Overview
Types of Economic Analysis

**BENEFIT-COST ANALYSIS**
- Good for Prioritzation
- Measures Cost-Effectiveness / “Bang for your Buck”
- Compares Users/Societal Savings to Agency Costs
- Focus on project and its direct effects
- Life-cycle perspective – story of effects over time
- Grounded in established theory
- More objective, geography doesn’t matter

**ECONOMIC IMPACT ANALYSIS**
- Good for Political / Public Support
- Measures Economic Growth, Not normalized by project costs
- Focus on the economy (indirect & induced effects)
- Snapshot of the future
- More controversial / disputed theoretical basis
- Subjective, regional, our gain vs. their loss
Benefit-Cost Analysis (BCA)

EXPERIENCE

• Why should you listen to me?
• Experience with BCA in 8 states
• Recent efforts of interest
  - PM for development of 1st BCA tool for activity-based model (San Diego)
  - FHWA research on new methods
    ▪ New open-source tool in AMPO’s ActivitySim framework (but works for both trip-based and activity-based models)
    ▪ Applications in San Diego, Tampa, Portland
  - Contributing enhancements to NCSTM’s BCA methods

NEW BENEFITS & EQUITY ANALYSIS

• Travel Time Reliability Improvements
• Environmental Impacts
• Active Transportation & Public Health Impacts
• Vehicle Ownership Cost Savings
Good Benefit-Cost Frameworks

- All benefits taken together should provide a comprehensive evaluation
- Benefits should be **mutually exclusive**
- Benefits should be **measurable**
  - Talk without measurement is "cheap"
  - Trying to count things, even when we fail, imposes a logical discipline
- Should produce an understanding of who benefits – **equity**
- Framework should be **transparent**
  - Engage stakeholders meaningfully
  - Publish both overall and component evaluation results
  - Fully disclose all analytic methods, assumptions, and limitations
  - Fully disclose all criteria composition and monetization methods
  - **Monetization** should be well-grounded
Benefits by “Triple-Bottom Line” Category
Portland Metro MCE Toolkit Example

- **Economic Vitality**
  - Travel Time
  - Reliability*
  - Vehicle Operating Costs
  - Vehicle Ownership Costs*

- **Environmental Stewardship**
  - Emissions
  - Surface Water*
  - Noise*

- **Social and Equity Values**
  - Vehicle Crashes
  - Physical Activity*
  - Travel Choices*

- Traditional Benefits
- Emerging Benefits
Economic Vitality Benefits
Travel Time
A Mobility Benefit

CONSUMER SURPLUS THEORY
• Travel time savings for existing trips are equal to difference between base and build
• Travel time savings for induced trips are half that of existing trips

MONETIZATION
• Value of time based on US DOT guidance and other research
• $14.66/hour for all passengers [$12.50 NCDOT]
• $41.00/hour for all trucks [$50.00 NCDOT]

IMPLEMENTATION
• Includes auto, transit and truck time savings
• Excludes walk and bike time savings
• Matrix-based “Rule of Half” RoH (linearizing demand function)
• No threshold/location criterion to deal with noise [new location criterion for NCSTM]
Travel Time Reliability
A Mobility Benefit

FUNCTION OF V/C

• Several methods now demonstrated (consistency with assignment)
  – Mean-Variance / “Reliability Ratio” (RR) from SHRP2 C04
  – Buffer Time
  – Perceived Time
• Based on level-of-service, travel time, speed, length, lanes, interchange distance, intersection control
• Reflects reliability on arterials and freeways

IMPLEMENTATION

• Estimated as a post-process to travel model
• Can also be incorporated in assignment / demand models (in the future)
Vehicle Operating Costs
A Mobility Benefit

**FUEL COSTS**
- Fuel consumption from MOVES by speed bin, vehicle type, year, and facility type
- Monetization
  - $2.80/gallon for passenger cars
  - $3.08/gallon for trucks

**NON-FUEL COSTS**
- Includes maintenance and tire costs for autos and trucks
- Includes fixed ownership costs (purchase, finance, insurance) for trucks
- Non-fuel operating costs by vehicle type
  - Cars = 6.28 cents/mile
  - SUVs = 7.22 cents/mile
  - All Light Vehicles = 6.49 cents/mile
  - All Trucks = 50.70 cents/mile

*Inflation Adjusted US Gas Prices, 1918-2015*
Vehicle Ownership Costs
A Mobility Benefit

**AUTO OWNERSHIP MODEL**
- Applies only to passenger cars
- Produces vehicles per household for 0, 1, 2, 3+ categories

**MONETIZATION**
- Includes purchase and depreciation, financing, insurance
  - avoid double-counting of maintenance under vehicle operating costs
- Based on AAA’s Your Driving Costs
  - Average annual ownership costs for autos = $6,611

