Transit Modeling Update

Principles of Transit Model Calibration/Validation

Contents

1 Introduction

The focus of this paper is on transit calibration and validation, with particular emphasis on the mode choice model. Clearly, the overall process of model calibration and validation for a complete model set is considerably more extensive[1]. And much has been written on validation practices across the country[2].

The single most important element of calibration and validation for transit is to demonstrate the ability of the model to grasp and understand each of the key travel markets for transit riders within the region. And in this regard, to carefully document what the model understands and does not understand about these markets and who travels within them.

Underlying the calibration and validation process for transit is the role of "current" on-board survey data[3]. Without this key data source, it is simply impossible to effectively calibrate and validate the model.

The next two sections of the paper address two important elements of the supply and demand side of the model which have significant influence on the ability of the mode choice model to accurately predict choices – specification of transit travel time functions and upper level model influences. Section 4 speaks to an overview and assessment of the plausibility of the mode choice model. Sections 5 and 6 represent the heart of the paper and describe the calibration, validation, and testing of the model. And finally, Section 7 highlights important elements that should be contained in model documentation.

2 Transit Travel Time Functions

The section documents the principles of transit model calibration/validation as it pertains to the characteristics that, together, comprise the total travel time needed by a transit user. The representation of these characteristics is important for many reasons. They provide the behavioral aspects of the model with a sound understanding of the available transit choices, which leads to better representation of impacts. Many model problems can be traced to the representation of the transportation system, so addressing them during calibration/validation avoids issues during application. Finally, for New/Small Starts projects transit travel time can be an important contribution to the project's user benefits.

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[1] "Travel Model Validation and Reasonableness Checking Manual", Second Edition, Federal Highway Administration, May 14, 2010.

[2] "Travel Model Validation Practices, Peer Exchange White Paper", Federal Highway Administration, June 10, 2008.

[3] "On-Board Survey – Synthesis of Practice", Task 1, Transit Modeling Upgrade, Florida Department of Transportation, March, 2012.

2.1 In-Vehicle Travel Time Functions: Mixed-Flow

The function to compute vehicle travel time depends on the environment in which the transit service operates. Vehicles that operate in mixed-flow conditions – that is, operate within general auto traffic – have their travel times constrained by the prevailing traffic speed, the number of stops to board and alight passengers, and the dwelling time at those stops. (While it is true that the amount of dwelling time will vary by the fare payment method and the number of boarding passengers, this variation is not significant at a regional level.) Consequently, the desired function for computing mixed-flow transit travel time for a specific link is:

$$TransitTime = AutoTime + (DwellTime * Stop)$$

Where:

TransitTime is the transit travel time on the link,

AutoTime is the auto travel time on the link commiserate to the time period,

DwellTime is the average dwell time for the route, and

Stop has a value of ‘0’ if there is no stop coded on the link and ‘1’ if there is a stop on the link.

Calibration and validation of mixed-flow transit travel times and speeds is a two-step process. The first step is to validate the underlying auto travel times and speeds, as these are the primary basis of transit travel times for mixed-flow vehicles. Validation is performed by comparing aggregate speeds and point-to-point travel times within the region, with an appropriate mix of highway and arterial facilities. Commonly used metrics are absolute difference, average absolute difference, and relative difference.

The following two tables provide examples of these comparisons. The first table compares observed and estimated aggregate congested speeds at the county-level for interstates/freeways and arterials. The second table compares observed and estimated point-to-point congested speeds for a variety of interstates/highways and arterials.

Example of Comparing Peak Period Auto Speeds: County-Level (mph)

County (Facilities)	Speed (mph)				
	Posted	Observed	Estimated	Absolute Difference	Avg. Abs Difference
Miami-Dade (Interstates/freeways)	55.0	36.4/39.5	40.9	1.4	10.4
Broward (Interstates/freeways)	65.0	55.7	57.5	1.8	9.0
Palm Beach (Interstates/freeways)	65.0	65.0	47.6	-17.4	14.4
Regionwide (Interstates/freeways)	63.0	51.0	50.5	-3.5	10.7
Miami-Dade (Arterials)	43.0	21.8	25.1	3.2	4.7
Broward (Arterials)	44.0	23.9	31.9	8.0	8.0
Palm Beach (Arterials)	43.0	30.4	36.9	6.5	6.2
Regionwide (Arterials)	44.0	24.4	30.3	5.8	6.5

Example of Comparing Peak Period Auto Speeds: Facility-Level (mph)

County	Roadway	Northbound/Eastbound		Southbound/ Westbound	
		Observed	Estimated	Observed	Estimated
Miami-Dade	I-95 General Purpose	62.7	48.8	28.9	31.9
	I-95 Managed Lanes	n/a	58.3	62.0	56.6
	US-1	21/1	19.4	19.8	26.2
Broward	I-95 General Purpose	53.4	52.0	57.9	49.5
	I-95 HOV	59.9	66.6	67.5	60.5
	I-595	37.6	40.8	61.1	63.7
	US-1	25.1	27.0	24.6	30.4
	Dixie Highway	21.7	32.0	19.7	27.6
	Oakland Park	21.7	29.0	26.1	36.3
	Sunrise Blvd	19.8	31.8	26.8	37.1
Palm Beach	I-95 General Purpose	65.2	60.1	61.4	35.9
	I-95 HOV	66.9	67.4	66.8	40.5
	US-1	30.3	35.9	30.4	33.6
	Old Dixie	39.8	38.4	35.0	38.2

Once the highway network speeds have been validated, the mixed-flow transit speeds can be calibrated. Routes are grouped into categories, organized first by agency and then, if necessary, expanded by route type (i.e., local, express, limited-stop, circulator, etc.) and/or geography. Each category is assigned an initial dwell time value per coded stop (DT/CS). Estimated travel times are generated and compared to the corresponding observed values by category and individual route. Commonly used metrics are absolute difference, relative difference, percent average difference and percent Root Mean Square Error (%RMSE). The formula for computing percent average difference is:

$$PercentAvgDiff = \frac{\sum_i EstTime_i - \sum_i ObsTime_i}{\sum_i ObsTime_i}$$

Where:

$EstTime_i$ is the estimated travel time for route i, and

$ObsTime_i$ is the observed travel time for route i.

The formula for computing the %RMSE is:

$$\%RMSE = \frac{\sqrt{\frac{\sum_i (ObsTime_i - EstTime_i)^2}{n-1}}}{\frac{\sum_i ObsTime_i}{n}}$$

Where:

$EstTime_i$ is the estimated travel time for route i,

$ObsTime_i$ is the observed travel time for route i, and

n is the total number of routes in the category being reported.

The following table shows an example of reporting percent average difference and %RMSE results by transit agency. During the calibration process, similar tables should be developed for all metrics for each route.

