A picture containing building

Description generated with high confidence

# Table of Contents

Chapter Page

1 Introduction 4

1.1 2004 Model 4

1.2 2012 Update 4

1.3 2014 Model 5

1.4 2017 Validation 6

2 Model Stability 8

2.1 Random Numbers 8

2.2 Sorted Probabilities 9

3 Survey Validation 11

3.1 Tour Frequency 11

3.2 Destination Choice 14

3.3 Number of Intermediate Stops 16

3.4 Intermediate Stop Locations 22

3.5 Initial Time of Day 25

4 Regional Validation 29

4.1 Tour Frequency 30

4.2 Destination Choice 32

4.3 Number of Intermediate Stops 36

4.4 Intermediate Stop Locations 38

4.5 Initial Time of Day 38

5 Assignment Validation 40

6 Next Steps 42

List of Tables Page

2-1 Results of Changing Random Seeds 10

3-1 Results of Initial TF Model Adjustment 12

3-2 Modified TF Models 13

3-3 Modified DC Models 15

3-4 Results of Initial DC Model Adjustment 17

3-5 Modified IS Models 18

3-6 Results of IS Model Adjustment 22

3-7 Detour Time Coefficient Adjustment 23

3-8 Results of SL Model Adjustment 24

3-9 Final SL Models 25

3-10 Final ToD Models 26

3-11 Results of Initial ToD Model Adjustment 29

4-1 Demographic Totals for 2015 30

4-2 Results of TF Model for 2015 31

4-3 DC Average Tour Lengths for 2015 35

4-4 Intermediate Stop Comparison 37

4-5 Comparison of Total Tour Time 38

4-6 Comaprison of Initial Time of Day 39

5-1 Highway Assignment Comparisons 41

List of Figures Page

3-1 HBW Tour Length Frequency Distribution 17

4-1 HBW TLFDs 32

4-2 SCH TLFDs 32

4-3 HBU TLFDs 33

4-4 HBS TLFDs 33

4-5 HBO TLFDs 34

4-6 ATW TLFDs 34

4-7 I/X TLFDs 35

4-8 Modified Attractiveness Function 37

# 1 Introduction

1.1 2004 Model

The Charlotte Department of Transportation (CDOT) serves as the lead agency in developing and operating the travel demand models for the Charlotte metropolitan region. CDOT developed the region’s adopted travel demand model in 2002 to support development of the Mecklenburg-Union Metropolitan Planning Organization’s (MUMPO) 2025 Long-Range Transportation Plan. In 2003, that model was used in planning for a light-rail transit system for the region, in connection with the New Starts process of the Federal Transit Administration.

In 2003, it became clear that because of growth in the region, expansion of the area included in air quality conformity analysis, and efficiencies of scale, that a new model should be developed to serve not only MUMPO but the other MPOs in the region: Cabarrus Rowan Metropolitan Planning Organization, Gaston Urban Area Metropolitan Planning Organization, and Rock Hill-Fort Mill Area Transportation Study. In addition, the increasingly stringent FTA requirements for the New Starts program suggested a number of enhancements to the “MUMPO model”.

In 2003, CDOT staff began the process of expanding the model’s data to cover all of Cabarrus, Gaston, Lincoln, Mecklenburg, Rowan, Stanly, Union, and York Counties and parts of Cleveland and Iredell Counties. This included revised highway and transit networks, zone-level socioeconomic data, and external trip totals on the expanded cordon. The work also used a home interview survey conducted in 2002. In addition, three consultants were retained to assist CDOT in developing the new model.

That work was completed in 2004 with a new model set that was based on the recent home interview survey and Census data and validated to year 2000 conditions. This included completely new trip generation, distribution, and time of day models, an updated mode choice model, and new assignment post-processing and reporting modules to estimate various impacts, including mobile source emissions. The calibration of this model is described in a separate document, *Metrolina Regional Travel Demand Model, Technical Documentation*.

1.2 2012 Update

In 2012, CDOT conducted another home interview study and retained the same consultant to use that survey to update the trip generation, trip distribution, and time of day models. The overall structure of those models was retained, but the coefficients and parameters were revised to reflect the new survey data. That work is documented in the reports *Travel Model Recalibration 2013* (12 December 2013), *User’s Guide for the Metrolina Travel Forecasting Model Trip Generation Program 2013* (27 November 2013), and *User’s Guide for the Metrolina Travel Forecasting Model Trip Distribution Program* 2013 (29 November 2013).

1.3 2014 Model

In recent years, a new approach to travel modelling has emerged and is being implemented by several larger MPOs: *activity-based modelling* (ABM). In this process, the principal unit of travel is the *round-trip tour*. Travel is no longer estimated as an aggregate total of zone-zone trips but instead, the travel activity of each person in the region is modelled in disaggregate fashion. In this approach, the model represents travel in a more realistic manner. In addition, a wider variety of household and personal characteristics are available throughout the model and can thus be used to appropriately influence nearly every travel choice. Replacing zonal averages with individual characteristics should improve model accuracy and sensitivity. Such models are also said to be more responsive to a wider array of transportation policy changes. New York, Atlanta, and San Francisco are examples of urban areas that have used this approach and several other large areas either presently have such models in development or are actively investigating the concept.

However, this new approach is not without its drawbacks. ABMs are *extremely* complex, because they are representing a set of travel relationships that could not be considered in prior trip-based models. The calibration of such models usually takes several years and budgets of around $1,000,000. The running time of most ABMs is measured in days and usually requires expensive, high-end computing resources. Also, some have argued that ABMs cannot be developed with a conventional home interview travel survey, but instead require a more detailed and intricate survey effort, to obtain information on the full range of respondents’ daily activities, both in-home and away from home. The application of ABMs requires extensive new software development, resulting in application code that is adequately understood by only a very few people.

In order to address these concerns, this study’s consultant has developed a different approach, called *simplified tour-based modelling*. This process bridges the gap between current aggregate trip-based models and true ABMs. This approach shares some common elements with ABMs: it treats travel in terms of individual tours, based on a synthesized set of households. But the simplified approach does not consider all of the complex relationships that are part of a typical ABM. It is less theoretically ambitious than an ABM but still represents an improvement over trip-based models in how travel is represented. Compared to an ABM, the new approach is much easier to understand, the application programs run much faster, the development time and cost are considerably less, and a special survey is not required. This simplified approach was implemented in 2010 in Brunswick, GA and was also used for tour-based truck models for Atlanta and Birmingham in 2014. After considerable deliberation, CDOT staff selected this simplified tour-based approach for its new model.

Certain on-going projects in the Charlotte region rely on the outputs of the current trip-based mode choice model. In order not to disrupt the progress of those projects (and in consideration of budget limitations), CDOT chose to implement a partial version of the tour-based approach to start with. Only the estimation of person tours is being pursued at this time. The person tours by major period (peak, off-peak) are then converted into conventional trips, which can then be input to the existing trip-based mode choice process in order to complete the model chain. CDOT will consider development of a complete tour-based process including mode choice, at a later time.

The initial development of this new model was completed in 2014. The model structure was developed and the variables and coefficients for each model were estimated. A preliminary version of the model application code was written in GISDK by Metrolina staff. However, due to limitations on budget and staff time, further development, testing, and validation steps were suspended in late 2014.

