

How Will Economics Figure in Your Engineering Career?

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Some economist comes up to you and says your elegant project is uneconomic

Today:

- How the disciplines of engineering and economics interact with each other
- Some fundamental concepts about economic applications
 - in relatively plain language
- Some examples of economics applied to contemporary issues

Economics and Engineering

- How does economics apply in an engineering career?
 - work with economists on assignments that have an economics dimension
 - demand, cost, price
 - economics looks at what should we build (allocative efficiency)*
- How does engineering apply in an economics career?
 - work with engineers on assignments that have an engineering dimension
 - capital and operating costs, technology, practices (integration and linkages)
 - engineering looks at how should we build it (productive efficiency)
- Private and Public employers and clients use economics very differently

* project selection allocative efficiency. Economics also looks at productive efficiency in how the legal and regulatory framework and practice affects both demand and supply.

Private Sector

- It is the part of the economy that we have set up to be independently self-administering
 - within a mixed market legal and regulatory framework
- It is exclusively concerned with financial questions, financial feasibility
 - allocative and productive efficiency are co-evaluated
- Uses economics for demand and price forecasting and macro business conditions, but not for overall feasibility evaluation
 - if it makes a financial profit, go ahead!
- Various jurisdictions organize the line between public and private in various ways, no single answer

Public Sector

- It is the part of the economy that we have set up to have active government participation, within a democratic governance framework
 - activities for which it is difficult to isolate users and/or specific benefits: health, education, public safety, legal system
 - not trying to identify specific benefits to an individual who can be charged for the benefit; revenue is from taxes, sometimes "user fees", not sales
- The public sector starts with economic analysis to evaluate overall social benefit before doing financial analysis
 - allocative and productive efficiency are separate
 - greater role for economics in the public sector than the private sector
 - wrong to dismiss "economics" as meaning "private profit"

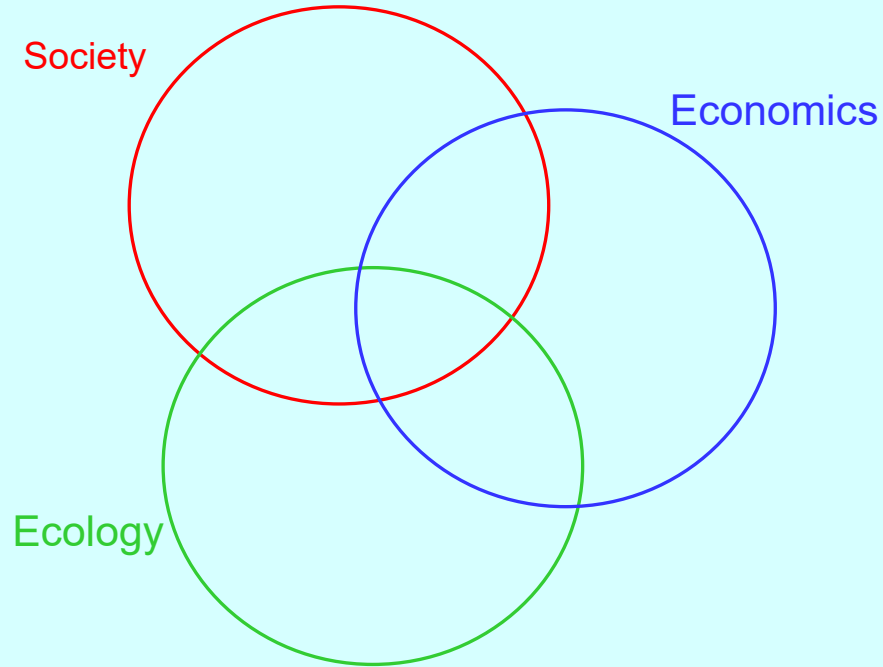
History of Science, greater abstraction

- 16th century: astronomy
 - empiricism, changed our conception of space and humanity in the cosmos
- 17th, 18th centuries: Newton physics, maths, chemistry, medicine
 - application of scientific method
- 19th century: geology (plate tectonics), biology (evolution)
 - changed our conception of time and history of humanity
- 20th century: Einstein physics, more math, psychology, economics
 - new levels of abstraction
 - application of science to human behaviour

21st Century, Sustainable Development

- "Sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations"
 - From the 1987 Brundtland Report, the concluding document of the UN's World Commission on Environment and Development

Three components of the “sustainability triad”



Sustainable Development

- The sustainable development "triad" provides a framework to look at issues in a complete and integrated way
 - Must consider each of the three domains of thought and analysis
 - Must integrate each with the others
 - Encourages more logical, consistent, complete, and empirical ("evidence-based") discussion

Climate Change

- The absolute quantity of carbon in the world atmosphere has to be limited to prevent run away climate change
- As population and income grow to only way to meet an absolute limit is to continuously reduce the amount of carbon per person and per activity
- Continuously higher efficiency in transportation services is an absolute requirement, we cannot afford inefficient investment

Oikos - the place where we live

- The Greek word "oikos", for house, or the place where we live, shows up in both economics (the management of the house) and ecology (the science of the house)
 - There is a clear connection between managing without waste and minimizing the disruption to natural processes
- How a society tries to meet "unlimited" human wants with limited resources: efficiently (allocation) and fairly (distribution)
- It is nicknamed "The Dismal Science" because it requires you to think about your choices and their implications
 - It is often about deciding what you cannot afford to do

