ECON 180

Introduction to Principles of Microeconomics and Financial Project Evaluation

Lecture 2: Benefits and Costs

September 9, 2022

Version 1

Recommended Reading

Recommended readings are chosen to be useful if you need more help with the lecture material. They are not required.

- Solis, S. S. (n.d.). *Engineering Economics and Incremental Benefit-Cost Method*. California: UC Davis Water Management Lab. http://watermanagement.ucdavis.edu/files/8615/8774/5196/Ex_6_Economics_Engineering.pdf
  - **Pages 11 – 16 go through worked examples step by step.**
- Arizona Department of Transportation. (2010). *The Arizona Highway Safety Improvement Manual*. https://web.archive.org/web/20160314004020/https://www.azdot.gov/docs/default-source/traffic-library/azhsip2010.pdf?sfvrsn=2
  - **Appendix D: Benefit-Cost Analysis Guidelines, on p. 42, describes the incremental BCR algorithm and provides a worked example**.

Recommended textbook reading

- Engineering Economics, 6th edition: Section 6.3 on pp. 217-218, and the section titled "Incremental BCRs" on pp. 423-424.
- Engineering Economics, 7th edition: Section 10.4 on pp. 330-335.

Optional Readings Part 1: Basic Info

Optional readings are for those wanting a deeper dive into the material. Not required.

- CBC News. (2014, December 9)., Deh Cho bridge impact impossible to gauge: N.W.T. gov't. *CBC News North*. http://www.cbc.ca/news/canada/north/deh-cho-bridge-impact-impossible-to-gauge-n-w-t-gov-t-1.2865201
  - **Non-technical News report on the Deh Cho Bridge**
- Fuguitt, D. & Wilcox, S. J. (1999). *Cost-Benefit Analysis for Public Sector Decision Makers*. Westport, CT: Quorum, pp. 89-92.
  - **Urges caution when using BCA, especially with independent projects and a budget**.
- Google Maps: Deh Cho Bridge: https://goo.gl/maps/NXh2sFZ11PSWzmn56
- R. D. Layton. (n.d.). *Critique of Chapter 8, “Prioritize Projects,” HSM 2010*. http://cce.oregonstate.edu/sites/cce.oregonstate.edu/files/hsm-critique.pdf
  - **Warns against common errors in using BCR and IBCR for project selection**. **Worked IBCR example starts on page 10**.

Optional Readings 2: Case Studies

- Apex Engineering. (2004). *Benefit Cost Analysis: Agassiz Rosedale Highway 9/Yale Road East Intersection Improvement*. https://web.archive.org/web/20171228234919/https://www.th.gov.bc.ca/publications/planning/Guidelines/Sample%20Business%20Cases/Agassiz-Rosedale.pdf
  - **Apex Engineering's BCA submission**
- Farid, F., Johnston, D.W., Laverde, M.A. & Chen, C. (1994). Application of Incremental Benefit-Cost Analysis for Optimal Budget Allocation to Maintenance, Rehabilitation, and Replacement of Bridges. *Transportation Research Record, 1442,* 88-100. https://trid.trb.org/view/414436
  - **A real-world application of incremental benefit-cost analysis to prioritizing a mix of independent and mutually-exclusive projects given a budget.**
- Penning-Rowsell, E.C., Haigh, N., Lavery, S. & McFadden, L. (2013). A threatened world city: the benefits of protecting London from the sea. *Natural Hazards, 66,* 1383-1404. https://doi-org.ezproxy.library.uvic.ca/10.1007/s11069-011-0075-3
  - **Incremental benefit-cost analysis is sometimes done poorly in published papers. This interesting paper is an example of this. I've added a tidied-up version of their analysis on Brightspace.**
- Nichols Applied Management, Management and Economic Consultants. (2003). *UPDATE Benefit-Cost Analysis of the Deh Cho Bridge*. Retrieved from http://www.reviewboard.ca/upload/project_document/EA03-008_Appendix_12_-_Nichols_Benefit-Cost_Analysis__Feb_2003.pdf
  - **Detailed BCA of Deh Cho Bridge**
- Alvinsyah & Halim, U. (2018). The optimum bus route selection for sustainable operation (case study: Tangerang bus lane). *IOP Conf. Series: Materials Science and Engineering*, 403. Retrieved from http://iopscience.iop.org/article/10.1088/1757-899X/403/1/012021/meta
  - **Bus Route Example**

Learning Objectives

- Be able to construct and interpret benefit-cost ratios and modified benefit-cost ratios.
- Be able to construct and interpret benefit-cost ratios and incremental benefit-cost ratios.
- Understand the difference between independent and mutually-exclusive projects.
- Be able to use benefit-cost analysis to select one project among a group of mutually exclusive projects.
- Be able to select appropriate independent projects to engage in, given a budget.
- Students are also expected to be able to perform these analyses using appropriately discounted values, once we learn about present and future values.