**UNCERTAINTY**
- Impact of ride-sharing services and emerging technologies such as automated vehicles is uncertain and not reflected yet – but will be in future
Environmental Stewardship
Vehicle Emissions
An Environmental Benefit

MOVES
- What level of consistency with MOVES / conformity analysis?
- Produce emissions by pollutant using link-based emission rate tables from MOVES by speed bin, vehicle type, year, and facility type

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Abbreviation</th>
<th>Unit Cost ($ per Metric Ton)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide Equivalents</td>
<td>CO₂e</td>
<td>$51.81</td>
<td>2010 Bay Area Air Quality Management District and San Diego Pollution Control District</td>
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<tr>
<td>Oxides of Nitrogen</td>
<td>Noₓ</td>
<td>$7,300</td>
<td></td>
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<tr>
<td>Volatile Organic Compounds</td>
<td>VOCs</td>
<td>$37,900</td>
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<tr>
<td>Fine Particulate Matter</td>
<td>PM₂.₅</td>
<td>$459,000</td>
<td>2012 Caltrans Life-Cycle Benefit-Cost Analysis Economic Parameters</td>
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<tr>
<td>Particulate Matter</td>
<td>PM₁₀</td>
<td>$139,000</td>
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</tbody>
</table>
Surface Water Pollution
An Environmental Benefit

DEFINITION
• Represents deposit of rubber particles, oil and other pollutants on roads that wash into storm water
• Does not account for the cost to mitigate these impacts
  - Option to exclude benefits if mitigation is addressed
• Does not distinguish
  - Cars and trucks
  - Drainage approaches on different roads

FUNCTION OF VMT
• Per VMT rate for all vehicles = $0.01625/mile
• Based on research from WSDOT, Volpe Institute, and Victoria Transport Policy Institute
Noise Pollution
A Livability Benefit

DEFINITION
• Largest source of noise pollution in urban environments
• Impacts public health
• General willingness to pay for noise reduction
• Does not account for the cost to mitigate these impacts
  - Option to exclude benefits if mitigation is addressed

FUNCTION OF VMT
• Marginal noise cost per 1,000 mile rates by functional class and vehicle type

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Interstate</th>
<th>Other Freeway</th>
<th>Principal Arterials</th>
<th>Minor Arterials</th>
<th>Collectors</th>
<th>Local Roads</th>
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<tbody>
<tr>
<td>Cars</td>
<td>$ 5.23</td>
<td>$ 7.51</td>
<td>$ 2.08</td>
<td>$ 1.01</td>
<td>$ 0.12</td>
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<tr>
<td>Medium Trucks</td>
<td>$ 15.02</td>
<td>$ 23.32</td>
<td>$ 12.40</td>
<td>$ 9.49</td>
<td>$ 1.86</td>
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<tr>
<td>Heavy Trucks</td>
<td>$ 29.49</td>
<td>$ 54.42</td>
<td>$ 35.46</td>
<td>$ 52.88</td>
<td>$ 8.71</td>
<td>$ -</td>
</tr>
</tbody>
</table>

• Source is Delucchi and Hsu (2004) as cited by AASHTO Red Book
Social / Equity Benefits
Motor Vehicle Crashes
A Safety Benefit

HIGHWAY SAFETY MANUAL
• Source is the Interactive Highway Safety Design Model (IHSDM) / HSM
• Total accidents allocated to fatal, injury and property-damage-only (PDO)
• Annual valuation for fatalities is $9.4 million and for injuries is $441,800
• Annual user cost for PDOs is $1,522, including deductible and premium hikes

ROAD SEGMENTS (rs)
\[ N_{rs} = C_r \times N_{SPFr_s} \times CMF_1 \times \cdots \times CMF_n \]
Where
- \( C_r \) = calibration factor for a geographic area
- \( N_{SPFr_s} \) = Safety Performance Function (of congestion)
- CMF = Crash Modification Factors (number of lanes, truck percentages and other factors)

INTERSECTIONS (int)
\[ N_{SPFin} = \alpha + \beta ADT on Highest Volume Approach + \gamma ADT on Lowest Volume Approach \]
Where
- \( \alpha, \beta, \) and \( \gamma \) are parameters for a given facility type and sometimes other specifics such as number of lanes
Physical Activity
A Livability Benefit

WHO HEAT MODEL
• Mortality reduction assuming linear dose-response rate (to a max) to walking and cycling (minutes per week)
• Value assigned to expected lives saved per year

INTEGRATED TRANSPORT AND HEALTH MODELING (ITHIM)
• Monetizes cost per illness based on EPA value of life = $7.4 million in 2010
• Estimates mortality and morbidity reductions
  - Based on average active travel times by age and gender
• Requires local/regional calibration