Transit Agency (period)	% Avg. Difference	% RMSE
Palm Tran (AM peak)	2%	13%
BCT Routes (AM peak)	1%	10%
MDT Routes (AM peak)	4%	16%
Palm Tran (off-peak)	2%	13%
BCT Routes (off-peak)	2%	11%
MDT Routes (off-peak)	-1%	16%

Major differences in travel times require an adjusted DT/CS values. The final values should be consistent with generally accepted rules. Heavily-used routes require more dwell time per stop than their less-used counterparts to allow more time for boarding and discharging passengers. Express and limited-stop routes require more dwell time per stop than local or circulator routes, since those routes typically have fewer stops. Hence, more passenger activity is required per stop. Routes that utilize off-board fare collection or do not charge a fare should have lower DT/CS values than routes with on-board fare collection. This rule recognizes that collecting the fare on-board slows the boarding process for each passenger. The following table shows the final DT/CS results for a recent calibration of the SERPM 6.7 transit travel times.

Example of Dwell Time per Coded Stop (DT/CS) for Mixed-Flow Transit Vehicle (minutes)

Transit Agency	Service	DT/CS Values	
		Peak	Off-peak
MDT	Local, MAX, KAT and Busway bus service	0.60	0.60
	95X express service	1.20	1.20
BCT	Local bus service	0.70	0.68
	Breeze (limited-stop) service	1.20	1.20
Palm Tran	Local bus service	0.46	0.47
MDT and BCT	I-95 Express (inter-count) bus service	1.20	1.20
SFRTA	Tri-Rail shuttles	0.70	0.70

2.2 In-Vehicle Travel Time Functions: Exclusive Right-of-Way

Transit vehicles that operate in exclusive right-of-way (e.g., fixed-guideway and bus-only lanes) are constrained only by the operating characteristics of the vehicle, the number of stops, and the dwelling time at those stops. Therefore, the desired function for computing mixed-flow transit travel time for a specific link is:

$$TransitTime = EOM + SignalDelay + (DwellTime * Stop)$$

Where:

TransitTime is the transit travel time on the link,

EOM is total time as computed by equations of motion for the transit vehicle, including acceleration, cruise, and deceleration time,

SignalDelay is any delay attribute to traffic signals (if applicable),

DwellTime is the average dwell time for the route, and

Stop has a value of '0' if no stop is on the link and '1' if there is a stop on the link.

Because these travel times are based on characteristics of the vehicle and alignment, there is no explicit need to calibrate them. However, the travel times should be validated by comparing them to peer systems and industry standards.

2.3 Observed Data Sources for Travel Times/Speeds: Roadway

Historically, travel speed/time information has been limited, due to its prohibitive collection expense.

The traditional speed/travel time survey has been the dominant method for collecting link speed and travel time data for many years. The survey usually enacted a "floating car" methodology, where a driver drives the roadway at the speed of surrounding traffic and the passenger records the appropriate times and distances.

Recent advances in technology, and changes in how people use technology, have vastly improved the observed data quantity and quality. Large-scale, passively-collected data are beginning to replace "floating car" surveys. Traffic monitoring centers typically offer second-by-second point speeds for major roadways (usually freeways or highways), and sometimes lower-resolution speeds on secondary roadways. Private companies such as Inrix, Google, Traffic.com, and Tom-Tom (among others) offer speed/travel time data in 1-60 minute increments and providing coverage for virtually all freeways/highways and major arterials. This data must be purchased, with prices varying by temporal resolution as well as geographic and temporal coverage.

Other data sources include Bluetooth monitors and automated traffic counters. Bluetooth monitors can be placed along a roadway to passively capture the electronic unique signatures and address emanating from cell and smart phones. As a vehicle traverses the roadway, the monitors record the signature and time. Collectively, the observations can provide a reasonable link speed estimate. This method can be used in urban areas where cell and smart phone ownership rates are sufficiently high. The advantage of this data source is that the data collection length (in terms of both distance and time) can be tailored as needed. Certain automated traffic counters also offer the ability to record speeds, although it should be noted that these counters are not typically placed at a sufficient enough density to provide reasonable estimates of link speeds/travel times.

It should be noted that some data sources provide “point” speed information while others directly provide “space-mean” or “link” speed information. “Point” speeds are those recorded at a specific geospatial point in time. “Space-mean” or “link” speeds provide the information over a specified length, sometimes in 1- or 5-mile increments. Space-mean speeds are statistically more stable than point speeds, particularly for short roadway segments or small travel times. (FHWA’s Travel Time Data Collection Handbook, p.1-8, http://www.fhwa.dot.gov/ohim/handbook/chap1.pdf)

2.4 Observed Data Sources for Travel Times/Speeds: Transit

Observed estimates of transit travel times are typically gathered through one of three sources. The primary data source are the publicly available transit time tables, which provide travel time estimates at several different points along each transit route. The time tables are usually freely available online. A disadvantage of the public time tables is that the travel time estimates typically reflect rounded or padded times, which allow individual buses the ability to better adhere to the schedule WHEN temporarily running behind schedule. A secondary source of transit travel times are the timepoints provided to the bus drivers, which provide the same information as the public time tables but usually exclude the rounded or padded times.

Automatic Vehicle Locators (AVLs) are another potential source. AVLs are placed on the transit vehicles and report their exact location and time. When cumulatively assembled and processed, AVL data can provide highly reliable estimates of travel times. However, it should be noted that not all transit agencies have AVL devices on their entire fleet.

2.5 Access Connectors

There are three different categories of connectors: walk, auto and transfer. Walk connectors should use commonly accepted walking speeds, which range from 2.5-3.0 mph, unless observed data indicates that slower or faster speeds are acceptable. Auto connectors, which reflect both park-ride and kiss-ride (drop-off) movements, should use speeds from the highway network for the commiserate time period. This will provide the best estimate of travel time for this type of connector.

Transfer connectors also use commonly accepted walking speeds except where vertical movements are represented. Vertical movements, which include escalators and elevators, must reflect the speed of those movements. Where appropriate, transfer connectors should reflect any people congestion at escalators or turnstiles.

2.6 Pathbuilding Parameters

Pathbuilding parameters are the weights of the individual travel components, including wait time, access time, transfer time, and any associated boarding and transfer penalties. While there are generally accepted weights for these travel components (shown in the following table), these should be verified using a trip table derived from the most recent on-board survey.

Component	Acceptable Range of Pathbuilding Weights
In-vehicle time	1.0
Wait time (less than 15 minutes)	1.5-3.0
Wait time (more than 15 minutes)	1.0-3.0
Access time	1.0-3.0
Transfer time	1.0-3.0
Boarding penalty	2.0-5.0 minutes
Transfer penalty	5.0-10.0 minutes

The first step in the verification process is to assign the survey trip table to the transit network. The resulting boardings by mode (and route) and mode-to-mode transfers should be compared to their observed values. Any major differences should be carefully reviewed to determine their cause. The reviewer should be mindful of network coding errors or misrepresentations. If network coding issues are not the issue, the component weights may be adjusted to better represent transit travel. After the adjustment, the survey trip table is re-assigned and the process is repeated until no meaningful differences remain.

3 Upper-Level Model Influences

The chapter documents the calibration and validation principles as they apply to upper-level model characteristics that directly influence transit model calibration/validation. These model characteristics are defined throughout the entire model – hence the term 'upper-level' – and therefore impact all sub-models and components. The two characteristics described in this chapter are the distribution of person trips and market segmentation influences and generalized cost relationships.