Relevant Solved Problems

- From *Engineering Economics, 6th edition*
- Costs and Benefits: Example 10.1, 10.1, 10.2, 10.15, 10.16, 10.17, 10.18, 10.19, 10.22, 10.23, 10.26, 10.41
- Calculating BCR and MBCR: Example 10.2, Example 10.3, Review Problem 10.1 (c), 10.3, 10.4.a. and 10.4.b., 10.5.a. and 10.5.b., 10.6.a. and 10.6.b., 10.24, 10.27, 10.28, 10.29, 10.34
- Mutually Exclusive Projects and incremental BCR: Example 10.4, Review Problem 10.1 (d), 10.4, 10.5, 10.6, 10.20, 10.25, 10.33, 10.38
- Multiple Independent Projects and a Budget: 10.36

Relevant Solved Problems are a useful source of practice material. The questions will usually be from *Engineering* Economics, 6th edition. Solutions for these are on Brightspace.

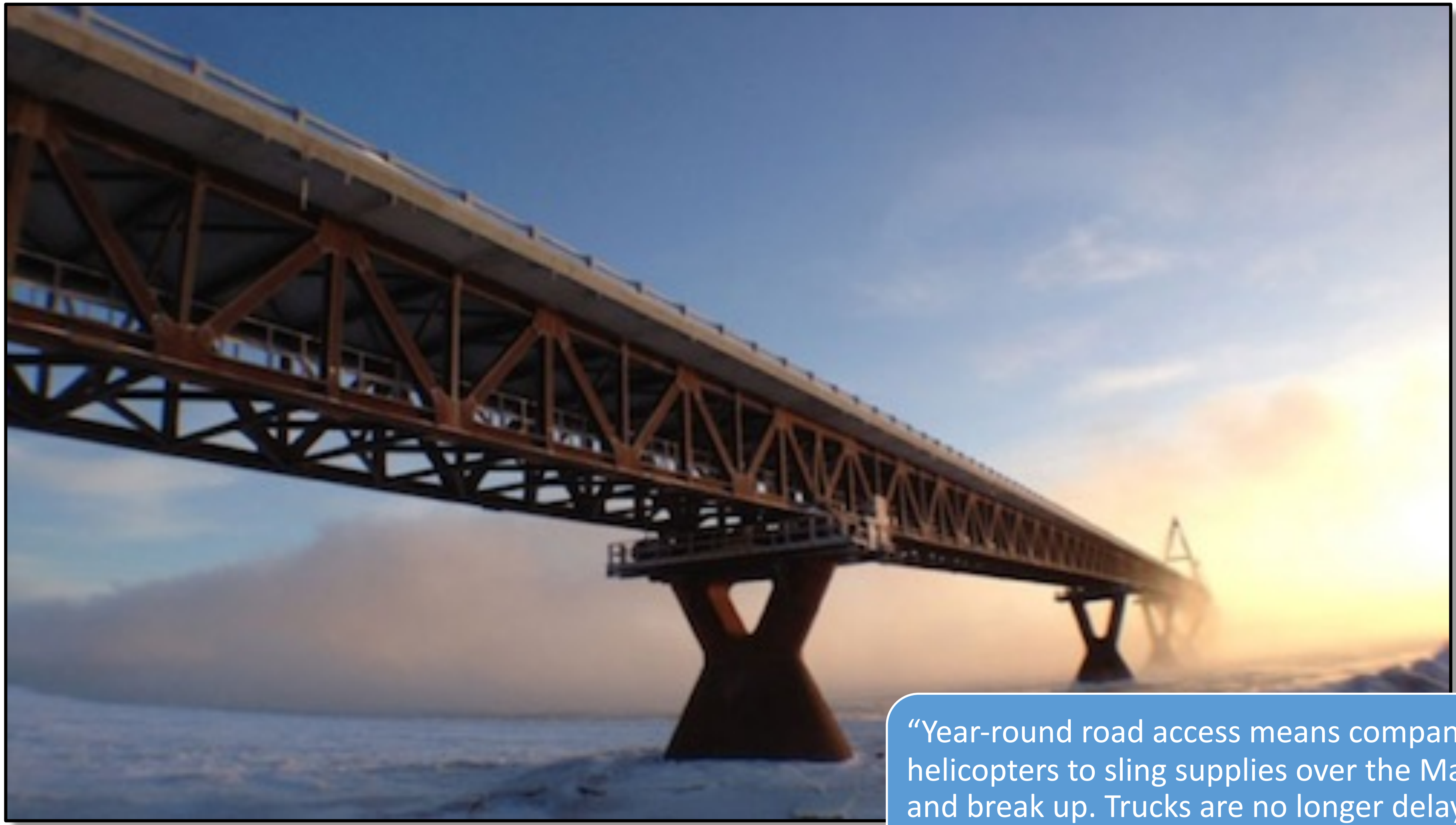
$f(x)$

Formulas Introduced

- Notation: The orange symbol on a slide indicates a formula sheet formula is introduced there.
- $\mathrm{IBCR}(\mathrm{X}-\mathrm{Y}) = \frac{\mathrm{B_X}-\mathrm{B_Y}}{\mathrm{C_X}-\mathrm{C_Y}}$

ESSENTIALS (23 slides)

The Deh Cho bridge: linking NWT and Alberta



(Source: CBC)

Crossing the McKenzie river used to require…

- Ferry
- Air travel
- Ice bridge (seasonal)

A bridge proposed in 2001 was finished in 2012 and fixes all that… but was it worth it?