1.4 2017 Validation

In 2017, CDOT engaged Citilabs and CDM Smith to complete the model validation and review the application code. The present report documents that effort, which was completed in December 2018. The remaining chapters are as follows:

Chapter 2 Model Stability

A review of the effect of using random numbers in model application and of sorting the probabilities of the choices.

Chapter 3 Survey Validation

Results from applying the estimated model to the 2012 survey records and the resulting adjustments.

Chapter 4 Regional Validation

Results from applying the adjusted model to the 2015 regional data.

Chapter 5 Assignment Validation

Results from the 2015 highway assignment comparison.

Chapter 6 Next Steps

Recommendations for future tasks.

# 2 Model Stability

2.1 Random Numbers

Every discrete travel model uses the Monte Carlo technique of estimating the choices made by each traveller. In this method, a random number is generated for each tour for each choice and then compared to a table of cumulative probabilities in order to select one choice from a set of alternatives. Even with this random component, it is possible for the results of each model run to have a certain level of stability. In this context, *stability* means that any significant aggregate difference in results between runs is due to changes in the inputs and not to the model itself.

Therefore one vital feature of the application code is that for each step, the generated sequence of random numbers should begin with a fixed seed. The *seed* is a value used by the software’s algorithm to generate a particular sequence of numbers. In the survey validation exercise, some of the model steps were combined in the same script. For example, consider the Intermediate Stop model. This model estimates the number of intermediate stops by half-tour. There are two separate models: one for the home to non-home (“P-A”) direction and one for the non-home to home (“A-P”) direction. During testing, it was discovered that the results for the P-A direction were influencing the results for the A-P direction in ways that were due entirely to the random number generation process. Although the effect on the aggregate regional output was small, this outcome was judged to be inappropriate.

The solution was to split up the model application scripts so that each half-tour was estimated using a separate script. This ensured that each model would begin with its own set of random numbers, unaffected by the particular sequence of numbers for any other step. The random number seed was set at the arbitrary value of 100 for all steps, for all models, purposes, and directions. This results in exactly the same sequence of random numbers being used for each model. During subsequent testing, the tour frequency model was run using different seed values and the results are shown in Table 2-1. As these figures show, at the regional level there is almost no difference in tour generation. However, the seed does have a noticeable difference at the level of the individual household. Therefore, regardless of the seed value used, it is important that the seed value for a particular step not be changed between successive model runs examining different scenarios.

**Table 2-1 Results of Changing Random Seeds**



An interesting feature of discrete models is that it is possible to remove the random number seeds entirely. In this case, the software determines a seed for each run of each script, usually as a function of the computer’s system clock. This ensures that each step will use a different set of random numbers and that the overall results will be different for each run. The value of this is that the user could run the model a number of times with the same inputs. The outputs will be slightly different for each run, which produces a range that indicates a presumably realistic variability of travel results, as happens in the real world from day to day. This can be used to establish confidence limits on the results of each model and of the entire model chain, which would be useful in certain situations.

2.2 Sorted Probabilities

Each component of the model (except for the Household Synthesis step) uses a set of logit models that compute the probability of each alternative in a set of options for each choice. In the original model application script, these probabilities were sorted in ascending order before applying Monte Carlo. The consultant chose to include that sort because examination of the literature on discrete choice models suggested that it was necessary.

However, further examination of the models indicated that it is actually *not* necessary. In fact, one specific test suggested that it produced counterintuitive results. The consultant ran a test of the Tour Frequency model. The initial run used the base zonal socioeconomic data and a test scenario was devised in which the median income of all households in Gaston and Union Counties was increased by 50%. Note that only the HBO TF model is directly sensitive to HH income. The results of the HBO TF model were compared for the income-adjusted case vs. the original data. The results were that HHs all over the region saw changes in the number of estimated HBO tours. This did not seem intutively correct. Another test was then applied in which the probabilities of a HH making 0, 1, 2, 3+ HBO tours was not sorted. In that case, the effect of the income shift on tour-making was limited to Gaston and Union Counties, which is more intuitively correct.

As a result of this test, the consultant decided to remove the sort step from all of the models. This also has the positive side effect of reducing the model run time.

# 3 Survey Validation

In theory, if you estimate a model from a set of data and then apply the model to that same data, the model results should match the survey exactly, in the aggregate. However, in practice that seldom occurs. The survey represents only a small segment of the regional population (typically under 1%) and it is common that the results of applying the model to such a small sample will not produce the desired results for the region. This usually means that the bias coefficients must be adjusted slightly in order to produce the desired results. This exercise also is helpful in confirming the validity of the model application code.

3.1 Tour Frequency

For the TF model, the consultant checked the distribution of HHs by the number of tours and various HH attributes such as size, workers, area type, life cycle, income group, and county. The following metrics were established:

- hit rate (for what percentage of the HHs did the model estimate the same number of tours by purpose as actually occurred?)

- correlation (estimated vs. observed tours by purpose at the HH level)

- comparison of the regional average number of tours per HH for each level of attribute

The consultant examined the metrics for each purpose. The objective was to maximize the hit rate and correlation, and for the stratified average tours/HH to be more comparable, between the model and survey. Table 3-1 shows the results, stratified by HH size. The figures for the other stratifications (workers, area type, life cycle, income, county) are similar.

**Table 3-1 Results of Initial TF Model Adjustment**



Notes:

1. SCH tours are not estimated for 1-person HHs.
2. The difference for 1- and 2-person HHs is not considered relevant, since many of these are students and were not included in the survey.

As this data shows, the initially estimated model was a fairly close match to the survey, but there was some room for improvement. In most cases, a minor change to the bias coefficient was all that was required. In other cases, adding selected variables to the model resulted in a noticeable improvement. Table 3-2 shows the modified TF models.