3.1 Distribution of Person Trips

The distribution of person trips plays an integral role in the correct assessment of transit trips, as the modal trips are, by definition, a subset of the total amount of trips. Historically, the validation of person trip or travel patterns has been largely nonexistent. Rather, it involved a calibration using aggregate measures. The most common calibration measures are trip length curves segmented by trip purpose. These do not alone provide sufficient information about the travel markets produced by the distribution model. Instead, a detailed inspection of the person trip flows is required to properly validate distribution models. Consequently, current practice encourages validating person trips by comparing observed and estimated travel flows by (a) sub-county district by purpose, (b) across multiple other dimensions and (c) "orientation" ratios.

Household surveys with very small sample sizes are not sufficient to be used in a meaningful verification of estimated travel patterns, as cells would be represented by five or fewer observations. Better and more data are needed to be able to make meaningful comparisons. Consequently, data sources such as the 2000 Census Transportation Planning Package (CTPP) data or American Community Survey are used to compare against the model results through the use of flow tables or orientation plots.

An example of comparison travel flows by sub-county district is shown in the following two tables. Although at first glance, it might appear that the estimated flows match well with the observed flows, this example highlights some of the issues likely to be discovered through this technique. One issue is the location of CBD workers. The estimated table indicates that 80% of CBD workers come from the urban areas close to the CBD. However, the observed data clearly shows this not to be the case, as it indicates that 70% of CBD workers actually live in the suburbs.

A similar issue occurs with tech center workers.

Example of Estimated Demand/Travel Patterns

	CBD	Urban	Suburbs	Tech Center	Rural	Total
CBD	1,000	1,000	--	--	--	2,000
Urban	40,000	1,000	--	1,000	--	42,000
Suburbs	7,000	1,000	10,000	35,000	2,000	55,000
Tech Center	1,000	3,000	3,000	1,000	--	8,000
Rural	1,000	19,000	7,000	3,000	--	30,000
Total	50,000	25,000	20,000	40,000	2,000	137,000

Example of Observed Demand/Travel Patterns

	CBD	Urban	Suburbs	Tech Center	Rural	Total
CBD	1,000	--	--	1,000	--	2,000
Urban	7,000	10,000	21,000	3,000	1,000	42,000
Suburbs	35,000	1,000	5,000	12,000	2,000	55,000
Tech Center	2,000	--	1,000	4,000	1,000	8,000
Rural	5,000	--	--	20,000	5,000	30,000
Total	50,000	11,000	27,000	40,000	9,000	137,000

Comparing travel flows by multiple dimensions provides more additional insights. Some additional dimensions are trip purpose, mode, time of day, socio-economic characteristics or market segments, sub-mode/occupancy/toll road use and mode of access. In some Florida cities, peak work trips comprise a dominant percentage of certain modes. A comparison of AM peak HBW travel flows provides a solid assessment of the model's ability to replicate that key transit market. Other key transit markets that should be checked in this manner are off-peak non-work trips and low-income or zero-car owning households.

Displaying "orientation" ratio plots is a good visual way to compare travel patterns to key attractions. The orientation ratio measures the propensity of trips from a zone to a particular attraction compared to all other zones. The formula for computing the orientation ratio for a zone is:

$$OR_i = \frac{\left(\dfrac{Trips_{i,x}}{\sum_i Trips_x}\right)}{\left(\dfrac{Trips_i}{\sum_i Trips}\right)}$$

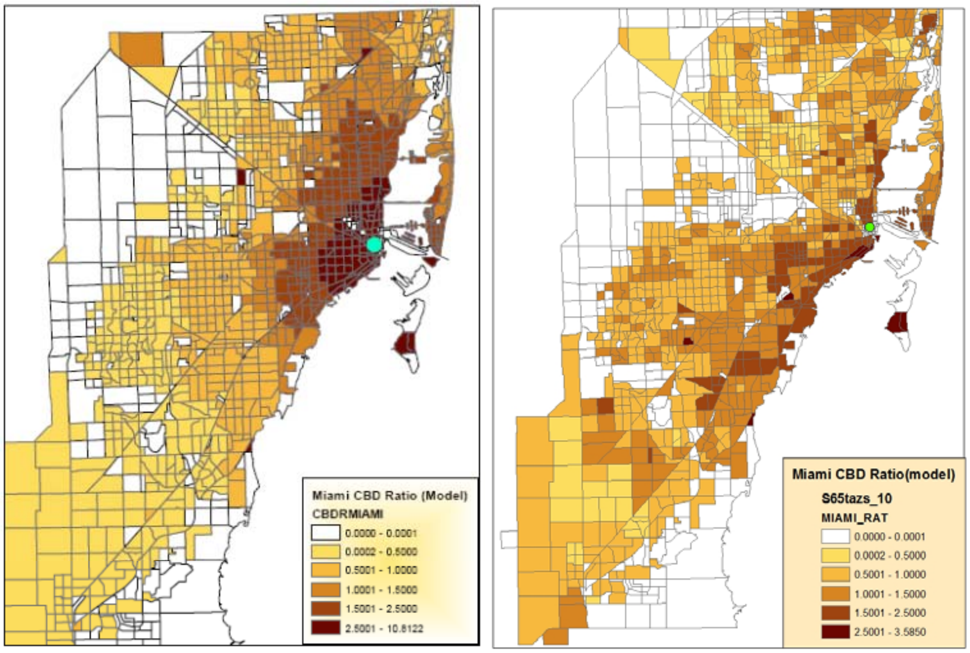
where:
i = origin zone
x = attraction zone(s)

The numerator captures the number of trips from a zone to a particular attraction in relation to all trips to the attraction. The denominator represents the percentage of trips from the zone as compared to all trips in the region. The ratio is computed for each zone in the model, so each zone has a value between zero and a very high number.

A ratio value equal to one means that the zone is not oriented to the attraction more than any other average zone. If the value is less than one, the zone is less orientated to the attraction than other zones in the region. If the value greater than one, the zone is more orientated to the attraction. A more intense orientation level results in a higher value.

Thematic maps of this ratio are created with darker colors representing higher values. The following pair of maps for downtown Miami work trips clearly shows that the travel distribution model does not reflect work trip travel patterns. The estimated map indicates that the model places a high propensity of Miami CBD workers near the downtown area (shown with the green dot). The observed map, which was created using CTPP 2000 data, contradicts the model's understanding. It shows that many Miami CBD workers live along key highway and transit facilities to the north and south of downtown Miami, with many workers several miles away from downtown Miami.

Downtown Miami Orientation Ratio Thematic Maps – Observed (Left) vs. Estimates (Right)



3.2 Market Segmentation and Generalized Cost Consistency

Travel models consist of many different parts, with each part evaluating a certain component of travel behavior. Each major step in the model – generation, distribution, mode choice and assignment and others – evaluates the behavioral component by weighting them at a certain level of disaggregation. Both highway and transit models require consistency in both the weighting schemes used as well as disaggregation level.