Scale of Economic Analysis

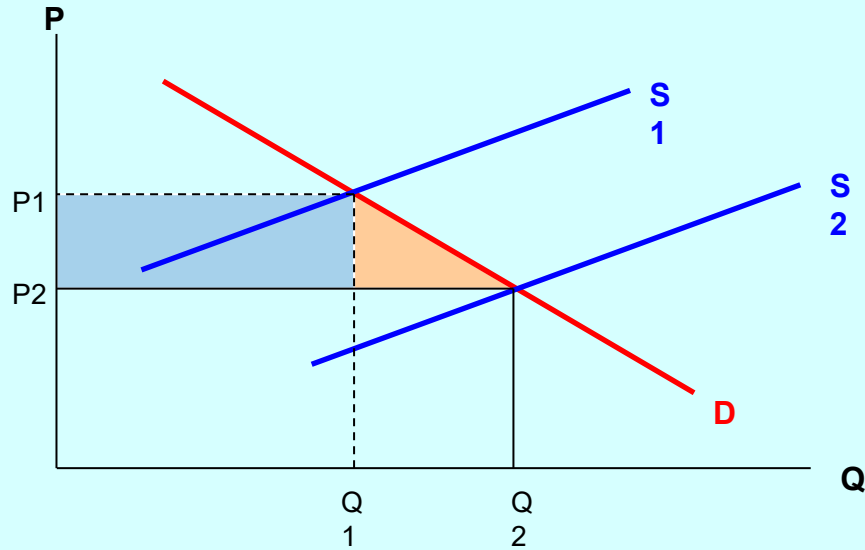
Scale	Analysis	Examples
Nation or Province	Macroeconomics	- Growth - Interest Rates
Industry	Macro and Microeconomics	- Competition - Productivity
Establishment(s) or Operating Unit(s)	Microeconomics	- Pricing - Logistics - Impact Analysis
Project	Microeconomics including Operational and Feasibility Analysis	- Cost Benefit Analysis

- “Economic” scale as used here is not the same as “Geographic” scale. It is concerned with the types of relationships not necessarily physical extent.
- Geographic scales at the international, regional, and urban level are of special interest in transportation economics.

Economics

- Economic resources include: labour, capital, land, time, natural resources, location, information, knowledge, management attention
- Economics is a management framework for considering combinations of these limited resources to efficiently achieve a desired result
- Economics is also about how the benefits of economic activities are distributed across society
- Aside from basic subsistence, there is no such thing as "need" in economics
 - there is "demand", when someone refers to "need" they are entering the realm of politics
- Political issues can be discussed in sustainable development under "Society"

First dichotomy: Micro and Macro



Supply and Demand



The Dismal Science

Micro-Welfare and Macro-GDP

Microeconomic welfare analysis is based on the specifics of the benefits to the economy and is sensitive to project characteristics

- Employment is a cost not a benefit

Macroeconomic GDP analysis is based on broad changes in the economy and is not sensitive to project characteristics

- “Multiplier” analysis is macroeconomics analysis, driven by total spending not project characteristics
- Larger projects always have a larger impact, so not useful for choosing between projects
- Expenditure multipliers show the benefit but leave out the **macro cost side**, which are the **higher taxes** or user fees needed to pay for the expenditure

Welfare and GDP, micro and macro

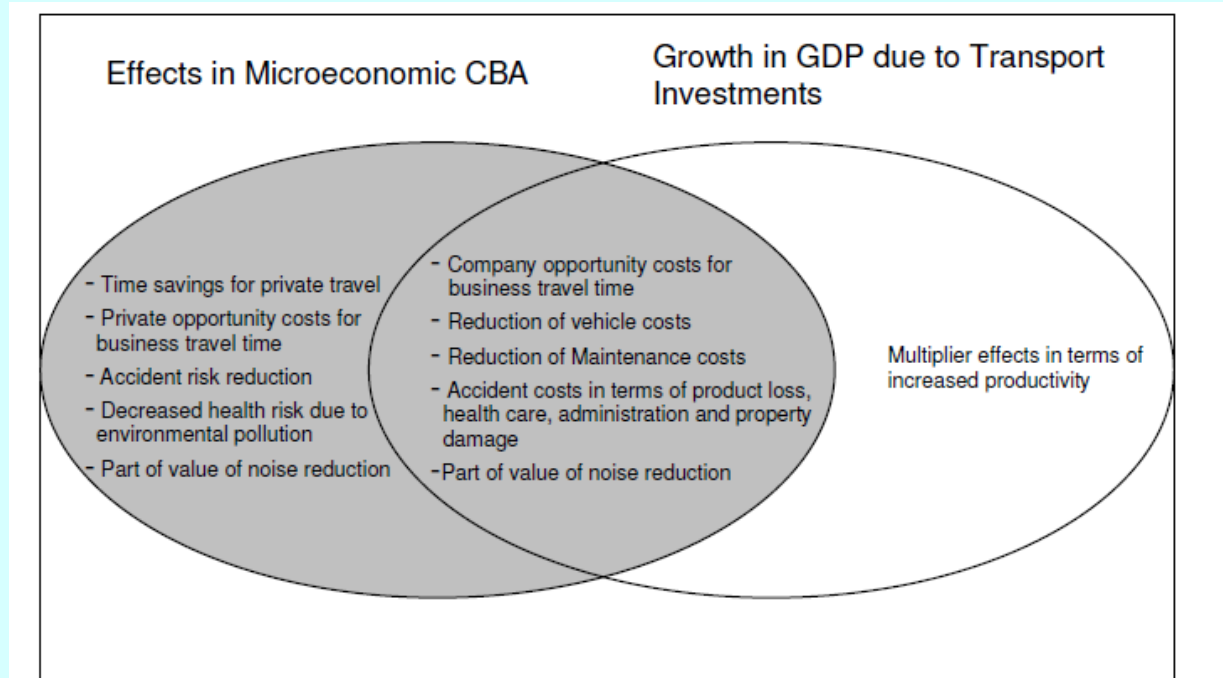


Figure 3: Microeconomic CBA and Macroeconomic GDP

Source: OECD: *Assessing the Benefits of Transport*, pg 23.