**Table 3-2 Modified TF Models**

|  |  |  |
| --- | --- | --- |
| Purpose | Tours | Utility Equation |
| SCH | 0 | 0 |
|  | 1 | -7.417 + 5.345\*LC2DUM + 0.8065\*SIZE34DUM – 0.5759\*WKR3DUM + 0.7053\*AVGSIZE + 0.15\*INC1DUM - 1.9\*CBDDUM + 0.1\*AT2DUM + 2.4\*LC1DUM - 0.2\*SIZE2DUM + 0.50\*SIZE5DUM |
|  | 2+ | -9.370 + 5.796\*LC2DUM + 2.915\*SIZE45DUM – 1.556\*WKR3DUM + 0.7053\*AVGSIZE + 0.57\*INC1DUM - 8.0\*CBDDUM - 0.2\*AT2DUM + 1.1\*LC1DUM - 3.0\*SIZE2DUM + 0.35\*SIZE5DUM |
| HBU | 0 | 0 |
|  | 1+ | -5.796 + 1.040\*SIZE – 0.7481\*SCHTOURS - 1.0\*LC1DUM - 0.8\*INC1DUM + 0.08\*INC2DUM + 0.3\*CBDDUM + 0.1\*AT2DUM + 0.8\*SIZ3DUM - 0.3\*RURDUM + 0.25\*WKR0DUM + 0.25\*WKR3DUM |
| HBW | 0 | 0 |
|  | 1 | -3.541 – 0.6602\*LC1DUM – 0.3886\*INC1DUM + 2.543\*WORKERS + 0.1779\*SIZE345DUM[1] + 0.1346\*SCHTOURS[2] + 0.50\*INC1DUM + 1.0\*WKR1DUM - 1.1\*CBDDUM + 1.0\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
|  | 2+ | -8.002 – 0.6602\*LC1DUM – 0.3886\*INC1DUM + 4.809\*WORKERS + 0.1779\*SIZE345DUM[1] + 0.1346\*SCHTOURS[2] + 1.0\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
| HBS | 0 | 0 |
|  | 1 | -1.126 + 0.3866\*SIZE – 0.5960\*LC2DUM + 0.5474\*SUBURB – 0.2518\*EDTOURS - 0.5492\*HBWTOURS - 0.25\*CBDDUM + 0.2\*WKR1DUM + 0.9\*SUBURB |
|  | 2+ | -2.984 + 0.3866\*SIZE – 0.5960\*LC2DUM + 0.5474\*SUBURB – 0.2518\*EDTOURS – 0.5492\*HBWTOURS - 0.1883\*WORKERS -  0.9\*CBDDUM - 0.3\*WKR1DUM + 0.9\*SUBURB |
| HBO | 0 | 0 |
|  | 1 | 0.7489 + 0.8086\*SIZE + 0.3765\*LC2DUM – 0.2502\*WORKERS – 0.05369\*ATYPE + 0.000005842\*MED\_INC – 0.6965\*EDTOURS – 1.035\*HBWTOURS – 0.8163\*HBSTOURS + 0.3254\*INC4DUM -  0.5\*SIZ1DUM + 1.5\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
|  | 2 | 0.4126 + 0.8086\*SIZE + 0.3765\*LC2DUM – 0.2502\*WORKERS – 0.05369\*ATYPE + 0.000005842\*MED\_INC – 0.6965\*EDTOURS – 1.035\*HBWTOURS – 0.8163\*HBSTOURS + 0.3254\*INC4DUM -  1.4\*SIZ1DUM + 1.5\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
|  | 3 | -1.940 + 1.421\*SIZE + 0.3765\*LC2DUM – 0.5127\*WORKERS – 0.05369\*ATYPE + 0.000005842\*MED\_INC – 0.6965\*EDTOURS – 1.035\*HBWTOURS – 0.8163\*HBSTOURS + 0.6236\*INC4DUM – 0.6706\*INC1DUM - 1.6\*SIZE1DUM + 1.5\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
|  | 4+ | -3.262 + 1.859\*SIZE + 0.3765\*LC2DUM – 0.5127\*WORKERS – 0.05369\*ATYPE + 0.000005842\*MED\_INC – 0.6965\*EDTOURS – 1.035\*HBWTOURS – 0.8163\*HBSTOURS + 0.6085\*INC4DUM – 0.7486\*INC1DUM - 2.0\*SIZE1DUM + 1.5\*URBDUM - 0.3\*RURDUM + 0.9\*SUBURB |
| ATW | 0 | 0 |
|  | 1+ | -2.659 – 0.3166\*WORKERS + 0.000003801\*MED\_INC[2] + 0.7615\*INC4DUM + 0.03204\*HHDENS |

Note: All coefficients have absolute t values over 2.0, except as follows:

[1] t=1.4 [2] t=1.9

*Variables*

|  |  |
| --- | --- |
| Variable | Definition |
| ATYPE | Area type of the home zone (1-5) |
| AT2DUM | 1 if area type is 2, else 0 |
| AVGSIZE | Average HH size of the home zone |
| CBDDUM | 1 if area type is 1, else 0 |
| EDTOURS | Sum of estimated SCHTOURS + HBUTOURS |
| HBSTOURS | Estimated HBS tours |
| HBWTOURS | Estimated HBW tours |
| HHDENS | HH/acre of the work zone |
| INC1DUM | 1 if HH is income 1, else 0 |
| INC4DUM | 1 if HH is income 4, else 0 |
| LC1DUM | 1 if HH is life cycle 1 (retired), else 0 |
| LC2DUM | 1 if HH is life cycle 2 (children), else 0 |
| MED\_INC | median HH income of home zone, dollars |
| RURDUM | 1 if area type is 5, else 0 |
| SCHTOURS | Estimated SCH tours |
| SIZE | HH size (1-5) |
| SIZE1DUM | 1 if HH has 1 person, else 0 |
| SIZE2DUM | 1 if HH has 2 persons, else 0 |
| SIZE5DUM | 1 if HH has 5 persons, else 0 |
| SIZE345DUM | 1 if HH has 3-5 persons, else 0 |
| SIZE34DUM | 1 if HH has 3-4 persons, else 0 |
| SIZE45DUM | 1 if HH has 4-5 persons, else 0 |
| SUBURB | 1 if area type is 3-4, else 0 |
| URBDUM | 1 if area type is 1-2, else 0 |
| WKR0DUM | 1 if HH has 0 workers, else 0 |
| WKR1DUM | 1 if HH has 1 worker, else 0 |
| WKR3DUM | 1 if HH has 3+ workers, else 0 |
| WORKERS | Number of workers in HH (0-3) |

3.2 Tour Destination Choice

For the Destination Choice (DC) model, analysis of the county-county comparison of observed and estimated trips suggested a number of changes. This primarily involved the addition of some new variables: CBD dummy, intrazonal flag, and intra-county flag. In addition, a re-analysis of the original model estimation showed that composite time (which combines auto and transit time) was more important than auto time alone for certain purposes. Also, some of the coefficients on travel time changed, especially for HBW, due to the incorporation of speed feedback. Table 3-3 shows the revised DC models.

The key metric for the Destination Choice model is the average tour direct travel time (*direct* means the network time from the tour origin to the tour destination, without any stops). Other measures of interest are the percent of tours that are intrazonal and the percent of tours that are attracted to the CBD. Table 3-4 shows these values from the survey, the initial estimates from the model, and the adjusted estimates. Figure 3-1 shows the resulting tour length frequency distribution for HBW tours. This confirms that these adjustments did not disturb the distribution of tours by travel time. The graphs for the other purposes are similar.

