BCA4ABM : A BENEFIT-COST ANALYSIS TOOL OPTIMIZED FOR ACTIVITY-BASED MODELS

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Main objectives of a U.S. Federal Highway Adminstration (FHWA) research project

- Investigate the use of logsum-based methods to include benefits beyond those that can be measured solely as a function of travel times and costs.

- Prototype a BCA software tool that can be applied for different regions using different models

- Test the tool in Tampa and San Diego
  - Tampa: a DaySim + Cube model
  - San Diego: a CT-RAMP + TransCAD model

Objectives of Florida DOT District 7 and San Diego MPO (SANDAG)

Based on meetings held at the beginning of the project…

- Both agencies are interested in measuring <u>accessibility benefits</u> beyond changes in travel time and travel cost.

- Both agencies very interested in <u>distribution</u> of costs and benefits across geographic and demographic groups.

- Both very interested in the benefits related to <u>active transportation</u>.

Types of calculations for benefit-cost analysis

Based on zone-to-zone matrices

Freight trips, travel times, and travel costs

External (I-X, X-I, X-X) trips, travel times, and travel costs

Special generators (i.e. visitors, airports) trips, travel times, and travel costs

Based on network link flows

Accidents of various severity levels

Costs of unreliability, delays

Vehicle operating costs (and emissions)

Based on ABM output (household-, person- and trip-level lists)

Resident internal travel time and travel cost expenditure

Resident auto ownership cost expenditure

Active transportation levels (walking and biking)

How can ABM outputs better inform benefit-cost analysis?

- The ABM produces a list of individual trips that can be linked to households and persons (a "*simulated travel survey*" for the entire region)

- So, we can obtain segment-specific benefit measures for particular "communities of concern", and specify those segments flexibly in terms of household and person characteristics

- The models produce inclusive utility measures ("*logsums*") that can capture consumer welfare benefits beyond those that can be measured solely as a function of travel time and cost changes.

- The models predict the time spent *walking and biking* per day for each person, to use in measuring health-related benefits.

- It could be possible to distribute benefits that are typically computed at the link level—like travel time reliability—to individual trips
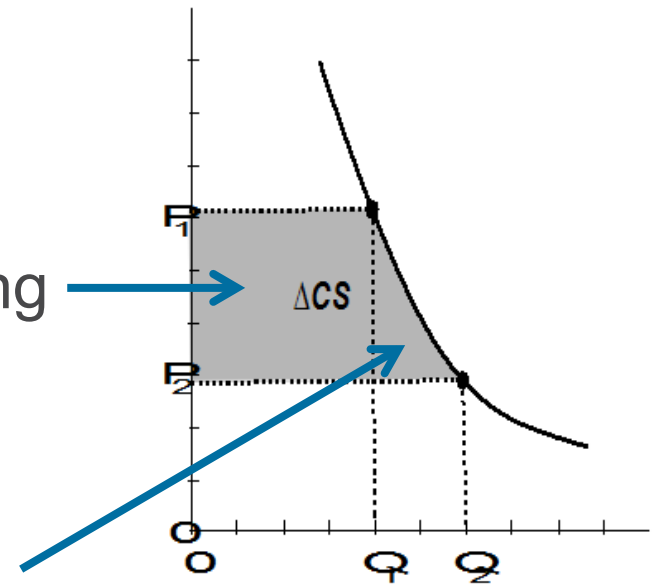
The traditional generalized cost-based "Rule of a half" approach

For a decrease in price (generalized cost), change in consumer surplus has two components:

(P1 – P2) * Q1 is the benefit for "existing users" in scenario 1 (Q1)

(P1 – P2) * (Q2 – Q1) / 2 is an approximation of the benefit for new users in scenario 2

The sum is
(P1*Q1 + P1*Q2 – P2*Q1 – P2*Q2) / 2

Key assumptions behind "Rule of a half"

(1) The demand curve is approximately linear between P1 and P2

(2) The effect of the cost change on available income is not large enough to significantly shift the demand curve. (The same applies to travel time changes and time budgets.)
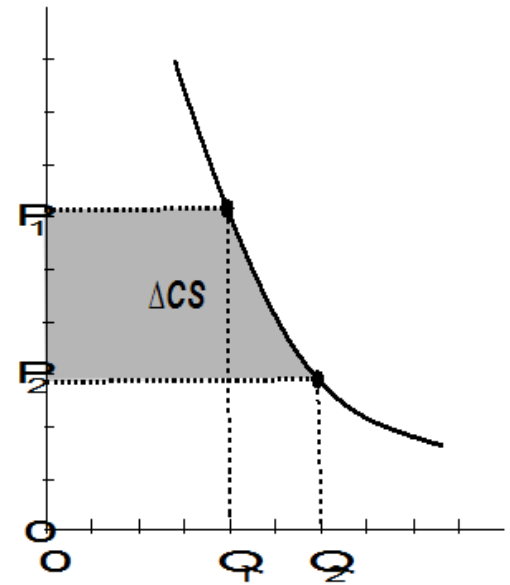
Both of these conditions are likely to be true for modest changes in travel times or costs, but may not hold for extreme policies

Flexibility of the "Rule of a half" approach

- Provides a general way of dealing with induced or suppressed demand across scenarios.

- Values for P and Q can be from various types of models, or can be from observed data.

- Values for P and Q can be from various levels of aggregation (links, zone pairs, trips, persons, …)

- "Cost" measures for P can be in the form of generalized cost, or in the form of more inclusive measures from demand model utility equations (*logsums*), provided they can be normalized to units of money or time.

Activity-Based Model Systems (where do we get the logsums from?)

CT-RAMP and DaySim have similar structures:

– Longer-term/mobility models

– Day-level models

– Tour-level models

– Half-tour (stop) level models
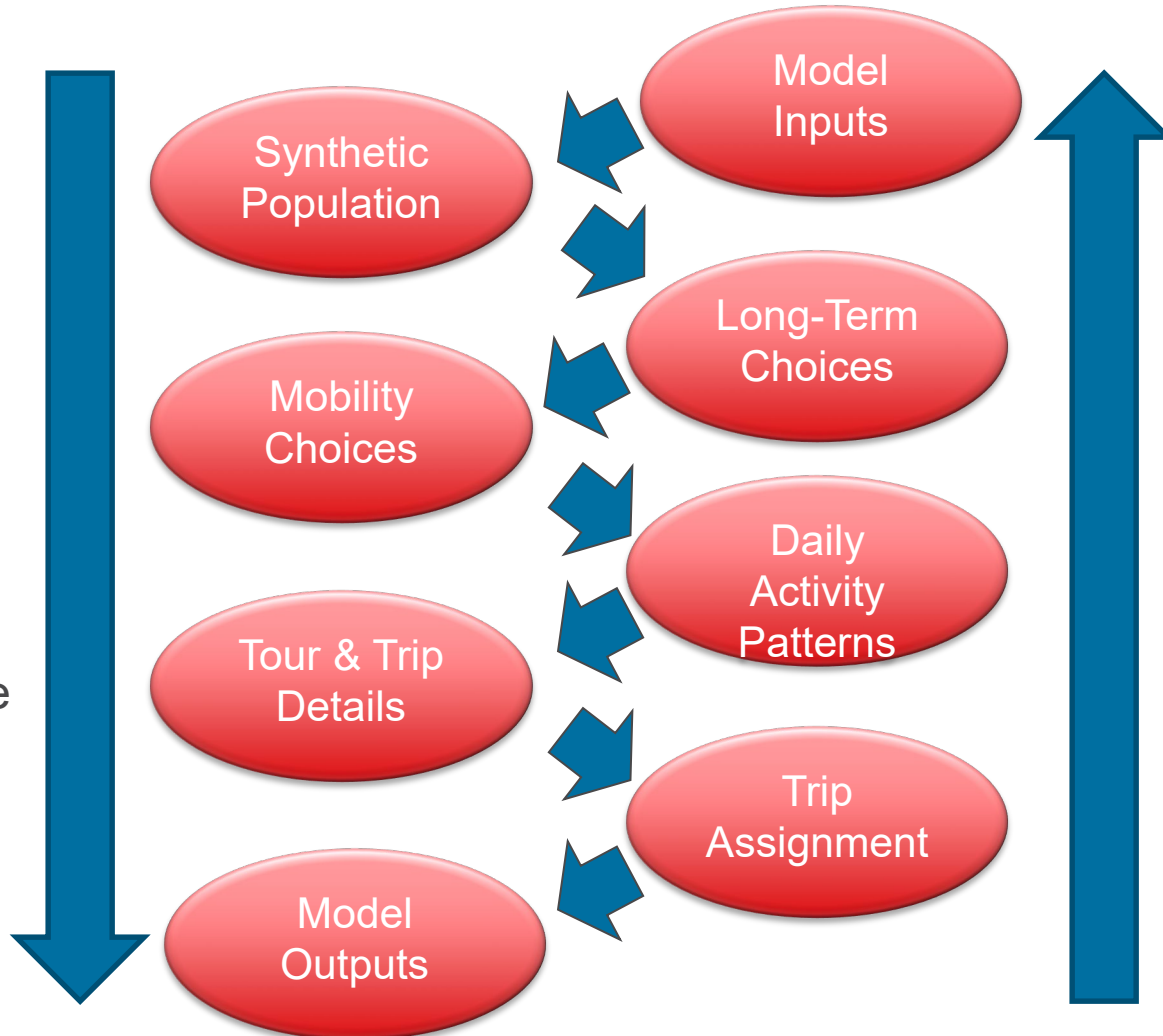
– Trip-level models

SANDAG uses CT-RAMP

Florida DOT District 7 uses DaySim
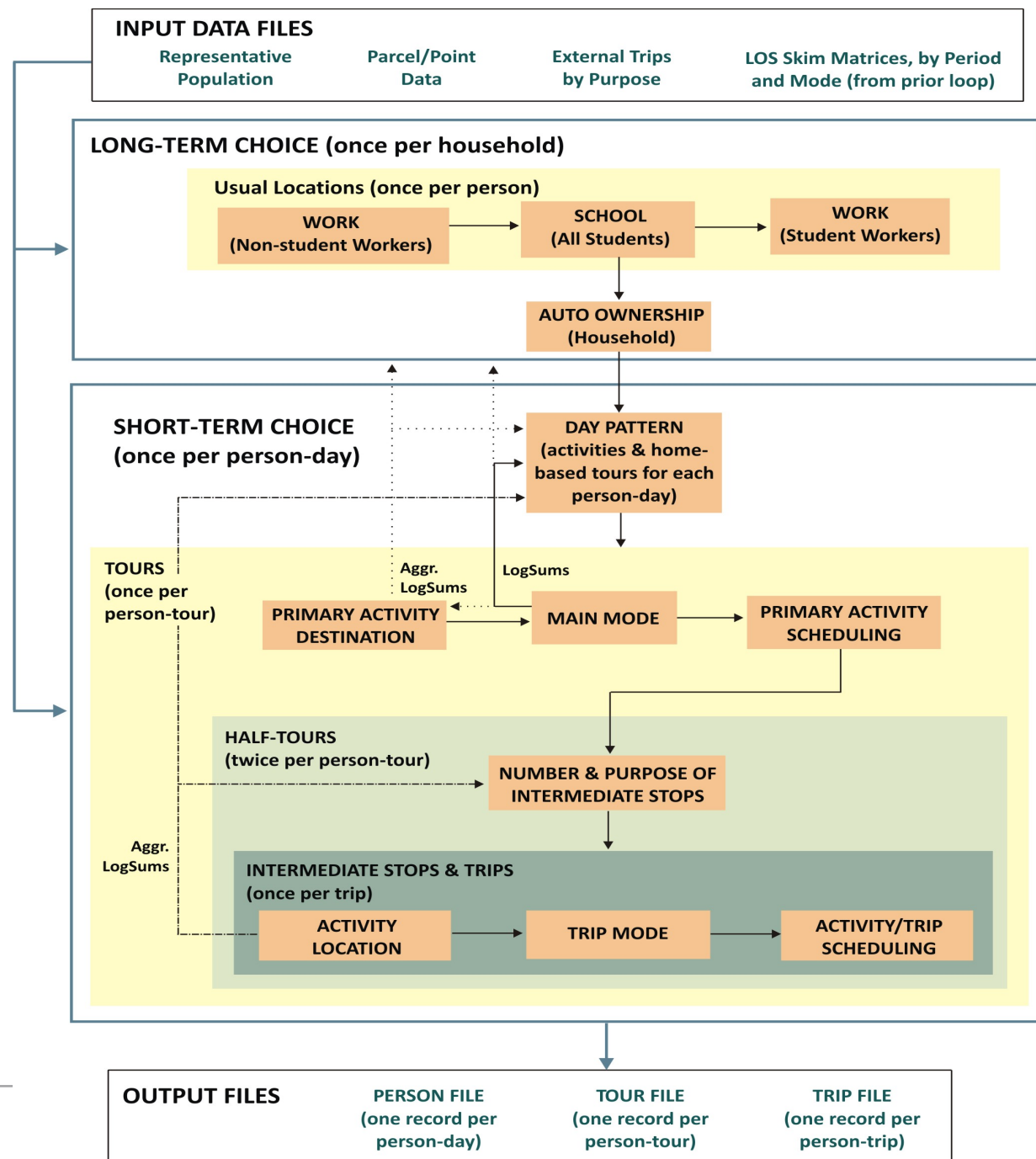
Accessibilities

Downward Integrity:

Choices made in higher models affect choices made in lower models

Synthetic Population

Mobility Choices

Tour & Trip Details

Model Outputs

Model Inputs

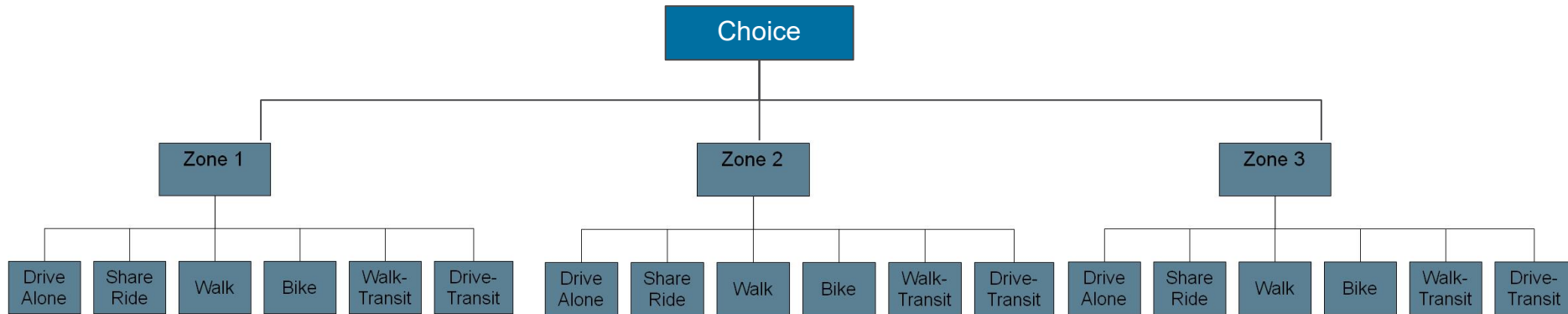Long-Term Choices

Daily Activity Patterns

Trip Assignment

Upward Integrity:

Expected utility of making choices in lower models affect choices made in higher models

The DaySim AB model structure for Tampa

# Accessibility to activities: Destination choice logsum

Destination choice logsum: Accessibility of origin to relevant activities in destinations, weighted by modal level-of-service. For MNL, the logsum is…

$$\ln\left[\sum_{z=1}^{Z}\sum_{i=1}^{I}e^{U_{p,i}}\right]$$

The logsum can be translated into minutes of travel time by dividing by the travel time coefficient from mode choice.

