during construction phase
- Psychology – optimism bias
- Incentives to overestimate benefits (at several levels and stages)
  - ”Strategic misrepresentation”, i.e. lying
- Selection effect – ”winner’s curse”
  - *Eliasson & Fosgerau (2014)*

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”Systematic misrepresentation, deceptions and lies”

“If misleading forecasts were truly caused by technical inadequacies, simple mistakes, and inherent problems with predicting the future, we would expect a less biased distribution of errors in forecasts around zero.” *(Flyvbjerg, 2009)*

“With errors and biases of such magnitude in the forecasts that form a basis for cost–benefit analyses, such analyses will also, with a high degree of certainty, be strongly misleading. ‘Garbage in, garbage out’, as the saying goes.” *(Flyvbjerg, 2009)*

(See earlier references on robustness)

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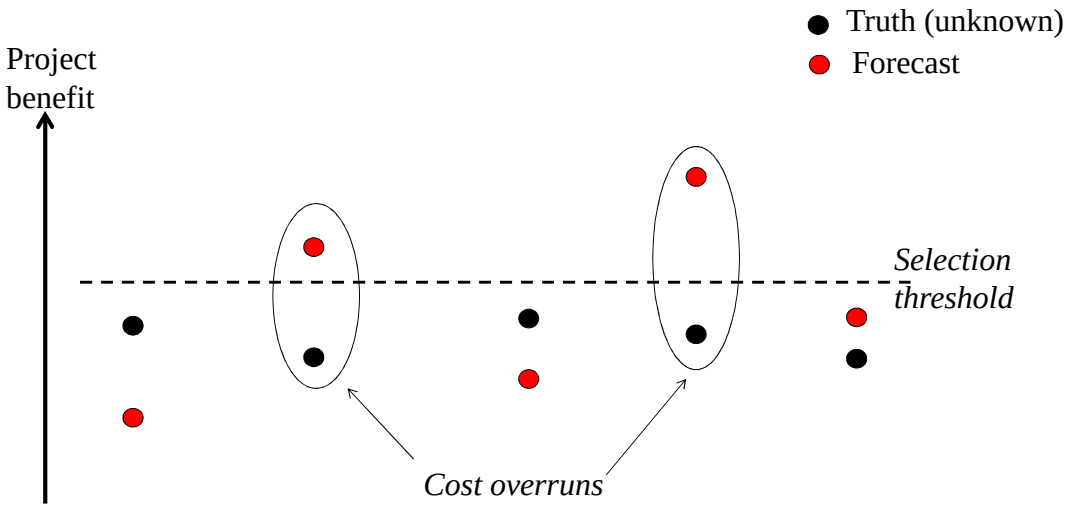
Selection *will* lead to ”optimism”



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Formalized model

X	True payoff
$Y = f(X,\varepsilon)$	Payoff estimate (ex ante); f is increasing in X
$E(Y) = X$	Estimates are unbiased

Projects are selected if $Z \equiv g(Y - c, \delta) \geq 0$ (δ random, c threshold)
(= The probability that a project is selected increases with Y)

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Propositions

(Proofs in the paper)

- *Payoffs are systematically overestimated for the realised projects:* $E(Y - X|Z \geq 0) > 0$.
  - *"Winner's curse" in auctions*
- *Selected projects yield higher average payoffs than a random project:* $E(X) \leq E(X|Z \geq 0)$.
- *A larger cutoff* c *implies a larger bias*
- *The gain from selection increases as the threshold is raised:* $\frac{\partial}{\partial c} E(X|Z \geq 0) \geq 0$.

