Systematic Validation of the Denver Activity Based Model – Preliminary Results and Guidance for Future Practitioners

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Introduction

This paper describes the systematic validation process for the new activity based model system, the Integrated Regional Model (IRM), being developed by the Denver Regional Council of Governments (DRCOG) for the Denver metropolitan area. Model estimation and application software have been completed and the first steps of an extensive model calibration and validation process have been initiated. In addition to traditional validation tests, the IRM model validation includes model sensitivity and temporal validation tests. Currently available, preliminary, results are shown for several model components to demonstrate the types of validation tests being performed. Final validation results for all model components will be available in March 2010.

Background on Model Validation and Sensitivity Testing

Many of the innovations and improvements made to the traditional four-step travel modeling process over the past two decades have been made incrementally and subjected to either formal or informal validation and sensitivity tests. Formal validation tests were normally applied at the end of the model calibration process and, quite frequently, focused on the "super test" – the concept that reproduction of observed traffic volumes and transit boardings at some reasonable level of aggregation somehow showed that the models were, in fact, valid. Informal validation and sensitivity tests, unfortunately, too often consisted of discovering modeling problems after illogical travel forecasts were produced.

In 1997, the Federal Highway Administration's (FHWA) Travel Model Improvement Program (TMIP) published the *Model Validation and Reasonableness Checking Manual*.[1] This manual focused on the validation of the individual four-step model components as well as the traditional overall model system validation focused on traffic volumes and transit boardings. In contrast to trip-based models, the design and increased detail of activity-based models such as the IRM provide greatly enhanced opportunities and challenges for the validation and sensitivity testing process:

[1] *Model Validation and Reasonableness Checking Manual*, Travel Model Improvement Program, Federal Highway Administration, February 1997.

- The activity-based model design[2] makes use of many of the most recent developments in activity-based model theory in order to provide better representation of the activity/travel decision making process and provide sensitivity to a wider range of future travel options and constraints. The increased detail of the activity-based model carries the price tag of an increased number of places where the models can fail.
- The focus of the activity-based model has changed from capturing travel patterns (the focus of traditional trip-based models) to capturing patterns of travel behavior. This paradigm shift forces an extension of the traditional validation process, requiring the development of new validation criteria and approaches only partly guided by the field's 40-50 years of experience working with trip-based models.

An example of a new approach is the decision to estimate the IRM using the DRCOG 1997 Travel Behavior Inventory (TBI) data but calibrate the model to reproduce 2005 travel patterns. Year 2005 travel patterns reflect an "equilibrium" situation after the opening of a major transportation improvement, the Southwest Light Rail line (opened July 2000). This procedure should provide more reliable models for forecasting. Formal temporal sensitivity testing will be accomplished by comparing 1997 travel behavior and patterns backcast using the calibrated model with observed 1997 travel patterns and behavior.

The IRM validation plan[3] generally defines validation and sensitivity tests as:

- *Disaggregate validation* tests focus on the reasonability of model parameters and the ability of the models to reproduce behavior of individuals – in effect, the ability of the models to *capture patterns of traveler behavior*. *Aggregate validation* tests focus on the ability of the models to reproduce *general travel patterns*. These validation tests are more traditional and focus on internal consistency tests and tests against independent observed data.
- *Sensitivity tests* focus on the reasonableness of the model response to changes in socioeconomic conditions, transportation networks and alternatives, changes in congestion, changes in pricing, etc. Three primary types of sensitivity tests may be performed: model component sensitivities, temporal sensitivity tests, and scenario sensitivity tests.

Custom application software has been written to implement the choice components of the IRM (with conventional modeling software handling networks, skimming and assignment). Figure 1 shows the structure of the new model system. A key design component was the decision to maintain all person information in a single database accessible by each of the individual model components. As the model components are applied, each individual in the region "gains" additional information such as their regular work or school locations, autos owned by the household in which they live, daily activities performed and the numbers of tours resulting from those activities, tour destinations, etc.

