



# Cost Benefit Analysis Workshop



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## Overview of Presentation

- Benefit cost framework
- Important concepts
- What are the benefits?
- Who benefits?
- What are the costs
- Quantifying the benefits and costs
  - Measuring nonmarket impacts



## Overview of Presentation

- Cost considerations
- Benefit considerations
- Comparing the costs and benefits
- Critique against Cost Benefit Analysis



## Benefit Cost Framework

- A technique to evaluate and prioritize projects that best meet objectives
- Evaluation
  - Assessing costs and benefits imposed on society
  - Involves quantification of impacts of different investment alternatives



## Benefit Cost Framework

- Evaluate alternative solutions to a particular problem or need
- Simply stated:
  - Involves comparison of monetary benefits and costs in the same base year
- Overall standard criterion
  - Establish whether a project will increase the economic welfare of society
  - Do the discounted benefits exceed the discounted costs of a particular investment?



## Benefit Cost Framework

- Valuation
  - Attempts to produce a parameter for comparing different solutions to the same problem
- CBA steps:
  - Identify the problem or need
  - Identify the alternatives
  - Evaluate and quantify the alternatives



## Benefit Cost Framework: Important Concepts

- Pareto optimality
  - Project will only be deemed beneficial to society if society will be better off and without harming anyone
  - Central to CBA
  - Most transportation projects produce winners and losers



## Benefit Cost Framework: Important Concepts

- Pareto optimality
  - Principal potentially preserved if winners are in position to compensate losers
    - To the extent that the losers are at least indifferent and the winners are still better off
  - However, no actual compensation is prescribed
    - Just ability of winner to compensate losers
  - Compensation seldom part of project
    - Difficult to identify individual winners and losers
    - Significant administrative cost



## Benefit Cost Framework: Important Concepts

- Discount rates
  - Rationale that benefits and costs incurred now receive higher weight than those incurred further in the future
  - Reflect opportunity cost of money or “time preference value” of money
  - Or \$1 received 5 years into the future is not as valuable as the same dollar received today
    - \$ could have been invested



## Benefit Cost Framework: Important Concepts

- Discount rates
  - Economists disagree about appropriate discount rate
  - In U.S. typically discount rates of 3 to 5 % are used
    - World Bank use 10% for developing countries
  - High rate of 7 % used for sensitivity testing



## Benefit Cost Framework: Important Concepts

- Time Frame
  - Costs and benefits are considered over the economic (useful) life of the investment
  - Few investments require analysis time frame of more than 20 years
    - Discounting reduces the significance of the benefits and costs in present value terms as the time frame lengthens



## Benefit Cost Framework: Important Concepts

- Taxes and subsidies
  - Do not represent a social cost or benefit
  - Rather considered a transfer from the taxpayer to the government or vice versa
  - Example is fuel tax
    - Does not represent a resource consumed, i.e., cost
    - Needs to be subtracted from fuel prices to reflect cost to society of using particular resource



## Benefit Cost Framework: Important Concepts

- Sunk costs
  - Past expenditures not considered in CBA
  - In CBA analyst considers only future cost and benefit streams
  - Exception – if past investment (i.e., capital asset) has an alternative use
    - Consider opportunity cost of asset in alternative use
    - For example, price equipment purchased earlier can attract in the resale market becomes opportunity cost of equipment when conducting CBA



## Benefit Cost Framework: Important Concepts

- Depreciation
  - Resource costs are accounted for in BCA through annual expenditures
  - If both expenditures and depreciation of assets are included in CBA, then capital costs would be double-counted



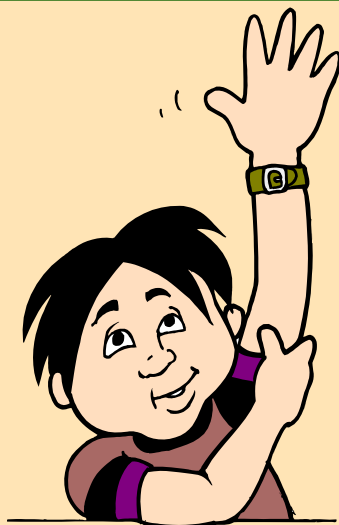
## Benefit Cost Framework: Important Concepts

