11-6-2015

Model-Based Analytics and Processes for Transportation Investment Alternatives Analyses: From Least Cost Planning to Multi Criterion Evaluation

Jeff Frkonja
*Oregon Metro Research Center*

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Decision Support for Transportation Investments

What to do with all those travel model outputs?

Portland State University, TREC
November 6, 2015
Jeff Frkonja, Director, Oregon Metro Research Center
Version 3b
Agenda

What are the decisions at hand?

What information is most useful to the decisions?

What analysis techniques provide useful information?

What ‘process’ elements should be in place to ensure successful decision support?
Decisions

Choose which alternative:
  - a OR b OR c OR...

Rank alternatives:
  - b BEFORE a, b and a BEFORE c

Design alternatives:
  c BETTER THAN a, c & a both BETTER THAN b, therefore,
  COMBINE BEST PARTS OF a and c to PRODUCE d
Decisions

Capital Investments

Policies (e.g. limited access facilities, pricing)

Programs (e.g. commute trip reduction, TDM, TSM)
What information?
What analysis?

How does the outcome affect ME?

*e.g. corridors’ travel times* from travel model

What information?
What analysis?

**How does the result affect US?**
*E.g. total system delay, etc.* from travel model

---

**Excerpts from Plan Alternative Comparison for Metro’s 2014 RTP**

<table>
<thead>
<tr>
<th>Vehicle Hours of Delay</th>
<th>VMT per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Week Day (AWD)</strong></td>
<td><strong>Weekday (VMT) &amp; Intra-UGB</strong></td>
</tr>
<tr>
<td>2010</td>
<td>2040NB</td>
</tr>
<tr>
<td>PM2</td>
<td>4,160</td>
</tr>
<tr>
<td>MD1</td>
<td>280</td>
</tr>
<tr>
<td>Average weekday, Intra-UGB</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Walk &amp; Bike Trips</th>
<th>Bicycle Miles Traveled (BMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>2010</td>
</tr>
<tr>
<td>505,500</td>
<td>814,100</td>
</tr>
<tr>
<td>Bike</td>
<td>178,400</td>
</tr>
<tr>
<td>(Average Weekday, Intra-UGB)</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Build Scenarios Relative to Baseline (No-Build) Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC Hypothetical</td>
<td></td>
</tr>
<tr>
<td>Number of years</td>
<td>58</td>
</tr>
</tbody>
</table>

**Summary**

| Lifecycle Benefits | $53,752,288,102 |
| Lifecycle Costs   | $29,153,987,133 |
| Net Present Value | $24,598,300,969 |
| Benefit / Cost Ratio | 1.84 |
| Internal Rate of Return (%) | 10.8% |

<table>
<thead>
<tr>
<th>Total Lifecycle Benefits by Category for Build Scenarios Relative to Baseline</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility - Residents</td>
<td>$33,936,027,894</td>
</tr>
<tr>
<td>Mobility - Trucks / Commercial</td>
<td>$9,143,327,429</td>
</tr>
<tr>
<td>Emissions</td>
<td>-$394,015,321</td>
</tr>
<tr>
<td>Accidents</td>
<td>$1,523,838,864</td>
</tr>
<tr>
<td>Reliability</td>
<td>$478,016,975</td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$6,337,078,938</td>
</tr>
<tr>
<td>Auto Ownership</td>
<td>$2,729,979,286</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>-$1,965,964</td>
</tr>
</tbody>
</table>

**Total**

| Total | $53,752,288,102 |

**VMT per Capita**

<table>
<thead>
<tr>
<th>Average Week Day (AWD) Vehicle Miles Traveled (VMT) &amp; Intra-UGB</th>
</tr>
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<tbody>
<tr>
<td>2010</td>
</tr>
<tr>
<td>VMT/capita</td>
</tr>
<tr>
<td>% Reduction</td>
</tr>
</tbody>
</table>

**Source:** Metro Staff Presentation During 2014 RTP Planning Process
What information?
What analysis?

What do we get for our $ (economic outcome)?
...hmmmmm...

Benefit-Cost Analysis! (and Economic Impact Analysis too!)