The database can be easily accessed and queried at any point in the modeling process. This design allows for tremendous flexibility in validation and sensitivity testing not available with traditional models. For example, rather than validating home-based work (HBW) trip

[2] DRCOG Model Design Plan, Draft 2b-R, Technical Memorandum submitted to DRCOG by Cambridge Systematics, Inc., January 2007.

[3] DRCOG IRM Validation Plan Memorandum - Draft 2a.doc, Technical Memorandum submitted to DRCOG by Parsons Transportation Group, September 2007.

distribution by comparing average trip lengths and trip length frequency distributions, the average distances to regular work locations can be compared for full-time and part-time workers, for teens and adults, for workers in zero-auto households and multi-auto households, etc.

The key themes of the tests presented in the remainder of this paper are the detail and flexibility of the model results that can be summarized in the validation and sensitivity testing process. This detail allows for increased understanding of travel behavior in the region and should lead to better model designs and better model calibrations.[4] In effect, the detail and design allow for the surgical adjustment of travel models as opposed to the heavy-handed approaches, such as k-factors, used for traditional trip-based models.

Validation and Sensitivity Tests for Selected Model Components

Regular workplace location choice

The regular workplace location choice model is the first model component executed after the generation of a synthetic population for the region. The regular workplace location choice for workers is based on socioeconomic and demographic characteristics of the worker as well as accessibility to work locations and the type of employment available at those locations. Regular workplace location choice is analogous to HBW trip distribution in traditional trip-based models although it is a closer analogue to Census Transportation Planning Package (CTPP) outputs than trip-based HBW tables. The model can be validated using many of the same tests including comparisons of average modeled home-to-work distance and distance frequency distributions and comparisons of district-to-district home-to-work patterns to observed results.

Figure 2 shows histograms of the modeled straight-line distance between the home and work locations for 2005 and the observed data from the 1997 TBI. As can be seen in Figure 2, the 2005 frequency distribution is similar to the 1997 observed distribution. The 2005 average distance from home to work is slightly greater than the 1997 observed distance as might be expected in a growing area.

With trip-based models, detailed analyses of trip distribution results may lead to the use of aggregate adjustments such as k-factors to improve the distribution. With activity-based models, the tie between individual characteristics and travel characteristics, such as those presented in Table 2, might permit more behaviorally-based adjustments in order to avoid aggregate adjustments.

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[4] The results presented are for model components "out-of-the-box" with no calibration of model constants to match aggregate data. In some cases, there has been some model calibration resulting from re-estimation of model coefficients. The models were originally estimated using 1997 TBI data and then applied using 2005 data. If the application of a specific model component using 2005 data showed anomalous results, alternative model specifications were developed, the model coefficients were re-estimated using the 1997 TBI data, and the models were reapplied for 2005 using the alternative coefficients. If the model revision produced better results for 2005, the model structure and coefficients were adopted.

School location choice

The regular school location choice model functions much like the regular work location choice model, identifying the school choices of students in pre-school, K-8, high school, and university. Regional data show a total of 1,040 schools in 2005 with a total enrollment of 644,778 students (compared to the population synthesizer's estimate of 674,545 students.) The R^2 comparing modeled attendees to reported enrollment at the schools for 2005 was 0.97 and the %RMSE was 47 percent. These results are reasonable considering that they were based on models "directly out-of-the-box" with no model calibration. However, the modeled straight line distances from home locations to regular school locations suggest that model calibration or modification may improve the R^2 and %RMSE results. Specifically, in comparison to data reported in the 1997 TBI, modeled distances from home to regular school location are underestimated for pre-school and K-8 students by 17 and 13 percent, respectively, while modeled distances are overestimated by 22 percent for high school students, and 250 percent for university students (9.5 miles versus 2.7 miles).

Daily activity pattern/exact number of tours

Figure 3 summarizes initial results from the daily activity pattern/exact number of tours models. The initial results show that the model estimates too many people making one tour and too few making no tours. Additional checks have been performed or are planned, including:

- Comparison of average modeled number of tours by purpose by person type to results from household survey data set. Person types include full time worker, part time worker, adult non worker under age 65, retired non worker, university student, driving age high school student, child age 5-15, and child under age 5. Tour purposes include work, school, serve passenger, personal business, shopping, meal, and social/recreation.
- Comparison of average modeled number of work-based subtours by person type to results from household survey data set.
- Comparison of average modeled number of stops per tour by purpose to results from household survey data set.

