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COMMUTER v2.0 Model Coefficients

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Transportation and Regional Programs Division
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The travel impacts calculated in the COMMUTER Model are based on logit mode-choice coefficients. The COMMUTER Model impacts are highly sensitive to the values of these coefficients, which are used to predict mode share changes in response to changes in travel time and cost associated with transportation control programs. Given this high degree of sensitivity, it is important that COMMUTER Model users understand the basis for these coefficients and how they are validated and used in transportation modeling. Potential users of the model should evaluate the influence of the coefficients, perform sensitivity tests to understand their impacts, and verify that there is consistency among the coefficient values used in related transportation planning models and the coefficient values used in this model for the city or local area being analyzed. The purpose of this discussion is to educate users about these issues. This discussion covers the following elements relating to the use of mode-choice coefficients in the COMMUTER Model:

- **Modeling Techniques** outlines the various modeling processes that use coefficients of this type and identifies how the coefficients are used in the various models.

- **Review of the Coefficient Values** identifies the coefficients used in the COMMUTER Model and defines the range of values, averages, and categories that are used in the model.

- **Documentation of Sources** lists the specific documentation of the coefficient sources.

Overview

The COMMUTER Model employs a simplified logit modeling process (called pivot point) that relies on locally derived coefficients to evaluate the influence of alternative measures on travel behavior. The coefficients are derived from observed travel behavior using standard survey techniques, statistical analysis, and modeling methods. Coefficients that have not been derived from observed travel behavior (such as composite measures or transferred coefficients) are not included as they could bias the average values. The fact that the coefficients are all derived using similar statistical methods explains why the coefficients are reasonably similar across the country. A review of the coefficients indicates that while they are relatively consistent across the country, there is enough variation in values between cities that it is essential that users understand the use of these coefficients. This report provides the user with this background information.

The mode-choice coefficients employed in the COMMUTER Model have been “validated” and are widely used in urban transportation modeling for a number of reasons, which include the following:

- The coefficients are derived from observed travel behavior using standard survey techniques, statistical analysis, and modeling methods.

- These coefficients are not estimated separately but rather as functions of the mode split behavior and are related to all variables included in mode-choice model equations.

- The coefficients are reasonably consistent across the country.

- Many metropolitan regions have used these coefficients to "backcast" known mode share conditions, e.g., to test the accuracy of their forecasting models.

- Metropolitan areas also have used these coefficients to verify before and after conditions of new transit services.

Modeling Techniques

Coefficient values are used in all types of modeling techniques and represent similar behavioral aspects of travel in each case. The primary difference in the modeling techniques is that standard logit models estimate probabilities that a person would choose a certain mode (e.g., driving alone, carpooling, transit, etc.) based on all variables that impact travel decisions. Conversely, pivot-point models estimate these probabilities based only on the changes in specific variables. Both the TDM Evaluation Model and the COMMUTER Model are based on a pivot-point technique.

The pivot-point logit technique is a simplified version of the logit modeling process found in most mode-choice models, which are developed at the metropolitan level by Metropolitan Planning Organizations (MPOs). The primary difference between the standard logit modeling process and the pivot-point technique is as follows:

- Standard logit mode-choice models, as applied in regional travel models, include many different parameters, such as transportation level of service (e.g., travel times, transit fares, parking costs); area characteristics (e.g., employment density); and socioeconomic and demographic characteristics (e.g., income, household type). In order to apply the models, *baseline levels* and *changes* in each variable must be known for all variables.

- Pivot-point models are a simplified form of the logit mode-choice model. Pivot-point models "pivot" off the baseline mode share, based on the *change* in value for certain variables of interest (e.g., transportation LOS). It is not necessary to know the baseline levels of any other variables, since these baseline levels are reflected in the starting mode share. It is also not necessary to know levels of other variables, such as demographic characteristics, that are assumed not to change.

Standard logit mode-choice models, as applied in regional travel models, can be used to test a broader variety of impacts than pivot-point models. However, since they are integrated with the full regional travel model, they can only be used in conjunction with the entire set of data and modeling processes incorporated in the model. Regional travel models are widely used by MPOs to test the impacts of changes in automobile and transit levels of service, population, employment, demographics, and other variables such as the pedestrian environment. Pivot-point models are based on the same behavioral information (coefficients) and modeling methodology used in regional travel models, yet they apply this methodology in a simplified approach that can be used in stand-alone analysis.