"Year-round road access means companies don't have to charter helicopters to sling supplies over the Mackenzie River during freeze up and break up. Trucks are no longer delayed when water levels falls too low for a ferry to cross." -CBC

A bridge too far?

overbudget

- Capital cost estimate: \$55m in 2002 → \$202m by 2012
- "The cost-benefit of the bridge has long been disputed. A 2002 report said the bridge would bring benefits if it cost \$55 million and was completed by 2005. An updated 2007 analysis found the benefits were marginal if it cost \$155 million."
- "In the end, what was once a public-private partnership became a government-owned bridge, opening in November 2012 with a final price tag of \$202 million."
- "The government projected that tolls would bring in about \$4 million each year. Instead, toll revenues are about \$400,000 short of that."
- From Nichols report: operating costs = \$4.1m/75 years ~ \$55,000/year.

The benefit-cost ratio (BCR)

$$\mathrm{BCR} = \frac{\sum \mathrm{Benefits}}{\sum \mathrm{Costs}}$$

- A Project is <u>worthwhile</u> if BCR > 1 (Benefits > Costs)
- A Project is <u>NOT worthwhile</u> if BCR < 1 (Benefits < Costs)
- If BCR = 1, the project is *marginally acceptable* (but in a world with uncertainty, probably won't go for it)

A few things to note:

- What the benefits & costs are, & where you stop counting, depend on *perspective*.
- To correctly see benefits & costs, need to compare world WITH to world WITHOUT project.
- World WITHOUT is not '0 cost, 0 benefit' – you'll be doing something else!
- For long-term projects, need to take into account inflation, etc.
- We'll do this later.
- For many items, depending on perspective not clear whether something is a + benefit or – cost, which means different consultants may get different BCR.
- (Thankfully, whether BCR > 1 or not is unchanged by this.)

With & Without Deh Choh bridge

WITH	WITHOUT
Deh Cho Bridge	Ferry
Ferry Salvage Income	Ice Bridge
Faster Traffic	Helicopter
Other savings (VOC, reliability)	Slower Traffic

A BCR for the Deh Cho Bridge

Item	Benefits ($m)	Costs ($m)
Bridge Capital Costs		202
Bridge Operating Costs		41.3
Ferry Salvage Value	1.1	
Avoided Ferry Costs	110.5	
Avoided Ice Bridge Costs	10.5	
Avoided Helicopter Costs	25.2	
Traffic Cost Savings	219.5	
Other Savings	101.5	
Total Benefits	**468.3**	
Total Costs		**243.3**

Benefits outweighs costs

Total Benefits	468.3
Total Costs	243.3
BCR=B/C	1.9

1.9 > 1, so the bridge is worthwhile.

Why worry, if the BCR is so favorable? Our analysis ignores the time value of money. Bring that in, & things are much less rosy (more on that soon). See the 5% & 10% discount rate columns in the Nichols report.

- These numbers differ from the Nichols report. In particular: changed capital costs to $202m, multiplied 2010 helicopter avoided cost by 75 to get an estimate of the lifetime avoided cost, entered it as its own line item. (Probably double-counting, if it was included in 'other savings'.)

Another BCR for the Deh Cho Bridge

Item	Benefits ($m)	Costs ($m)
Bridge Capital Costs		202
Bridge Operating Costs		41.3
Ferry Salvage Value	1.1	
Avoided Ferry Costs		-110.5
Avoided Ice Bridge Costs		-10.5
Avoided Helicopter Costs		-25.2
Traffic Cost Savings	219.5	
Other Savings	101.5	
Total Benefits	**322.1**	
Total Costs		**97.1**

Total Benefits	322.1
Total Costs	97.1
BCR	3.3

- We can get different valid BCRs for the same project, depending on whether we count something as a +benefit or –cost.
- BUT: this doesn't change whether BCR > 1.

" This project is better than itself which is nonsense "