- Inflation
  - Ideally costs and benefits should be forecasted in nominal dollars and converted to constant dollars by removing inflation effect
  - In reality, simplified approach is often adopted
    - Assume costs and benefits would remain same in constant dollar terms



## Benefit Cost Framework: Important Concepts

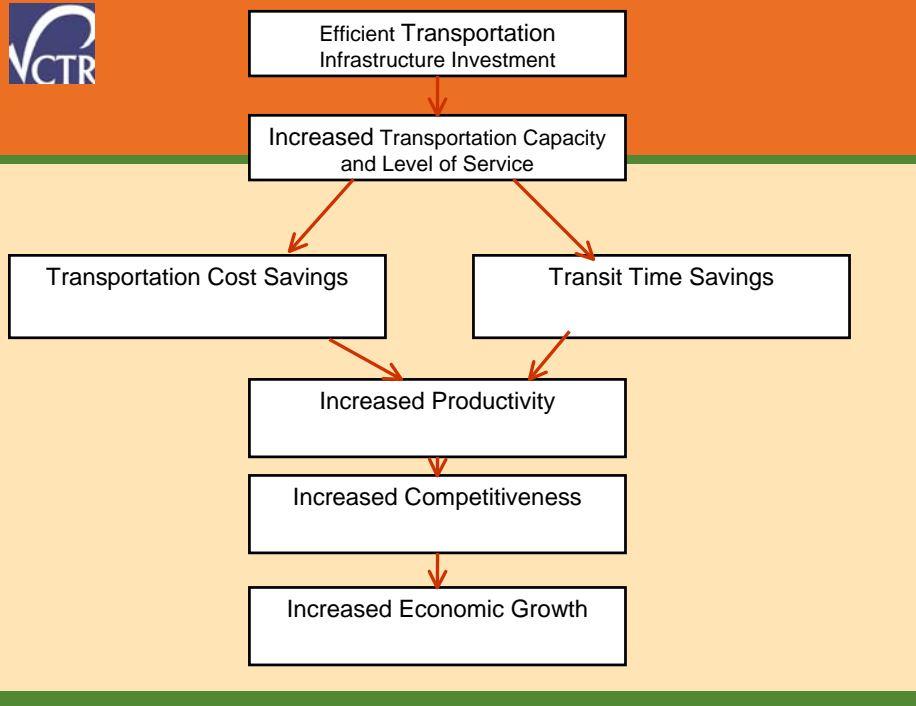
- Interest payable
  - Interest payable on capital funds required to implement project should not be included in CBA
  - Implicitly accounted for in discount rate





## What are the Benefits?

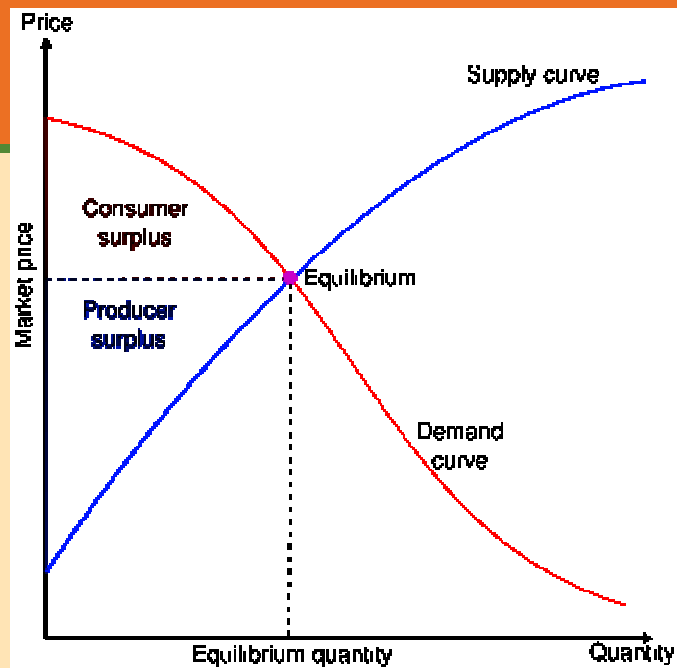
- Three types of benefits associated with transportation investments
  - Direct benefits
  - Secondary benefits
  - Indirect benefits
- In CBA
  - Only direct benefits are counted
    - Resource savings and a benefit that beneficiary is willing to pay for