Second dichotomy: Economics and Finance

- Some things about economics are tricky
 - Economics and finance both use the word "dollar" but the "dollars" measure very different things
 - Economics is about value of **all of society's resources** (constant collars)
 - Finance is about **ownership** and value of **owned resources** (current dollars)
 - They are not the same "dollars", they cannot be added together
- Economics values accuracy over precision, it is better to be imprecisely accurate than precisely inaccurate
 - Complete analysis, the full picture including alternatives, supports accuracy
- Economics has no professional regulatory body
 - No "Professional Economist", "Chartered Economist", no "GAEP"

What economic costs and benefits?

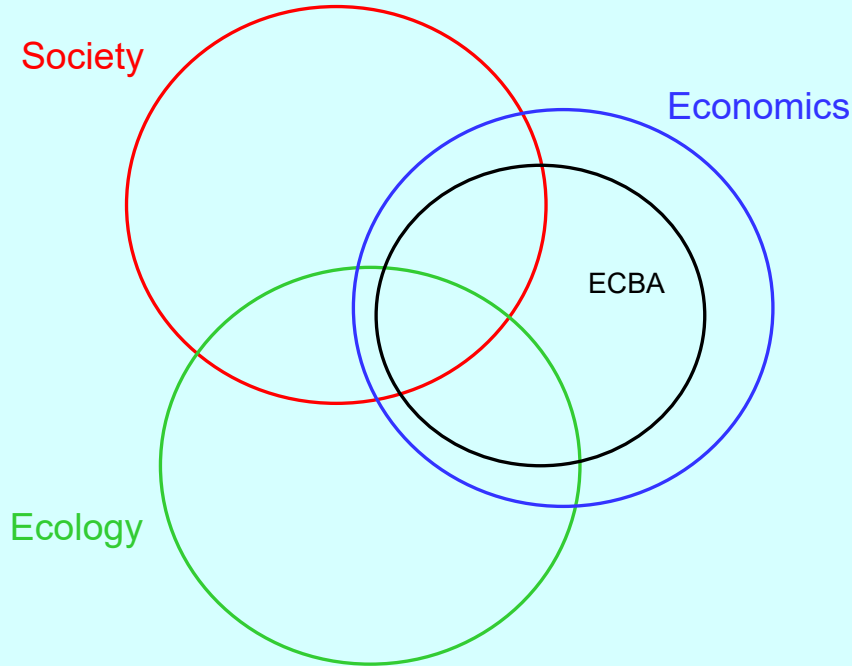
- A conventional transport Economic Cost Benefit Analysis (ECBA):
 - Measures costs and benefits for all of society's resources, they are "owned" by all of us together
 - Costs: Construction costs, major rehabilitation costs, operating and maintenance costs
 - Benefits: Travel time changes (all modes), vehicle operating cost savings, safety cost savings, GHG emissions savings
 - All in constant dollars. The total benefit is called "surplus" not profit.
- These measures are approximations of the concepts underlying welfare and surplus
- All travellers want to reduce their transport cost. Most travellers behave relentlessly to reduce their travel time

What financial costs and benefits?

- A conventional transport Financial CBA (FCBA) :
 - Costs: Construction costs, major rehabilitation costs, operating and maintenance costs
 - Benefits: Revenue from user fees, other operations, transfers from government ("subsidies")
 - “Dollars” measures the value of financial resources to their owners in current dollars. Owners can be public or private sector or a mix.
 - All in current dollars. The total benefit is called "profit" not surplus.
 - Finance does not measure economic welfare and social surplus
- The main difference from economic analysis is that benefits are from revenues and fiscal transfers

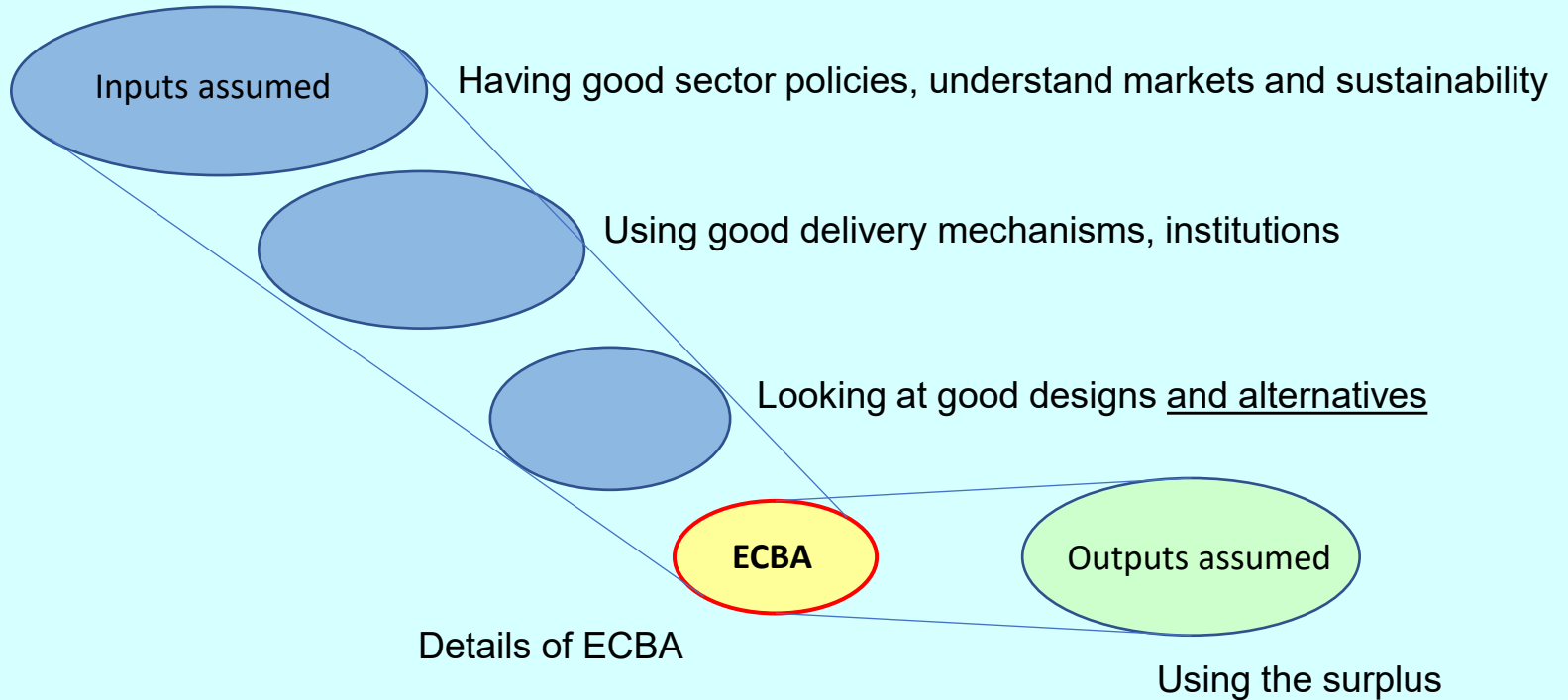
Economic Cost Benefit Analysis (ECBA)