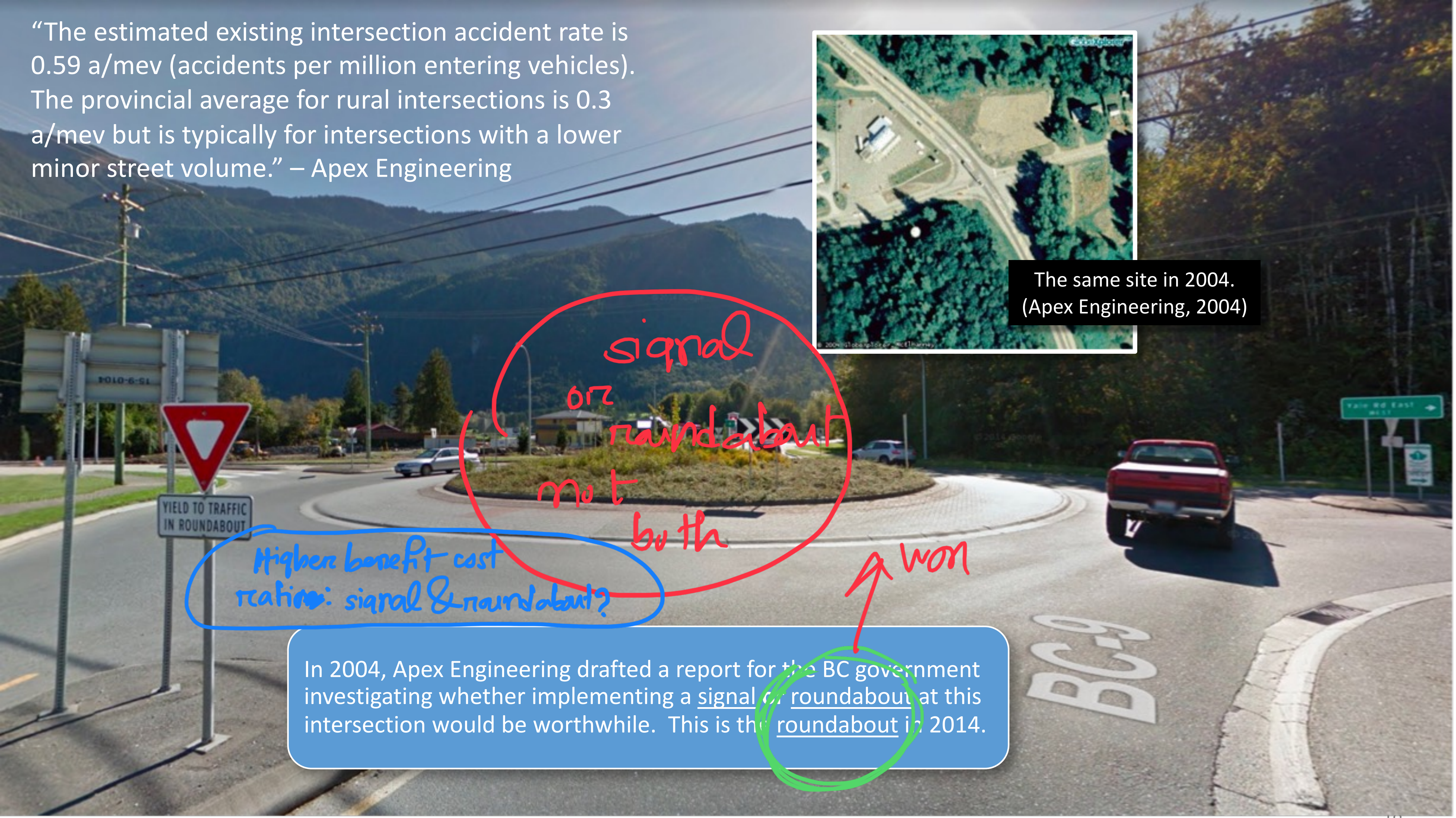
1.9 and 3.3 → ratios are meaningless as long as the number is greater than 1.

Let’s see this in action…

- Usually, operating costs are seen as a cost.
- Sometimes, operating costs are seen as a negative benefit.
- Let B = Benefits, C = Capital costs, T = OperaTing Costs
- BCR = B/(C + T), so if BCR > 1, B = C + T + X, for some X > 0
- Let our **m**odified BCR be BCRM = (B – T)/C
- If BCR > 1, we can re-write BCRM as [(C + T + X) – T]/C
- → $\boxed{\text{BCRM}}$ = (C + X) / C = C/C + X/C = $\boxed{1 + \text{X/C}}$
- Since X>0 and C>0, X/C > 0 and so BCRM > 1
- →When BCR > 1, BCRM > 1

"The estimated existing intersection accident rate is 0.59 a/mev (accidents per million entering vehicles). The provincial average for rural intersections is 0.3 a/mev but is typically for intersections with a lower minor street volume." – Apex Engineering

The same site in 2004.
(Apex Engineering, 2004)



signal or roundabout not both

Higher benefit cost ratio: signal & roundabout?

won

In 2004, Apex Engineering drafted a report for the BC government investigating whether implementing a signal or roundabout at this intersection would be worthwhile. This is the roundabout in 2014.

Image Captured September 2014 © 2017 Google

Signal or Roundabout?

The signal and roundabout are <u>mutually exclusive</u>. You can have one OR the other. Which do you pick?

($ millions)	Roundabout (R)	Signal (S)
Project Cost	0.85	0.43
Salvage Value	0.18	0.09
Increased Maintenance	0.02	0.06
Delay Reduction	1.7	0.5
VOC Reduction	0.6	-0.5
Accident Reduction	4.4	2.8
Total Benefits	6.7	2.8
Total Costs	0.69	0.4
BCR	**9.7 (>1)**	**7.0 (>1)**

(Source: Apex Engineering)

benefit cost ratio magnitude doesn't matter.

What matters is $\boxed{> 1}$

- BCR > 1 for both, so both projects are worthwhile.
- Yes, BCR magnitudes can vary: +cost, -benefit, etc.
- BUT same company did both evaluations at the same time – surely they're compatible?
- →Pick higher BCR → Pick Roundabout (9.7 > 7.0)

NO, YOU CAN'T JUST GO FOR THE HIGHER BCR

Comparison of the benefit-cost ratio of two projects is <u>meaningless</u>.
-*Engineering Economics*, 6th edition, p. 361

If it weren't meaningless, you could say that a project is better than itself: e.g. our BCRs of 1.9 and 3.3 for the Deh Cho Bridge

Another way this can go wrong

- For mutually exclusive projects, selecting one project automatically discards the rest. (e.g. Cut your hair short, or leave it long?)
- BCR magnitudes hide the *scale* of the project → choosing the highest BCR could leave a lot of worthwhile benefits unused.
- Example: Project A and Project B are mutually exclusive.
- Project A has Benefits = $10 Costs = $1 → BCR = 10
- Project B has Benefits = $1,000,000, Costs = $200,000 → BCR = 5
- BCR(A) > BCR(B), but choosing A forgoes a lot of benefits!
- Suppose you consider the project of 'upgrading' from Project A to the more expensive Project B.
- The additional costs would be $199,999, and the additional benefits would be $999,990.
- This **incremental analysis** shows B is the better choice. The extra benefits are worth the extra cost.