## What are the Benefits?

- Direct benefits are only
  - Transportation cost savings (e.g. vehicle operating costs)
  - Transit time savings
  - Increased reliability
- Double counting
  - Include transportation cost savings to producer and increased profit/ or increased property value
  - Latter reflects reduced travel time and costs
- Economists have shown
  - Consumer and producer benefits attributable to cost savings from transportation investment can be estimated from the transportation outcome





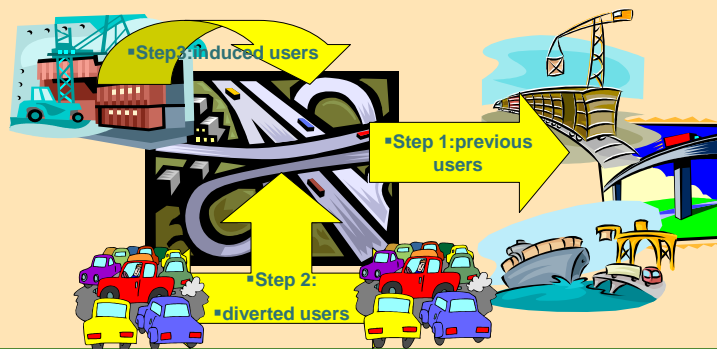
## What are the Benefits?

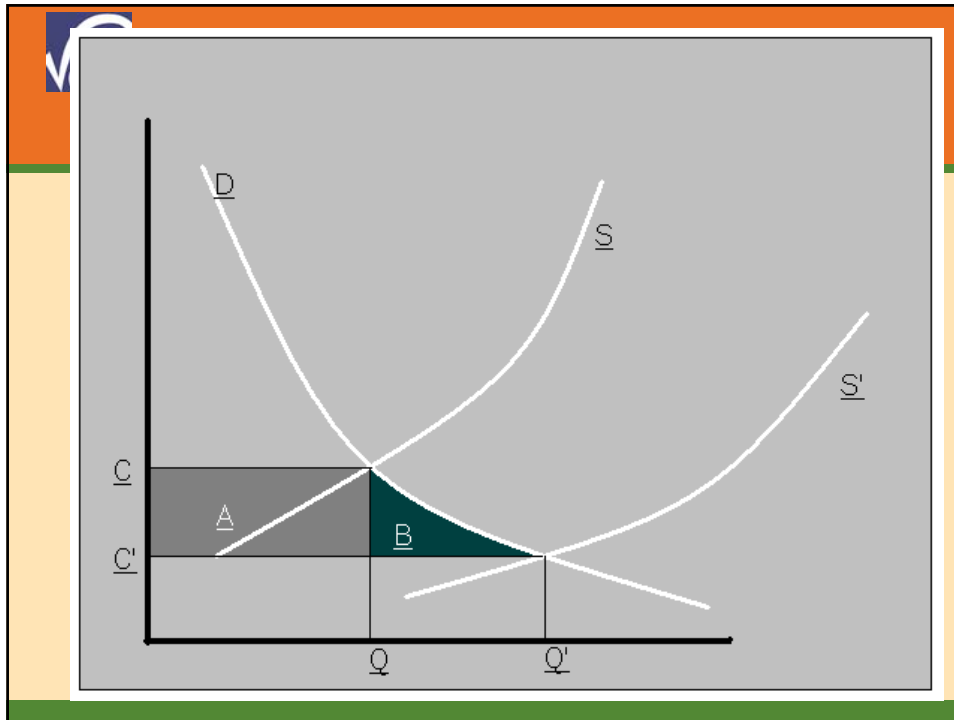
- Time savings
- User operating cost savings
- Agency cost savings
- Safety benefits
- Air quality/ emissions benefits
- Predictability