Tour destination choice

Table 2 shows the initial average tour lengths for the 2005 model versus the 1997 TBI data. The results suggest that additional model calibration efforts are needed for the tour destination choice model, though this need may be reduced as models applied prior to the application of the tour destination choice model are calibrated. Additional validation tests are planned, including:

- Comparison of modeled tour length (home to primary activity location) frequency by purpose to results from household survey data set. Checks are being performed regionally and by market segment such as income level.
- Comparison of modeled district-to-district tour interchanges to expanded observed tour interchanges

Remaining model components

Initial results at this stage also appear reasonable for the tour mode choice, tour time of day, and intermediate stop generation models. The detailed model validation plan, which focuses on individual model components as well as overall model validation, is scheduled for completion by April 2010.

Conclusions

The design of the IRM coupled with the initial planning for model validation and the design of the implementation software and IRM database have formed the basis for a robust validation of the IRM. Detailed validation tests of sub-populations of the region, not possible with aggregate, trip-based models, can be easily performed. This will lead to improved understandings of the traveler behavior represented by the model and the sensitivity of the model to different socioeconomic, transportation system, transportation policy changes.

Initial validation tests of the IRM model components have been very encouraging. The tests show reasonable matches of the modeled travel behavior to observed behavior even without calibration of model constants and adjustments of the models.

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Figure 1. Model Process Flow Chart