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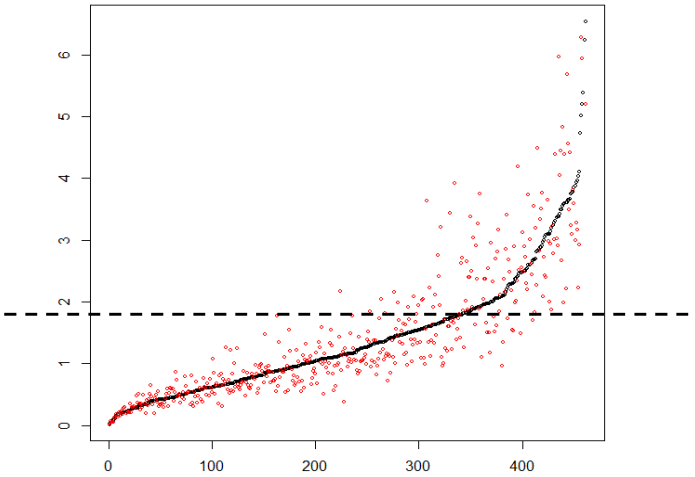
True and estimated *BCR*s



True
Estimated

Selection threshold

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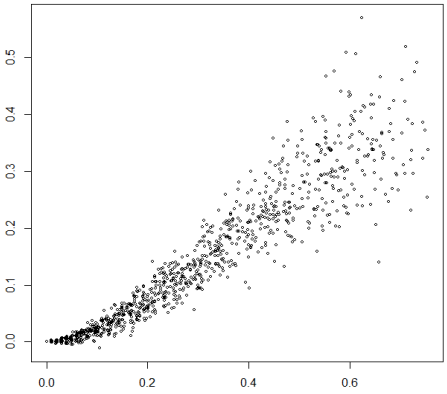
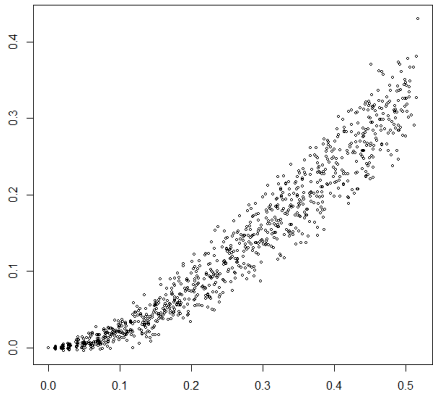
B and *C* of selection become upwards biased

Cost error $\left(\frac{C}{C'}-1\right)$



Benefit error $\left(\frac{B'}{B}-1\right)$



Larger uncertainty ⟶

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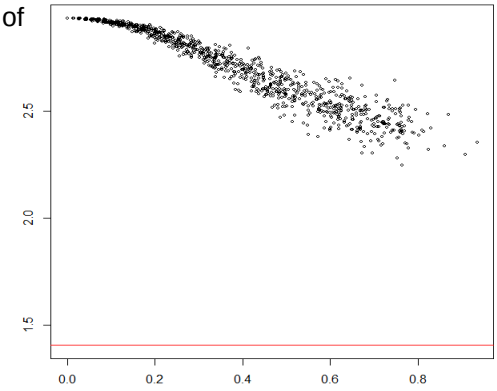
CBA remains good criterion despite uncertainties *(repeat)*

Mean BCR of selection



Average BCR of all candidates

Relative stddev of BCR' ⟶

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Methodological pitfalls 1: Railway timetables

Eliasson, J. and Börjesson, M. (2014) On timetable assumptions in railway investment appraisal. Transport Policy 36, 118-126.

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Sample appraisal of a railway investment

- Currently 3 trains/hour
- Wants to increase to 6 trains/hour
- Investment in capacity needed to keep travel time constant
  - Increase number of meeting points

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Benefits of capacity improvement

	No investment	Investment
Trains/hour	6	6
Travel time	46	40
Passengers	1015	1104
Consumer surplus		7 400
Producer surplus		16 300
Total social benefits		23 700

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Benefits of capacity improvement – version B

Version A

	No investment	Investment
Trains/hour	6	6
Travel time	46	40
Passengers	1015	1104
Consumer surplus		7 400
Producer surplus		16 300
Total social benefits		23 700

Version B

	No investment	Investment
Trains/hour	3	6
Travel time	40	40
Passengers	1000	1104
Consumer surplus		8 800
Producer surplus		2 700
Total social benefits		11 500