**Table 3-3 Modified DC Models**

|  |  |  |
| --- | --- | --- |
| Purpose | Income | Utility Equation |
| HBW | 1-3 | -0.06521\*HTIME + 0.8109\*INTRACO - 0.03048\*CBDDUM  - 0.001735\*EMPDEN +0.7\*IIFLAG + ln(EMP) |
|  | 4 | -0.04812\*HTIME + 1.1500\*INTRACO – 0.02652\*CBDDUM + 0.0005294\*EMPDEN + 0.7\*IIFLAG + ln(EMP) |
| SCH | all | -0.3418\*HTIME + 1.681\*INTRACO + 0.2\*IIFLAG + ln(K12ENR) |
| HBU | all | -0.1635\*HTIME + 0.47\*INTRACO + 0.2\*IIFLAG + ln(CUENR) |
| HBS | 1-3 | -0.3782\*CTIME – 0.1907\*ATYPE[1] – 2.1877\*CBDDUM - 0.8\*IIFLAG + 0.0011\*TIMESQ + ln(RET + 0.003874\*POP) |
|  | 4 | -0.3175\*CTIME – 0.2576\*ATYPE – 1.5588\*CBDDUM[2] + 0.0000000468\*ACCH15C - 0.5\*IIFLAG + 0.0011\*TIMESQ + ln(RET + 0.003135\*POP) |
| HBO | 1-3 | -0.2201\*CTIME - 0.4972\*ATYPE + 0.1709\*SAMEAT + 0.03015\*DISTCBD - 0.00000002033\*ACCE15C + 0.4836\*PCT4 + 0.2\*CBDDUM + 0.45\*INTRACO +  0.2\*IIFLAG + ln(EMP + 0.192242\*POP) |
|  | 4 | -0.2453\*CTIME - 0.4178\*ATYPE + 0.2998\*SAMEAT + 0.02397\*DISTCBD - 0.000000015\*ACCE15C + 1.128\*PCT4 + 0.2\*CBDDUM + 0.45\*INTRACO +  0.2\*IIFLAG + ln(EMP + 0.109481\*POP) |
| ATW | all | -0.3148\*CTIME - 0.3274\*ATYPE - 0.00000001045\*ACCE15C - 0.58\*IIFLAG - 0.33\*CBDDUM - 0.80\*INTRACO + ln(NRET + 4.5676\*RET + 0.1475\*POP) |
| I/X | all | -0.08577\*HTIME + ln(STAVOL) |

Variables shown in logarithmic form [ln()] are “Size” variables. The coefficients shown have already been transformed by taking the exponential of the value estimated by ALOGIT.

*Variables*

|  |  |
| --- | --- |
| Variable | Definition |
| ACCE15C | Accessibility to employment within 15 min of composite time |
| ACCH15C | Accessibility to HH within 15 min of composite time |
| ATYPE | Area type (1-5) |
| CBDDUM | 1 if destination is in the CBD\*, else 0 |
| CTIME | Composite travel time, O/D |
| CUENR | College/university enrollment |
| DISTCBD | Distance to CBD (TAZ 10002), mi. |
| EMP | Total employment |
| HTIME | Auto travel time, O/D (incl. terminal time) |
| IIFLAG | 1 if origin and destination are in the same zone, else 0 |
| INTRACO | 1 if origin and destination are in the same county, else 0 |
| K12ENR | K-12 enrollment (STU\_K8 + STU\_HS) |
| NRET | Total non-retail employment (TOT – RET) |
| PCT4 | Fraction of income 4 HHs (0.0 – 1.0) |
| POP | Total population |
| RET | Total retail employment (RTL + HWY) |
| SAMEAT | 1 if origin and destination zones have the same area type, else 0 |
| STAVOL | External station volume (daily vehicle count) |
| TIMESQ | Square of composite travel time |

\* CBD zones: 10001-10035, 10052, 10086, 10116-10119, 10144-10146, 10160 10161, 10164, 10165, 10235 (using system of 3,490 internal zones as of 2017).

**Table 3-4 Results of Initial DC Model Adjustment**



**Figure 3-1 HBW Tour Length Frequency Distribution**

3.3 Number of Intermediate Stops

The first part of the Intermediate Stop model is to estimate the number of intermediate stops on each half of the tour. The statistics of interest are the number of tours by the number of stops (by purpose and direction and the average number of stops. These statistics were also stratified by various key attributes such as HH size, income, number of tours, origin and destination area type, and tour direct time. The analysis of the ALOGIT model results suggested that there was a small amount of bias with respect to these variables, so the solution was to add some variables to some of the utility equations and to adjust some of the coefficients slightly. Table 3-5 shows the final models and Table 3-6 shows the results of these adjustments.