Evaluating mutually exclusive alternatives

$f(x)$

- Check if the EXTRA benefits are worth the EXTRA costs of the pricier option.
- Let X and Y be two mutually exclusive projects.
- These projects have benefits $B_{X,Y}$ and costs $C_{X,Y}$.
- Suppose BCR > 1 for X and Y, and $C_X \geq C_Y$
- We evaluate whether the higher cost of X is worth it by calculating the *incremental* BCR, or IBCR:

$$\mathrm{IBCR(X-Y)} = \frac{\mathrm{B_X - B_Y}}{\mathrm{C_X - C_Y}}$$

- If IBCR(X – Y) > 1, the jump in cost from Y to X is worth it. If not, it isn't.
- In case of a tie, pick the project with higher B or lowest C.

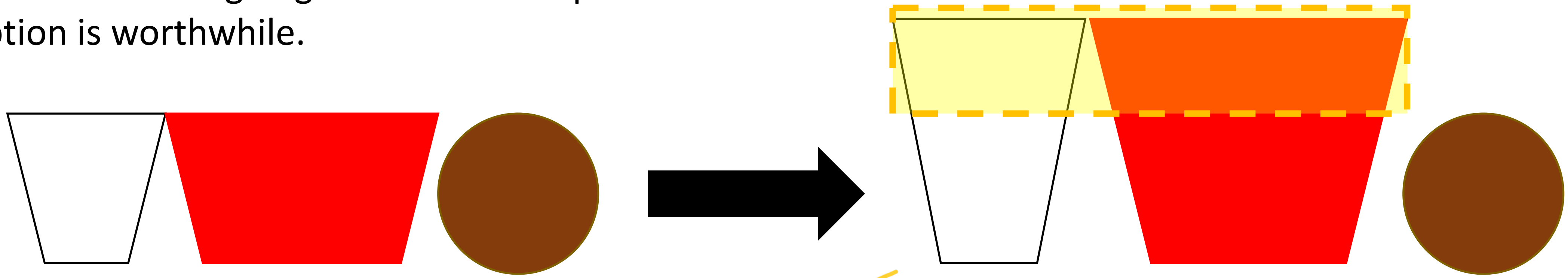
Intuition: ‘Do you want to supersize that?’

- McDonald’s used to offer to ‘supersize’ your combo meal. (A combo has a burger, soda and fries). By paying additional money, you would receive larger fries and more soda.
- When asked ‘do you want to supersize that?’, the customer would have to ask themselves: “are the additional (incremental) benefits (more fries, more drink) worth more to me than the additional (incremental) cost (supersize charge)?”
- That’s what we’re doing here: the roundabout costs more, and provides more benefits than the signal. Are the additional benefits worth more than the additional cost?

- When comparing two *mutually exclusive* (XOR) alternatives, cancel out what's the same.
- Compare the *extra* benefits to the *extra* costs to decide whether going for the more expensive option is worthwhile.

We care about the *differences* between choices.