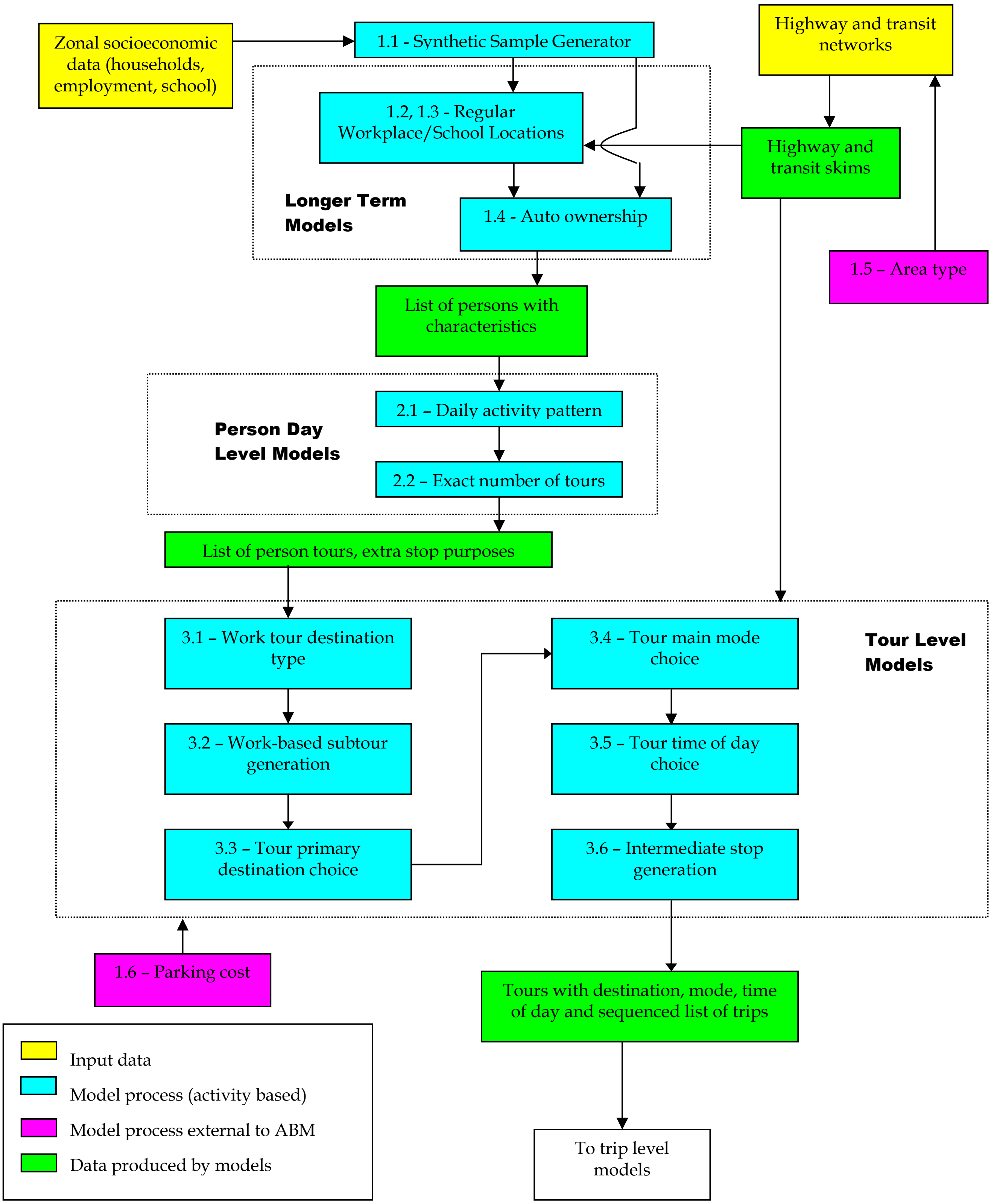

Figure 1. Model Process Flow Chart (continued)