An example of disaggregation inconsistency occurs today in many Florida models: differences in trip aggregation between generation and distribution. In generation, productions are computed at a very disaggregate level: households by workers (or people) per household, autos owned and children. Attractions are computed separately for each service category. However, prior to distribution these productions and attractions are typically combined by purpose. The result is direct competition among very different categories. For work trips, this model structure would allow both high-income and low-come works both compete for attractions from high-income jobs. For non-work trips, this structure would not allow any variations in shopping travel patterns by type of retail (i.e., grocery store, regional mall, destination retail).

This inconsistency tends to cause unfortunate consequences relevant to transit model calibration. The most likely consequence is a poor estimate of travel flows. This in turn leads to poor mode choice calibrations as the mode choice model must produce artificially higher (or lower) shares. In some instances, this can result in observed data shows more transit trips than the model produces total person trips. The resulting transit trips, while fine in aggregate number, will not reflect the actual flows by mode, sub-mode and access mode.

Another important model characteristic is a consistency of generalized cost relationships throughout the entire model. The generalized cost relationships relate the in-vehicle time, out-of-vehicle time, distance, fare and other travel time components to each other. It is important that all such relationships be consistent to avoid causing illogical calibration adjustments and forecasting results. In transit, this occurs when the weights of the transit path algorithm are not aligned with those of the mode choice generalized cost. This situation can result in cases where the path-builder finds a better path (by its criteria) which the mode choice model evaluates as being worse according to its criteria. When this happens, project dis-benefits are generated even though the path-finder has found a better path. The solution to this problem is to align the transit path weights to match those implied by the mode choice model. This consistency is also needed for other elements of the model, including highway path-building, mode choice and assignment.

4 Model Coefficient Assessment

In specialty workshops over the years, FTA has presented many lessons learned about mode choice models, their formulation, and application that have important implications for travel forecasts and New Starts evaluation[4]. They seem to fall into four general categories – unusual coefficients, bizarre alternative specific constants, alternative specific constants for new modes, and problems in choice-set formulation.

The wide range of unusual coefficients encountered by FTA revolves around the in-vehicle coefficient. FTA has consistently indicated that the in-vehicle coefficient for Home-Based Work related travel should range between -0.020 and -0.030. However, the values for Non-Work and Non-Home based travel will not necessarily fall within this range. This is particularly true for Non-Work travel which is thought to exhibit an in-vehicle coefficient that can be as much as one-third to one-fourth the value for Home-Based Work. The consequence of an in-vehicle time coefficient that is not within accepted ranges is very different elasticities, with a corresponding impact on user benefits.

The out-of-vehicle to in-vehicle ratio is another example of potential for illogical forecasting results if the values are not within generally accepted ranges. In most instances, this ratio should be somewhere between 2.0 and 3.0 times the in-vehicle coefficient. FTA experience has shown that they have been as low as 0.25 and as high as 16. The impact of illogical ratios is a significant impact on ridership and user benefits that distort those results.

[4] "Lessons Learned about Models", Session 6, Federal Transit Administration, San Francisco Workshop, July 2003.

5 Model Calibration

The overarching goal of model calibration and validation is to ensure that the model reasonably reproduces current observed travel patterns. In its travel demand forecasting workshops, FTA refers to it as “meaningful calibration”, to reinforce the notion that the goal is to demonstrate that the model understands the travel markets, rather than simply match some aggregate measures of transit trip-making. This Chapter discusses the various tasks involved in calibrating and validating a model. While some of these tasks can be seen as purely mechanical, it is important to keep in mind this notion of “meaningful” calibration, to avoid forcing the model to reproduce certain patterns without thoughtful consideration of what the model is and is not able to understand.

In very general terms, model calibration consists of first establishing calibration targets, adjusting the alternative-specific constants to meet these targets, and examining how well the model matches observed transit boardings. As discussed below, the calibration process is far more thoughtful and nuanced than this simple description suggest. It requires a thorough understanding of all upper level models, in addition to the mode choice model itself, and an equally thorough understanding of the travel patterns prevalent in the model area.

5.1 Target Value Computations

Model calibration starts with the computation of calibration target values. The accuracy of the transit model is assessed by comparing the transit forecasts against observed transit trip patterns. These observed transit trip patterns are known as calibration target values. The calibration target values represent a full accounting of all trips in the region; in addition to transit trips, they include highway trips and may also include non-motorized trips. These target values consist of tabulations of observed trips across various dimensions—trip purpose, time period, trip market, mode and geography. In addition target values may be developed for the proportion of trips that transfer to/from other modes.

Calibration targets represent *linked* trips, not boardings. A linked trip represents the entire journey from the production zone to the attraction zone. More than one transit vehicle or mode may be used by a linked trip. For example, if a bus is used to access light rail, then the linked trip includes two boardings, one on bus and one on light rail. Similarly, if the linked trip includes a transfer from one rail line to another, then the trip includes two rail boardings. The mode of the linked trip is defined from the mode(s) of the transit vehicles used, as described below. The definition of modes used in the computation of calibration targets should be consistent with the choice set of the mode choice model.

5.1.1 Data Sources

The best practice is to compute the calibration target values from “current” on-board survey data and a recent household travel behavior survey. The on-board survey provides information about the transit trips, while the household survey provides information about highway and non-motorized trips. Although household travel surveys capture some transit trips, the size of the transit trip sample is most often times too small to be representative of the transit user population, and for this reason it is not a reliable source for computing transit calibration targets.

Supplemental sources of travel pattern information may be required when the on-board and household surveys are insufficient to fully characterize base year travel in the model region, such as when some transit agencies were not surveyed or when the calibration year does not coincide with the survey year. Typical supplemental data sources include Census Journey to Work data, the National Transit Database, and transit agency boarding counts.

5.2 Survey Data Preparation

Prior to tabulating the calibration target values a number of data preparation steps must be taken. These steps include trip linking and calculation of expansion factors, and identification of usable records. These steps apply to both on-board surveys and household surveys, although some of the discussion below is specific to on-board surveys.

5.2.1 Trip Linking and Expansion Factors

Trip linking and a general description of the development of expansion factors for on-board surveys are discussed in another technical memorandum[5].

5.2.2 Usable Records

A usable trip record must include all the key data required to build the targets:

- trip origin & destination TAZ, activity and location type (home/other)
- boarding and alighting station (for rail trips)
- production and attraction trip end flag
- valid travel mode
- time period
- relevant household stratification variables (income, auto ownership and/or car sufficiency, for example)
- trip expansion factor

Transit Mode Coding

The identification of the transit mode is a critically important step in the preparation of calibration target values. Two cases can be distinguished, related to whether the trip required transfers:

i. The intercepted trip is the only transit boarding required to complete the trip between its origin and destination. In this case, the linked trip mode is the same as the mode corresponding to the route where the trip was surveyed.
ii. The intercepted trip is one of two or more boardings required to complete the trip. In this case, the linked trip mode depends on the mode(s) of the routes transferred to/from in addition to the mode of the route on which the trip was intercepted.