## Who Benefits?

- Existing Users
- Diverted Demand
- Induced Demand





## VCTR Economic Growth Benefits

- Economic development benefits
  - Investment reduce costs (travel time & user costs)
  - Result in increase in demand
  - Induced traffic considered a proxy
  - Small when considering increased accident risks, environmental costs and operating costs



## What are the Costs?

- Land acquisition
- Construction
- Maintenance
- Operation



## Quantifying the Benefits and Costs

- Estimation and quantification of benefits and costs require
  - Information about demand
  - Magnitude of the impacts
  - Values to quantify impacts
- Values should reflect opportunity cost
  - Value of resource in best alternative use
  - In competitive markets, market prices are used



## Quantifying the Benefits and Costs

- Example
  - Resource cost of vacant land would be market value of the vacant land
- Distorted markets require calculation of shadow prices
- Also
  - Many costs and benefits are not traded in the market – i.e., no market price
  - Examples include time savings, pain or environmental air quality



## Quantifying the Benefits and Costs

### Market and Non-Market Effects of Accidents

■Market	■Non-market
Property damages to vehicles and other objects	Pain and suffering for crash victims
Lost income	Lost quality of life for crash victims
Emergency response services	Uncompensated grief and lost companionship for crash victims' family and friends
Medical treatment costs	Reduced non-motorized mobility
Crash prevention and protection expenditures	

Source: Litman, 2002



## Measuring Nonmarket Impacts

- Quantifying nonmarket impacts can be controversial
- Valuation Methods
  - Revealed preference
  - Stated preference
  - Prevention cost
  - Damage cost
  - Compensation cost



## Measuring Nonmarket Impacts

- Revealed preference methods
  - Estimates implicit values by observing actual choices made
  - Example
    - Estimate noise cost by comparing two similar houses (neighborhood, design, and amenities) next to freeway with one located on residential street
    - Price differential assume to be estimate of negative costs associated with freeway noise



## Measuring Nonmarket Impacts

### ■ Revealed preference methods

#### ● Example

- Estimate value of visiting nature reserves, forests, etc. as function of the number of visitors and the travel costs incurred



## Measuring Nonmarket Impacts

### ■ Stated preference methods

- Surveys administered that ask respondents hypothetical questions on how much they are willing to pay to achieve or avoid a particular outcome
- Willingness to pay – amount society would pay to reduce negative effects
- Willingness to accept – amount society would accept as compensation for the negative effects imposed



## Measuring Nonmarket Impacts

### ■ Prevention cost methods

- Abatement/ alternative/ opportunity/ prevention cost approach involves determining expenditure needed to prevent or offset a particular effect or outcome
- Examples
  - Provide rare animal species with tunnels to cross new road ways
  - Construction cost of noise barriers to alleviate noise pollution
  - Financial losses avoided by implementing measure (e.g. fishing revenues when adopting measures to prevent oil spill)



## Measuring Nonmarket Impacts

### ■ Damage Cost Methods

- Estimates total economic losses associated with an impact
- May require revealed preference and stated preference methods to value some components
- Examples
  - Determine value of an accident by accounting for vehicle damage, medical and emergency expenses, loss in productivity for anyone disabled or killed, as well as nonmarket costs, such as the pain and suffering caused by the accident