Accessibility to activities: Destination choice model
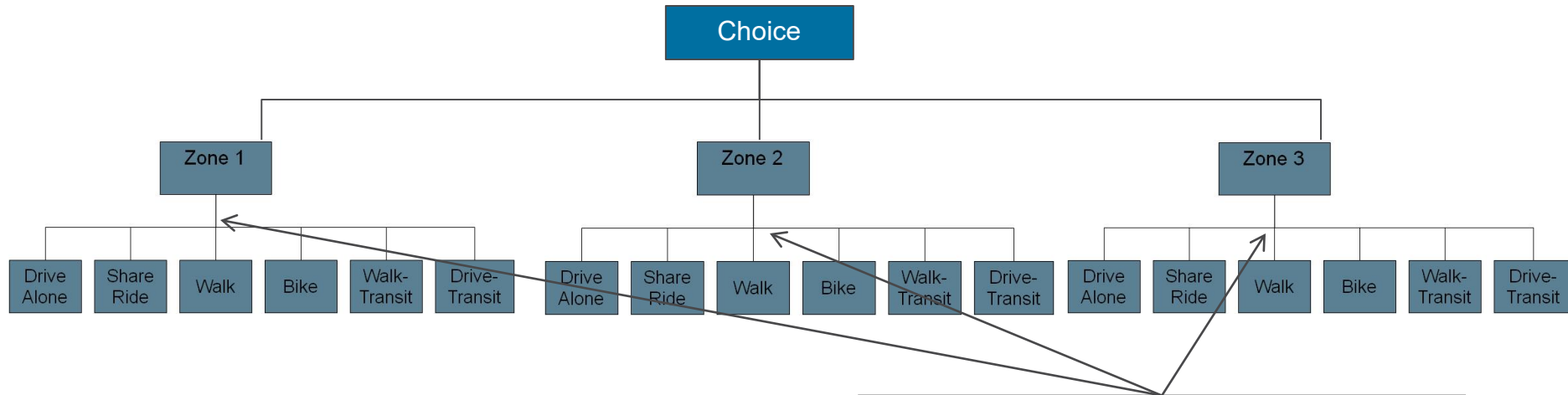
Sample Utility Equation:

$$U_j = \beta_{LS} * \text{mode\_choice\_logsum}_{ij} + \beta_{...} * X_{...}$$
$$+ \ln(\text{retail\_emp} + \theta_{\text{service\_emp}} * \text{service\_emp})$$

Mode Choice Logsum

Quantity variables (size term)

Initial tests run with the Tampa ABM

- Very controlled tests using only DaySim, factoring the travel time and cost input matrices

  (no feedback from Cube traffic assignment)

  – A base run

  – Four runs changing travel costs for all O-D pairs…

    - Cost_0.5: All travel costs reduced by 50%
    - Cost_0.75: All travel costs reduced by 25%
    - Cost_1.25: All travel costs increased by 25%
    - Cost_1.5: All travel costs increased by 50%

  – Four runs changing travel times for all O-D pairs…

    - Time_0.5: All travel times reduced by 50%
    - Time_0.75: All travel times reduced by 25%
    - Time_1.25: All travel times increased by 25%
    - Time_1.5: All travel times increased by 50%
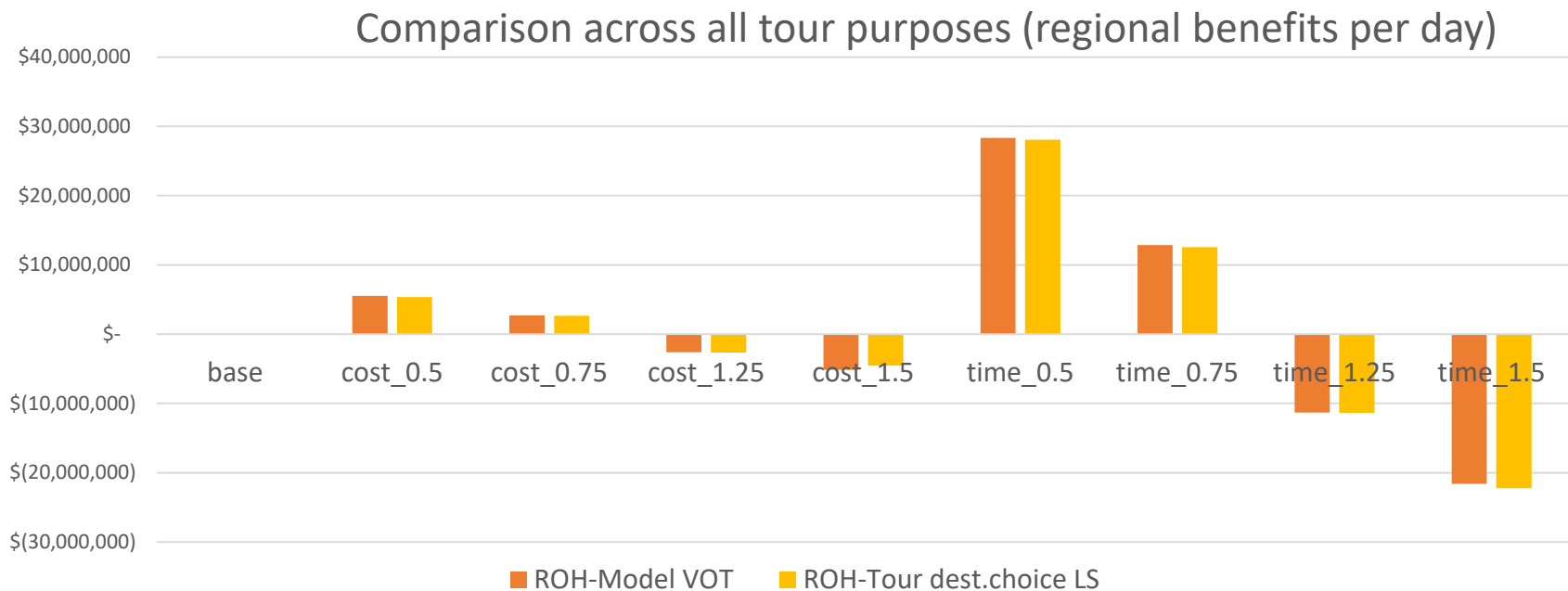
In the controlled tests…