**Table 3-5 Modified IS Models**

| Purpose | Direction | Stops | Utility Equation |
| --- | --- | --- | --- |
| HBW | PA | 0 | 0 |
|  |  | 1 | -1.182 + 0.2392\*INC4DUM + 0.9609\*LC2DUM + 0.00004341\*RET30P + 0.00001594\*RET30A - 0.2817\*TOURS – 0.5\*DESTAT |
|  |  | 2+ | -4.062 + 0.2392\*INC4DUM + 0.9609\*LC2DUM + 0.00004341\*RET30P + 0.00001594\*RET30A - 0.3017\*TOURS - 0.5\*DESTAT |
|  | AP | 0 | 0 |
|  |  | 1 | -2.114 + 0.4851\*PASTOPS + 0.3553\*INC4DUM + 0.00003103\*RET30P + 1.0\*AT1DUM |
|  |  | 2+ | -2.744 + 0.4851\*PASTOPS + 0.3553\*INC4DUM + 0.00003103\*RET30P + 1.0\*AT1DUM |
| SCH | PA | 0 | 0 |
|  |  | 1 | -3.705 + 0.0253\*HTIME + 0.7772\*DESTRUR + 0.0000429\*RET30P + 0.1217\*TOURS + 0.2\*CBDDUM |
|  |  | 2+ | -6.030 + 0.0253\*HTIME + 0.3872\*DESTRUR + 0.0000429\*RET30P + 0.1217\*TOURS + 3.5\*CBDDUM |
|  | AP | 0 | 0 |
|  |  | 1 | -3.416 + 0.9709\*PASTOPS + 0.02292\*HTIME - 0.1922\*SIZE + 0.2626\*ORIGAT + 0.00006084\*RET30P + 0.08723\*TOURS |
|  |  | 2+ | -3.786 + 0.9709\*PASTOPS + 0.02792\*HTIME - 0.1922\*SIZE + 0.2126\*ORIGAT + 0.00006084\*RET30P + 0.11723\*TOURS |
| HBU | PA | 0 | 0 |
|  |  | 1 | -2.790 - 1.154\*INC4DUM + 0.1311\*TOURS – 0.4\*AT5DUM |
|  |  | 2+ | -3.835 - 1.154\*INC4DUM + 0.1311\*TOURS – 0.4\*AT5DUM |
|  | AP | 0 | 0 |
|  |  | 1 | -1.280 + 0.5613\*PASTOPS + 0.00004232\*RET30A - 0.1311\*TOURS |
|  |  | 2+ | -1.979 + 0.5613\*PASTOPS + 0.00004232\*RET30A - 0.1311\*TOURS |
| HBS | PA | 0 | 0 |
|  |  | 1 | -1.855 + 0.03799\*HTIME - 0.6824\*INC1DUM + 0.0000362\*DDENSP- 0.1139\*TOURS + 0.13\*INC4DUM |
|  |  | 2 | -2.867 + 0.03799\*HTIME - 0.7324\*INC1DUM + 0.0000362\*DDENSP - 0.1139\*TOURS + 0.30\*INC4DUM – 1.0\*AT1DUM – 1.0\*AT1DUMA |
|  |  | 3+ | -3.478 + 0.03799\*HTIME - 0.7124\*INC1DUM + 0.0000362\*DDENSP - 0.1139\*TOURS + 0.20\*INC4DUM – 1.0\*AT1DUM – 1.0\*AT1DUMA |
|  | AP | 0 | 0 |
|  |  | 1 | -1.768 + 0.2972\*PASTOPS + 0.01944\*HTIME - 0.5592\*INC1DUM + 0.00004218\*RET30A - 0.1683\*TOURS – 2.0\*STOP4DUM |
|  |  | 2 | -3.105 + 0.2972\*PASTOPS + 0.01944\*HTIME - 0.5592\*INC1DUM + 0.00004218\*RET30A - 0.1683\*TOURS – 2.0\*STOP4DUM |
|  |  | 3+ | -3.755 + 0.2972\*PASTOPS + 0.01944\*HTIME - 0.5592\*INC1DUM + 0.00004218\*RET30A - 0.1683\*TOURS – 2.0\*STOP4DUM |
| HBO | PA | 0 | 0 |
|  |  | 1 | -0.947 + 0.03097\*HTIME - 0.62\*INTRAZ – 1.3354\*DESTCBD + 0.5026\*DESTRUR + 0.00003275\*RET30P – 0.4\*ORIGAT – 0.1\*TOURS |
|  |  | 2 | -3.849 + 0.03097\*HTIME - 0.62\*INTRAZ – 1.3354\*DESTCBD + 0.1026\*DESTRUR + 0.00003275\*RET30P – 0.4\*ORIGAT – 0.1\*TOURS + 0.5\*INCOME |
|  |  | 3+ | -4.435 + 0.03097\*HTIME - 0.62\*INTRAZ – 2.2354\*DESTCBD + 0.9526\*DESTRUR + 0.00003275\*RET30P – 0.4\*ORIGAT – 0.1\*TOURS + 0.5\*INCOME |
|  | AP | 0 | 0 |
|  |  | 1 | -1.555 + 0.3102\*PASTOPS + 0.02345\*HTIME - 0.4550\*INTRAZ - 0.3154\*INC1DUM - 0.2879\*ORIGRUR - 0.06909\*TOURS |
|  |  | 2 | -2.745 + 0.3102\*PASTOPS + 0.02345\*HTIME - 0.4550\*INTRAZ - 0.3154\*INC1DUM - 0.2879\*ORIGRUR - 0.06909\*TOURS |
|  |  | 3+ | -3.134 + 0.3102\*PASTOPS + 0.02345\*HTIME - 0.4550\*INTRAZ - 0.3154\*INC1DUM - 0.2879\*ORIGRUR - 0.06909\*TOURS |
| ATW | PA | 0 | 0 |
|  |  | 1+ | -3.566 + 0.05033\*HTIME + 1.559\*DESTRUR + 0.1313\*TOURS |
|  | AP | 0 | 0 |
|  |  | 1+ | -2.209 + 1.161\*PASTOPS + 0.04672\*HTIME + 1.525\*DESTCBD  - 0.00008081\*RET30P |
| I/X | PA | 0 | 0 |
|  |  | 1 | -2.744 + 1.250\*NWDUMMY + 0.9095\*INC4DUM - 0.263\*ORIGRUR + 0.6864\*LC2DUM + 0.0001245\*RET30P – 0.3\*TOURS |
|  |  | 2+ | -2.736 + 1.250\*NWDUMMY + 0.9095\*INC4DUM - 0.263\*ORIGRUR – 0.2136\*LC2DUM + 0.0001245\*RET30P – 0.3\*TOURS |
|  | AP | 0 | 0 |
|  |  | 1 | -0.911 + 1.0979\*PASTOPS + 0.0125\*HTIME + 0.3412\*ORIGRUR – 0.1\*ORIGAT – 0.2\*TOURS |
|  |  | 2+ | -1.295 + 1.0979\*PASTOPS + 0.0125\*HTIME + 0.3412\*ORIGRUR – 0.1\*ORIGAT – 0.2\*TOURS |

*Variables*

|  |  |
| --- | --- |
| Variable | Definition |
| AT1DUM | 1 if tour origin zone is in area type 1, else 0 |
| AT1DUMA | 1 if tour destination zone is in area type 1, else 0 |
| CBDDUM | 1 if tour origin zone is in the CBD\*, else 0 |
| DDENSP | Origin zone density function: (800\*POP + 300\*EMP)/ACRES |
| DESTAT | Tour destination zone area type (1-5) |
| DESTCBD | 1 if destination zone is in CBD, else 0 |
| DESTRUR | 1 if destination zone is Rural (area type 5), else 0 |
| HTIME | Auto travel time, origin-destination |
| INC1DUM | 1 if HH is income 1, else 0 |
| INC4DUM | 1 if HH is income 4, else 0 |
| INCOME | HH income code (1-4) |
| INTRAZ | 1 if origin zone = destination zone, else 0 |
| LC2DUM | 1 if HH is life cycle 2 (children), else 0 |
| NWDUMMY | 1 if tour purpose is non-work, else 0 |
| ORIGAT | Origin zone area type (1-5) |
| ORIGRUR | 1 if origin zone is Rural (area type 5), else 0 |
| PASTOPS | Number of estimated stops for the P-A direction (first half-tour) |
| RET30A | Retail employment in zones whose centroid is within 3 mi of destination zone centroid |
| RET30P | Retail employment in zones whose centroid is within 3 mi of origin zone centroid |
| SIZE | HH size (1-5) |
| STOP4DUM | 1 if there are 4+ stops on first half-tour, else 0 |
| TOURS | Total number of estimated tours for the HH |

**Table 3-6 Results of IS Model Adjustment**



3.4 Intermediate Stop Locations

As with the tour Destination Choice model, a good way to evaluate the model fit is by examining the average tour time, which in this case now includes all of the intermediate stops. This can also be stratified by various measures. Table 3-8 shows this data, stratified by tour purpose, direction, and the area type of the home zone (1 = CBD, 5 = rural). In most cases, the initial model underestimated the total tour time. This was corrected with a small adjustment of the coefficient on the detour time, as shown in Table 3-7. In addition, a separate model was added for HBU, stop 1. The full final models are shown in Table 3-9.

**Table 3-7 Detour Time Coefficient Adjustment**

|  |  |  |
| --- | --- | --- |
| Model | Original Coefficient | Revised Coefficient |
| HBW, stop 1, inc 1-3 | -0.09805 | -0.09805 |
| HBW, stop 1, inc 4 | -0.08703 | -0.08676 |
| HBW, stop 2 | -0.0402 | -0.04077 |
| SCH, stop 1 | -0.1678 | -0.02 |
| HBS/HBO/ATW, stop 1, inc 1-3 | -0.18 | -0.15 |
| HBS/HBO/ATW, stop 1, inc 4 | -0.1665 | -0.13 |
| Non-work, stop 2 | -0.01755 | -0.01 |
| All purposes, stop 3 | 0 | 0 |
| All purposes, stops 4-7 | 0 | 0 |
| HBU, stop 1 | 0 | -1.0 |