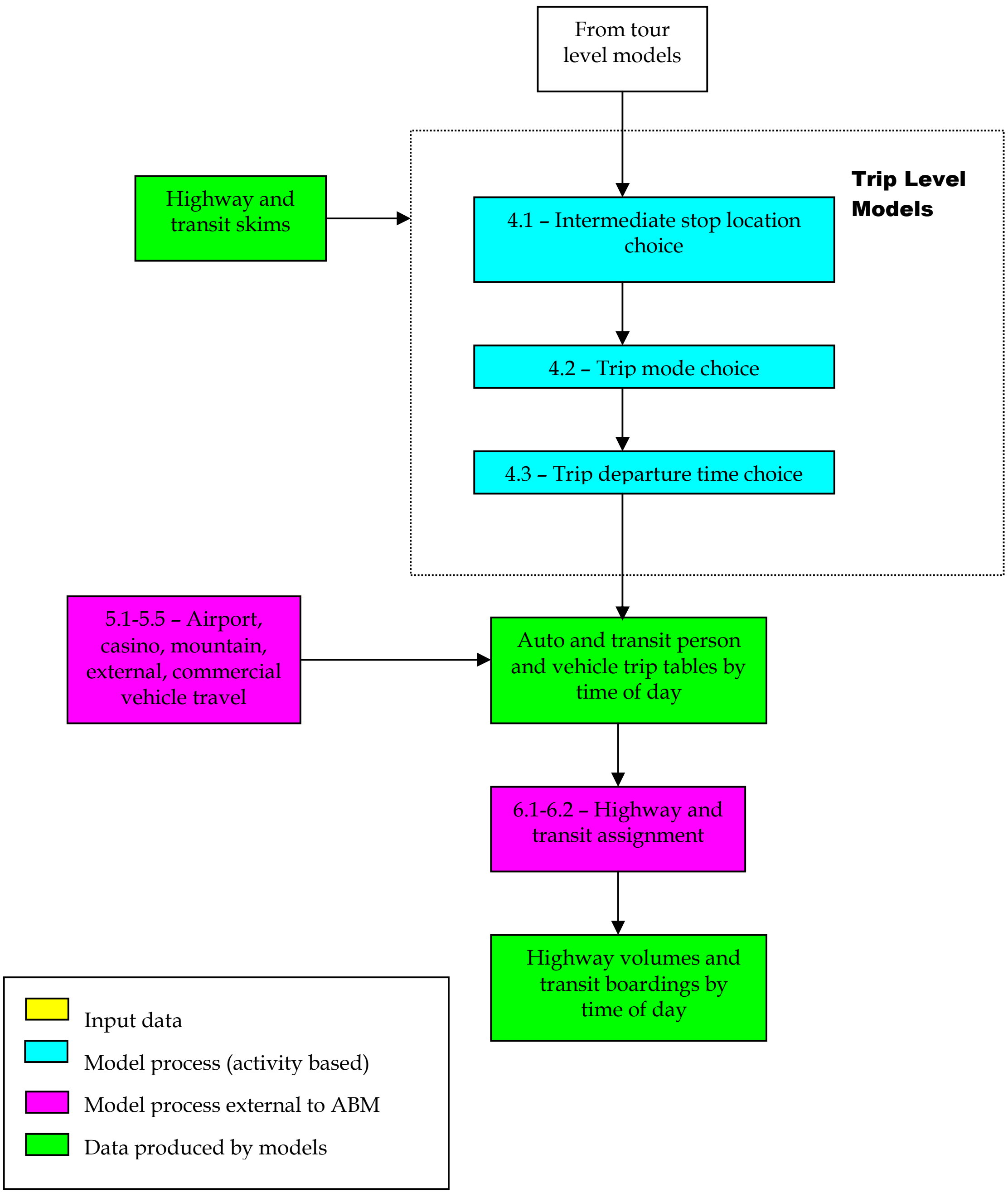

Figure 2. Percent of Workers by Straight Line Distance From Home to Regular Workplace (where Work is Outside the Home)