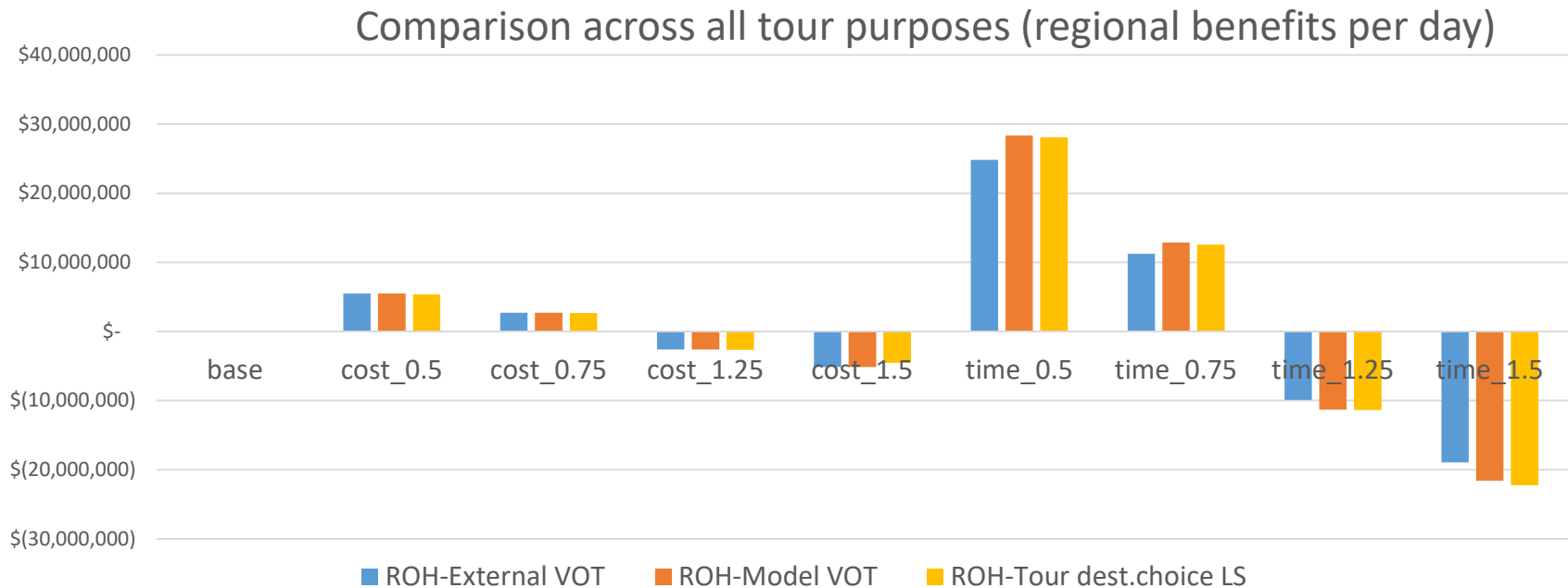**-Tour-level destination choice logsums gave the most similar results to generalized cost-based ROH**

- Tour-level logsums do not incorporate utility of making more or fewer tours, so a ROH-type measure is still needed

- Calculation of logsums for each tour or trip in the alternative scenario for ROH (P1*Q2 and P2*Q1) is computationally intensive.

Comparison across all tour purposes (regional benefits per day)

Legend: ROH-Model VOT, ROH-Tour dest.choice LS

In the controlled tests…

- Generalized-cost ROH using externally-specified VOT (instead of the VOT for each ABM trip) are slightly lower in this example, but have the advantage of being income-neutral

- Calculating what the tour destination choice logsums would be using an income-neutral VOT would be computationally intensive

Comparison across all tour purposes (regional benefits per day)

Legend: ■ ROH-External VOT ■ ROH-Model VOT ■ ROH-Tour dest.choice LS

DaySim aggregate destination choice logsums

Logsums pre-calculated at the start of the simulation to all zones in the region by all available modes for every combination of ….

Origin TAZ

Distance to transit
(1) Nearest stop within ¼ mile of origin parcel
(2) Nearest stop ¼ to ½ mile from origin parcel
(3) No stops within ½ mile of origin parcel

Auto availability
(1) 0 vehicles in HH
(2) HH vehicles/adult >0 and <1
(3) HH vehicles/adult >=1
(4) Child under age 16

VOT / Household Income
(1) Low (< $4/hr, $20,000/year)
(2) Medium
(3) High (>=$12/hr, $80,000 year)

Activity purpose
(1) HB Escort
(2) HB Personal business
(3) HB Shopping
(4) HB Meal
(5) HB Social/Recreation
(6) HB Composite
(7) Work-based Composite

$$= 3 \times 4 \times 3 \times 7 = 252 \text{ values per TAZ}$$

Potential benefits of using more aggregate destination choice logsum measures

- They are already calculated and output for every origin zone and population segment in every scenario. No need to go back and re-calculate logsums.

- Making them income-neutral can be done by simply using the logsums for the same VOT category for all cases.

- They are calculated across all possible destination zones, whereas tour-level models use random sampling of destinations >>> *less chance for random stochastic simulation error.*

- The models are relatively simple, including only the most important accessibility effects in mode and destination choice, and not so conditional on day-pattern and scheduling effects from higher level models >>> *less chance for random stochastic simulation error.*

- They can be calculated for simpler trip- and tour-based models also.

Further tests run with the Tampa ABM

- More varied sensitivity tests using the full Tampa ABM with feedback between DaySim and Cube traffic assignment:

    – An infrastructure scenario (adding lanes on I-275)

    – A land use scenario (doubling the population in downtown zones)

    – Each of those compared to the base scenario under 4 variants:

        A) The base VOT distributions and random number sequence
        B) A run using a different random number sequence for simulating choices
        C) A run removing the random component from VOT distributions
   D) A run removing the random <u>and</u> income components from VOT distributions
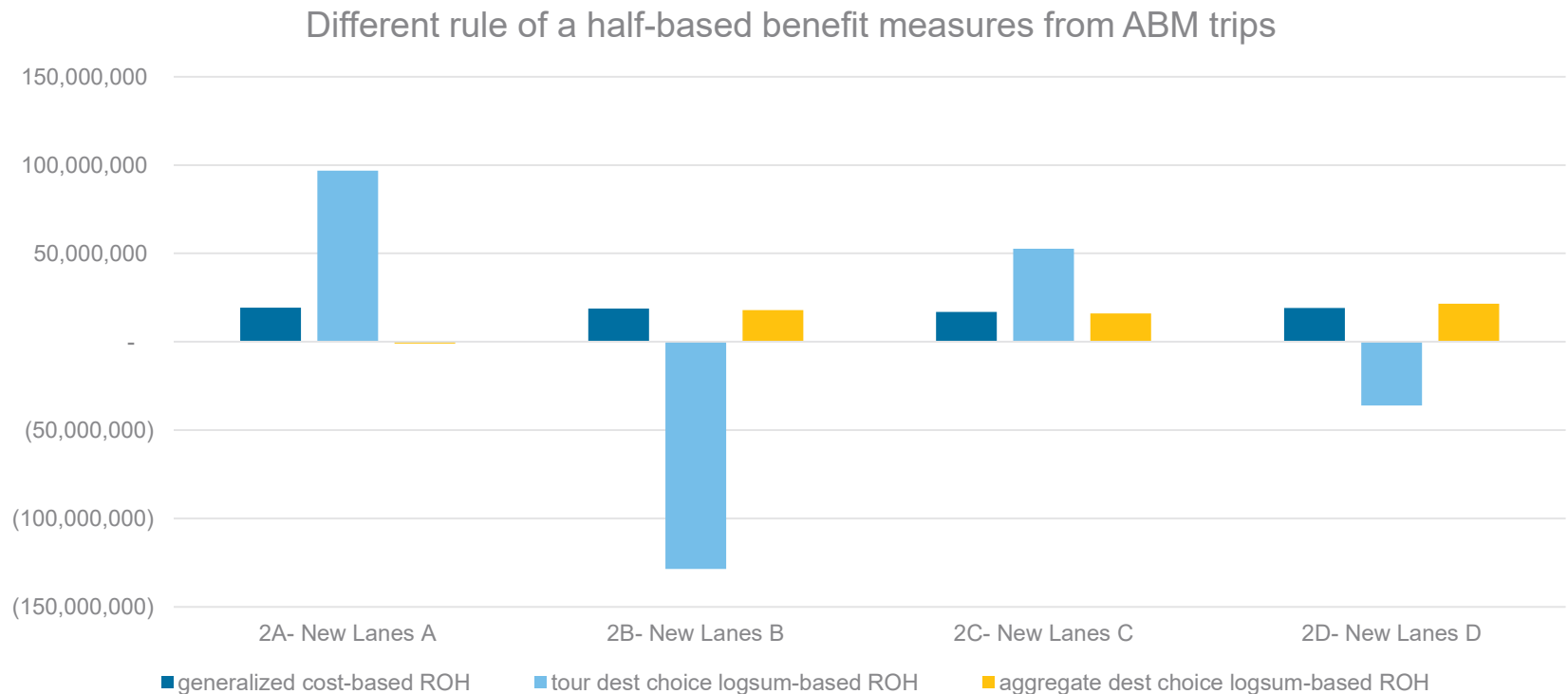
Individual Parameter Variation Applied to Value of Time
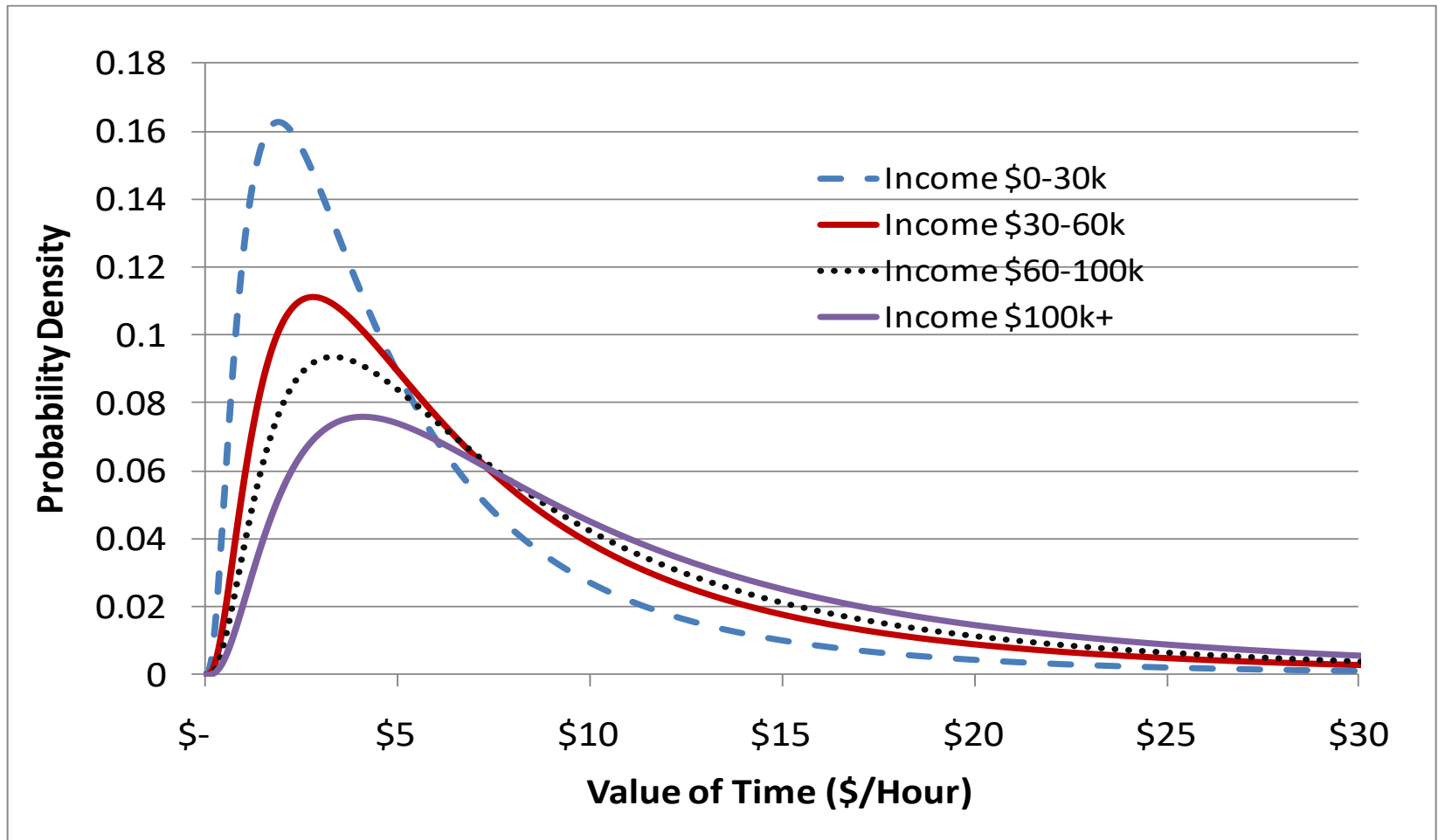
An infrastructure-related test…

The "*new lanes*" scenario was created by editing the Cube network file to add a lane in each direction to a long, congested stretch of I-275, stretching from St. Petersburg across the Frankland bridge and through central Tampa to the I-4.
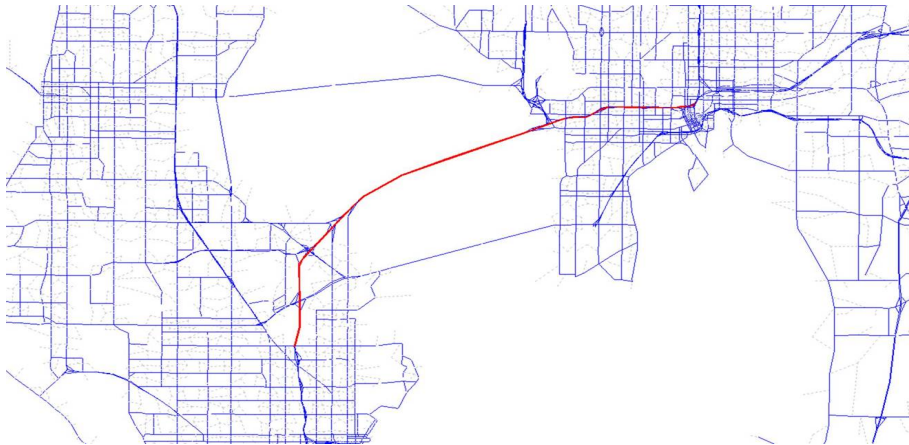
An infrastructure-related test…

- A measure based on tour level destination choice logsums is sensitive to random stochastic error and assumptions about VOT distributions

- A measure based on aggregate destination choice logsums gives more stable and reasonable results than those based on tour-level logsums