In selecting a trip mode for Case ii above the overall goal is to identify the primary mode used as part of the entire transit trip. Typical examples of unlinked trip chains are using a local bus to access a light rail line, transferring from one rail line to another, or driving to commuter rail and then hopping on a

[5] "Task 1, On-Board Survey – Synthesis of Practice", Technical Memorandum, Florida Department of Transportation, prepared by Parsons Brinckerhoff, February 2012.

downtown circulator or shuttle bus to access the final destination. The most commonly-used approach to identifying the trip mode is to choose the mode according to a pre-defined hierarchy of regional transit modes. At the top of the hierarchy are the types of services most often perceived as line-haul modes (commuter rail, urban rail), while at the bottom of the hierarchy are the services that tend to function as feeder services (local bus). Then, when a linked trip consists of multiple boardings, the top-ranked mode boarded is chosen as the mode for the linked trip, under the assumption that the other modes are likely used only to access this main mode. Table 1 shows a common hierarchy of transit modes.

Table 1- Transit Mode Hierarchy Example

Modes used by the linked trip	**Linked trip mode**
Commuter rail, plus any other mode	Commuter rail
Urban rail, plus any other mode except Commuter rail	Urban rail
Bus Rapid Transit, plus any other mode except Commuter or Urban rail	BRT
Express bus or local bus	Express bus
Local bus only	Local bus

When the on-board survey has been administered on more than one transit mode (bus and rail, for example), this method of identifying the trip mode will double-count some of the higher-ranked mode trips. To avoid double-counting, the observations that involve transfers from bus to rail (or vice-versa) and that were intercepted in the bus leg of the trip are excluded from the computation of calibration targets.

This trip double-counting arises because the on-board surveys are usually expanded using route boardings as control totals. Consider the case of a region that has two types of transit, local bus and rail. Some people use the local bus to access the rail. When the local bus passengers are surveyed, some will report that they are going to transfer to rail. Since rail is higher-ranked than bus, the analyst will code these trips as rail trips. When the rail passengers are surveyed, some will report that they used a bus to transfer to rail. The analyst will code these trips as rail trips, too. The rail on-board survey expands to the total number of linked rail trips, while the bus on-board survey expands to the total number of bus trips plus some rail trips. Therefore, the bus on-board surveys contribute linked rail trips that are already accounted for in the rail on-board survey. If 100%of the trips were surveyed, then the estimate of bus-to-rail trips obtained from the local bus survey would be the same as the estimate of bus-to-rail trips obtained from the rail survey, so that either one could be used in the calibration target computations. In practice, the two estimates are different, and common practice is to use the estimate from the rail observations.

5.3 Target Value Computation Method

The most basic set of calibration target values is a tabulation of total trips by trip purpose, mode, market segment and time period. This tabulation is built up from the household survey and on-board survey data following these steps:

i. Obtain the total number of trip productions by purpose, time period and trip market forecasted by the trip generation model. These are the trip generation control totals.
ii. Based on on-board survey records and expansion factors, tabulate the total number of transit trips by purpose, time period, trip market, transit mode and access mode.
iii. Based on household survey records and expansion factors, tabulate the total number of non-transit trips by purpose, time period, trip market and mode.
iv. Develop expansion factor adjustments for the non-transit trips such that the sum of transit plus non-transit trips equal the trip generation control totals.

The key principle in this computation method is to hold the estimate of transit trips obtained from the on-board survey constant, while the non-transit trips are adjusted until the sum of trips from both surveys equal the model estimated trip generation total. If the on-board transit trip estimate is adjusted, then the model will not generate the correct number of boardings during the transit assignment step.

Table 2 shows an example calculation of calibration target values. The table shows the transit trip estimates (by mode and market segment) obtained from the on-board survey, followed by the non-transit trip estimates obtained from the household interview survey. The sum of these transit and non-transit trips does not equal the trip generation total trips for each market segment, as shown in the table. Since the calibration targets must be equal to the trip generation totals, the survey trip estimates must be adjusted. As shown in the table, the transit calibration targets are identical to the on-board survey estimates. To compute the non-transit targets, the household trip estimates are grown (or reduced) proportionally so as the sum of the calibration targets equals the trip generation control totals. In this example, the calibration target computations are done independently for each market segment.

Table 2 – Calibration Target Value Computation Example

Source	Mode	Income 1	Income 2	Income 3	Income 4
On-Board Survey (OBS)	Walk to Bus	228,800	74,398	26,894	1,401
	PNR to Bus	3,826	3,862	3,931	67
	KNR to Bus	5,780	3,747	2,516	-
	Walk to Rail	41,425	14,752	10,826	913
	PNR to Rail	2,950	6,462	19,319	11,316
	KNR to Rail	1,696	1,805	2,869	1,149
	Subtotal	*284,479*	*105,025*	*66,355*	*14,846*
Household Survey	Walk & Bike	85,979	72,074	50,607	7,390

(HS)	Drive Alone	519,917	1,082,786	1,943,722	1,002,026
	Shared Ride 2	87,917	114,174	106,363	28,027
	Shared Ride 3+	64,367	69,823	54,972	20,694
	Subtotal	*758,180*	*1,338,857*	*2,155,663*	*1,058,137*
OBS + HS	***Total***	***1,042,659***	***1,443,882***	***2,222,019***	***1,072,983***

Trip Generation	**Control Total**	**881,902**	**1,632,493**	**2,326,928**	**1,177,908**

	Calibration Target Values				
	Mode	**Income 1**	**Income 2**	**Income 3**	**Income 4**
	Walk to Bus	228,800	74,398	26,894	1,401
	PNR to Bus	3,826	3,862	3,931	67
	KNR to Bus	5,780	3,747	2,516	-
	Walk to Rail	41,425	14,752	10,826	913
	PNR to Rail	2,950	6,462	19,319	11,316
	KNR to Rail	1,696	1,805	2,869	1,149
	Walk & Bike	67,749	82,227	53,070	8,122
	Drive Alone	409,679	1,235,323	2,038,317	1,101,388
	Shared Ride 2	69,276	130,258	111,539	30,806
	Shared Ride 3+	50,719	79,659	57,647	22,746
	Total	***881,902***	***1,632,493***	***2,326,928***	***1,177,908***

5.4 Alternative Specific Constants

The alternative-specific constants represent the effect of mode attributes that are not included in the mode choice utility function. Examples of un-included attributes are comfort, schedule or travel time reliability, availability of real-time next vehicle information, frequency of off-peak service (for peak trips), and vehicle and station amenities, among others. Both the relative and absolute value of the alternative-specific constants are important, because they represent the importance of un-included attributes relative to level of service attributes, as well as the utility of each mode relative to all other modes, all else equal. When comparing a build transit alternative against a baseline alternative, some of the user benefits result from measurable changes in level of service attributes (such as travel time savings), while other benefits are simply a function of the constants assumed for the baseline and project modes. When the alternative-specific constants for the premium modes are very large, and/or when they do not logically relate to un-included attributes, then the user benefits and trips attributed to the alternative mode may not be commensurate with the differences in real and perceived attributes between the base and alternative modes. For this reason a mode choice model must be carefully calibrated, so that not only it reproduces the observed mode shares, but also so that it exhibits adequate and logical values for its alternative-specific constants.