A microeconomic welfare, partial equilibrium, approach



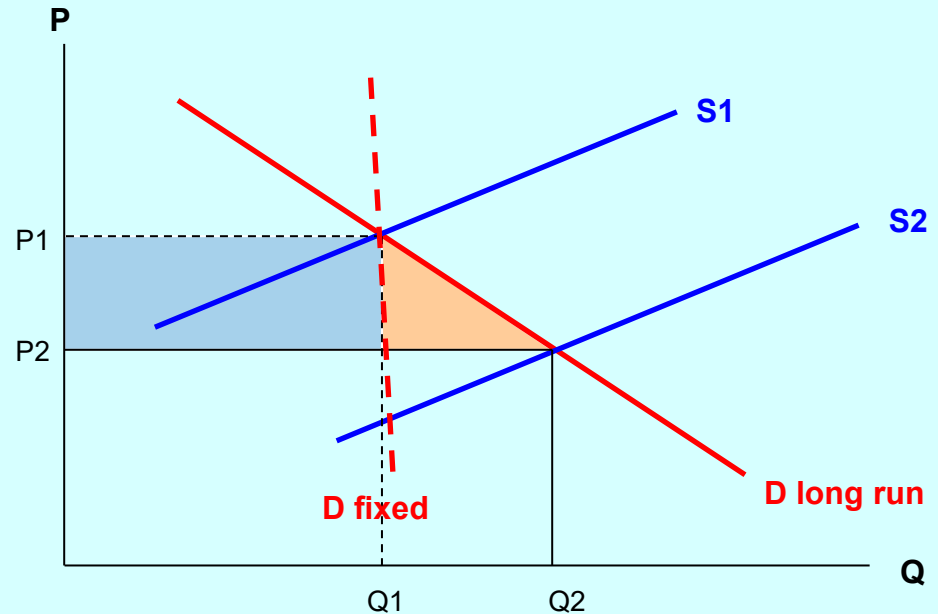
- In microeconomic welfare, the focus is on individual behavior and how we generate economic surplus for society
- In partial equilibrium, the focus is on supply and demand details of a project, rather than the whole economy

Partial Equilibrium



Project Analysis - Economic Effect

- Building a project increases supply from S1 to S2.
- The cost to users & society (slide 18) goes down from P1 to P2
- Immediate and short run response shows little change in quantity
- In the long run the amount of use (demand) goes up from Q1 to Q2
- Transport demand modelling in Toronto over the last 25 years has worked with a **fixed population and employment in the forecast year** (i.e. 2041) **across all scenarios**
- This means that almost no increase in total demand is modelled, as shown on the dashed demand curve (D fixed)



Mechanics of ECBA

- Project alternatives are compared against “business as usual”, to evaluate the net new contribution of the project to the economy
- Costs and benefits are estimated over time, called discounted "cash flows" and representing the life of the project
- The result is expressed as a "net present value" (NPV) of the entire flow of costs and benefits
- Debate about the details of the costs and benefits is less important than applying the same assumptions and scope to a wide variety of alternatives in order to ensure consistent comparisons, accuracy over precision
- An unduly pessimistic base case may overstate project benefits, BAU should include municipal investments consistent with past behaviour, i.e. they will provide piped services and will expand their arterial roads

Travel demand estimates are critical and largely provided by engineers

- Requires a network-wide travel demand forecast with and without the project
- Only two key model outputs are needed for economic analysis
 - (1) total travel time across all modes, all routes, all purposes
 - (2) total veh km by car and by truck across all modes, all routes, all purposes
 - Microeconomics is Macroeography, lots of modelling needed to explore alternatives, more on this below
- Economic value depends only on saving these time and vehicle resources
 - In the Toronto modelling context with a fixed amount of total travel, **ridership** on a segment, or **new ridership** on a segment, or persons **new to transit** on a segment; **are irrelevant to ECBA**
 - The total travel stays the same, the choice of mode or route has resource implications for all of society across the whole network for all travel

Optimization, Limits of Partial Equilibrium

- By itself ECBA does not tell you if the investment is the best investment
 - It will only tell you the specific return on a given investment
- To find the best bang for the buck, ECBA must be applied to a whole range of possible solutions
 - An alternatives analysis is critical, so that the solution with the highest value to society ("best" alternative) can be identified
- ECBA must include a series of analyses to explore the impact of the cash flow parameters, the costs, the benefits
 - Sensitivity testing, switching value analysis