Different rule of a half-based benefit measures from ABM trips

Legend:
- generalized cost-based ROH
- tour dest choice logsum-based ROH
- aggregate dest choice logsum-based ROH
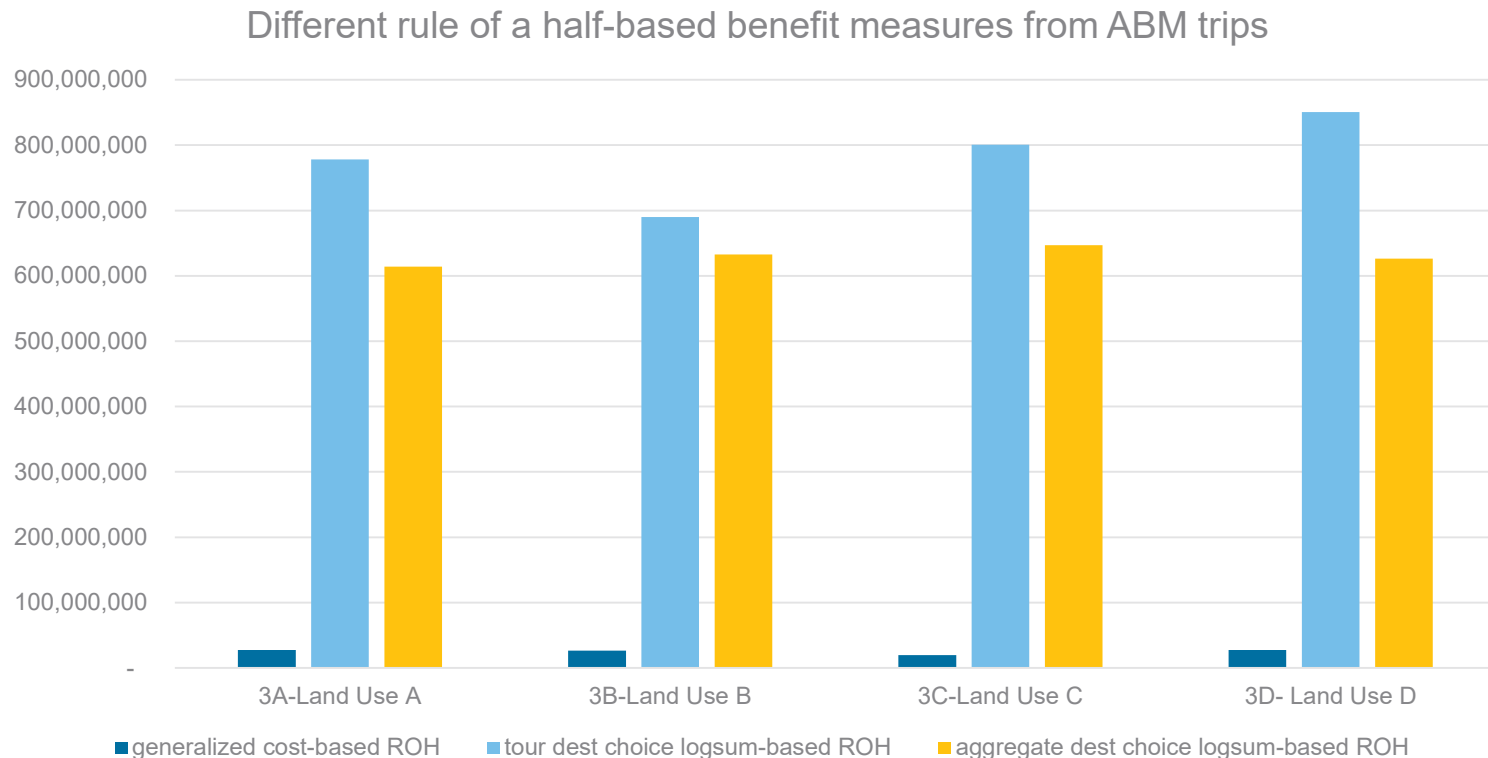
A land use-related test…

The "*more infill*" scenario was created by editing the synthetic population and parcel land use file to simulate a doubling of population in two areas in downtown Tampa and downtown St. Petersburg that had the highest accessibility to jobs and transit in the base scenario.

Each of these areas had roughly 40,000 households in the base scenario, so this scenario has about 80,000 households (about 6% of region households) moving from other areas into the downtown areas with the highest walk and transit accessibility.
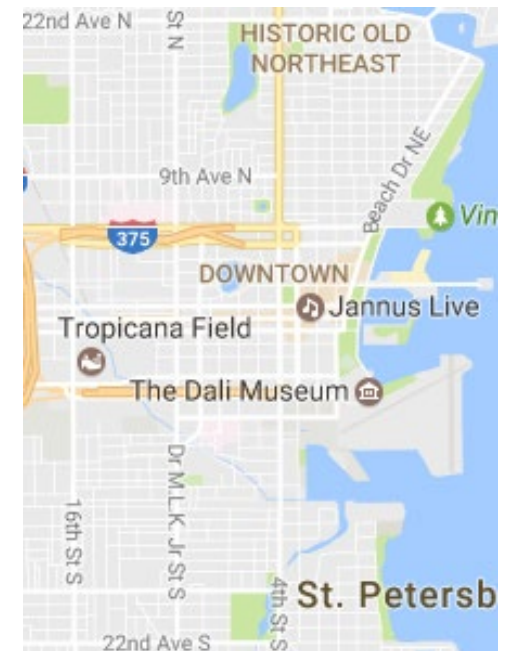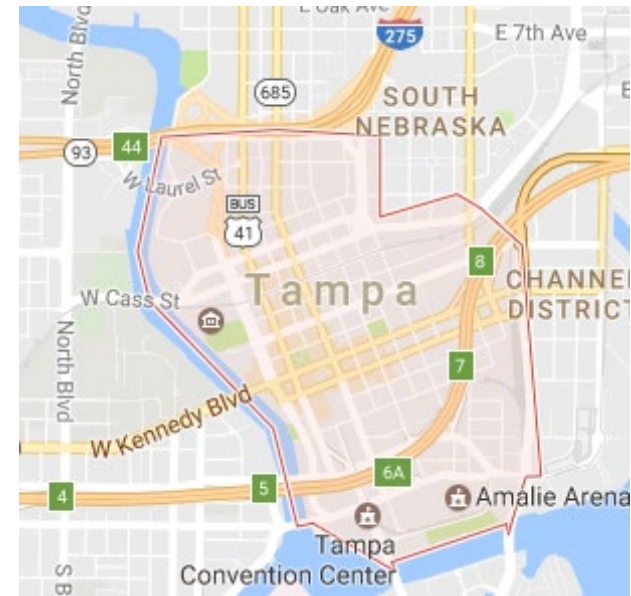
A land use-related test…

- The aggregate dest. choice logsum ROH again gives more stable results than the tour dest.choice logsum ROH, but MUCH higher than generalized-cost based ROH

- Most benefits are from the changes in accessibility due to residence relocation (not from changes in network speeds or costs)

Different rule of a half-based benefit measures from ABM trips

Legend: ■ generalized cost-based ROH ■ tour dest choice logsum-based ROH ■ aggregate dest choice logsum-based ROH