**Table 3-8 Results of SL Model Adjustment**



**Table 3-9 Final SL Models**

|  |  |  |
| --- | --- | --- |
| Model | Description | Utility Equation |
| 1 | HBW stop 1, inc 1-3 | -0.09805\*DETOUR + 1.192\*SHORTDUM – 0.2450\*ATYPE + ln(RETEMP + 0.16268\*NRETEMP + 0.18637\*POP + 0.53741\*K12ENR) |
| 2 | HBW stop 1, inc 4 | -0.08676 \*DETOUR + 0.8392\*SHORTDUM + 1.284\*STOPTMDUM +ln(RETEMP + 0.17464\*NRETEMP + 0.08425\*POP + 0.34750\*K12ENR) |
| 3 | HBW stop 2 | -0.04077\*DETOUR + 1.283 \*SHORTDUM - 0.09997\*LASTTM + ln(RETEMP + 0.11919\*NRETEMP + 0.07251\*POP + 0.30789\*K12ENR) |
| 4 | SCH, stop 1 | -0.02\*DETOUR + 1.137\*SHORTDUM + 0.6999\*URBANDUM + 0.02983\*DISTCBD + 1.1290\*STOPTMDUM – 4.736\*10-6\*EMPACC + ln(TOTEMP + 0.32078\*POP) |
| 5 | HBS/HBO/ATW, stop 1, inc 1-3 | -0.15\*DETOUR + 0.5490\*SHORTDUM + 0.6805\*URBANDUM  + 3.731\*10-6\*HHACC + ln(RETEMP + 0.08821\*NRETEMP + 0.08383\*POP + 0.17222\*K12ENR) |
| 6 | HBS/HBO/ATW, stop 1, inc 4 | -0.13\*DETOUR + 0.5221\*SHORTDUM + 0.7392\*URBANDUM + 0.04428\*DISTCBD + 0.9373\*STOPTMDUM + ln(RETEMP + 0.12051\*NRETEMP + 0.06522\*POP + 0.20577\*K12ENR) |
| 7 | All non-work, stop 2 | -0.01\*DETOUR + 0.9098 \*SHORTDUM + 0.6989\*URBANDUM - 0.15\*LASTTM – 0.1322\*STOPDEST + ln(RETEMP + 0.04559\*NRETEMP + 0.08433\*POP + 0.09283\*K12ENR) |
| 8 | All purposes, stop 3 | 1.4720\*SHORTDUM + 0.4874\*URBANDUM – 0.1938\*LASTTM – 0.1284\*STOPDEST + ln(RETEMP + 0.02352\*NRETEMP + 0.07646\*POP + 0.10445\*K12ENR) |
| 9 | All purposes, stops 4-7 | 1.4270\*SHORTDUM + 0.4711\*URBANDUM – 0.2163\*LASTTM] – 0.1394\*STOPDEST + ln(RETEMP + 0.06829\*NRETEMP + 0.14016\*POP + 0.10445\*K12ENR) |
| 10 | HBU, stop 1 | -1.0\*DETOUR + 1.5\*SHORTDUM + 0.6999\*URBANDUM + 0.02983\*DISTCBD + 1.5\*STOPTMDUM – 4.736\*10-6\*EMPACC + ln(TOTEMP + 0.32078\*POP) |

Additional validation adjustment for A-P direction only: I/X: multiply coefficients on DETOUR and LASTTM by 15.

*Variables*

|  |  |
| --- | --- |
| Variable | Definition |
| ATYPE | Area type (1-5) |
| DETOUR | Detour time, min. |
| DISTCBD | Network distance to CBD (TAZ 10002), mi. |
| EMPACC | Accessibility to employment within 15 min. of composite time |
| HHACC | Accessibility to HH within 15 min. of composite time |
| K12ENR | K-12 enrollment (STU\_K8 + STU\_HS) |
| LASTTM | Time from the last stop, min. (only for stops 2+) |
| NRETEMP | Non-retail employment (TOTEMP – RETEMP) |
| POP | Total population |
| RETEMP | Retail employment (RTL + HWY) |
| SHORTDUM | 1 if detour time <= 10 min., else 0 |
| STOPTMDUM | 1 if stop-destination time <= 5 min., else 0 (this is the half-tour’s destination) |
| STOPDEST | Stop-destination time, min. (this is the half-tour’s destination) |
| TOTEMP | Total employment |
| URBANDUM | 1 if zone is area type 1-2, else 0 |

3.5 Initial Time of Day

The “initial” Time of Day model splits the daily person tours by purpose into peak and off-peak periods. The period is actually estimated for each half-tour, so that there are four categories: PK/PK, OP/PK, PK/OP, OP/OP. As part of the validation effort, some of these models were re-estimated, with a greater attempt made to incorporate accessibility into the models, which proved to be useful for most purposes. The final models are shown in Table 3-10.

The best way to evaluate this model is simply to compare the percent of observed vs. estimated tours, stratified by the periods of the first and second half-tours. This is shown in Table 3-11, along with the initial and final total error (the sum of the absolute percentage error for each of the four categories).

**Table 3-10 Final ToD Models**

| Purpose | Direction | Period | Utility Equation |
| --- | --- | --- | --- |
| HBW | PA | offpk | 0 |
|  |  | peak | 0.6 – 0.3487\*INC1DUM + 0.6100\*INC4DUM + 0.2482\*LC2DUM – 0.1196\*WORKERS – 0.0119\*TIME + 0.1067\*TOTSTOPS  + 0.00093\*DEMPDEN – 0.001813\*HHACC |
|  | AP | offpk | 0 |
|  |  | peak | 0.38 + 0.3488\*PAPERIOD + 0.3288\*INC4DUM – 0.2031\*WORKERS + 0.02571\*TIME - 0.04171\*PEAKDIFF - 0.2064\*APSTOPS - 0.6715\*DPCTRET |
| SCH | PA | offpk | 0 |
|  |  | peak | 3.45 – 0.2844\*SIZE5DUM – 0.03058\*TIME – 0.3803\*PASTOPS – 0.01649\*HHACC |
|  | AP | offpk | 0 |
|  |  | peak | -1.95 + 0.9821\*PAPERIOD + 0.4100\*INC4DUM – 0.1340\*SIZE + 0.02676\*TIME – 0.02017\*ODISTCBD – 0.01189\*HHACC |
| HBU | PA | offpk | 0 |
|  |  | peak | 0.9 – 0.4295\*WORKERS + 1.9760\*PASTOPS  + 0.05470\*DEMPDEN |
|  | AP | offpk | 0 |
|  |  | peak | -0.85 – 0.6133\*PAPERIOD + 0.2871\*WORKERS – 0.04278\*TIME + 0.02974\*ODISTCBD |
| HBS | PA | offpk | 0 |
|  |  | peak | -1.29 – 0.4369\*LC1DUM + 0.3766\*LC2DUM + 0.1282\*WORKERS + 0.2912\*ORIGRUR + 0.007277\*HHACC |
|  | AP | offpk | 0 |
|  |  | peak | -5.5 + 2.04\*PAPERIOD – 0.01512\*TIME – 0.2588\*ORIGRUR + 0.05532\*HHACC |
| HBO | PA | offpk | 0 |
|  |  | peak | -0.14 + 0.1482\*INC4DUM + 0.5276\*LC2DUM – 0.1095\*WKR0DUM -0.08573\*TOTSTOPS – 0.1844\*ORIGURB |
|  | AP | offpk | 0 |
|  |  | peak | -2.02 + 0.9648\*PAPERIOD + 0.2769\*LC2DUM + 0.08202\*NONWKR - 0.04538\*PEAKDIFF – 0.1104\*TOTSTOPS + 1.4410\*LONGDUM - 0.3655\*ORIGRUR – 0.001521\*HHACC |
| ATW | PA | offpk | 0 |
|  |  | peak | -5.25 + 0.07064\*TIME + 0.4848\*TOTSTOPS + 0.07846\*ODISTCBD + 0.01448\*EMPACC |
|  | AP | offpk | 0 |
|  |  | peak | -8.3 + 2.7930\*PAPERIOD – 0.6643\*TOTSTOPS + 0.05729\*DDISTCBD + 0.0287\*HHACC |
| I/X | PA | offpk | 0 |
|  |  | peak | -1.52 + 0.3444\*OATYPE – 0.5838\*SHOP |
|  | AP | offpk | 0 |
|  |  | peak | -0.2050 – 1.8860\*ORIGURB – 0.5487\*SHOP |

Note: in application, the HBW model is used for XIW and the HBO model is used for XIN.