Route, Technology, Service

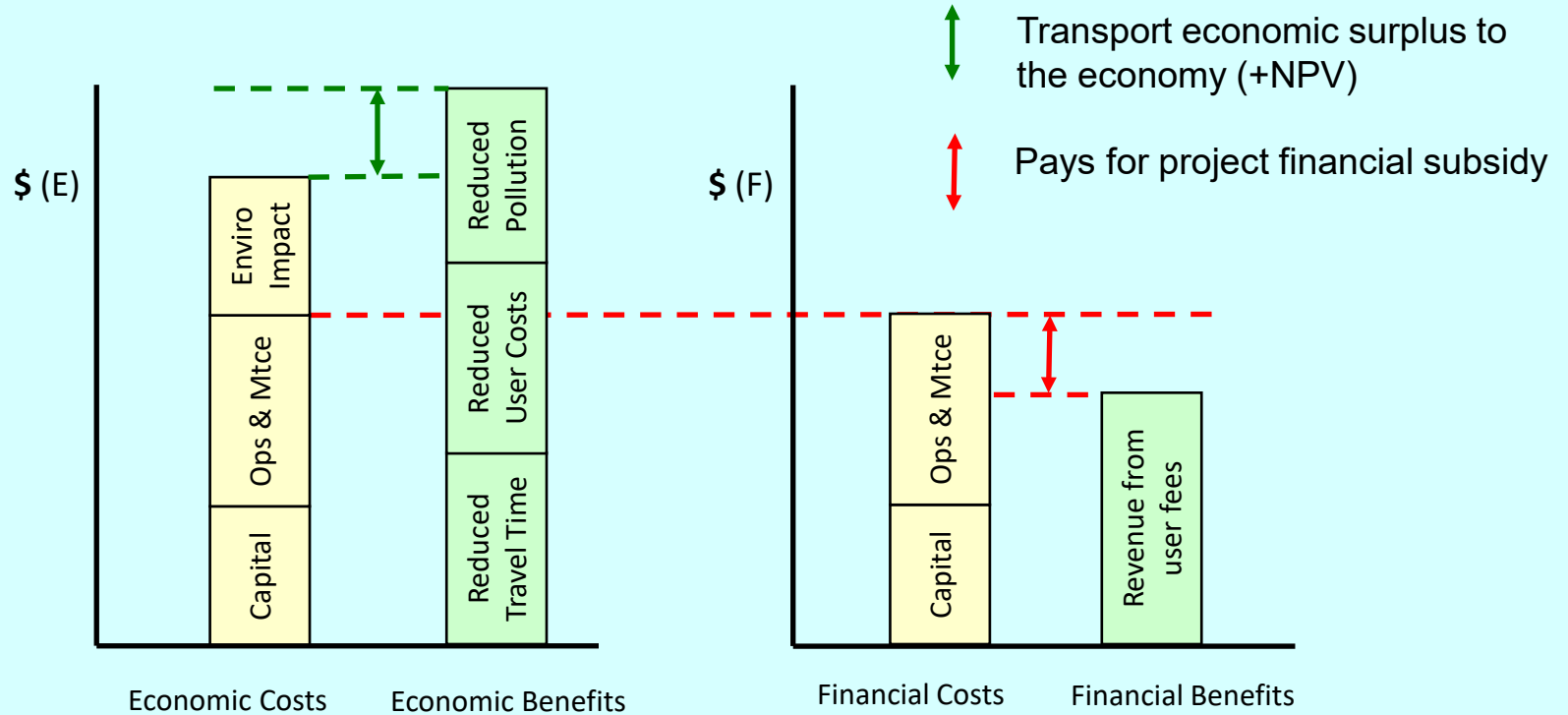
- The classic definition comes from Professor Vuchic at the University of Pennsylvania who summarized alternatives as:
Route, Technology, Service (R - T - S)
- By revealing the differences between project alternatives, ECBA forces consideration of genuine alternatives and so stimulates sustainable innovation
 - The response to a low or negative NPV is not to do nothing, but says to evaluate different R-T-S options until you find some with positive NPV
- As the engineer on a project team you have a particular role to play in encouraging technology and service alternatives
 - This means bread-and-butter alternatives (such as more bus service, or express bus service, or bigger buses) as well as the latest, newest thing

Decision Rules

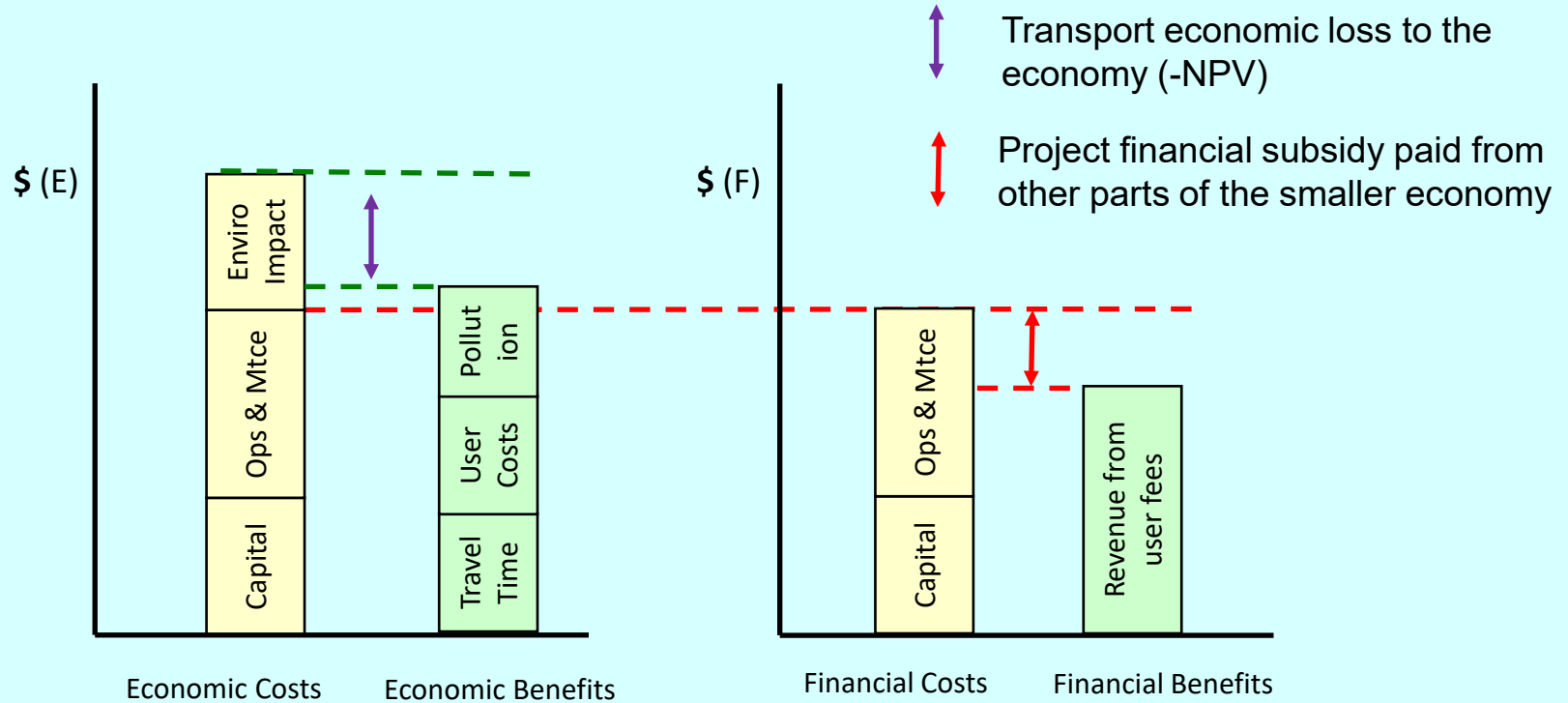
From the World Bank Operations Manual on ECBA:

- “The value of the project must not be negative”
 - No negative NPVs, prevents building a wasteful project
- “The selected project must have the highest value from a set of mutually exclusive project alternatives”
 - The comparison is between real alternatives of route, technology, or service, not just variations of one solution
 - We have to compare truly different possibilities

Use of Economic Surplus



Uneconomic Case



Equity

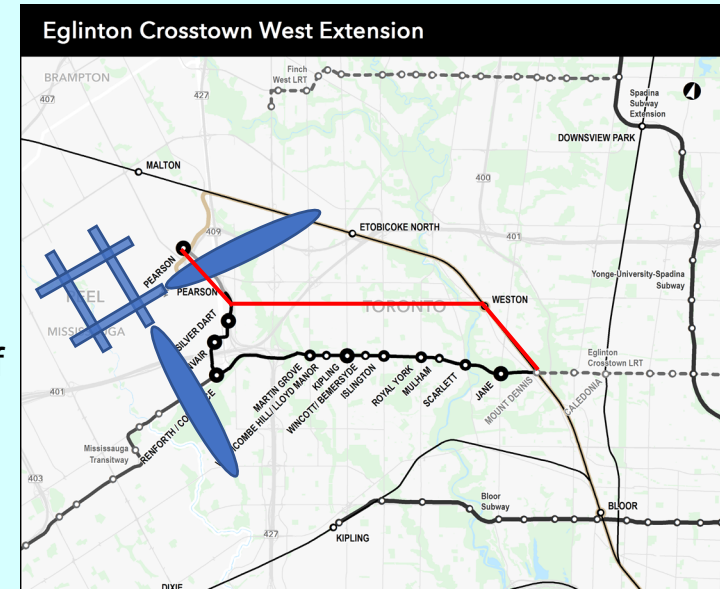
- ECBA uses a society-wide average value of time
 - People earning less than the average, or earning zero, have their trips valued at the overall average - higher than their personal situation
 - People earning more than average have their trips valued at less than their personal situation
- Region-wide travel advantages may accrue across many neighbourhoods, not just the ones located immediately beside a new line
 - We expect a broad travel benefit, across many neighbourhoods, from a large strategic investment, the region-wide model includes this macrogeography
- Just as economic surplus can pay for operating subsidies, it also allows for more revenue for all other government spending
 - All government programs can benefit from having a larger economics surplus in society, and so projects with higher surplus should be valued more

February 2020 Metrolinx business cases

- CTV covered the story as, "The costs associated with both the Scarborough subway extension and the Eglinton West LRT exceed the economic benefits they will provide by billions of dollars, according to new business cases released by Metrolinx".
- The political response was, that the investment will “stimulate huge numbers of jobs”, and "if anyone is building transit on the basis that it should be profitable than we never would have built any” (sic).
- The political response mixes up the two dichotomies described earlier.
 - In microeconomic terms the jobs are a cost not a benefit. Huge number of jobs just means a huge cost project.
 - The economic analysis showed a negative surplus, it said nothing about a profit.
- A negative economic surplus is a reduction in the size of the economy
 - Precisely why the World Bank prohibited lending to NPV negative projects
- The media and the general public have a hard time sorting out the different messages

Eglinton Crosstown West Extension (ECWE)

- The business case looked at four different combinations of stations along the same route, same technology - not really alternatives
 - NPV's of $-\$2.6$ to $-\$4.5$ billion, all very negative
- If on Eglinton, why not a busway, with various service & stopping options?
 - A former freeway ROW, lots of surface width
 - Removed from consideration in earlier report because of the transfer penalty to bus, with no analysis.
- If tunnelled why not on Dixon Road? _____
 - The historic activity corridor to the airport with retail, commercial, and high-density hotel development through a neighbourhood with elevated vulnerable population and a more direct connection to airport