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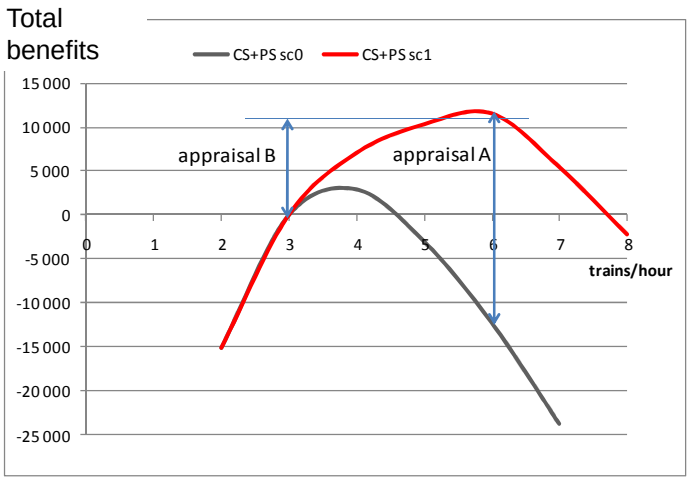
What happened?



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Appraisal outcomes are determined by timetable assumptions

- Both scenarios reasonable
- No way to spot the problem without comparing several scenarios
- Easy to be strategic for promoters/opponents
- Reality *much* more complex

- Need **explicit, verifiable, comparable** principle for timetable scenarios
  - *Both* in ”base” and ”do-something” scenarios
- Current practice likely exaggerates benefits
  - ”Base” is usually current timetable – not necessarily ”CBA-optimal”
  - ”Do-something” chosen to yield high benefits *in CBA*

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Methodological pitfalls 2: Agglomeration effects

Eliasson, J. (2015) How wider are “wider economic impacts”? On the overlap between standard CBA and agglomeration benefits. Working paper.

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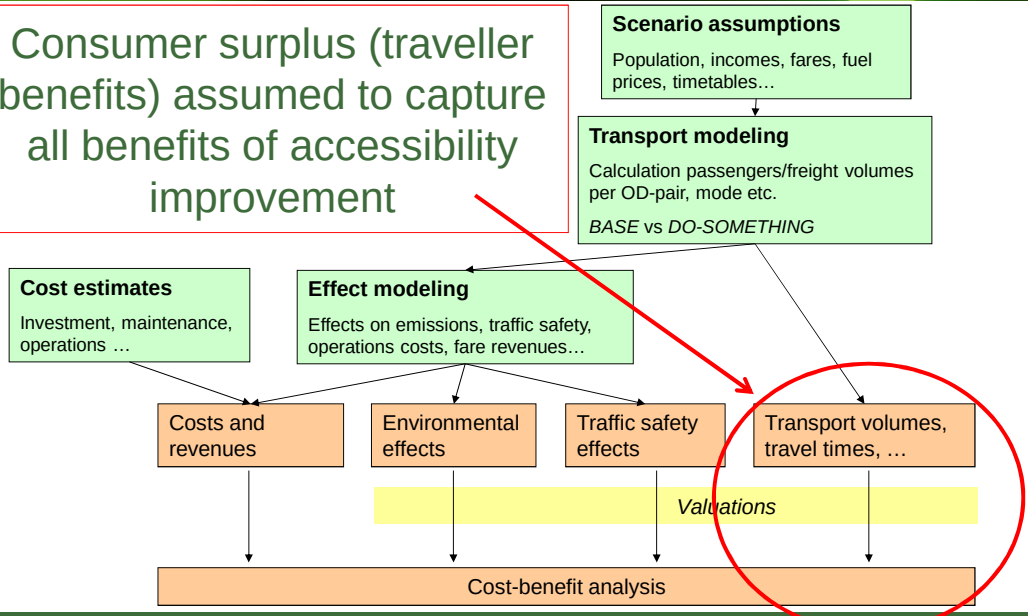
Consumer surplus (traveller benefits) assumed to capture all benefits of accessibility improvement