5.4.1 Constant Specification

As indicated above, the specification of the model constants is directly a reflection of the attributes un-included in the model. One should distinguish between un-included attributes that are a function of the line-haul mode, and un-included attributes that vary with the trip maker. Attributes that are purely a function of the line-haul mode do not vary with the household markets, and for this reason the constant intended to capture these attributes should not be stratified by household market. In contrast, attributes that vary with the trip maker, or that reflect varying preferences of the trip maker for certain service characteristics, obviously vary with the household market and therefore should be stratified accordingly. As a result, the constant of a particular mode and market segment can be decomposed into parts that reflect the separate contribution of the un-included line-haul attributes and the un-included trip-maker attributes. As is discussed below, care must be taken to specify values for the constants such that each contributing part is the same across the different modes and market segments of the model.

The constants that are typically stratified by market segment include the overall transit constant, the drive to transit constant, and the park-n-ride constant. These constants express a preference (or dislike) for using transit in general, as well as travelers' access to private automobile. They can also be thought as associated with the inconvenience of relying on scheduled transportation. This preference or dislike is typically associated with traveler attributes such as household income, auto availability or car sufficiency. Thus for example, low income zero car household travelers (transit dependents) are more likely to use transit than high income, car sufficient travelers (choice riders), all else equal. As such, the transit constant tends to be less negative (or positive) for transit dependent travelers, while very negative for the choice riders.

The constants that are typically not stratified by market segment include all the line-haul constants (express bus, urban rail, commuter rail, etc.). These constants capture preferences for attributes that only some modes exhibit. For example, express bus service tends to be very infrequent or completely absent during off-peak travel times. This can be inconvenient for some travelers because the service may not be available when they need it. This inconvenience is reflected in a lower constant for express bus compared to modes that are available at all times of day. A second example is travel time reliability; fixed-guideway modes such as light rail experience relatively little deviation from their schedule, while buses running on mixed-flow traffic get delayed due to congestion, sometimes significantly. This reliability is reflected in a more positive constant for fixed-guideway modes compared to bus modes.

In some cases the contribution of an un-included attribute to the utility function varies with the duration of the trip. In such cases the effect can be modeled by using a different in-vehicle time coefficient, in addition to a mode-specific constant. One classic example is the comfort associated with certain commuter rail services. It can be argued that the perceived benefits of a wide seat, a table, and internet services in terms of productive use of travel time are larger for longer trips than for shorter trips. As such, this effect is modeled by assuming a somewhat less negative in-vehicle travel time coefficient for commuter rail than for all other modes (auto included).

5.4.2 Calculating Constant Values

Calibration target values such as those shown in Table 2 are used to compute the value of the alternative-specific constants, using an iterative process that compares the model estimates to the target values. This process, detailed below, can be easily automated; however the real effort is in ensuring that resulting constants exhibit values that logically and reasonably represent the expected contribution of the un-included attributes to the utility functions.

Mechanically the calibration process is as follows:

i. Assume an initial value for each alternative specific constant (zero if there is no better estimate).
ii. Apply the mode choice model.
iii. Summarize the model forecasts into relevant trip sub-categories.
iv. Compare, for each trip sub-category, the target value and estimated trips.
v. Compute the required change in each alternative specific constant so as to reduce the difference between the estimated trips and the target value.
vi. Repeat the process until the difference between the observed and estimated trips is small.

The change in the alternative specific constant is computed as:

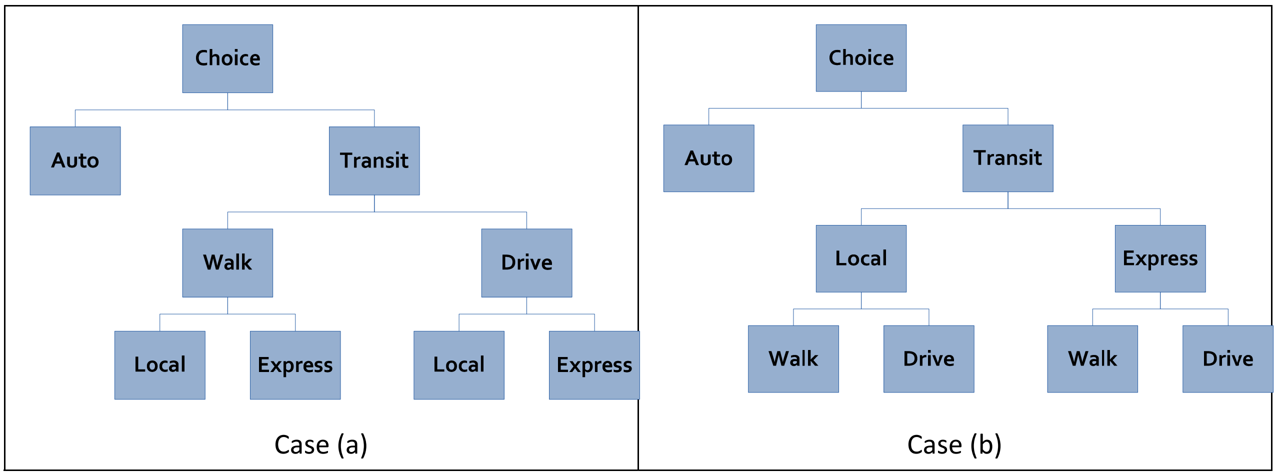
$$\Delta K = \log\left[\frac{P_{obs} * P_{est} - P_{obs}}{P_{obs} * P_{est} - P_{est}}\right],$$

where P_{obs} is the observed trip share, and P_{est} is the estimated trip share. The constants can be adjusted until the model exactly matches the calibration targets. Matching the calibration targets is a necessary but not sufficient condition for a calibrated model. The model is calibrated only when the constants themselves exhibit reasonable, logical values, and when a number of other checks on the forecasted trip patterns, discussed below, are met.

Care must be taken to calculate the shares above in a manner consistent with the expectation regarding un-included attributes. Consider for example the two mode choice model structures shown in Figure 1. In Case (a), the choice of line-haul mode is considered more elastic than the choice of access mode, while in Case (b) the reverse is true. The un-included attributes of express bus are the same regardless of whether it is accessed walking or driving, and regardless of the attributes of the person using the bus. In both cases the constant that captures the express bus mode differences relative to local bus is the same, and is calculated as the total number of express bus trips (regardless of access mode or household market) divided by the number of transit trips.

In this same example, the un-included attributes of walking to a bus versus driving to a bus are often assumed to be independent of the line-haul mode (i.e., walking to an express bus is similar to walking to a local bus). However the preference for driving over walking, all else equal, is oftentimes not independent of the household market: in relative terms, high income people are more likely to drive than to walk to transit, compared to low income people. This preference is captured by the alternative-specific constant for transit drive access. In this case, the constant must be stratified by household market, so that the relevant share for calibration purposes is the number of drive to transit trips (regardless of line-haul mode) for each market group, divided by the number of transit trips for the same market group.