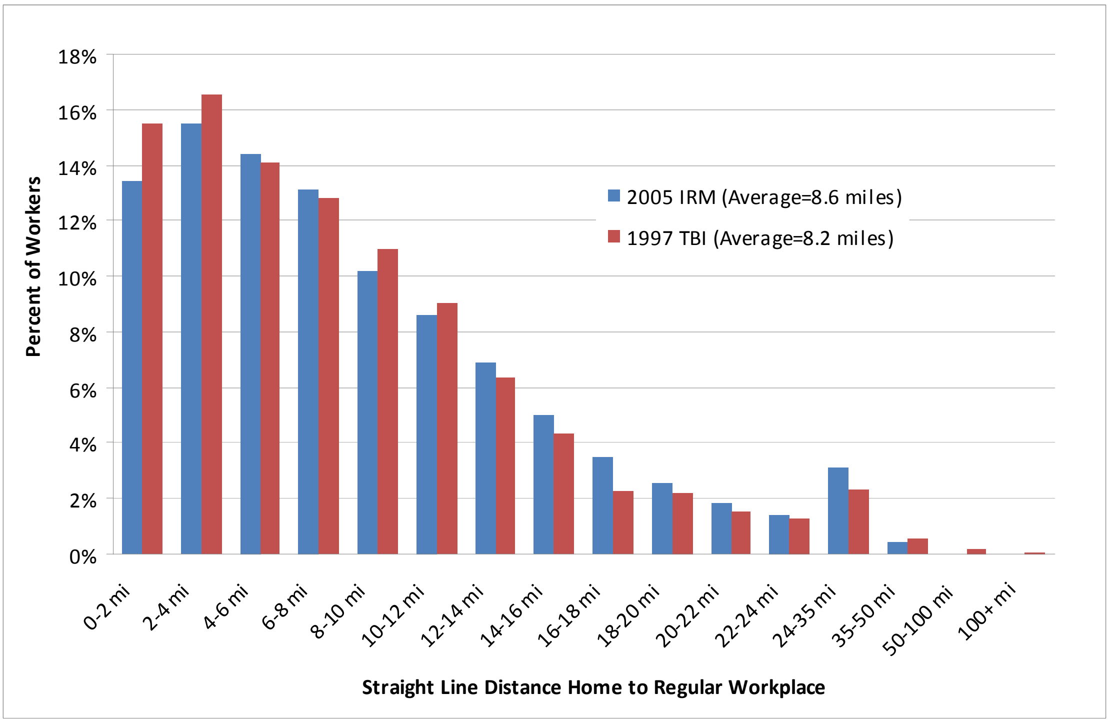

Figure 3. Number of Home-Based Tours by Percent of Persons

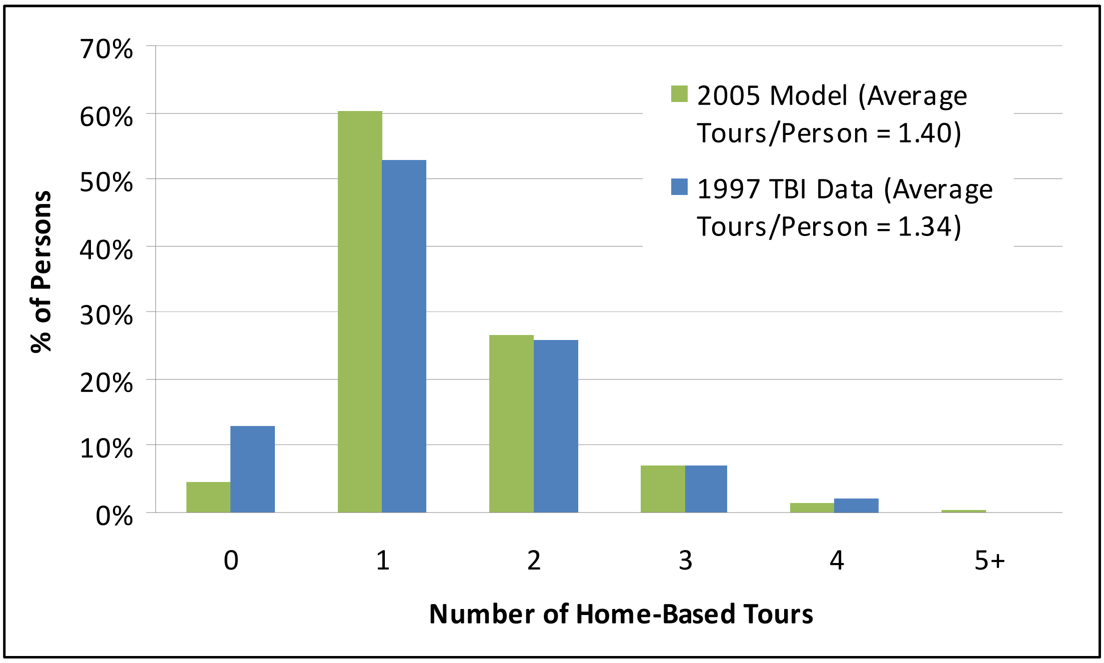

Table 1. Average Straight-Line Distance from Home to Regular Workplace for Selected Population Subgroups

Subgroup	2005 IRM Modeled Distance (Miles)	1997 TBI Observed Distance (Miles)	Difference (Miles)	Percent Difference
Women	8.0	7.4	0.6	8%
Men	9.1	8.9	0.2	2%
Women with Children Under 5	7.7	7.3	0.4	5%
Women with No Children Under 5	8.0	8.0	0.0	0%
Full Time Worker	9.3	8.7	0.6	6%
Part Time Worker	6.2	5.7	0.5	8%
Household Income < $35 K	7.1	6.3	0.8	13%
Household Income $35-$100K	8.7	8.6	0.1	1%
Household Income > $100K	9.4	8.9	0.5	6%
Age Under 20	5.3	4.7	0.6	13%
Age Over 20	8.8	8.3	0.5	6%
All Workers	8.6	8.2	0.4	5%

Table 2. Average Home-Based Tour Distance by Tour Type

Tour Type	Average Distance in Miles			Percent Difference
	Modeled	Observed	Difference	
Work	8.8	8.0	0.8	10%
School	4.2	2.9	1.3	47%
Escort	6.4	3.1	3.2	103%
Personal Business	8.9	4.4	4.5	104%
Shop	8.7	3.4	5.3	156%
Meal	7.6	3.6	4.0	113%
Social Recreational	8.7	5.4	3.2	60%