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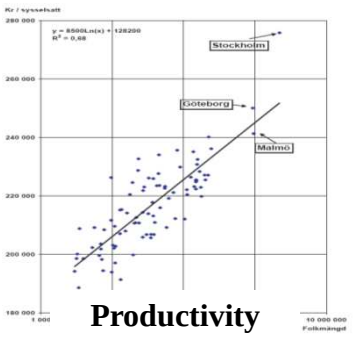
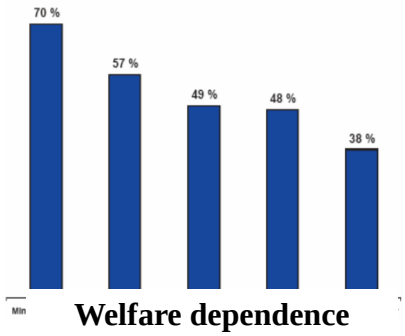
Agglomeration effects make the world go 'round

- Well-known relationship between accessibility and productivity
  - E.g. between city size and wages, and city size and employment
- How much is causal – how much is self-selection?
  - At least *some* of this seems to be causal



Productivity



Welfare dependence

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Are all accessibility benefits captured ”on the road”?

- Better accessibility => more agglomeration effects
  - Better ”connectedness” => better spillovers and matching
  - Cities need infrastructure to grow larger
- How much of these benefits accrue to *travellers*?
  - =captured in CBA
  - *Some* of the benefits go to other workers or firms
  - Tax revenues go to society as a whole
- **Unknown!**
  - UK adds *all* productivity benefits
  - Sweden adds *only* additional benefits
  - Most countries add nothing
- *At least* the tax revenue effect should be added
  - Employment effects particularly important

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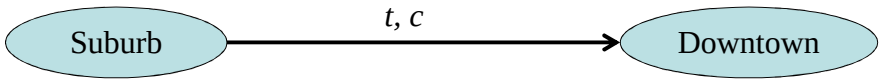
A small model

All workers live in the suburb
Choose where to work and the number of working hours W



Wage w_0

Heterogeneous wage w
Increases with number of commuters N
Distribution $f(w;N)$

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Three sources of agglomeration benefits

- Lower generalised commuting cost → higher wages

- **Labour supply**: shorter commuting time → more working hours
- **Matching**: lower commuting time/cost → more commute → higher average wage rate
- **Spillovers:** lower commuting time/cost → more commute → higher wage rate offers (for *all* commuters)

- First two *will* be captured by standard CBA
- Third one will *not*
- Hence, *source* of agglomeration matters

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Sources are indistinguishable on aggregate scale

- Model 1: Only wage heterogeneity
- Model 2: Only spillover (+heterogeneity in preferences)

	Model 1	Model 2
Mean wage rate ($/h)	7.32	5.42
Mean working hours (h)	7.86	7.97
Mean income ($/day)	57.41	43.12
Elasticity of travel wrt. time	-0.22	-0.23
Elasticity of mean wage rate wrt. accessibility	-0.044	-0.047
Wider economics benefits: benefits outside CBA relative to standard CBA	-1%	+42%

Impossible to know whether ”wider economic impacts” are really ”wider”

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Methodological pitfalls 3: Long term effects

Börjesson, M., Jonsson, R. D., & Lundberg, M. (2014). An ex-post CBA for the Stockholm Metro. Transportation Research Part A: Policy and Practice, 70, 135–148.

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”Transformative investments”

- “Cost-benefit analysis cannot be used to evaluate large transformative investments - there are so many omitted effects”
- “If CBA had been used 1850, we would never had built the railway system”
- “If CBA had been used in the 1950’s, the Stockholm Metro had never been built”
- “A CBA of the Stockholm Metro would have showed a huge negative result – this shows you can’t use CBA for transformative investments”

- Let’s check.

