Measuring Environmental Benefits

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Benefit/Cost Analysis for Transportation Infrastructure: A Practitioner's Workshop

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Environmental Benefits

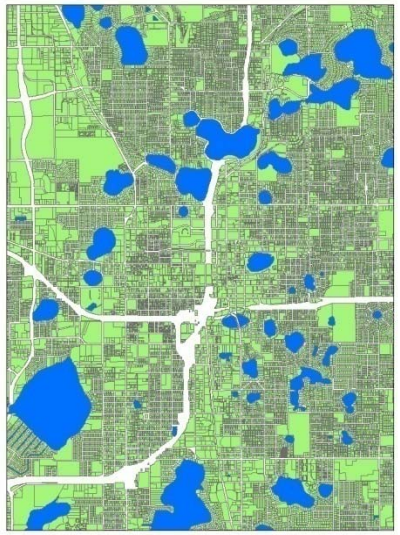
- The benefit of environmental protection are estimated the same way we do for the private market – we quantify the willingness to pay for the environmental commodity.
- Value is determined by what consumers are willing to pay for a commodity, not what the analyst believes the value to be!
- Because environmental protection it is a public good, the benefits of a policy are the sum total of each affected individual's willingness to pay for the policy.
- But, how can we put a price on environmental improvements? Unlike the private sector, we do not readily observe prices for clean air, clean water ….

How do we measure monetary benefits?

- Unlike the private sector, we do not readily observe prices for clean air, clean water …

- Market Valuation - Some prices do exist. (e.g., commercial value on increased fish, tree stands

- Non-Market Valuation
  - Revealed preference: examine real behavior
    - Recreation demand: link value of recreational experience to environmental quality
    - Hedonics: link wages or housing prices to environmental quality
    - Averting behaviors: examine actions people take to avoid negative impacts of reductions in environmental quality
    - "Cost of illness"
  - Stated preference methods
    - "Contingent Valuation," interviews, questionnaires (e.g., valuation for the Exxon Valdez spill)



Benefit Categories

Benefit category	Examples	Commonly-used economic valuation methods
Mortality & morbidity risk	Reduced risk of ▪ Cancer fatality ▪ Acute fatality ▪ Cancer ▪ Asthma ▪ Nausea	➢ Averting behaviors ➢ Hedonics ➢ Stated preference
Market products	▪ Food ▪ Fuel ▪ Timber	➢ Production function
Recreation activities & aesthetics	▪ Wildlife viewing ▪ Fishing ▪ Swimming ▪ Hiking ▪ Scenic views	➢ Production function ➢ Averting behaviors ➢ Hedonics ➢ Recreation demand ➢ Stated preference
Valued ecosystem functions	▪ Climate moderation ▪ Flood moderation ▪ Pollination by wild species ▪ Water filtration	➢ Production function ➢ Averting behaviors ➢ Stated preference
Nonuse values	Relevant species, communities, or ecosystems	➢ Stated preference

Standard Methods for Valuing Mortality Risk Reductions

- Economists examine how people react to risks in their own lives and make tradeoffs between small risk and income
  - What prices paid for bottled water, organic food, smoke detectors, and other safety devices, and what risk reductions do people believe they are getting from these purchases?
  - How much more must workers be paid to take on riskier jobs?
  - In surveys, what do people say they are willing to pay to reduce mortality risks?

- These tradeoffs, applied to small risk changes over a group of people, have historically been summarized as a "value of statistical life" or VSL.
  - For example, if each of 10,000 people exposed would pay $700 then in total one statistical life is "saved " and total WTP is $7 million. Thus, $7 million is the "value of a statistical life."

- DOT Guidance
  - $.5.8 million (2007$)
  - Sensitivity analysis using $3.2 million and $8.4 million
  - Different from EPA's income-adjusted estimate of $7.7 million (2006$)

Measuring Morbidity

- Using "willingness to pay" to measure the complete value of avoiding a health outcome
  - Stated preferences from "contingent valuation" studies provide values for chronic illnesses and acute respiratory effects

- If necessary, we can use the "cost of illness"
  - Captures the direct dollar savings to society of reducing a health effect
  - Ignores the value to individuals of reduced pain and suffering
  - Generally a lower bound when no WTP estimates are available

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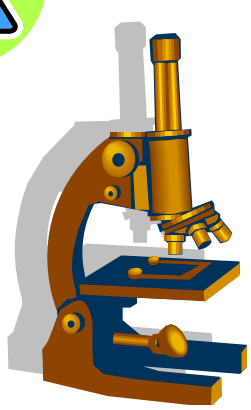
Damage Function Approach

Emissions → Environmental concentrations → Exposure → Effects (dose-response) → Benefits ($ for each effect)

Benefits analysis draws upon results of other disciplines:

- Epidemiology
- Toxicology
- Chemistry
- Biology
- Risk Assessment
- Sociology



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Ecological Benefits

- Improvements in human well-being that are derived from ecosystem services

Components of Total Value of a Resource

(According to M. Freeman)

- **Total Value:**

  An individual's willingness to pay to preserve or maintain a resource in its current state. Total Value = use value + non-use value.

- **Use Value:**

  Economic value associated with the use of a resource (e.g., through visiting a recreation site). Typically measured using travel cost models or other market methods.

- **Non-Use Value:**

  All of the remaining components of total value that arise independent of use (may include existence values). Non-use values are likely to be particularly important in cases where the resource in question is unique or special in some way and when the loss is irreversible.

Example: What Are the Benefits of Reduced Air Pollution?