A land use-related test…

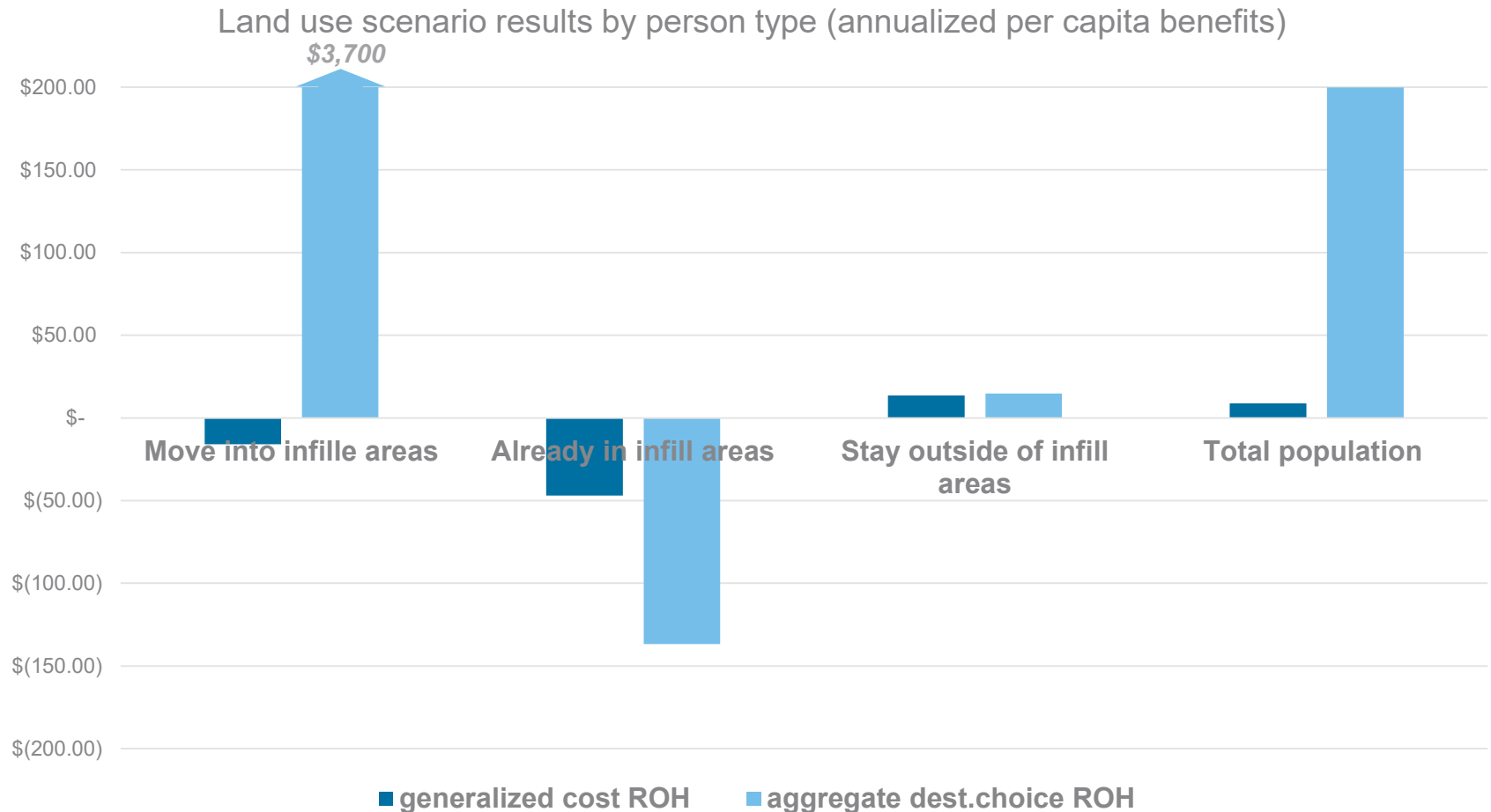**- Using a generalized cost-based measure, the benefits are dominated by those who move into the infill areas. Those benefits would be (mostly?) captured by the real estate market.**

Land use scenario results by person type (annualized per capita benefits)

Legend: ■ generalized cost ROH ■ aggregate dest.choice ROH
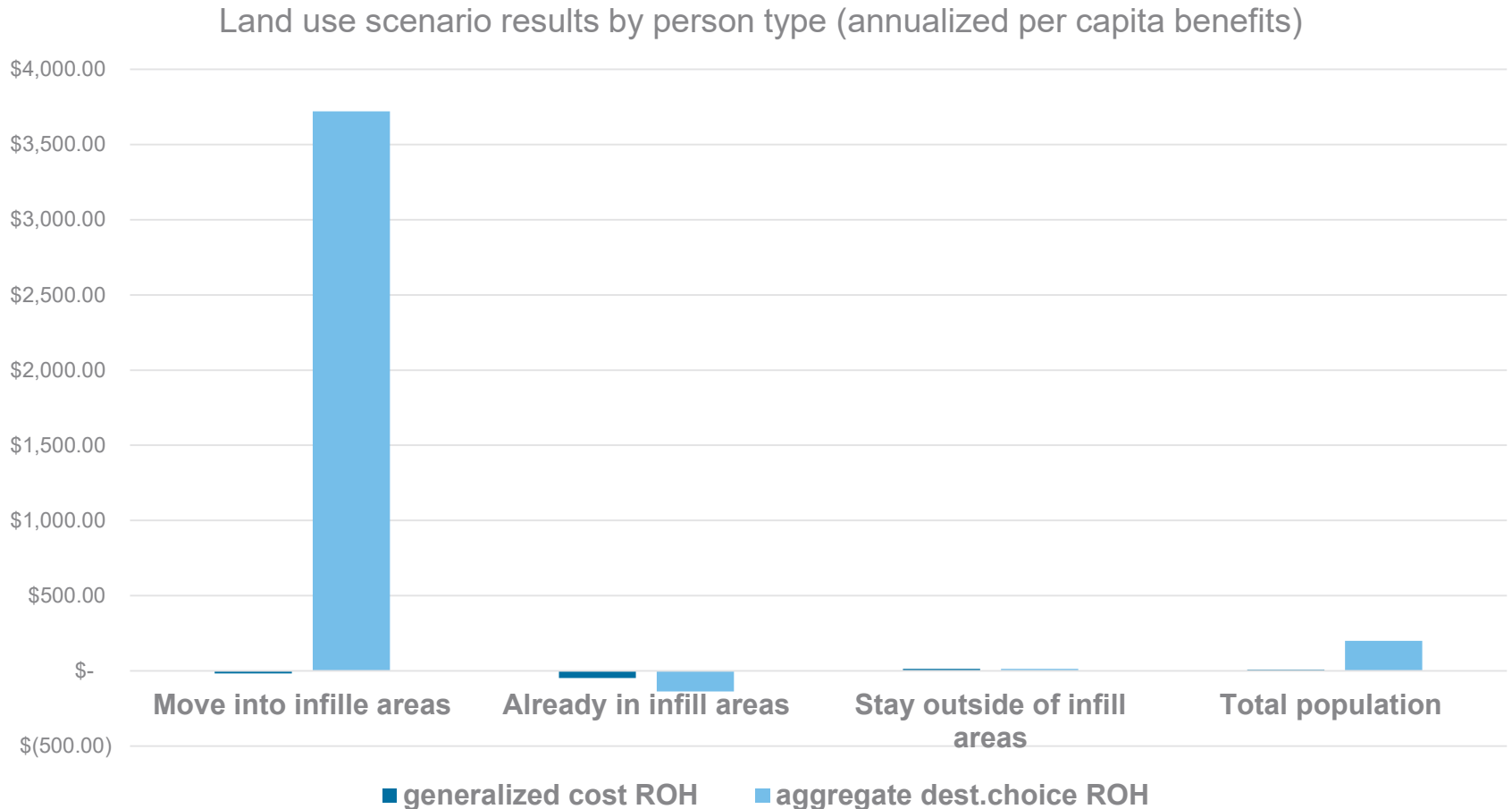
A land use-related test…

- The two measures are very similar outside the infill areas, where benefits come from minor reductions in congestion

Land use scenario results by person type (annualized per capita benefits)

Legend: ■ generalized cost ROH ■ aggregate dest.choice ROH

Categories: Move into infille areas, Already in infill areas, Stay outside of infill areas, Total population

$3,700

Recommendations for Practice

- A ROH measure based on zone/market segment-level accessibility logsums is recommended over one based on detailed tour destination choice logsums, because it is easier to implement, and the results appear more stable and reasonable (while still achieving the benefits of using a logsum-based measure)

- In the short term, it may be useful to calculate both the traditional generalized cost-based ROH measure and the alternative logsum-based ROH measure, to build up a wider basis of empirical comparison.