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CBA with current and simulated land-use

	Current Land-Use	Simulated Land-Use
Billon €		
Car travel time savings, work trips	0.1	0.2
Car travel time savings, other trips	0.1	0.1
Transit travel time savings, work trips	1.1	1.0
Transit travel time savings, other trips	1.2	1.1
Increased transit capacity, work trips[1]	5.6	5.4
Increased transit capacity, other trips	5.9	6.1
Sum consumer surplus	**14.0**	**14.0**
Running costs	-1.2	-1.0
Ticket revenue	2.2	2.2
Sum producer surplus	**1.0**	**1.2**
Emissions	0.1	0.2
Accidents	0.2	0.3
Sum externalities	**0.3**	**0.5**
Congestions charges	0.0	0.0
VAT	0.5	0.6
Fuel taxes	-0.2	-0.3
Sum government	**0.3**	**0.3**
Net present value	**15.6**	**15.9**
Net investment cost	-2.0	-2.0
Marginal cost of public funds	-0.6	-0.7
BCR	**5.9**	**6.0**
External benefit - income taxation	5.63	
External benefit - agglomeration effects	1.04	
Total external labor market benefit	**6.7**	
BCR (2.5) with ex. labor market benefit	**8.5**	

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Other applications than investments

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The Stockholm congestion charges

million SEK per year	**Loss/gain**
Shorter travel times	536
More reliable travel times	78
Loss for evicted car drivers, gain for new car drivers	-74
Paid congestion charges	-804
Increased transit crowding	-15
Consumer surplus, total	***-279***
Less greenhouse gas emissions	64
Health and environmental effects	22
Increased traffic safety	125
Other effects, total	***211***
Paid congestion charges	804
Increased public transit revenues	184
Decreased revenues from fuel taxes	-53
Decreased road maintenance costs	1
Necessary increase in public transport capacity	-64
Operational costs for charging system	-220
Public costs and revenues, total	***652***
Marginal cost of public funds	196
Opportunity cost of public funds	-65
Total socioeconomic surplus, excl. investment costs	***714***

Eliasson, J. (2009) A cost-benefit analysis of the Stockholm congestion charging system. Transportation Research A 43(4), pp. 468-480.

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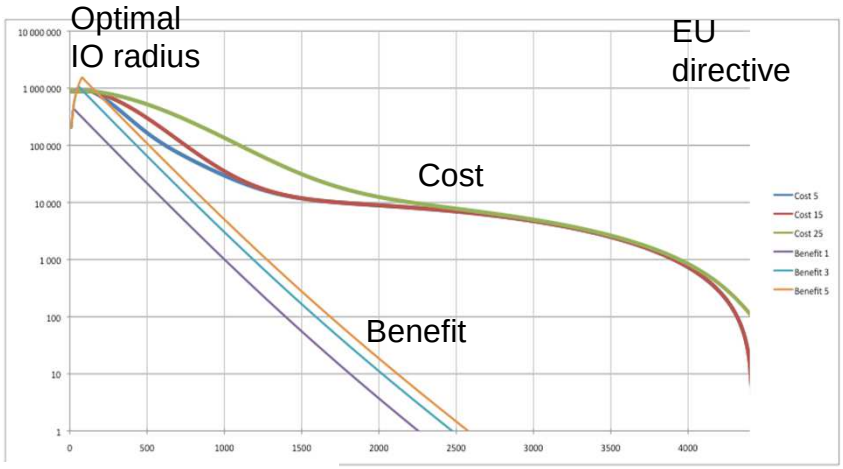
Compulsory interoperability between road toll systems



Hamilton, C. and Eliasson, J. (2013) Costs and benefits of the European directive on road tolling interoperability. Transportation Research C 30(0).

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Quick summary

- Humans need structure and objective input to be consistent, judge magnitudes and (possibly) change initial gut-feeling
- CBA results less sensitive to uncertainty than most think
- Even investments shortlisted by professionals show huge variation in value for money
- Agglomeration and long-term effects matter – but are often just smokescreens used to avoid having to change opinion
- Incentive to window-dress results
- Many more applications than just investments

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Nothing is more practical than good theory.