Extra (Incremental) Benefits



Regular Combo **Supersize Combo**

$

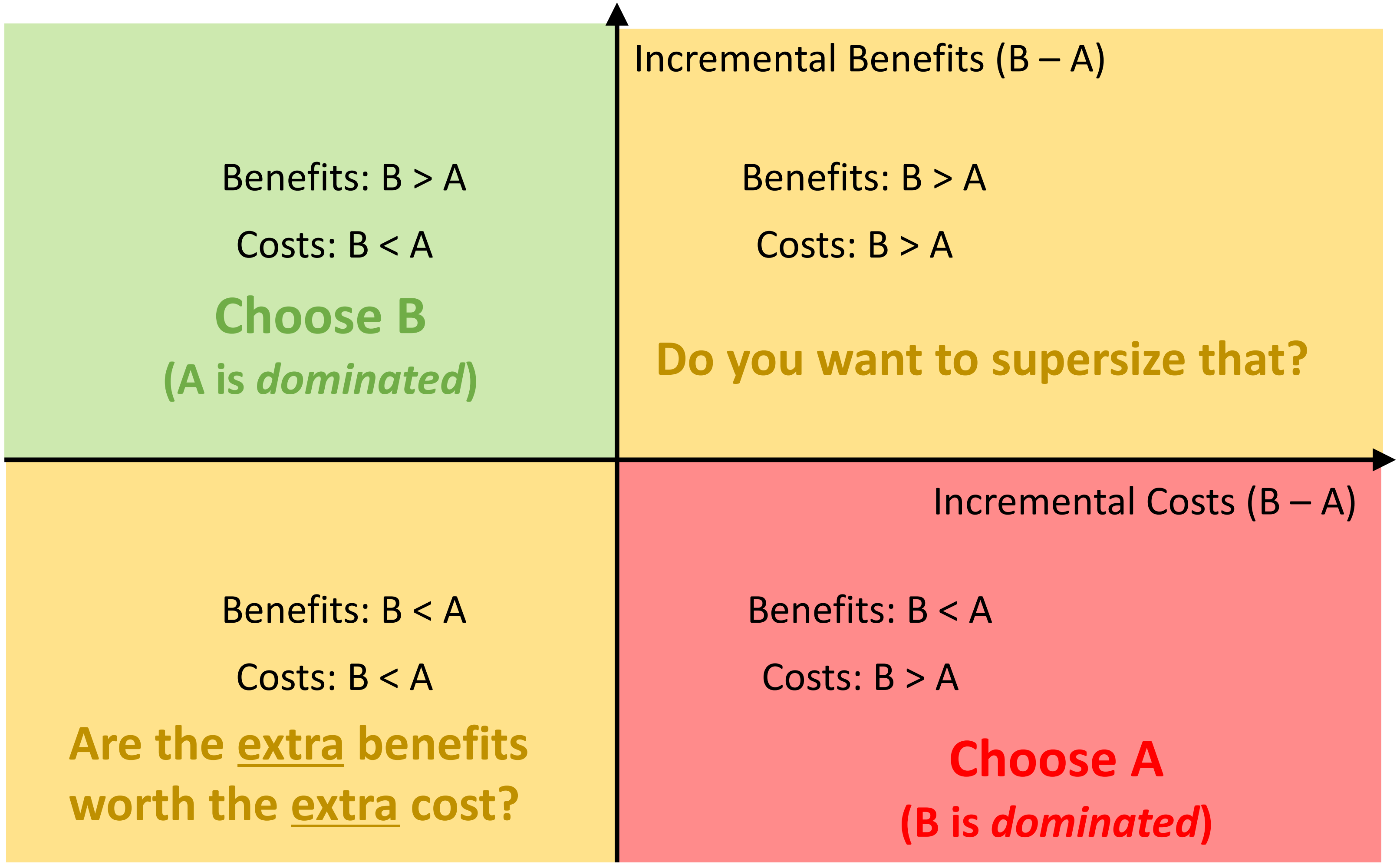
Eating and drinking more → understanding the benefit

$ $ **Extra (Incremental) Costs**

- Why 'extra benefits' and 'extra cost'? What if we don't have those conditions?
- Then the choice is trivial: no big analysis needed. We say one choice is *dominated* by the other.
- Extra benefits, cheaper costs: go for the cheaper option.
- Fewer benefits, fewer costs is just extra benefits, extra costs seen from the other side.
- Fewer benefits, extra costs is just extra benefits, cheaper costs seen from the other side.

Comparing Two Alternatives, A and B

At the origin, the benefits and costs of A and B are equal.



Assume that individually, both B and A are worthwhile (BCR > 1).

Incremental analysis

Inc benefit cost report

- BCR > 1 for R and S, and $C_R > C_s$.

$$IBCR(R - S) = \frac{B_R - B_S}{C_R - C_S} = \frac{6.7 - 2.8}{0.69 - 0.4} = 13.4 > 1$$

Incremental

- Since IBCR(R – S) > 1, the increased cost of the roundabout is worth it.

> "The benefit cost analysis returns a B/C ratio of 9.9 for the Roundabout and 7.1 for the signal. Both options would be beneficial in a benefit cost context but the roundabout is preferred. It offers lower accident severity and rate without increasing intersection delay significantly for Highway 9 traffic."
>
> –Apex Engineering

What if projects *aren't* mutually exclusive?

- Mutually exclusive: A OR B. Choosing one automatically excludes the other, even if you can afford both.
- Keep your hair long **OR** cut it short.
- Restore an old house **OR** turn the site into a parking lot.

- Independent: (A AND B) is a possibility, given a large enough budget.
- Cut your hair short **and** buy a long-haired wig.
- Restore an old house **and** build a parking lot on a second site.

- Loosely: Mutually Exclusive? XOR. Independent? OR

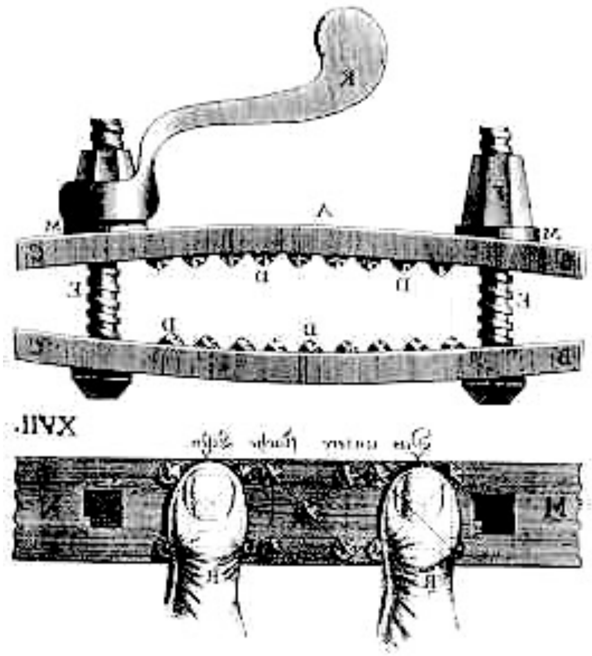
What if we have independent projects?