What is the outcome for the environment?
...hmmmmm...

Emissions, noise, water-quality, habitat analyses!

What are the social/health outcomes?
...hmmmmm...

Environmental Justice analysis, health impact assessments!
Plenty of decision/analytic frameworks

...you can probably think of several more...

- Economic Impact Analysis
- Least Cost Planning
- Benefit-Cost Analysis
- Environmental Impact Analysis
- Health Impact Assessment
- Equity Assessment (EJ)
- Individual Measures

Triple Bottom Line?
How can we make sense of all this information?

*Multi-Criteria Evaluation*

*Analytic Hierarchy Processing*
Conceptual Architecture for the “Toolkit”

- Population and Employment Forecast Tool
- Land Use Forecast Tool (Metroscope)
- Travel Demand Model
  - Cost & Other Data
  - Qualitative Information
  - Qualitative Evaluation Tools
  - Benefit-Cost Analysis Tool
  - Non-Monetized Quantitative Criteria Evaluation Tools
- Multi-Criteria Evaluation Toolkit
- Multi-Criteria Evaluation Findings
Tools & References

USDOT


AASHTO “Red Book” (project-level BCA)


ODOT Mosaic MCE Tool

- http://www.oregonmosaic.org/

TRB Transportation Economics Committee

- http://bca.transportationeconomics.org/home

CALTRANS BCA Tool

- http://www.dot.ca.gov/hq/tpp/offices/eab/LCBC_Analysis_Model.html
Example: Mobility Evaluation (part of economic leg)

Sources:
Example: Economic Evaluation

VS. $ spent in various places

Source:
Example: **Environmental Evaluation**

VS. **tons of pollutants**

Source:
Example: “Rollup”

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<td>Scenario: Mobility - Residents</td>
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<tr>
<td>Emissions</td>
</tr>
<tr>
<td>Accidents</td>
</tr>
<tr>
<td>Reliability</td>
</tr>
<tr>
<td>Vehicle Operating</td>
</tr>
<tr>
<td>Auto Ownership</td>
</tr>
<tr>
<td>Physical Activity</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Source:
- Author’s archive of DRAFT work done by RSG, Inc. for San Diego Association of Governments
Example: Equity Evaluations

Source:

VS. projects or $ in EJ communities
Example: Equity/Social Justice Evaluation

<table>
<thead>
<tr>
<th>POVERTY COC</th>
<th>Total</th>
<th>COC Poverty</th>
<th>Non-COC Poverty</th>
<th>COC Poverty</th>
<th>Non-COC Poverty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility - Residents</td>
<td>$33,936,027,894</td>
<td>$12,234,571,104</td>
<td>$21,701,456,790</td>
<td>36.1%</td>
<td>63.9%</td>
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<tr>
<td>Mobility - Trucks / Commercial</td>
<td>$9,143,327,429</td>
<td>$6,337,078,938</td>
<td>n/a</td>
<td></td>
<td></td>
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<tr>
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<td>n/a</td>
<td></td>
<td></td>
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<tr>
<td>Accidents</td>
<td>$1,523,838,864</td>
<td>$1,987,327,688</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>$478,016,975</td>
<td>$678,056,799</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$6,337,078,938</td>
<td>$23,408,823,856</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto Ownership</td>
<td>$2,729,979,286</td>
<td>$1,089,639,193</td>
<td>$1,640,340,093</td>
<td>39.9%</td>
<td>60.1%</td>
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<tr>
<td>Physical Activity</td>
<td>-$1,965,964</td>
<td>-$1,171,576</td>
<td>-$794,387</td>
<td>59.6%</td>
<td>40.4%</td>
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<tr>
<td>Total</td>
<td>$53,752,288,102</td>
<td>$48,464,305,288</td>
<td>$23,341,002,496</td>
<td>67.5%</td>
<td>32.5%</td>
</tr>
</tbody>
</table>

Source:
- Author’s archive of DRAFT work done by RSG, Inc. for San Diego Association of Governments
Summary: what can MCE do for a region like Portland Metro?