The TDM Evaluation Model, developed by Comsis Corporation in 1993 and sponsored by Federal Highway Administration, uses the same pivot-point methodology as described in this memorandum and the COMMUTER Model User Guide, with the following exception. The TDM Evaluation Model applies the coefficients to zone-to-zone trip activity data (trip tables generated by regional models are input directly into the TDM Evaluation Model); in other words, coefficients are applied separately to trip characteristics and LOS changes between each pair of origin and destination zones. The COMMUTER Model, in contrast, applies the coefficients to a single set of trip activity data, whether it is aggregate metropolitan area data or individual employer data.

The coefficients used in the TDM Evaluation Model and the COMMUTER Model are also very similar. Composite coefficients used in the TDM Evaluation Model were derived from MPO area travel demand models, and average COMMUTER Model coefficients for small, medium, and large size metropolitan areas were also developed from MPO area travel demand models. The primary difference in the coefficient values is that those in the COMMUTER Model are based on more, recent data.

Review of Coefficient Values

Review - The coefficient values used in the COMMUTER Model are defined as follows:

- In-vehicle travel time (in minutes) for transit modes.*
- Out-of-vehicle travel time (in minutes) is divided into walk and wait parameters. The walk coefficient is used for both auto and transit modes, and the wait coefficient is exclusive to transit modes.
- Cost (in cents) is separated by auto (parking costs) and transit (fare). Auto

* The COMMUTER model was not designed to assess impacts from large changes in the transportation system. As a result, it assumes that in-vehicle travel time remains constant for auto modes (drive alone, carpool, and vanpool) and only allows in-vehicle travel time changes to be applied to transit. Transportation system changes that produce measurable impacts on in-vehicle travel time for auto modes cannot be assessed with the COMMUTER model and must be treated with a full “four step” travel demand model.

operating costs were also considered, but are typically the same as transit-fare coefficients.

These parameters are typically established in units of minutes and cents for inclusion into travel demand models and are set to match these units in the COMMUTER Model for consistency. Since there is no guarantee that these units would match an individual city's travel demand forecasting model coefficient units, this should be checked prior to use of the COMMUTER Model. Recognizing that the typical units for cost change inputs and outputs in travel demand forecasting models are dollars, the COMMUTER Model internally applies a cents-to-dollars conversion factor to the cost-related coefficients that are typically reported in cents when combining cost coefficients with cost inputs in dollars. If the user supplies their own local coefficients (instead of using the model's city-specific or area size defaults), the time-related coefficients must be entered in units of minutes and the cost coefficients must be in cents.

All coefficients identified above are expected to be negative, to represent the fact that as the value of the parameter (time or cost) increases, the probability that a person would choose that mode (auto or transit) decreases. The larger the negative value for a coefficient, the greater its impact on the affected mode. A review of a range of values shows that the coefficient values change from city to city and apparently change over time, and these changes in the coefficients can have significant impacts on the results of modal choices.

Table 1 presents the ranges of values for all cities and shows the average coefficient values by city size and over time. The average values in this table demonstrate some trends that transportation planners rely on, such as the following:

- Walk time is twice as onerous as in-vehicle travel time.

- Wait time is more onerous than walk time.

- Approximately three cents of parking cost is equal to one minute of in-vehicle travel time, which translates to an average rate of only $1.80 per hour.

- Transit fares are less onerous than parking cost.

The city-specific and overall average coefficient values supplied with the COMMUTER Model were updated for COMMUTER release version 2.0 (2005). This update included a review of current modeling practice in various metropolitan areas to identify the most

Table 1 Range of Coefficient Values

Range of Values	In-Vehicle (minutes)	Walk Time (minutes)	Transit Wait Time (minutes)	Auto Parking Cost (cents)	Transit Fare (cents)
Minimum	-0.0450	-0.0931	-0.0978	-0.0173	-0.0135
Maximum	-0.0113	-0.0186	-0.0155	-0.0004	-0.0004
Overall Average	-0.0253	-0.0473	-0.0466	-0.0056	-0.0040

recent model coefficients, and removal of all coefficients that were more than 20 years old (i.e., developed prior to 1986). Following this review, coefficients were compared among metropolitan area size class. Unlike in the review of coefficients for COMMUTER version 1.0, however, no statistically significant differences by size class were identified. Also, trends in coefficients over time were evaluated; again, however, no statistically significant basis was identified for establishing a clear time-trend for the coefficients.