*Variables*

|  |  |
| --- | --- |
| Variable | Definition |
| APSTOPS | Number of stops on second half-tour (AP direction) |
| DDISTCBD | Tour destination zone distance to CBD (TAZ 10002), mi. |
| DEMPDEN | Tour destination zone employees/acre |
| DPCTRET | Tour destination zone percent retail employment |
| EMPACC | Tour origin zone accessibility to employment (000) |
| HHACC | Tour destination zone accessibility to HHs (000) |
| INC1DUM | 1 if the HH is income 1 (low), else 0 |
| INC4DUM | 1 if the HH is income 4 (high), else 0 |
| LC1DUM | 1 if the HH is life cycle 1 (retired), else 0 |
| LC2DUM | 1 if the HH is life cycle 2 (children), else 0 |
| LONGDUM | 1 if O/D direct network travel time is more than 45 min., else 0 |
| NONWKR | Non-workers in the HH (Size – Workers) |
| OATYPE | Tour origin zone area type (1-5) |
| ODISTCBD | Tour origin zone distance to CBD (TAZ 10002), mi. |
| OFFPKDUM | 1 if first half-tour (PA direction) was in the off-peak, else 0 |
| OPOPDEN | Tour origin zone population/acre |
| ORIGRUR | 1 if tour origin zone is Rural (AT=5), else 0 |
| ORIGURB | 1 if tour origin zone is CBD/Urban (AT=1,2), else 0 |
| PAPERIOD | 2 if first half-tour (PA direction) was in the peak, else 1 |
| PASTOPS | Number of stops on first half-tour (PA direction) |
| PEAKDIFF | O/D direct network travel time difference, peak minus off-peak |
| SHOP | 1 if tour is for shopping, else 0 |
| SIZE5DUM | 1 if HH has 5 people, else 0 |
| TIME | O/D direct network travel time (peak for HBW, off-peak for other purposes) |
| TOTSTOPS | Total number of stops on tour (both directions) |
| WKR0DUM | 1 if HH has no workers, else 0 |
| WORKERS | Number of workers in HH |

**Table 3-11 Results of Initial ToD Model Adjustment**



# 4 Regional Validation

After the initial round of validation of the model to the 2012 survey data was completed, the consultant began the next round of validation: applying the adjusted model to the new 2015 regional input data and comparing those results to the survey data.

For 2015, a few changes have been made to the regional input data. The Metrolina region has recently been expanded (by including all of Iredell and Cleveland Counties) and some existing zones have been subdivided, so that the number of zones has been changed to 3,490 internal zones and 88 external stations. The demographic inputs have been updated to reflect a base year of 2015, using data from the 2010 Census. The highway and transit networks have been updated to reflect the most recent transportation system changes. Table 4-1 contains a summary of the demographic totals.

**Table 4-1 Demographic Totals for 2015**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 2010 | 2015 | change |
| POP\_TOT | Total Population | 2,174,375 | 2,473,879 | 14% |
| POP\_HHS | Population in Households | 2,140,679 | 2,436,098 | 14% |
| POP\_GRP | Population in Group Quarters | 33,696 | 37,781 | 12% |
| HH | Households | 833,570 | 946,229 | 14% |
| MED\_INC | Median HH Income | $ 58,066 | $ 57,770 | -1% |
| LOIND | Low Densty Industrial | 210,531 | 230,314 | 9% |
| HIIND | High Density Industrial | 138,787 | 125,785 | -9% |
| RTL | Retail | 112,997 | 151,215 | 34% |
| HWY | Highway Retail | 120,031 | 135,211 | 13% |
| LOSVC | Low Density Service | 101,162 | 150,408 | 49% |
| HISVC | High Density Service | 133,255 | 147,366 | 11% |
| OFFGOV | Office/Government | 317,551 | 375,126 | 18% |
| EDUC | Education | 86,359 | 89,420 | 4% |
| EMP\_TOT | Total Employment | 1,220,673 | 1,404,845 | 15% |
| STU\_K8 | K-8 Enrollment | 264,461 | 297,955 | 13% |
| STU\_HS | High School Enrollment | 122,784 | 126,698 | 3% |
| STU\_CU | College/Univ Enrollment | 158,592 | 170,096 | 7% |

Application of the tour model to this new data produced slightly different results. It was decided that the 2012 home interview survey was still sufficiently representative of the Metrolina region that it would be valid to compare the estimated 2015 results to that survey. This comparison indicated the need for a few additional adjustments. Note that the models shown in Tables 3-2, 3-3, 3-5, 3-7, 3-9, and 3-10 reflect those adjustments and represent the most recent versions of each model.

4.1 Tour Frequency

Table 4-2 shows the comparison of total tours/HH from the survey and the 2015 model application and the average tours/HH stratified by HH size. From this, it can be seen that the model is still reasonably matching the survey data.

**Table 4-2 Results of TF Model for 2015**



4.2 Destination Choice

Figures 4-1 – 4-7 show the survey and 2015 model tour length frequency distributions and Table 4-3 shows the average tour lengths (both exhibits reflect the direct O/D time, excluding all intermediate stops). The HBW estimate is slightly high, which may be due to increased congestion between 2012 and 2015, but the other purposes are sufficiently close.

**Figure 4-1 HBW TLFDs**

**Figure 4-2 SCH TLFDs**

**Figure 4-3 HBU TLFDs**

**Figure 4-4 HBS TLFDs**

**Figure 4-5 HBO TLFDs**

**Figure 4-6 ATW TLFDs**

**Figure 4-7 I/X TLFDs**

**Table 4-3 DC Average Tour Lengths for 2015**

|  |  |  |  |
| --- | --- | --- | --- |
| average tour direct time | | |  |
| purpose | survey | model | difference |
| HBW | 29.88 | 30.39 | 2% |
| SCH | 12.18 | 12.15 | 0% |
| HBU | 21.27 | 20.90 | -2% |
| HBS | 13.74 | 14.09 | 3% |
| HBO | 14.98 | 14.98 | 0% |
| ATW | 13.13 | 13.57 | 3% |
| I/X | 28.41 | 29.70 | 5% |

Another change was made in the DC model to solve a problem that was newly observed regarding average tour lengths. The DC model uses a non-iterative process to implement the destination choice constraint: it calculates the number of tour attractions by purpose for each zone. During the DC process, every time a tour is assigned to a specific destination zone, 1 is subtracted from the number of attractions for that zone. The modified attraction total is used to reduce the attractiveness of that zone for subsequent tours. The main reason for sorting the tour record file randomly by origin zone is to minimize bias in this process.