- Make extensive use of the "community of concern" feature to learn more about the relative costs and benefits that accrue to different segments of the population.

- Monetizing and visualizing changes in logsums across alternatives is a great way to better understand your model

Recommendations for Further Research

- Test a wider range of types of scenarios, with the Tampa and San Diego ABM systems, as well as other ABM's in other regions.

- Test the effects of assignment convergence level and global system convergence level on the benefit results, particularly for scenarios with significant infrastructure changes.

(This is an area which needs more testing for travel demand modeling in general—not just for benefit-cost analysis.)

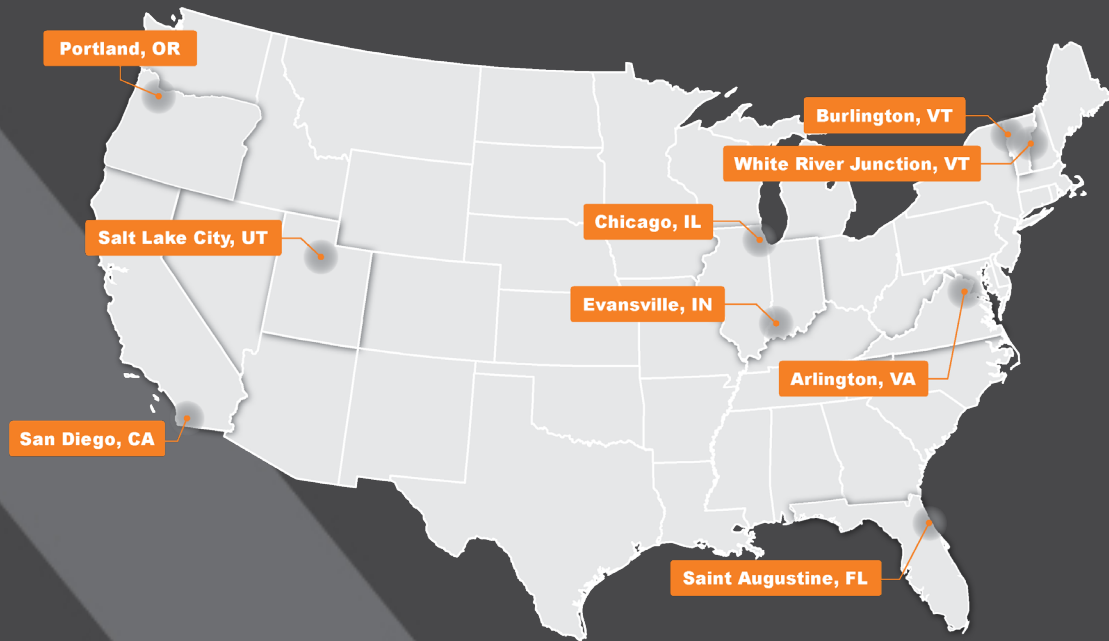- Test ways of dealing with the "new alternative" problem.

(This is an issue in both generalized-cost and logsum-based methods, but can be dealt with differently for logsum-based methods)

The BCA4ABM Tool

- Is an open platform for comparing scenarios generated by travel demand models

- Is a general expression-based framework for aggregate (matrix), disaggregate, and link-based calculations

- Implemented with the same technology as ActivitySim – the next generation AB modeling platform sponsored by a consortium of transportation planning agencies

- Is being used for trip-based model BCA as well by Portland Metro

- https://github.com/rsginc/bca4abm

Portland, OR

Burlington, VT

White River Junction, VT

Salt Lake City, UT

Chicago, IL

Evansville, IN

Arlington, VA

San Diego, CA

Saint Augustine, FL

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Physical activity health benefits

The World Health Organization (WHO) *HEAT* method addresses the question…

If x people cycle or walk for y minutes on most days, what is the economic value of the health benefits that occur as a result of the reduction in mortality due to their physical activity?

Uses linear dose-response equations applied to minutes biking and walking for each person-day:

Reduced risk of mortality/year =
*Minutes/day of cycling/15 * 10%, capped at 45%*
*Minutes/day of walking/24 * 11%, capped at 30%*
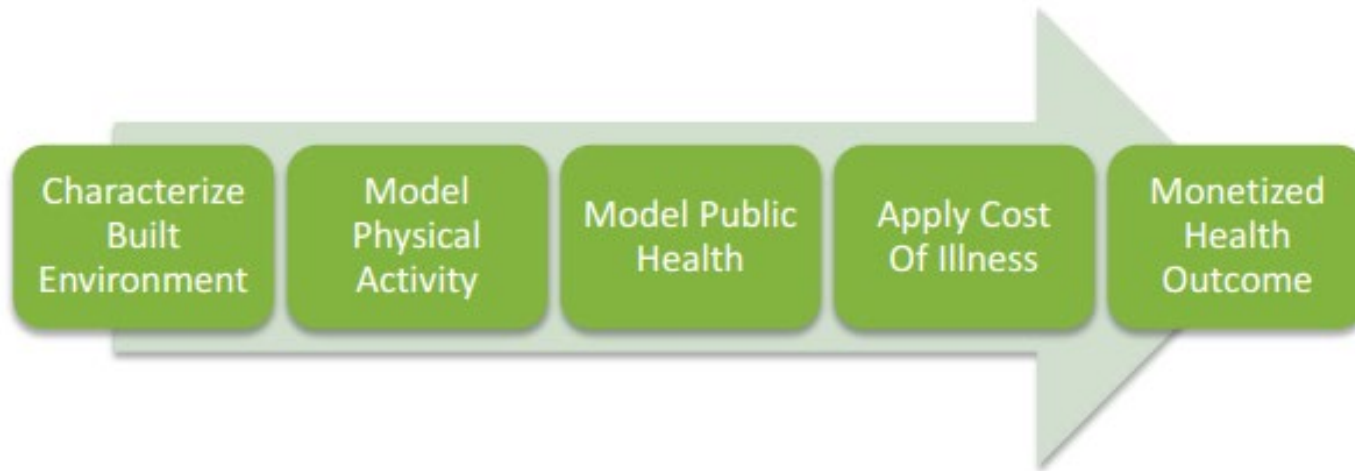
Walking and cycling benefits added, but capped at 45%

The dollar value of mortality risk/year is a user input

Alternative method: Urban Design 4 Health

- Used extensive travel survey and health survey data for California. Current projects for Southern California Association of Governments and U.S. Environmental Protection Agency.

- Could use AB model to better capture first part > land use and infrastructure effects on utilitarian walking and biking

Another alternative method: Integrated Transportation Health Impacts Model (ITHIM)

Being integrated with the Sacramento AB model (SACSIM).

The synthetic population and AB walk and bike outcomes can be used to provide higher spatial resolution in the results.