The ranges shown in Table 1 exclude a handful of outliers that lay substantially out of the range expected for these types of coefficients.

Examples

The values of the coefficients can best be described with examples, as shown in Table 2. The first example shows the impacts of improved transit service by itself. The second example shows the impacts of improved transit service combined with an additional charge for parking. These examples present the type of sensitivity analysis that some regional agencies conduct to compare the effects of variables both individually and in combination. The size of the coefficient affects the impact of the variable on the mode share, but only in context with the pivot-point logit model equation. One description of this approach can be found in "Modeling Transport" by J. de D. Ortuzar and L.G. Willumsen (Wiley Publishers, 1990), page 302.

Table 2 Examples of Sensitivity Testing of Coefficient Values

Example #1: Reduced Transit Travel Time								
	Travel Time (min.)				Cost (cents)			
	Auto in-vehicle	Transit in-vehicle	Transit Walk	Transit Wait	Auto	Transit		
Original	20	40	10	10	100	150		
Improved	20	35	10	10	100	150		
Difference	0	-5	0	0	0	0		
							New Mode Shares:	
Utility Change							Auto	Transit
City 1		0.082					89.2%	10.8%
City 2		0.126					88.8%	11.2%
City 3		0.171					88.4%	11.6%
Example #2: Reduced Transit Travel Time + Increased Parking Cost								
	Travel Time (min.)				Cost (cents)			
	Auto in-vehicle	Transit in-vehicle	Transit Walk	Transit Wait	Auto	Transit		
Original	20	40	10	10	100	150		
Improved	20	35	10	10	150	150		
Difference	0	-5	0	0	50	0		
							New Mode Shares:	
Utility Change							Auto	Transit
City 1		0.082			-0.029		89.0%	11.0%
City 2		0.126			-0.281		85.7%	14.3%
City 3		0.171			-0.533		81.7%	18.3%

The calculations presented in Table 2 include default coefficients by population size input into the COMMUTER Model, and assume current mode shares of 90% auto and 10% transit. In the first example:

- Level of service (LOS) changes include improved transit service (five minutes faster in-vehicle travel time); and

- Computations indicate an expected increase in transit use from 10% to 11.0%, 11.1%, and 11.3% for small, medium, and large size metropolitan areas, respectively.

In the second example:

- LOS changes include improved transit service (five minutes faster in-vehicle travel time) combined with a parking cost increase from \$1.00 to \$1.50.

- The computations show an expected increase in transit use from 10% to 14.6%, 15.2%, and 16.9% for small, medium, and large size metropolitan areas, respectively. The greater shift to transit in Example #2 illustrates the combined effect of the service changes.

Each coefficient, when multiplied by the corresponding change in LOS, indicates a change in "utility" for the mode. Utility is a relative measure of attractiveness; essentially, the coefficients are converting changes in different units (minutes, cents, etc.) into similar terms so they can be directly compared. Larger coefficient values on variables with the same units indicate a higher value on that variable. For example, as shown in the Table 1 coefficients, out-of-vehicle travel time is valued more highly than in-vehicle travel time (people dislike to wait). The utility changes from each LOS component are then combined to determine an overall change in mode share using the logit model equation.

The underlying computations are shown below for Example #1 with a small metropolitan area.

Utility change: ΔU = Coefficient × Change in LOS

Transit utility change: $\Delta U_{Trans} = (-0.207) * (-5) = 0.103$

New transit mode share:

$$P'_{Trans} = \frac{P_{Trans} \times e^{\Delta U_{Trans}}}{(P_{Auto} \times e^{\Delta U_{Auto}}) + (P_{Trans} \times e^{\Delta U_{Trans}})} = \frac{0.10 \times e^{0.103}}{(0.90 \times e^{0}) + (0.10 \times e^{0.103})} = 11.0\%$$

where

P'_{Trans} = new transit mode share
P_{Trans} = base (existing) transit mode share
P_{Auto} = base auto mode share
ΔU_{Trans} = transit utility change
ΔU_{Auto} = auto utility change

Area-Specific Coefficients

Table 3 shows the area-specific coefficients provided with the COMMUTER Model. In most cases, these coefficients were obtained from travel model documentation or personal communication with travel demand forecasters in each area. For COMMUTER version 2.0, forecasting staff in the 10 largest metropolitan areas of the country were contacted in December 2004 to identify the most recently available coefficients. In addition, updated coefficients were obtained through available documentation from other metropolitan areas. Special effort was made to update older coefficient values; values based on data from before 1986 were discarded in COMMUTER version 2.0.