Figure 1: Alternative Mode Choice Nest Structures



In the utility specification, the contribution of the access mode and line-haul constants is expressed as shown below. The constant for local bus and for walk access are assumed to be zero, to avoid over-specifying the model.

5.4.3 Expected Transit Constant Values

The value of an alternative-specific constant may be expressed in "equivalent minutes of in-vehicle travel time", to illustrate the contribution that the constant makes to utility relative to the utility contribution of one minute of travel time savings. To express the constant in equivalent minutes of travel time, the value of the constant is divided by the in-vehicle time coefficient. Also, since in a logit model only the difference between utilities influences the choice of mode, by convention the value of the local bus constant is often assumed to be zero. Table 3 shows the expected range of values for various mode-specific constants. However, because the value is dependent upon the actual implementation of the mode within a given region, FTA guidelines can be used to independently assess the likely value of the constant[6][7][8].

[6] "Proposed Guidance on New Starts/Small Starts Policies and Procedures", February 5, 2007, Federal Transit Administration.
[7] "Final Guidance on New Starts/Small Starts Policies and Procedures", June 4, 2007, Federal Transit Administration.
[8] "Mobility Benefit Changes from Unmeasured Transit Attributes", October 2008, Federal Transit Administration.

Table 3 – Alternative-Specific Constants

Mode	Constant Range (relative to Local Bus)	Rationale
Commuter Rail	15 – 20 minutes	Reliable (fixed-guideway), vehicle and passenger amenities, visibility, station amenities, etc.
Urban Rail	10 – 15 minutes	Reliable due to dedicated, fixed-guideway, well-identified, stations and routes, etc.
BRT	5 – 10 minutes	Reliable when running on semi-dedicated lanes, often times uses low access and especially branded vehicles
Express Bus	-10 to 10 minutes	Non-stop, single-seat ride, comfort, reliable when running on semi-dedicated lanes Infrequent off-peak service, unreliable when subject to road congestion

In cases where the calibrated constants take values well outside the ranges shown in Table 3, various analyses should be conducted to understand the reason for the large constant values. Some likely reasons include:

- Network coding errors. The walk access connectors may be too short, or some park-n-ride locations may be missing. The representative level of service for some modes may not be accurate; for example short runs may be missing from the peak period skims, or the fare required to transfer is not properly computed. Another possibility is that access, egress and mode transfers at and around rail stations do not reflect actual walk times.
- Excessive number of transfers. This can be partially addressed by modifying the transfer penalties, or by calibrating transfer coefficients, as explained in the next section.
- Upper level model errors. The constants may be compensating for upper level model errors, in particular trip distribution errors or inadequate household market trip stratification.
- Inaccurate and/or insufficient mode choice calibration targets. Care should be taken to ensure that all transit trip-making in the region is included in the targets, and to use recent and appropriately expanded on-board survey data whenever possible.
- Software application bugs. The application software should be well-tested and verified against manual calculations for several representative origin-destination pairs.

5.5 Calibrated Parameters

In addition to the alternative-specific constants, there are various other model parameters that may be calibrated, as opposed to asserted, in cases where the mode choice model is not estimated with local data. They include transfer rates, CBD or other destination constants, and urban fabric measures. These parameters are highly dependent on local conditions, and as such they are not as transferable as level of service parameters. As is the case with the alternative-specific constants, these parameters are calibrated by comparing model results against on-board survey data summarized in meaningful ways. Three different types of calibrated parameters are discussed below.

5.5.1 Transfer rates

Transfer behavior is often times not well-captured by the mode choice model without the inclusion of calibrated global or mode-specific transfer parameters. To some extent these parameters compensate for the limitations of path building algorithms, which tend to find more transfer opportunities than people in reality do, or which they may not think convenient. Transfer parameters tend to be negative, that is, they penalize transfers, since they are generally considered undesirable, all else equal. The utility function may distinguish between transfers that occur at the production end of the trip (for example, bus to rail transfers), and transfers that occur at the attraction end of the trip (such as rail to bus transfers).

5.5.2 Urban fabric influences

The nature of the neighborhood urban fabric has been shown to affect transit ridership, above and beyond level of service attributes. High density areas with many retail opportunities tend to attract transit users. Various indicators have been proposed in the literature to capture these effects. Collectively they are known as the 3D or 4D variables – density, design, diversity and destinations. A simple measure of urban fabric is for example a composite density based on population and employment at the production or attraction end of the trip. This type of measure can be included in the transit utility function, weighted by a calibrated coefficient. This coefficient is calibrated by examining the residual difference between observed and estimated trips, with and without the urban fabric measure. The urban fabric effects should not be used to compensate for upper model errors or for poor network access representation, so it is recommended to perform as good as possible a calibration without these effects, and then to introduce them only as necessary.

5.5.3 CBD destination constant

A CBD attraction constant is sometimes required to forecast the correct number of CBD transit attractions. The CBD constant is typically positive, reflecting that transit trips tend to be more CBD oriented than auto trips, all else equal. The constant should apply to all transit modes equally.

5.6 Examination of Markets

As mentioned at the beginning of this Chapter, calibrating the mode choice model is all about demonstrating that the model understands travel markets. Travel markets are typically defined by a combination of geography, socio-economic strata, mode and access mode. As such, these dimensions define the sorts of comparisons that are to be examined as part of the model calibration process.

5.6.1 District Level Comparisons

A district system should be constructed to isolate key travel markets, defined both by trip production and trip attraction geographies. In a typical CBD oriented region, the CBD itself is one of the districts, and the areas surrounding it are divided into districts generally along major transit corridors. In large regions, areas far from the CBD that are served by commuter rail (now or in the future) may need to form their own districts. A district system should consist of approximately 10 to 15 districts, to provide sufficient but not excessive detail. Once a district system is in place, then the on-board survey data can be used to develop transit trip flow patterns by mode or by socio-economic strata. District level model estimates are easily created with any transportation planning software, and are also a standard SUMMIT output. District level comparisons help to understand how well the model reproduces the spatial variation of transit trips. It may show for example that the model over-estimates short distance markets (close to the CBD) while under-estimating long distance markets. Implied mode shares calculated at a district level help to find shortcomings in the trip distribution model, by uncovering production-attraction pairs with unreasonable implied transit shares.

5.6.2 Segmented Level

Socio-economic strata, mode and access mode transit trip tabulations can also provide key insights to understand how well the model is reproducing observed patterns, and equally important, which patterns it is unable to grasp. The number of dimensions that may be combined in any single table is to some extent a function of the on-board survey sample size. Care should be taken not to subdivide the survey observations into so many classes that they are no longer representative of the various market subgroups. Other possible dimensions to examine include production or attraction area type (such as defined by the urban fabric measures), and trip distance (particularly important in regions with long distance commute markets).

5.7 Transit Assignment Comparisons

The final set of model calibration and validation comparisons involve transit boardings. Transit agencies traditionally provide route-level boardings and station boardings and alightings for fixed-guideway transit. Boardings may be available as total daily or for different times of the day. More recently some agencies are also able to provide route-stop boardings for trips that use a smart card for fare payment. These data can be summarized to provide a meaningful comparison to the model estimates.