• **More apples-to-apples comparison***
• **Benefit-cost analysis findings**
  – Summarizes region-wide outcomes ("rolls things up")
  – Simultaneous cost and benefit accounting
  – Enables geographic and market segment benefit reporting (e.g. by Council District)
• **More robust criteria evaluations**
  – Equity
  – Health & Safety
  – Reliability

* To the extent methods enable.
Principles of Successful MCE

- All Criteria taken together should provide a comprehensive evaluation
- Criteria should be mutually exclusive
- Weights should be set using information from the actual decision-makers (democratic)
- Process 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 weights
Potential **Analytic** Complications

- Many criteria may be relevant but not monetizable
- Some criteria may not be quantifiable at all
- *Apples-to-apples criteria comparability may not be possible*

* Best-practice principle: Even if criteria are not quantifiable or directly comparable they should still be explicitly treated in some way
**BCA Founded in Economic Theory**

**Consumer Surplus**
- “Good” = travel from O to D
- $ Willing to Pay
- $ Actually Paid
- Willing minus Actual = Surplus
- Build Alternative Changes Surplus
- Added Surplus has economic value

Generalized Cost

Case 1: $T_B > T_A$ & $C_B < C_A$

- Base
- Build

Consumer Surplus

\[ \Delta \text{Consumer Surplus} \approx T_A(C_A - C_B) + \frac{1}{2}(T_B - T_A)(C_A - C_B) \]

\[ = \frac{1}{2}(C_A - C_B)(T_A + T_B) > 0 \]

Where GenCost = (Cost of Travel Time) + (Out-of-Pocket Costs) + (Cost of Unreliability) + (Costs Related to Effects on Consumer Options)

In-Vehicle Travel Time (auto and transit)

Trips on work tours
- \( c(i) = -0.15/\$ / \left[\left(\frac{\text{income}(i)}{30,000}^{0.6}\right) \times \left(\text{occupancy}(i)^{0.8}\right)\right] \)
- \( b(i) = -0.030/min \)

Trips on non-work tours
- \( c(i) = -0.15/\$ / \left[\left(\frac{\text{income}(i)}{30,000}^{0.5}\right) \times \left(\text{occupancy}(i)^{0.7}\right)\right] \)
- \( b(i) = -0.015/min \)

Where \( c(i) \) is the cost coefficient for user \( i \) in \( 1/\$ \)

And \( b(i) \) is the time coefficient for users in \( 1/\text{minutes} \)

In the Mode Choice logit utility expressions

## In-Vehicle Value of Travel Time
($/hr for trucks)

<table>
<thead>
<tr>
<th>Study</th>
<th>Heavy Trucks</th>
<th>Light Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATRI, 2010</td>
<td>89.23</td>
<td></td>
</tr>
<tr>
<td>Smalkowski &amp; Levinson, 2005</td>
<td>58.10</td>
<td></td>
</tr>
<tr>
<td>Outwater &amp; Kitchen, 2008</td>
<td>53.32</td>
<td>42.66</td>
</tr>
<tr>
<td>Miao et al., 2011</td>
<td>33.94 - 57.65</td>
<td></td>
</tr>
<tr>
<td>Almy et al., 2010</td>
<td>45.15</td>
<td></td>
</tr>
<tr>
<td>Mei et al., 2013</td>
<td>33.29 - 52.22</td>
<td>26.06 - 46.14</td>
</tr>
<tr>
<td>BLA, EDRG &amp; RSG, 2013</td>
<td>36.05</td>
<td>22.26 - 27.24</td>
</tr>
<tr>
<td>Kawamura, 1999</td>
<td>32.25</td>
<td></td>
</tr>
<tr>
<td>Kawamura, 2003</td>
<td>21.96 - 34.94</td>
<td></td>
</tr>
<tr>
<td>Cal-BC</td>
<td>28.70</td>
<td></td>
</tr>
<tr>
<td>USDOT*</td>
<td>26.43</td>
<td></td>
</tr>
</tbody>
</table>

*Driver's time only, USDOT acknowledges there is value to commodities' time*
Travel Time Reliability
(auto & freight / truck)

