Discussion-piece #11
Illustrative Mode-Choice and Summit Calculations for Travel by One Market Segment between a Pair of Zones for Base and Build Alternatives
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1. The accompanying spreadsheet file illustrates the extraction of information from a mode choice model and the use of this information by Summit to compute user benefits for one zone-to-zone interchange and one market segment. The first worksheet in the file applies a simple mode choice model to compute auto and transit shares and trips – and to prepare the information needed by Summit to compute user benefits. The second page replicates the Summit calculations of user benefits for travel between this pair of zones by this one market.

Mode Choice

2. The mode choice model considers three modes: auto, transit with walk access, and transit with drive access. The model uses the multinomial logit formulation and assumes no nesting among the three modal choices. It recognizes three attributes of each mode: in-vehicle time in minutes, out-of-vehicle time in minutes, and out-of-pocket cost in cents. The alternative-specific constant for auto is 0.0, so the alternative-specific constants for the two transit modes represent the net effect of their unincluded attributes (reliability, safety, convenience, etc.) compared to the auto mode. (Note that this specific model specification is for illustrative purposes only. The concepts described here work with any logit formulation, including nested logit, so long as the summed exponentiated non-transit utility, market sizes, and transit shares are extracted correctly from the mode choice model.)

3. The first block of the mode choice calculations contains several identifiers and inputs to the calculations. For the base alternative, 75 percent of the trips produced in zone 11 are within walking distance of a transit stop while 50 percent of the trips attracted to zone 20 are within walking distance of a transit stop. For this trip purpose, the upstream models (generation and distribution) predict that 100 of the person-trips produced in zone 11 are attracted to zone 20. This prediction applies to both alternatives. Walk-access transit coverage expands in the alternative, increasing in zone 11 to 100 percent and in zone 20 to 75 percent.

4. The second block computes the transit-access markets for this zone-to-zone market. Trips that "can walk" to transit are computed as the product of the walk-access shares in the two zones time the total number of person trips: 75 x 50 x 100 = 37.5 trips in the base and 100 x 75 x 100 = 75 trips in the alternative. Trips that "can walk" <u>may</u> also drive to transit. Trips that "must drive" to transit are computed as the product of the non-walkable share of zone 11 and the walkable share of zone 20 times the number of person-trips: (100-75) x 50 x 100 = 12.5 trips in the base and (100-100) x 75 x 100 = 0 trips in the build. Trips with no transit option are computed as the non-walkable share of zone 20 times the number of person-trips: (100 – 50) x 100 = 50 trips in the base and (100 – 75) x 100 = 25 trips in the build.

5. The third block applies the mode choice model, beginning with the values of the attributes of each mode for travel between zones 11 and 20. The model uses the coefficients on each attribute and the mode-specific constants to compute the utility for each mode and then exponentiates those utilities. In the can-walk market, all three modes are available, so the mode share for each available mode is its own exponentiated utility divided by the sum of the exponentiated utilities for all three modes. In the must-drive market, the transit/walk choice is not available, so the share calculations are done using only auto and transit/drive. The model computes total trips by mode by summing the trips by mode across each of the three transit-access markets: “can walk,” “must drive,” and “no transit.”

6. The last block in the mode choice calculations prepares the information needed by Summit. The information includes three identifiers (I-zone, J-zone, and segment number) and seven data items:

1 – Total person trips	the total number of person trips between I and J, regardless of mode
2 – Motorized person trips	person trips between I and J in autos or transit, excluding walk and bicycle; equal to total person trips in this example because the mode choice model considers only motorized trips
3 – Exponentiated utility(other)	the sum of the exponentiated utilities for non-transit modes; equal to the exponentiated utility for auto in this mode choice model
4 – Fraction, can walk	the fraction of trips between I and J that can-walk (and may drive) to transit
5 – Transit share, can walk	the transit share of the trips between I and J that can walk to transit
6 – Fraction, must drive	the fraction of trips between I and J that must drive to transit
7 – Transit share, must drive	the transit share of the trips between I and J that must drive to transit

7. The mode-choice application program writes these seven information items and their three identifiers to a single record in a binary file for each alternative. Summit computes user benefits from the differences between the binary files for a pair of alternatives. (The absence of exponentiated transit utility from the information passed to Summit may seem to be an omission. However, Summit computes the exponentiated transit utility from the passed information. A binary logit mode choice model computes transit share as

   (1) $\text{Transit share} = e^{U(\text{transit})} / [\, e^{U(\text{transit})} + e^{U(\text{other})} \,]$.

   Rearranging terms, the exponentiated transit utility is

   (2) $e^{U(\text{transit})} = e^{U(\text{other})} / [\, 1 - \text{transit share} \,]$.

Summit uses this expression to compute the separate exponentiated utilities of transit from the separate transit shares in the can-walk and must-drive markets.)

Summit Calculations of User Benefits

8. Summit reads the records for I-zone 11, J-zone 20, and market segment 1 – one from the base and one from the build alternative – and computes user benefits from the differences between the forecasts for the two alternatives.