- Unlimited budget? Buy any project with BCR > 1.
- Limited budget? Standard procedure in many organizations is to order by BCR, and then buy projects in that order until there's not enough to buy the next.
- This **rule of thumb** works great if you can subdivide projects – buy 73% of a project, etc. (Can't afford 1,000 textbooks? Buy 940.) There's trouble if projects are *lumpy* and have a required, inflexible size.
- If part of the budget is left over, then chances are good this policy *won't* give the best value-for-money.
- Solution: consider **all** affordable combinations of projects (*this can get messy*) and pick the permutation with highest **Net Present Value** (we'll learn about this soon).

Pictured: Ancient electrum hekte coin (Public Domain)

Example (Adapted from Fuguitt and Wilcox Table 10.2)

Project	Benefit	Cost	BCR
A	17	7	2.4
B	67	32	2.1
C	45	25	1.8
D	100	60	1.7



- Suppose your budget is 100
- Projects in the table are already sorted by BCR, and are all worthwhile (BCR>1).
- Following standard procedure, you'd buy projects A, B and C at a cost of 64, for a total benefit of 129 and 36 left over in the budget.
- BUT it would be better to buy projects A, B and D at a cost of 99, for a total benefit of 184 and only 1 left over in the budget.
- **Consider your options carefully, and don't blindly follow rules of thumb!**

A note on independence

- In the previous slide, the budget was not large enough to pay for all worthwhile (BCR > 1) projects.
- In this sense, the projects were **not** independent: money used to pay for one project was not available to pay for another.
- For the purpose of simple BCR analysis, two projects are considered independent if, with an unlimited budget, each may be undertaken without affecting the performance of the other.
- For **mutually exclusive** projects, choosing one project eliminates the rest from consideration.

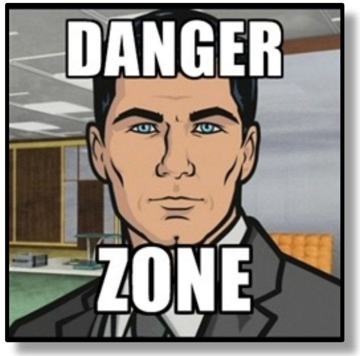
> "Examples of independent projects are those at separate roadway sections or spots. Mutually exclusive project examples are represented by various alternatives at a railroad crossing, such as, cross bucks with a stop sign, gates with flashing signals, and an over-crossing."
>
> -Robert D. Layton

Summarizing exclusive vs independent projects

List of projects with BCR > 1

- Mutually exclusive → Incremental BCR algorithm → Select winning project, discard the rest
- Independent with a budget → Rank by BCR (High to Low) → Purchase in order until budget spent

BUT be careful if there's a lot of money left over!
→ Consider alternatives.



Archer © Fox Entertainment Group

Algorithm for incremental benefit/cost analysis

"2 projects enter, 1 project leave."

- Calculate the BCR for each exclusive project.
- List projects with BCR > 1 in order of increasing cost.
- Check for dominated projects (see next slide) and remove them.
- Calculate the incremental BCR, IBCR(X – Y), of the second lowest-cost project, X, compared to the lowest-cost project, Y.
- If IBCR(X – Y) = 1, pick the project with the highest benefit. (Practical note: some organizations require picking the project with the lowest cost, instead.)
- If IBCR(X – Y) > 1, pick X and discard Y. Otherwise, pick Y.
- "Continue in order of increasing costs to calculate the incremental [BCR] for each [project] compared to the last-picked [project]."
- Stop once there is only one project left.

(Lightly adapted from ADOT Traffic Engineering Policies, Guidelines, and Procedures June 2009 Section 200 http://azdot.gov/docs/businesslibraries/230.pdf?sfvrsn=2)

Side note: Dominated projects?

For home use: We'll zoom over these slides in the lecture.

- A dominated project is one that is strictly and obviously inferior to another project under consideration.
- Checking for dominated projects is a time-saving 'pre-screen' that avoids unnecessary calculations.
- Two main rules:
- 1) If two projects have the same cost, but different benefits, the project with the lower benefit is dominated.
- 2) Benefits must increase with costs.
- We'll see how this works (along with the rest of the algorithm) with a simple example…

Don't use incremental BCR for <u>independent</u> projects!

- It is *incorrect* to use incremental BCR analysis when the projects under consideration are independent.
- The reason is that the algorithm requires you to *discard* an alternative in each iteration of the loop.
- This may lead to perfectly good projects (BCR > 1) being discarded
- Such an approach makes sense when the projects are mutually exclusive. By definition, you will want to exclude all but one.
- This is NOT the case when projects can co-exist!
- For a fully worked example, see Exhibit 7 starting on p. 13 in http://cce.oregonstate.edu/sites/cce.oregonstate.edu/files/hsm-critique.pdf

AFTER HOURS

- Extended example (9 slides)
- Real world example – Indonesia (2 slides)
- Real world example – Arizona (1 slide)

A sample set of mutually exclusive projects

Project ID	Benefit	Cost	BCR
A	1	5	0.2
L	12	8	1.5
G	7	4	1.8
O	15	14	1.1
R	18	13	1.4
I	9	13	0.7
T	20	17	1.2
H	8	6	1.3
M	13	9	1.4

Benefits < Costs: Projects A and I have a BCR less than 1, and are therefore not worthwhile.