However, more detailed examinations indicated that this process had the result that the latter group of tours were exhibiting unusually long tour times. It was discovered that this was because the latter group of tours had increasingly limited potential destination zones. This was causing the model to send such tours to unusually distant locations, in order to satisfy the overall attraction constraint.

This was judged to be an inappropriate outcome, since the destination pattern of a group of tours should in theory not be influenced by where those tour records happen to be located within the file. The consultant and CDOT staff examined many different techniques for modifying the double-constrained DC process. They discovered that one set of methods solved the average tour length problem, but produced attractions that did not closely match the originally estimated attractions by zone. Another set matched the zonal attractions but exhibited too much bias in the average tour length for each group of tours (here, arbitrarily defining a group of tours as a *decile* -- 10% of the total tours).

The preferred solution achieved a reasonable balance between estimating similar average tour lengths by decile and approximately matching the originally estimated tour attractions by zone. This requires a change in the model’s *attractiveness function*, as shown in Figure 4-8. The attractiveness function is no longer allowed to decrease to zero, as a zone “fills up” with tours. As Figure 4-8 shows, the function decreases more sharply at first and then flattens out so that it more gradually reaches a bottom limit of 10% of the original zonal attractions. In this manner, no zone ever “runs out of” attractions. Although this method does relax the absolute constraint on attractions vs. attracted tours, this is judged to be a reasonable trade-off in that the destination pattern demonstrates far less bias and the average tour time is approximately the same for each decile. The revised attractiveness function is:

4.3 Number of Intermediate Stops

Table 4-4 shows the comparison of the percentage of tours by the number of intermediate stops, by purpose and direction. The average number of stops is also shown and is very close between the model and the survey.

**Figure 4-8 Modified Attractiveness Function**

**Table 4-4 Intermediate Stop Comparison**



4.4 Intermediate Stop Locations

Table 4-5 shows the comparison of survey and 2015 model average tour time by purpose. This represents the average of both halves of the tour. These times now include the deviation time to make intermediate stops. The HBW and I/X estimates are slightly high, but the other values are very close.

**Table 4-5 Comparison of Total Tour Time**

|  |  |  |  |
| --- | --- | --- | --- |
| average of both directions | | |  |
|  |  | 2015 |  |
| purpose | survey | estimate | difference |
| HBW | 33.73 | 36.38 | 8% |
| SCH | 14.32 | 14.68 | 3% |
| HBU | 24.29 | 23.75 | -2% |
| HBS | 18.55 | 18.34 | -1% |
| HBO | 18.55 | 18.17 | -2% |
| ATW | 15.11 | 15.27 | 1% |
| I/X | 31.77 | 38.81 | 22% |
|  |  |  |  |

4.5 Initial Time of Day

Table 4-6 shows the comparison of survey and 2015 model percent of tours by period and direction. These are shown to be very close.

**Table 4-6 Comparison of Initial Time of Day**



# 5 Assignment Validation

The modified models described above were applied to the 2015 base data. The resulting person tours were converted to conventional trips using the trip-based model’s purpose definitions and then input to the trip-based model’s mode choice and second time of day processes (the second time of day model splits vehicle trips into four assignment periods). The resulting vehicle trip tables by assignment period and occupancy were assigned to the roadway network and the resulting daily link volumes were compared to the weekday counts. This chapter describes the results of that process and the changes that were suggested so as to improve the assignment validity.

In addition, the peak skims, which are used for HBW and XIW estimation, were subjected to a speed feedback process in which part of the model was iterated until the input and output speeds were very similar.

Throughout most of the model validation process, the consultant used Cube scripts and data to estimate travel, while CDOT staff developed a parallel process using GISDK scripts and TransCAD data. For the most part, these two methods produced identical results but towards the later stages of validation, the results differed slightly. The assignment results entirely reflect the TransCAD output.

As part of this project, the subconsultant (CDM Smith) reviewed the CDOT GISDK scripts used to apply the model. These were checked for accuracy and efficiency. Minor adjustments were suggested in order to reduce run time.

The assignment validation focuses mainly on passenger car travel. Although the consultant developed a tour-based process for truck trips (light-duty commercial, medium truck, heavy truck), CDOT has expressed a preference for using the truck trips that are estimated by a separate process from a study sponsored by NCDOT. For the purpose of testing the assignments from the tour-based model, a “hybrid” truck process was adopted. This consists of:

* 95% of the trips estimated by the consultant’s tour-based COM model
* 45% of the trips estimated by the NCDOT trip-based MTK model
* 80% of the trips estimated by the NCDOT trip-based HTK model

These trips were added to the passenger car trips from the tour model and the trip-based mode choice and second time of day models to be assigned to the regional network and compared to the 2015 traffic counts.

Several iterations were made using various adjustments to the original model parameters, as described above, in an attempt to both better match the 2012 survey results and the 2015 traffic counts. Table 5-1 shows the results of the final highway assignment comparison.

As these tables show, the assigned highway volumes are fairly close to the traffic counts. There is a slight underestimation, especially in area types 3 and 4. But in general, the volume/count ratio and RMSE are within acceptable limits. These results are very similar to those achieved by the trip-based model.

**Table 5-1 Highway Assignment Comparisons**



Source: CDOT

# 6 Next Steps

CDOT plans to implement the tour-based process using the “hybrid” methodology described above. The tour model will be used to calculate person tours by purpose and peak vs. off-peak, and then those tours will be converted to conventional trips for input to the trip-based mode choice model and second time of day model. In the future, the mode choice and second time of day models will be re-calibrated using the tour-based structure. Most likely, the mode choice model will be developed to follow the destination choice model. Although there is clearly some interaction between mode choice and intermediate stop choice, it is likely that the choice of mode is the more important of those two choices and once the mode has been chosen, this has a strong influence over the traveller’s choice of making intermediate stops. This will extend the tour process throughout the entire model structure.

Typically, the simplified tour-based model assumes that a tour has only one mode (in this context, “drive to transit” is considered a single mode). As part of the subsequent mode choice work, that assumption should be confirmed or adjusted as necessary. One example involves “serve passenger” tours in which someone is driving someone else to a destination. In certain such tours, the mode technically changes from HOV to SOV, once the passenger is dropped off.

The mode choice model should be updated to include a mode for taxi/Transportation Network Company (Uber, Lyft) travel. Or, maybe this should be two separate modes.

The truck model should be revisited. The consultant’s prior work, as well as the work of other researchers in this field, suggests that the tour structure is more important for truck travel than for person travel. It should be possible to merge the consultant’s original tour-based truck model with the NCDOT model of external truck travel to provide a complete picture of Metrolina truck travel. This model should then be validated to truck counts at the link level.

In addition, future versions of the Metrolina model should be able to estimate the effects of autonomous vehicles (AVs). The tour-based structure greatly simplifies AV analysis. The consultant has conducted research that shows how to incorporate AVs into a tour-based model in a logical and reasonable fashion.