IMPLEMENTATION
• New version of ITHIM in R
  - Existing deaths, years of life lost and years of life lost due to disability by age and gender
  - Costs per illness
  - Amount of time and distance spent walking and biking per day
Travel Options / Choices
An Accessibility Benefit

DEFINITION
- Value of the availability of alternative modes and destinations
- Calculated by income group and trip purpose

METHODOLOGY
- Based on destination and mode choice logsums
- Includes value of travel time and operating cost
- To avoid double-counting and isolate the benefit of additional options traditional benefits must be subtracted from the change in logsums
Equity Analysis
## Defining Populations of Interest

<table>
<thead>
<tr>
<th>Type</th>
<th>SANDAG</th>
<th>MTC</th>
<th>PSRC</th>
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</thead>
<tbody>
<tr>
<td>Low Income</td>
<td>Social</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Minority</td>
<td>Social</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Zero-Vehicle HH</td>
<td>Mobility</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disabled</td>
<td>Mobility</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Seniors</td>
<td>Mobility</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Youth</td>
<td>Mobility</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Limited English</td>
<td>Social</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>No High School Diploma</td>
<td>Social</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Single Parent</td>
<td>Mobility</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Rent-Burdened</td>
<td>Social</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Regional Growth Centers</td>
<td>Mobility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing and Industrial Centers</td>
<td>Mobility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Who Benefits?
Portland Metro MCE Toolkit Example

COMMUNITIES OF CONCERN
- Age Groups: Under 18 & Over 65
- Low English Proficiency (LEP)
- Household Income < $25k/year
- Racial & Ethnic Minorities
Equity Summaries

SAN FRANSICO
- LRTP projects by category

PORTLAND
- Test Case Forecast 2040
  Annual Equity Benefit Measures
  Low Income vs. All Travelers
  (thousands of 2040 $)
Model Convergence
Poor Convergence: Build vs. No Build

Unexpected significant volume change due to convergence – hard to explain EIM results
Poor Convergence: Build vs. No Build

Issue: Geographic distribution of economic impact doesn’t make sense
Ok Convergence: Build vs. No Build
Why Convergence Matters

Economic Impacts

• Loosely converged assignment results for improved US 30 east of Canton show major benefits in Cincinnati, Cleveland, Toledo, etc.
Why Convergence Matters

Economic Impacts

- Tighter, but still not totally converged results show economic impacts mostly clustered properly in the US 30 corridor, but still some noise elsewhere.
Final Thoughts
Potential for Benefit-Cost Analysis
A Tool for Compromise

COUNTING WHAT MATTERS TO EVERYONE

• In the past, BCA in transportation planning was commonly critiqued
  - Overly focused on economic considerations
  - Not sensitive to environmental / social concerns
  - Not fair to non-auto modes

• New, comprehensive benefit methods combined with equity analysis address these concerns and make BCA a potential tool for getting political buy-in from disparate groups who subjectively value different benefits (if there is buy-in / acceptance of the monetization scheme)

• Can help remove ideological blinders for the public / elected officials:
  - Can help economic/highway oriented to recognize cases where other modes might actually make more economic sense
  - Can help socially/environmentally oriented to recognize some highway projects really make sense and have significant social benefits even when environmental concerns, etc., have been factored in
Contact

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## Summary of Benefits

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Source</th>
<th>Agency Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic Vitality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel Time</td>
<td>US DOT</td>
<td>Extensive</td>
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<tr>
<td>Travel Time Reliability</td>
<td>SHRP2 C04</td>
<td>SANDAG</td>
</tr>
<tr>
<td>Vehicle Operating Costs</td>
<td>EPA, AAA, ATRI</td>
<td>Extensive</td>
</tr>
<tr>
<td>Vehicle Ownership Costs</td>
<td>AAA</td>
<td>Extensive</td>
</tr>
<tr>
<td><strong>Environmental Stewardship</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Emissions</td>
<td>EPA, BAAQMD, Caltrans</td>
<td>SANDAG</td>
</tr>
<tr>
<td>Surface Water Pollution</td>
<td>VTPI, Volpe</td>
<td>WSDOT</td>
</tr>
<tr>
<td>Noise Pollution</td>
<td>Delucchi and Hsu</td>
<td>AASHTO, VTPI</td>
</tr>
<tr>
<td><strong>Social and Equity Values</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Vehicle Crashes</td>
<td>AASHTO</td>
<td>Extensive</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>CIPH, CADPH</td>
<td>SANDAG, MTC, SACOG, Nashville</td>
</tr>
<tr>
<td>Travel Options / Choices</td>
<td>FHWA</td>
<td>Tampa</td>
</tr>
</tbody>
</table>