- Health
  - Reduced risk of premature death
  - Reduced risk of chronic illness, for example chronic bronchitis
  - Reduced risk of hospitalization
  - Reduced risk of respiratory illnesses and symptoms
  - Reduced sick days
  - Increased productivity for outdoor workers
- Welfare
  - Visibility improvements
  - Improved agricultural and forest yields
  - Reduced damage to structures
  - Reduced cleaning costs
  - Reduced ecosystem damages

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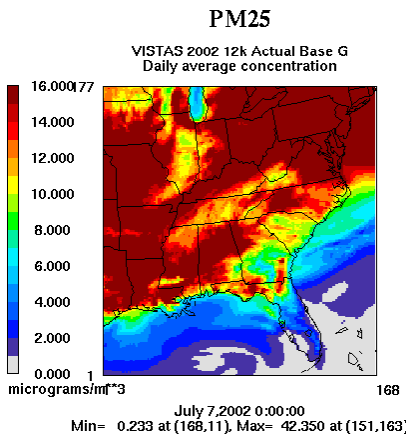
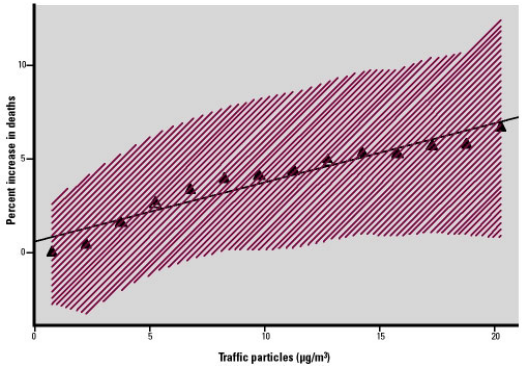
How do we measure these benefits?

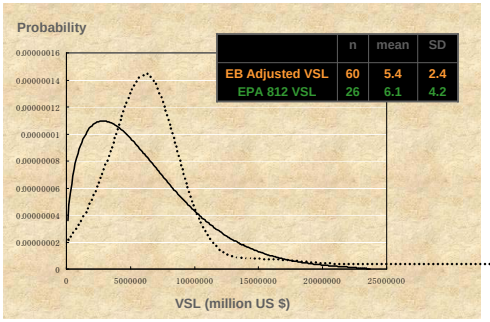
- Air quality models tell us how air quality is expected to change



- Epidemiology studies give us concentration-response relationships to predict how health effects will change



- Economic studies tell us how much the changes in health and welfare effects are worth



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What health effects do we quantify?

	PM	Ozone
Mortality	✓	✓
Chronic bronchitis	✓	
Hospital Admissions	✓	✓
Asthma ER visits	✓	✓
Acute respiratory symptoms	✓	✓
Asthma attacks	✓	✓
Work loss days	✓	
Worker productivity		✓
Myocardial infarctions	✓	
School absence rates		✓
Cardiovascular ER visits	✓	

What welfare effects do we quantify?

	Base	Sensitivity
Visibility in National Parks	✓ (partial coverage)	✓ (complete coverage)
Visibility in Residential Areas		✓
Reductions in Household Cleaning Expenditures		✓
Reductions in Nitrogen Deposition to Sensitive Estuaries		✓
Reductions in Acid Deposition		✓
Improved Agricultural Yields	✓	
Improved Forest Yields		✓ (not monetized)

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Nonroad Diesel Engines

- By 2030, reduces NOx emissions by over 800,000 tons and diesel PM by over 126,000 tons
  - 9,600 premature mortalities avoided
  - 5,700 cases of chronic bronchitis avoided
  - 16,000 nonfatal heart attacks avoided
  - Millions of acute respiratory symptoms and work loss days avoided
- Annual benefits of over $80 billion in 2030 (relative to $2 billion in costs)

Chapter 9 of the RIA (http://www.epa.gov/nonroad-diesel/2004fr.htm#ria)

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Sources for Unit Values of Benefits from Reduced Air Pollution

- Benefits and Costs of the Clean Air Act
  - Retrospective Study, 1970 to 1990 (1997 - Appendix I)
  - Prospective Study, 1990 to 2010 (1999 - Appendix H)

    http://www.epa.gov/air/sect812/

- Regulatory Impact Analyses for the National Ambient Air Quality Standards (note: values reported for 2020 income levels!)
  - Ozone (2008 - Chapter 6)
  - Lead (2008 - Chapter 5)
  - Sulfur Dioxide (2009 - Chapter 5)
  - Nitrogen Dioxide (2010 - Chapter 4)

    http://www.epa.gov/ttn/ecas/ria.html#ria2007

- Regulatory Impact Analyses for the Light-Duty Vehicle Greenhouse Gas Emissions Standards (2010 – Chapter 7)

  http://www.epa.gov/otaq/climate/regulations/420r10009.pdf

The Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year.

That is, it is the increase in aggregate income that would make society just as well off as a one unit decrease in greenhouse gas emissions in a particular year.

$$SCC_t \equiv \frac{dY_t}{dE_t} = -\frac{\partial W_t / \partial E_t}{\partial W_t / \partial Y_t}$$

It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

SCC Values for use in Regulatory Analyses

- The interagency group selected four SCC values for use in regulatory analyses. These values are given below in dollars per metric ton reduced of CO2.

- Benefits from reduced emissions can be estimated by multiplying changes in tons of CO2 in any year by the SCC value for that year.

- The net present value of the benefits can be calculated dividing each future year benefits by one plus the appropriate discount rate and summing across all affected years.

Social Cost of CO_2, 2010 2050 (in 2007 dollars)

	Discount Rate			
	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

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