For some areas, model coefficients were provided for specific categories (e.g., by mode or by income level). In these cases, coefficients had to be combined for consistency with the coefficient categories used in COMMUTER. Coefficients were combined in the following ways:
In-Vehicle Travel Time – For areas with different auto and transit in-vehicle travel time coefficients, a combined IVTT coefficient was developed by weighting the mode-specific coefficients by commute mode share from the 2000 U.S. Census. This was done for the following cities:

- Dallas
- Detroit
- Philadelphia
- Seattle

Transit Wait Time – For areas where transit time coefficients are split between less than 7 minutes and greater than 7 minutes, the transit time coefficient for greater than 7 minutes was used. This is because the transit time coefficient for less than 7 minutes is a 2 to 3 times the transit time coefficient for greater than 7 minutes. The reason for this is that it is anticipated that for headways of over 15 minutes, a traveler will attempt to "schedule" his or her arrival at the transit stop and therefore the wait is less onerous. This was done for the following cities :

- Atlanta
- Denver
- San Diego
- Tucson

Transit Fare – For areas where the transit fare was calculated based on income, a combined transit fare coefficient was developed by weighting the income specific coefficients by income shares reported in the household survey. This was done for the following city:

- Denver

Also, a handful of coefficients either were unavailable for specific models, or were removed because their values lay outside the expected range for such coefficients. In cases in which coefficients were unavailable or removed, substitute values were inserted based on other coefficients in the area's model, using the ratio of two different categories based on an average ratio of coefficients across other cities. For example, in Los Angeles, the substitute walk time coefficient shown in Table 3 (-0.1073) is equal to the Los Angeles in-vehicle travel time coefficient times the average ratio of in-vehicle travel time to walk time coefficients calculated across other cities in the dataset (2.38). Cost coefficients were substitute based on an average value of time computed at $5.79 per hour. The following substitute coefficients are included in Table 3:

- Los Angeles – Walk Time
- Sacramento, Tucson – Auto Parking and Transit Fare
- San Diego – Transit Fare

Substitute coefficients were not included in the calculation of average coefficient values. Also, the Baltimore coefficients were not included because they are taken from the travel demand model for the Washington, D.C. area which is already included in the dataset.

Table 3 Area-Specific Coefficients

		In-Vehicle Travel Time (min)	Out-of-Vehicle Travel Time (min)		Out-of-Pocket Travel Cost (cents)	
Location	**Year**	**All Modes**	**Walk Time**	**Transit -- Wait**	**Auto - Parking**	**Transit - Fare**
Albuquerque	1992	-0.0209	-0.0219	-0.0978	-0.0031	-0.0031
Atlanta	2002	-0.0256	-0.0639	-0.0256	-0.0031	-0.0013
Baltimore	1993	-0.0300	-0.0750	-0.0750	-0.0043	-0.0043
Boston	1991	-0.0314	-0.0330	-0.0550	-0.0173	-0.0083
Chicago	1990	-0.0282	-0.0440	-0.0960	-0.0021	-0.0008
Cleveland	1994	-0.0178	-0.0444	-0.0378	-0.0034	-0.0024
Columbus	1999	-0.0213	-0.0640	-0.0465	-0.0016	-0.0016
Dallas	1996	-0.0544	-0.0640	-0.0640	-0.0056	-0.0055
Denver	1997	-0.0180	-0.0540	-0.0180	-0.0014	-0.0012
Detroit	1996	-0.0512	-0.0186	-0.0186	-0.0041	-0.0041
Houston	1985	-0.0220	-0.0568	-0.0568	-0.0154	-0.0061
Los Angeles	1996	-0.0450	-0.1073	-0.0423	-0.0025	-0.0025
Milwaukee	1991	-0.0157	-0.0412	-0.0412	-0.0045	-0.0045
New York	1996	-0.0113	-0.0380	-0.0554	-0.0004	-0.0004
Philadelphia	1986	-0.0391	-0.0316	-0.0511	-0.0026	-0.0012
Phoenix	1991	-0.0167	-0.0206	-0.0304	-0.0053	-0.0053
Portland	1994	-0.0394	-0.0646	-0.0397	-0.0135	-0.0135
Reno	1991	-0.0275	-0.0550	-0.0550	-0.0167	-0.0067
Sacramento	2001	-0.0250	-0.0380	-0.0380	-0.0025	-0.0025
San Diego	1995	-0.0250	-0.0500	-0.0250	-0.0069	-0.0025
San Francisco	1990	-0.0333	-0.0931	-0.0523	-0.0021	-0.0021
San Juan	1990	-0.0366	-0.0717	-0.0752	-0.0066	-0.0066
Santa Cruz	1990	-0.0163	-0.0325	-0.0325	-0.0045	-0.0036
Seattle	1990	-0.0176	-0.0206	-0.0155	-0.0024	-0.0024
Tucson	2000	-0.0178	-0.0400	-0.0200	-0.0018	-0.0018
Washington D.C.	1994	-0.0300	-0.0750	-0.0750	-0.0043	-0.0043