## Measuring Nonmarket Impacts

### ■ Compensation Methods

- Use settlement amounts granted in legal judgments to compensate for similar damages in the past
- Examples
  - Cost of water pollution can be determined by previous trials in which victims have been compensated for their illnesses, pain, and suffering



## Cost Considerations

### ■ Project costs

- Planning
  - All costs incurred prior to procurement and construction
- Construction costs
  - Land acquisition, construction cost, equipment purchase, project related training, decommissioning costs, contingencies ....
- Operation and maintenance costs



## Cost Considerations

- Departments of Transportation have considerable expertise and resources to determine costs
- In U.S., Federal government has funded numerous studies to aid in estimation of costs associated with road infrastructure
  - Less so for other modes of transportation



## Benefit Considerations

- Infrastructure investments, benefits are typically
  - Transportation system efficiency benefits
    - Travel time savings
    - Reliability
    - Accessibility
  - User operating cost savings
  - Agency cost savings
  - Environmental impacts



## Time Savings

- Value of time savings
  - Usually main motivation for many road projects
  - Is founded in opportunity cost of travel time
    - Time save could be productively employed
  - Estimating travel time savings
    - Deducted from average speeds with and without the investment



## Time Savings

- Value of time savings (VOT)
  - Trip purpose (work vs non-work)
    - Traveling for work purposes vs traveling during own time
  - Business travel
    - Wage rate plus markup to account for overhead
  - Non-business travel
    - Usually use percentage of wage rate (usually 50 % in U.S.)
- Caveats of using wage rate
  - Assume time spent traveling is unproductive
  - Small time savings
    - 200 one minute savings = 10 twenty minute savings



## Predictability

- Predictability/ reliability
  - Often more important than savings in travel time
  - Measurement presents major challenge
    - Often calculated as the standard deviation from the average travel time
  - Impose costs
    - E.g., manufacturers and distributors have to carry inventory
    - But what value to use ?
  - Few studies predict/value increase in reliability/ predictability



## Accessibility

- Accessibility
  - Improved access to basic services, quality of life destinations, and markets
  - Usually measured in terms of reduced travel time and vehicle operating costs
  - Beware of double counting!



## Vehicle Operating costs

- Typically includes:
  - Fuel, oil, tires, maintenance
- Function of
  - Traffic conditions (average speed, number of stops, accelerations and decelerations)
  - Vehicle characteristics (model, maintenance record)
  - Driver characteristics
- U.S. – National averages exist
  - Expressed per mile



## Safety

- Second most important benefit
- Measured as reductions in
  - Property damage costs
  - Number of injuries
  - Number of fatalities
- Some aspects can be valued
  - Damage to property and vehicles
  - Health services
  - Ambulance and police costs
  - Loss of production



## Safety

- Others more difficult to value
  - Pain, grief and suffering
- Accident prediction models
  - Number of incidents/ vmt
  - Distinguish property damage and casualties (fatalities & injuries)
- US DOT publishes standard unit costs
  - Fatalities
  - Injuries
  - Damage only incidents



## Safety

- Assigning monetary value to human life can be an ethical and sometimes controversial issue
  - Value potential years of life lost

*“Assigning a dollar value to fatalities avoided reflects widespread recognition of a need for guidance on what should be spent to reduce the risks of transportation accidents ....., i.e., to determine the amount that society is willing to invest to reduce the statistically predicted number of accidental deaths in transport. Of course, this is a different concept from what would be spent to save a particular individual whose life might be at risk at a particular time”*

- Environmental Impacts
  - Noise
  - Vibration
  - Air and water pollution
  - Community severance
  - Visual intrusion
  - Land degradation
  - Disposal of contaminated soil
  - Disruptions during construction



## Environment

- Air quality (emissions)
  - U.S. EPA substantial research in estimating air pollution impacts
    - EPA MOBILE 5 and 6 calculate grams/mile by model year and average speed for different vehicle categories
  - Value emissions impacts
    - Damage value method
    - Control cost method