Typical transit boarding comparisons consist of tabulations of boardings by mode, access mode, and corridor. Route-level comparisons may also be performed, with the understanding that low volume routes tend to perform poorly. Transit assignments in trip-based, four step models are typically performed in production-attraction format, and therefore the transit boardings data need to be summarized accordingly.

Comparisons of boardings by boarding and alighting station are extremely helpful to examine how well the model understands the fixed-guideway transit system. Matrices of boarding/alighting station pairs are useful when the sample size supports them. As indicated above, care should be taken to express all survey data in production-attraction format so they are comparable to the transit assignment estimates.

In order to examine the park-n-ride market, it is helpful to collect data about park-n-ride users, in particular their home location, socio-economic strata, and transfer behavior. With these data in hand, the model estimates can be examined to ascertain whether it understands where park-n-ride trips originate for each lot, and the socio-economic makeup of each lot users. It is often found that some lots draw only very short distance users, while others have a more regional “catchment” area. At a minimum, it is helpful to count the number of users/vehicles at each park-n-ride lot over several days and seasons, and compare this count against the model estimates.

6 Forecast Testing

Once the base year forecasts have been developed, calibrated and validated to the base year observed data, it is ready to be applied in a forecast mode. However, while the base year model forecasts may generally agree with base year observed data; how well the model reacts to changes in input data is another very important validation check. This chapter discusses approaches to checking the model validity with regard to forecasts, and the use of the model to support the case for the project and demonstrate the level of uncertainty with particular forecast scenarios.

6.1 Model Applications

The primary outcome of the model execution is to establish the performance of the alternatives being tested in terms of specific, quantitative measures. In addition, the model application runs can also be used to strengthen model forecast credibility, increase understanding of forecast results, and gain insights to the sensitivity to key variable assumptions on the forecast results.

6.1.1 Step-wise Forecasts

Travel demand forecasts are almost always compared with existing, or base year travel forecasts. Typically, a future year forecast includes changes to the following variable inputs:

1. Socioeconomic data,
2. Highway Network capacity and connectivity,
3. Transit Network capacity, connectivity, coverage and service levels,
4. Miscellaneous inputs, such as special generators and externally-based trip demand.

Comparing the future to base year forecasts, therefore, is a product of all of these changes. It is useful to understand how each element might affect the model results. For example:

- How much of a new transit line's ridership is due to growth in overall trips in the region?
- How much is due to increased service levels compared to existing conditions?
- What portion of the ridership is due to improved service levels already planned for the corridor?

These and other similar questions can be investigated by a step-wise model analysis. A stepwise analysis conducts several model runs, each time changing just one key input variable. For example, the base year highway and transit network could be run using the future year socioeconomic data, to determine the change in transit ridership due to regional growth. Conversely, the proposed highway and transit networks may be tested with the current socioeconomic data to determine the effect of the proposed increase in service levels alone. The results of these model runs allows the analyst to more fully describe the nature of the change in demand to decision-makers, and increases the credibility of the forecasts by offering a logical explanation for the increased demand.

6.1.2 Backcasting

Backcasting is one of the purest validation techniques for models. It is the application of the model to a previous year. If the necessary data is available, the model may be set up to represent a past year, preferably in 5-10 year span from the calibration year. An important assumption in this approach that must be acknowledged is that there have been no fundamental changes to travel behavior between the backcast year and calibration year. This assumption is also why backcasting should not be done over a very long (15 to 20 or more years) period of time, since basic travel behavioral changes, such as workers per household, major new roadway facilities, or a change in the nature of area commercial profile is likely to have occurred.

The other requirement for backcasting is the availability of both input and observed data for model comparison. Comparison data may include traffic counts, transit boardings, and/or region-wide travel behavior surveys, such as home interview surveys. Census years (1990, 2000, and 2010) will often be selected so that census data is available to inform socioeconomic inputs as well as travel outputs (i.e., the 2000 CTPP.

Evaluating the results of backcasting provides a good benchmark that the model is not only calibrated to base year data, but is able to respond properly to changes inputs, which is critical to useful forecasts.

6.1.3 Key Exogenous Variables

Sensitivity testing is a valuable exercise to determine the relative importance of key model parameters and input assumptions and applied in the future forecast mode. Typical parameters tested might include:

- A Major Highway or Transit investment
- Downtown Parking Costs
- Fuel price
- Transit operating assumptions, including
    - Fare
    - Operating speeds
    - Transit Wait time
- High and low estimates for socioeconomic growth

By testing reasonable variations in these and other parameters, the analyst can assess the model's sensitivity to these assumptions. If the model has a high sensitivity to a particular model assumption, this parameter or input value can be further refined, or the results presented with commentary on the importance of the input assumptions to the resulting forecast values. Alternatively, high and low estimates of the forecast demand can be presented, possibly associated with a probability or likelihood.

7 Documentation

An important element of model calibration and validation is documentation of each element of data processing, model design, calibration, validation and testing. The exact outline of the Calibration and Validation report will logically vary depending upon setting and the regional context. With that in mind, the following is a very general outline that can be considered in structuring the report:

INTRODUCTION & OVERVIEW

- Model Description Overview
- Summary of Model Improvements

HIGHWAY NETWORK AND LEVEL-OF-SERVICE PREPARATION

- Network Verification
- Skim Building Process and Parameters
- HOV and Toll Networks & Skims
- Travel Time Verifications
- Isochronal charts to/from activity centers
- Scatter-plot to compare actual vs. modeler time

TRANSIT NETWORK AND LEVEL-OF-SERVICE PREPARATION

- Transit Route Coding Procedures and Definitions
- Mode Definitions
- Headway computation methods
- Walk and Transfer Access Coding Procedures and Definitions (Metro)
- Transit Fares
- Station Attribute Definitions/Descriptions
- Transit Travel time Function Development
- Path Building Process and Parameters
- Percent Walk Value Preparations

TRANSIT ON-BOARD SURVEY ASSIGNMENT

- Description of Methodology
- Analysis Results
- Implications for Model Development

CALIBRATION TARGET VALUE DEVELOPMENT

- Data Sources
- On-Board Survey Data Preparations and Procedures
- Home-Interview Survey Preparations and Procedures
- Missing Survey Data Methods and Representation

MODE CHOICE MODEL DESCRIPTION

- Basic Logit Mathematics
- Nested Structure Graphic
- “Asserted” Model Coefficients
- Other Model Coefficients

MODEL CALIBRATION

- Basic Calibration of Constants
- Primary Transit Mode Constants
- Equivalent In-Vehicle Minutes of Time/Expected Ranges
- Aggregate Trip Level Comparisons
- Purpose/Time Period/Access Mode by Primary Transit Mode
- District Level Comparisons

FORECAST TESTING

SUMMARY AND CONCLUSIONS

- Model Uncertainties
- Adequacy of Model for New Starts Project Forecasts
- Potential Areas for Refinement/Improvement