Documentation of Sources

Model documentation – Coefficients for the following cities were obtained from model documentation (date after city indicates year of source data):

- Atlanta (2002) - Atlanta Regional Commission, Mobility 2030 : Model Documentation, December 2004.
- Baltimore (1993) - Metropolitan Washington Council of Governments, COG/TPB Travel Forecasting Model Version 2.1 D #50 Calibration Report, November 17, 2004.
- Columbus (1999) - PB Consult / Parsons Brinckerhoff for the Mid-Ohio Regional Planning Commission, The MORPC Travel Demand Model: Validation and Final Report, December 17, 2004.
- Dallas (1996) - Cambridge Systematics for the North Central Texas Council of Governments, NCTCOG Mode Choice Model, August 2002.
- Los Angeles (1996) - Cambridge Systematics, Inc., SCAG Regional Mode Choice Model Development Project, Final Report, October 28, 1996.
- Milwaukee (1991) - Southeastern Wisconsin Regional Planning Commission, Travel Simulation Models for the Milwaukee East-West Corridor Transit Study, May 1993.
- New York (1996) – Parsons Brinckerhoff Quade & Douglas with Cambridge Systematics and others for New York Metropolitan Transportation Council, Transportation Models and Data Initiative : Technical Memorandum Task 14.15 &16 / Milestone C Best Practice Model Development – Travel Details: Pre-Mode, Mode Choice, and Stops Model and Travel Patterns: Journey Frequency and Destination Choice, August 2001.
- Portland (1994) - Metro, The Phase III Travel Demand Forecasting Model: A Summary of Inputs, Algorithms, and Coefficients, June 1, 1994.
- Sacramento (2001) - DKS Associates for Sacramento Area Council of Governments, Model Update Report, Sacramento Regional Travel Demand Model, Version 2001 (SACMET 01), March 8, 2002.
- San Francisco (1990) - Metropolitan Transportation Commission, Travel Demand Models for the San Francisco Bay Area (BAYCAST-90) Technical Summary, June 1997.
- Seattle (1990) - Cambridge Systematics, Inc. with Urban Analytics for Puget Sound Regional Council, Land Use and Travel Demand Forecasting Models : New Model Documentation, June 30, 2001.
- Tucson (2000) - Cambridge Systematics, Inc. for Pima Association of Governments, PAG Model Evaluation and Improvement Plan : Travel Demand Forecasting Model, August 2003.
- Washington D.C. (1994) - Metropolitan Washington Council of Governments, COG/TPB Travel Forecasting Model Version 2.1 D #50 Calibration Report, November 17, 2004.

Personal Communication - Many of the coefficients were obtained directly from the consultant travel demand modelers responsible for regional model estimation. These metropolitan areas included the most recent model updates conducted in the following:

- Cleveland (1994);
- Denver (1997);
- Detroit (1996);
- Phoenix (1991);
- Reno (1991).
- San Diego (1995);
- Santa Cruz, California (1990).

Previous Model – The following coefficients were taken from COMMUTER Model Version 1.0:

- Albuquerque (1992);
- Boston (1991);
- Chicago (1990);
- Phoenix (1991); and
- San Juan (1990).

Summary

The COMMUTER Model will be a more powerful tool to the user if the impacts of the coefficients are understood. The best means to achieve this understanding is to use sensitivity testing similar to that presented in this discussion. This will serve to indicate the general impacts to changes in cost or time variables as well as to identify that the model and data are being applied correctly.