## Environment

- Damage cost method
  - Identify emission sources
  - Estimate emissions
  - Simulate air pollutant concentrations in the atmosphere
  - Estimate exposure of humans and other objects to air pollutant concentrations
  - Identify physical effects of air pollutant concentrations on humans and other objects
  - Value physical effects
  - Calculate emission values in dollars per ton



## Environment

- Requires placing values on human mortality, morbidity, discomfort, and restricted physical activity using SP or RP methods
- Steps are fraught with uncertainties
- Can produce wide range of estimates
  - E.g. cost of air pollution amount to between \$55 and \$670 billion (1990)



## Environment

- Control cost method
  - Based on expenses for preventing an impact or the effect of an impact
    - Costs and emission reductions over the entire life of control measure (i.e., initial capital costs, operation costs, maintenance costs, and deterioration rate of measure)
    - Allocation of cost among pollutants if measure reduces number of pollutants
  - Estimated values also uncertain



## Agency Cost Savings

- Important benefit in rail studies
- Trucks impacts pavements
- Divert to rail
  - Reduced maintenance expenditure



## Comparing Costs and Benefits

- Net Present Value
  - Difference in present value of the benefits and costs
- Internal Rate of Return
  - Rate at which discounted benefits and costs are equal
- Benefit-Cost Ratio
  - Higher than 1 when benefits exceed costs
- Payback period
  - Number of years for annual net benefits to equal investment costs



## Comparing Costs and Benefits

$$P = F \left[ \frac{1}{(1+i)^n} \right]$$

P = Present Value

F = Future Value

I = Interest Rate

N = Number of years



## Comparing Costs and Benefits

$$P = A \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right]$$

P = Present Value

A = End of period payment or receipt in a uniform series of payments or receipts

I = Interest Rate

N = Number of years



## Road Investment

	Traffic Growth (Alternative Assumptions)	
	High	Low
<b>Costs</b>		
Construction cost	2,491	2,491
Maintenance cost	72	72
Delays during construction	32	32
<b>Total PV Cost</b>	<b>2,595</b>	<b>2,595</b>
<b>Benefits</b>		
Time and operating cost savings	4,218	2,658
Accident savings	417	304
<b>Total PV Benefits</b>	<b>4,635</b>	<b>2,962</b>
<b>Net Present Value</b>	<b>2,040</b>	<b>367</b>

Costs and benefits in present values, 1979 prices, discounted at 7%



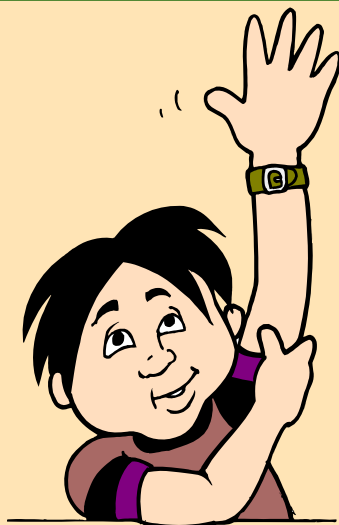
## Critique Against Cost Benefit Analysis

- Usually conducted by economists
  - Tend to be more aware of monetary impacts
- Not concerned about equity
  - How benefits and costs are distributed among different income groups, regions, generations, etc.
- Tend to favor present generation



## Critique Against Cost Benefit Analysis

- Necessary to predict consequences of alternatives over long time periods
- Morality of reducing everything to a monetary value
- Evidence to suggest that people cannot or will not provide meaningful answers when asked WTP questions
  - WTP linked to ability-to-pay





## Additional Resources

- Guide to Benefit-Cost Analysis in Transport Canada
  - Available at:
    - [http://www.tc.gc.ca/Finance/BCA/en/TOC\\_e.htm](http://www.tc.gc.ca/Finance/BCA/en/TOC_e.htm)