Dominated Project: Projects R and I have the same cost, but different benefits. Since Project I has the lower benefit, it would be ruled out even if its BCR were greater than 1.

Step 1: Eliminate projects with BCR < 1

Project ID	Benefit	Cost	BCR
A	1	5	0.2
L	12	8	1.5
G	7	4	1.8
O	15	14	1.1
R	18	13	1.4
I	9	13	0.7
T	20	17	1.2
H	8	6	1.3
M	13	9	1.4

Project ID	Benefit	Cost
L	12	8
G	7	4
O	15	14
R	18	13
T	20	17
H	8	6
M	13	9

Step 2: Sort by cost, check for dominance

Project ID	Benefit	Cost	Δ Benefit
G	7	4	
H	8	6	1
L	12	8	4
M	13	9	1
R	18	13	5
O	15	14	-3
T	20	17	5

Sort by Cost: Projects have been arranged from lowest to highest cost.

Check for Dominance: Δ Benefit lists the incremental benefit from one project to the next. Since cost goes up, so should benefits.

Incremental benefit from R to O is negative, so project O is dominated by (lower cost, higher benefit) project R. We can eliminate O.

Step 3: Eliminating dominated projects

Project ID	Benefit	Cost	Δ Benefit
G	7	4	
H	8	6	1
L	12	8	4
M	13	9	1
R	18	13	5
O	15	14	-3
T	20	17	5

Project ID	Benefit	Cost
G	7	4
H	8	6
L	12	8
M	13	9
R	18	13
T	20	17

Step 4: Incremental BCR (IBCR) and Iteration

Project ID	Benefit	Cost	Δ Benefit	Δ Cost	IBCR
G	7	4			
H	8	6	1	2	0.5
L	12	8			
M	13	9			
R	18	13			
T	20	17			

The Incremental BCR from G to H, IBCR(H – G), is less than 1, so the additional cost of H is not worth it.

→ Keep G and eliminate H

Next round (H eliminated)

Project ID	Benefit	Cost	Δ Benefit	Δ Cost	IBCR
G	7	4			
L	12	8	5	4	1.25
M	13	9			
R	18	13			
T	20	17			

The <u>Incremental BCR</u> from G to L, IBCR(L – G), is greater than 1, so the additional cost of L is worth it.

→ Keep L and eliminate G

Next round (G eliminated)

Project ID	Benefit	Cost	Δ Benefit	Δ Cost	IBCR
L	12	8			
M	13	9	1	1	1
R	18	13			
T	20	17			

The Incremental BCR from L to M, IBCR(M – L), is exactly equal to 1, so we need to compare benefits.

The benefit from M is greater than the benefit from L, so M is preferred to L.

→ Keep M and eliminate L

Next round (L eliminated)

Project ID	Benefit	Cost	Δ Benefit	Δ Cost	IBCR
M	13	9			
R	18	13	5	4	1.25
T	20	17			

The <u>Incremental BCR</u> from M to R, IBCR(R – M), is greater than 1, so the additional cost of R is worth it.

→ Keep R and eliminate M

Final round (M eliminated)

Project ID	Benefit	Cost	Δ Benefit	Δ Cost	IBCR
R	18	13			
T	20	17	2	4	0.5

The last project standing is Project R, so that's our winner!

The Incremental BCR from R to T, IBCR(T – R), is less than 1, so the additional cost of T is not worth it.

→ Keep R and eliminate T

Real world example: Bus routes in Indonesia

- The Tangerang bus lane corridor has two choices for a bus route:
- Route A has lower costs, but fewer paying passengers.
- Route B has higher costs, and more paying passengers.
- Individually, each proposed route is profitable: benefits, in the form of revenue, are greater than costs. (BCR > 1)
- The routes are mutually exclusive: the planners must decide on Route A OR Route B. It’s not possible to operate both routes simultaneously.
- →We need to use incremental benefit-cost analysis to choose between them.

The numbers (Alvinsyah & Halim, 2018)

	Daily, in Rupiah			Incremental		
	Cost	Revenue	BCR	Cost	Revenue	IBCR
Route A	15,068,729.0	42,976,500	2.9			
Route B	16,322,702.7	44,569,000	2.7	1,253,973.7	1,592,500	1.3

- The Rupiah is the Indonesian currency. $1 CAD is about 10,625 Rp.
- This example shows why you can't choose between mutually exclusive projects by picking the one with the highest BCR.
- Although Route A has a higher BCR, the incremental BCR shows that Route B is preferred: the additional benefits exceed the additional costs.

Illustration of Incremental B/C Analysis

(From p. 45 of (Arizona Department of Transportation, 2010).)

Counter-measure	Annual Benefit	Annual Cost	B/C	Comparison of Counter-measures	Incremental Benefit	Incremental Cost	Incremental B/C Ratio (ΔB/ΔC)
B	$15,200	$1,510	10.1				
				B and C	$-2,400	$200	-12.0 (Pick B)
C	$12,800	$1,710	7.5				
				B and A	$25,600	$19,750	1.3 (Pick A)
A	$40,800	$21,260	1.9				
				A and D	$12,000	$3,240	3.7 (Pick D)
D	$52,800	$24,500	2.2				