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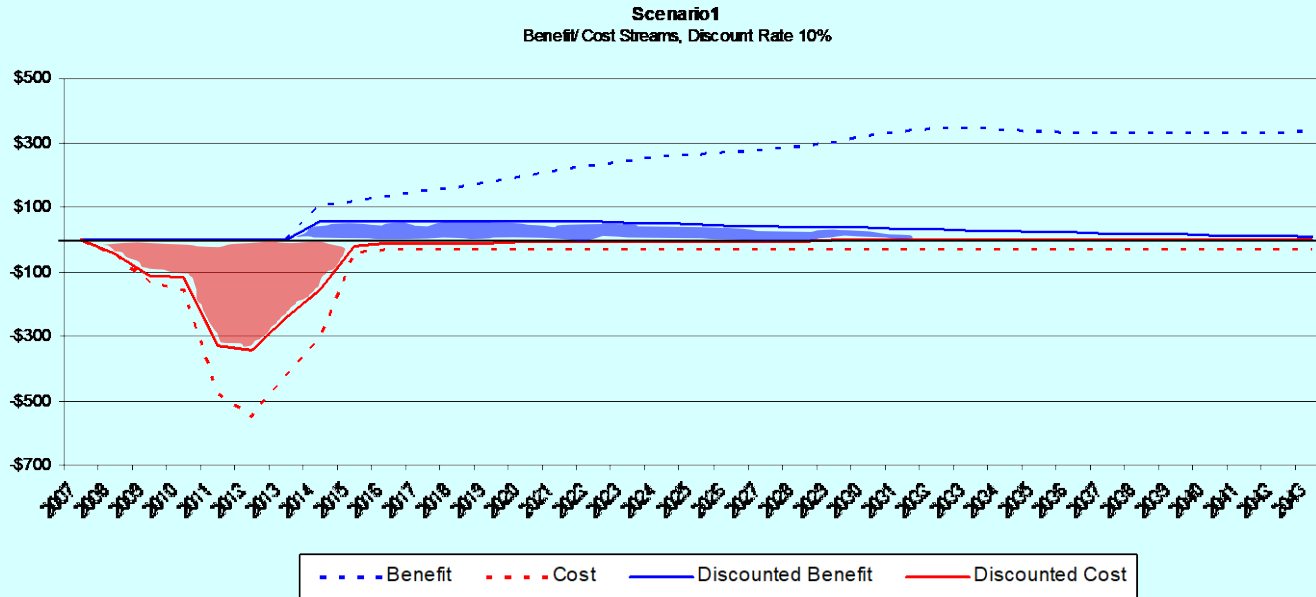
- A verdict of "uneconomic" is not an indication to do nothing
 - It says think more deeply about the specific problem you are trying to solve
- Supply and demand are out of balance, usually too much supply
 - Thoroughly examine alternative supply options, wide scope of R - T - S
- Expend demand modelling resources with abandon
 - Millions now is worth billions later, run many scenarios, including land use changes
 - Learn about the nature of the demand situation from each scenario
- Economic projects with positive NPV, have greater resonance with the general public as being sensible
 - Economics is 1/3 of sustainability, do it honestly as a science and let another dimension deal with social questions, the two will interact

Thank you for your attention
Feel free to contact me for copies of the slides
or to continue the discussion

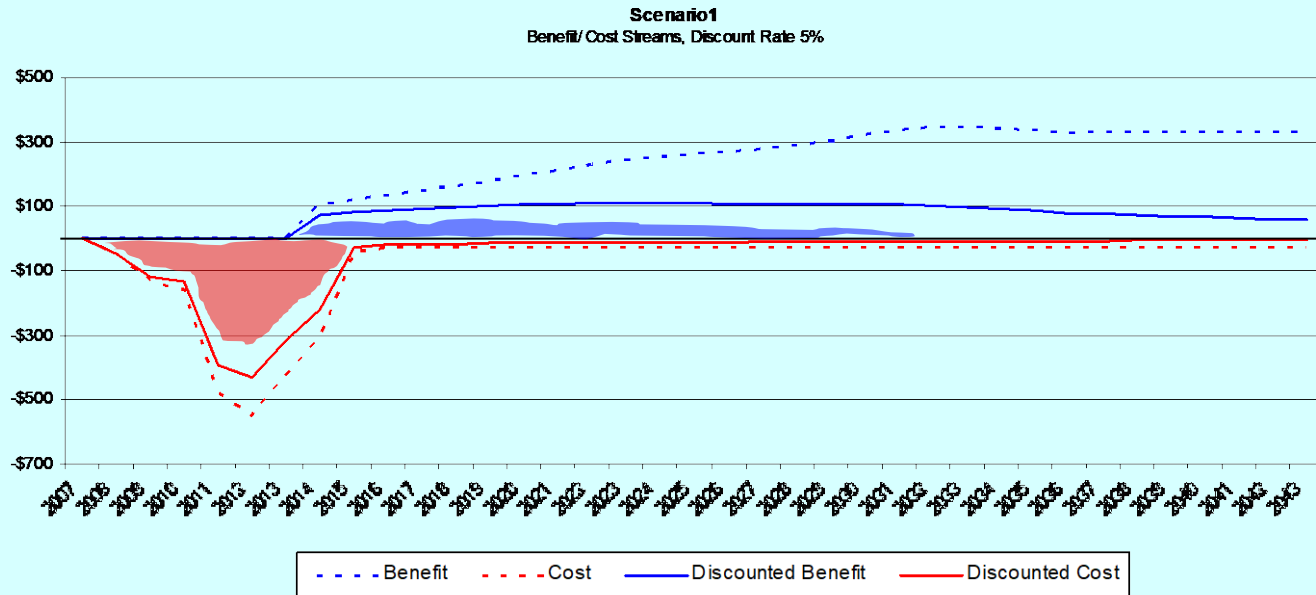
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Outtakes

"Cash" Flows (10% discount rate)