Calculate “Total Equivalent Delay”
Link-level calculation
– Segmentation limited to assignment classes
– Trucks / auto
Set VOR equal to IVTT VOT
Source: SHRP2 L05

Collisions

- Segmented by collision type
- Link-level calculation
  - Facility type segmentation only
  - SANDAG staff updating VMT-based rates using SWITRS
- Auto only
- Source: USDOT Memo (2/28/2013) on the value of statistical life, Cal-B/C

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Value</th>
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<tbody>
<tr>
<td>Fatality</td>
<td>$9,100,000</td>
</tr>
<tr>
<td>Injury</td>
<td>$427,700</td>
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<tr>
<td>Property damage only</td>
<td>$10,200</td>
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</table>

# Emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Monetization</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>$55.35 / ton</td>
</tr>
<tr>
<td>PM2.5</td>
<td>to be imputed from MTC monetization factors and SANDAG weighted distribution of PM2.5 by type</td>
</tr>
<tr>
<td>NOx</td>
<td>$7,800 / ton</td>
</tr>
<tr>
<td>ROG</td>
<td>to be imputed from MTC monetization factors and SANDAG weighted distribution of ROG by type</td>
</tr>
<tr>
<td>SO2</td>
<td>$40,500 / ton</td>
</tr>
</tbody>
</table>

Segmented by pollutant
Link-level calculation

Source: BAAQMD

Auto Ownership Costs

- MTC = $6,290 / year
- AAA = $6,000 / year
- Household-level calculation
- Source: MTC

What does the Process look like?

Multi-Criterion Evaluation (or pick your label...)

- Identify the **actions** that will be decided
- Choose **criteria** that inform the decision
- Devise **evaluation methods** that make the criteria comparable *
- Engage decision-makers to **weight the criteria**
- **Apply the evaluation** to the actions
- **Report the evaluation findings** to the decision-makers

* To the extent feasible
Some Process Observations

A few lessons learned...

• “Rollup” intended to simplify discussion but still need to ensure participants understanding & trust methods
• People care about different things: transparently report every criterion even when you report the “rollup”
• Be forthright about assumptions, methods, and analytic limitations
• Have a communications plan—MCE produces a lot of information
• Stakeholders will always disagree about validity of analytic methods for both tangible and tactical reasons

Suggestion: if someone values it then address it
Discussion

Are MCE techniques valuable for regional stakeholders?

What technical features are particularly important to this region?

What outreach, education, and information should regional stakeholders be given to best understand and participate in this type of decision-support process?
Background

Least Cost Planning:

- **Originated in power generation** industry, based on benefit-cost analysis
- A structured planning **process** that provides **decision support information** to the decision-makers
- **Analytic tools are necessary but not sufficient**. Decision-maker consultation and stakeholder involvement are also required
- **Has evolved since its inception** and during its applications to transportation decisions
- Proven **successful applications** in transportation are better described in current terminology as **multi-criteria evaluation (MCE)**
- Technical and best-practice **successful transportation examples exist**
Aggregate vs. Activity-Based Analysis

- Aggregate potential level of detail:
  - Zone
  - Market Segment (e.g. Home-Based-Work-Low-Income)

- Activity-based potential level of detail:
  - Person, along any characteristic (e.g. HH income, age, etc.)
  - Person-trips
Activity-Based Analysis

Environmental Justice (“Communities of Concern”): In aggregate modeling the zone becomes a proxy for the people

Typical: Green is an “EJ” zone because threshold percent of residents meet EJ criteria; assume global proportion of trips

Activity-Based Analysis

Environmental Justice ("Communities of Concern"): In ABM modeling we know exactly who the EJ individuals are (dark green arrows) because model simulates individual characteristics: ABM enables more-precise accounting by person and characteristic.

Activity-Based Analysis

Physical Activity Threshold = 22 min/day

- Aggregate model sees three trips below threshold

8 min
10 min
14 min

Activity-Based Analysis

Physical Activity Threshold = 22 min/day

- ABM sees one daily activity that in total crosses threshold

Geographic Subarea Analysis

Possible with Aggregate and Agent approaches