9. The first block of calculations develops a 3x3 classification of the trips between I and J according to their transit-access conditions in both the base and the build alternatives. This classification is a key perspective on the sources of transportation benefits because shifts among access conditions represent changes in the geographic coverage of the transit system while changes within the same access condition represent changes in the quality of service provided by the transit system. Summit computes the same-access cells (the upper-left to lower-right diagonal) as the minimum of the market fraction in the two alternatives. So, for example, the can-walk/can-walk fraction is 37.5 percent, computed as the minimum of the base can-walk fraction of 37.5 percent and the build can-walk fraction of 75 percent. Summit computes the off-diagonal cells independently for each row. Within each row, the "loss" in each market is defined as any decrease in the access relevant fraction in the build compared to the base. The drive-access market, for example, has a "loss" of 12.5 percent because it declines from 12.5 percent in the base to 0.0 percent in the build. The loss in each market is allocated across the non-diagonal cells in its row in proportion to the "gains" in each column for the build alternative. In this example, only the can-walk market gains in the build alternative – from 37.5 percent in the base to 75 percent in the build. Because all of the gains occur in the can-walk market, 100 percent of the losses in the base must-drive market must go to the build can-walk market. By definition, the sum of the access fractions across the 3x3 table must equal 100 percent because the table classifies all of the trips between I and J.

10. The second block computes the change in the price of travel by all other (non-transit) modes taken together. In this case, auto is the only non-transit mode considered by the mode choice model. The calculation applies to "all" transit-access markets since the same auto travel characteristics are available to travelers regardless of transit access. The price of auto travel in each alternative is computed from the exponentiate utility of the auto mode written by the mode choice model to the binary file read by Summit. The price is equal to the natural logarithm of the exponentiated utility for non-transit modes (the "logsum") divided by the mode-choice coefficient on in-vehicle time (to convert "utility" to minutes). In this example, the price of auto travel increases from 63.5 minutes in the base to 65.5 minutes in the build (reflecting the 2.0-minute increase in in-vehicle time for auto, the only non-transit mode in the mode-choice model).

11. The third block computes the changes in the price of transit travel for the 3x3 table of transit-access conditions. (These computations are needed only to display and, where necessary, cap change in transit price. The calculation of user benefits is done with the change in overall

price for all modes, not just transit.) Changes in transit price are defined only for the four cells in which transit is available in both the base and build alternatives. Because the price of transit is infinite where it does not exist, differences cannot be computed for the five cells in which transit is unavailable in the base, the build, or both alternatives. Computation of transit prices is analogous to the computation of non-transit (auto) price: the natural logarithm of the exponentiated transit utility, divided by the coefficient on in-vehicle time. In the can-walk market, the exponentiated transit utility is the sum of the exponentiated utilities for transit/walk and transit/drive – hence the "sum" in "logsum" – the transit price reflects the quality of service provided by both transit choices considered by the mode choice model. In contrast, only transit/drive is available in the must-drive market. Price changes in the four applicable cells are simply the build price minus the base price.

12. Summit supports application of a "cap" on the change in transit price – needed, unfortunately, to limit the egregious effects of various problems in current mode choice models in some metropolitan areas proposing New Starts projects. The cap on delta transit price defaults to 45 minutes and applies to both increases and decreases in transit price for cells on the diagonal (can-walk/can-walk and must-drive/must-drive). The cap does not apply to off-diagonal cells because that would hide the extent to which geographic coverage differences exist between the two alternatives – a generally undesirable condition that tends to confound the evaluation of major transit projects.

13. The fourth block computes changes in the overall of price of travel by all modes taken together. Again, the price in each market is computed as a natural logarithm of exponentiated utility, divided by the coefficient on in-vehicle time. In this case, the exponentiated utility is the sum of the exponentiated utilities for the transit modes and the other (auto) modes. The price difference in each cell of the 3x3 table is simply the price in the build alternative minus the price in the base alternative. Summit does a parallel calculation of the price changes using the capped transit price in the can-walk/can-walk and must-drive/must-drive cells. Where the uncapped price change exceeds the cap, these calculations recompute the overall price change using a transit price change equal to the cap. In this example, neither cell triggers application of the 45-minute cap.

14. The fifth block computes user benefits as the cell-by-cell product of the number of person trips in the cell times the overall price change for the cell. The computations are done for both uncapped and capped price changes.

15. The sixth and final block computes the share of overall user benefits that are caused by changes in transit prices (as distinct from changes in the non-transit price), again both uncapped and capped. Summit computes the share as the fraction of change in exponentiated utility contributed by transit:

$$(3)\quad \text{Share caused by transit} = \frac{e^{U(\text{transit})}{}_{\text{build}} - e^{U(\text{transit})}{}_{\text{base}}}{(e^{U(\text{transit})}{}_{\text{build}} - e^{U(\text{transit})}{}_{\text{base}}) + (e^{U(\text{other})}{}_{\text{build}} - e^{U(\text{other})}{}_{\text{base}})}$$

16. In each cell, this share times the total user benefits yields the subset of user benefits that are caused by transit changes.

17. In the example, transit-caused user benefits are greater than total user benefits because the higher price of auto travel in the build alternative (caused perhaps by the taking of a traffic lane for the transit improvements) partially offsets the lower price of transit travel.