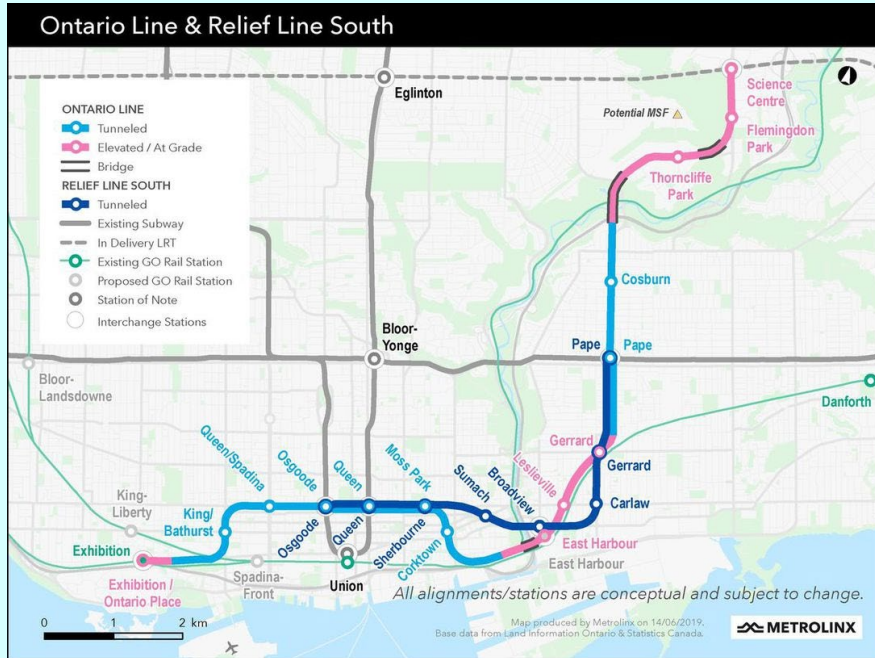
"Cash" Flows (5% discount rate)



Solving Capacity Constraints

- A transport bottleneck, such as the Yonge Line today, is nice because it says you already have excess demand seeking supply
- There are always two ways to solve a transport bottleneck
 - Build capacity at the bottleneck
 - Build capacity around the bottleneck
- In the 1970's Los Angeles built parallel freeways to go around congestion. In Ontario, MTO doubled the width of Highway 401 through Toronto
- If **clustering and agglomeration** are beneficial then building **capacity at the bottleneck** should be considered to support and encourage this
 - There is already proven demand to work with
 - Established activity corridors are not well considered by Metrolinx

Unasked Question



- As we talk about the "best" route to solve access from the north there is an unasked question
- How do we know that an east-west subway is the best solution to a north-south problem, without looking at a north-south solution?
- Alternative subways should have been considered

Untested Alternative

- Take some string and put it on a map of Toronto. Start the string at Pape and Danforth, down to Queen, and along Queen over to Spadina. Cut off this length of string
- This is roughly the old Relief Line. Move it around and this is roughly the centre section of the Ontario Line
- Pick up the string, put one end on Yonge Street just north of Eglinton put the other end on Union Station (try it, you'll see)

Yonge Express Subway (YES) - Downtown



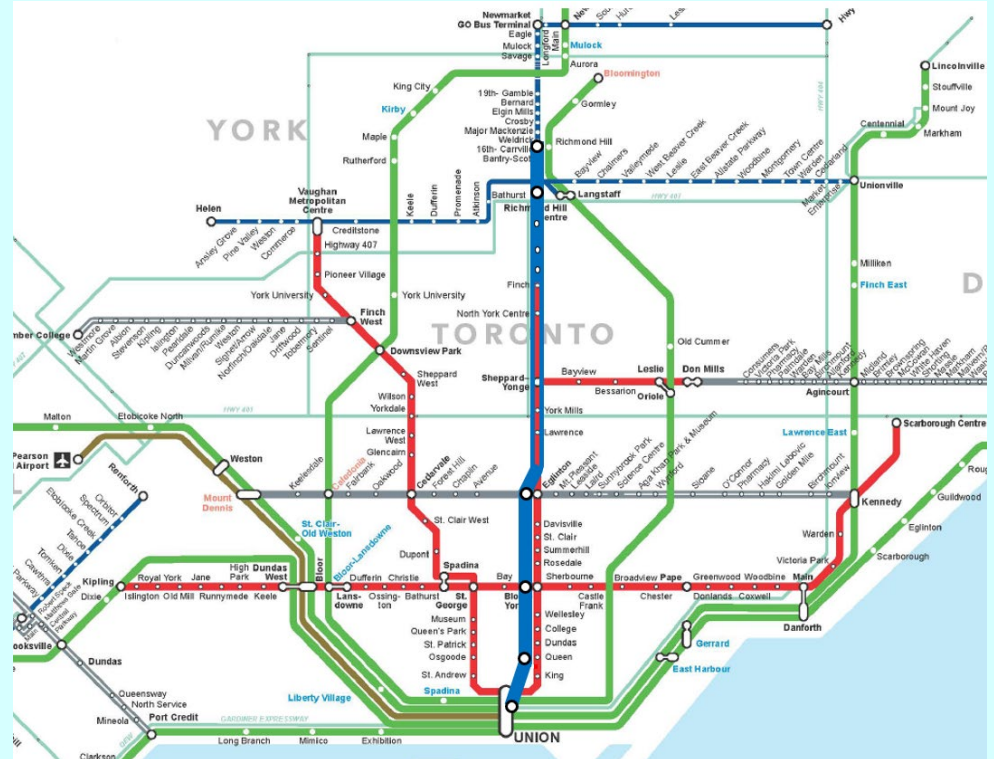
- Build a new subway somewhere around the 1950 original Yonge alignment (about half of which is on the surface)
- Would be expensive and fun for the civil engineers

Express and Local Service

- When we evaluate the merits of the DRL/OL we should include an analysis of a Yonge Express Subway like this string example
- This line would have stops only at Eglinton, Bloor, around Queen/Richmond, and Union
- Services from north of Eglinton would come into the new Eglinton Express Station and follow the new alignment from there
- Eight stops are skipped between Eglinton and Union
- All the existing Yonge stations from Union to Eglinton would be served by the Yonge Local Service

Yonge Express Subway - Regional

- Combine the Yonge Express Subway south of Eglinton with the extension of the Yonge Line north to Richmond Hill
- This is a true regional metro in an established activity corridor
- Without running the travel demand model and completing an ECBA we can't say that this does or does not make sense



- 30 -