FSUTMS-Voyager Transit Model – Theoretical Framework

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Abstract

This document's purpose is to describe the theoretical underpinnings and coordination between the elements of the proposed FSUTMS-Voyager Transit Model (FVTM). It is a companion document to the Application Framework document. It will serve as a "working" document as the details and its application evolve.

Background

The existing transit model system in Florida, the FSUTMS-Tranplan Transit Model (FTTM), was developed in the early 1980s with the advent of the FSUTMS-Tranplan software and micro-computers. The FTTM served Florida well throughout the 1980s and early 1990s. In the last 10 years, however, changes in computer power, software, level of analysis and regulatory oversight have highlighted some issues with its approach. Consequently, over the past several years, transit modeling for the larger cities in Florida has evolved into a somewhat unique set of procedures for each urbanized area.

In 2005, the Florida Department of Transportation and the Model Task Force agreed to develop a new transit modeling system for FSUTMS-Voyager. This new system is quite different from its FTTM ancestor in a number of different ways. Two areas stand out in particular. The first is Public Transport (PT), FSUTMS-Voyager's public transportation modeling module. PT is a multi-path path-builder, meaning that it can internally evaluate different path and sub-modal choices. The mode choice structure would select the access mode only (i.e., walk, park-and-ride or kiss-and-ride), with the path-builder effectively determining ridership on local bus, premium bus and rail modes. Recently, Citilabs added an option that forces PT to select a best path, in theory mimicking single-path builder similar to the FTTM's path-builder.

The other major difference deals with the increasing federal regulations on travel forecasts. The Federal Transit Administration's (FTA's) oversight of forecasts related to the New Starts program over the past five years have provided a number of adjustments to transit model "state of the practice" concepts. Modeling insights gained from FTA indicate that many ideas initially considered good practice in fact have many bad or undesirable properties during forecasting. In fact, they may render the model results inexplicable. Consequently, FTA has released recommended model properties and other findings to the modeling community in the hopes that future modeling systems will avoid these practices (or continuing them in some cases). This system is being developed with these properties in mind.

Furthermore, this modeling system is being developed with a New Starts level-of-scrutiny in mind. Since New Starts is essentially an "investment grade" level-of-analysis, the FTA has extremely high review criteria (compared to highway modeling) to validate the project benefits and evaluate whether those benefits are sufficiently cost-effective. So while it is recognized that most of the models in Florida may not pursue New Starts funding (or the upcoming Small Starts program), FTA's model requirements and suggestions are generally considered good modeling practice. For some elements, there are separate guidelines for general and New/Small Starts use because some techniques would likely be too burdensome for general long-range or highway planning efforts.

Overview

There are three possible approaches for the FSUTMS-Voyager Transit Model: (1) PT multi-path, (2) PT single-path and (3) PT-TRNBUILD hybrid. The first approach uses PT as it was originally designed. The multi-path path-builder determines the transit mode while mode choice determines the access mode. Although this setup is the desired long-term approach, testing and conversations with the Federal Transit Administration and Citilabs indicate that further testing is needed to identify its best approach for New Starts/Small Starts analysis.

The second approach would exploit the single-path setting in PT v4.1 (using the "best path only" parameter). This would be similar to the FTTM design, with the mode choice model determining both access and transit mode. One of its advantages is that it should maintain the structure of many existing FSUTMS mode choice models.

The third approach maximizes the use of PT's network coding procedures and the nationally-known path-building procedures of TRNBUILD. TRNBUILD is the single-path path-builder in TP+/Voyager. It has been commercially available for over 20 years, beginning as TRNPATH in the MINUTP software. It is used nationally, although not in Florida, and is well-respected for its path-building properties. The PT-TRNBUILD approach is being used in the latest version of the Southeast Florida Regional Planning Model. All three approaches will minimize the use of non-scripted programs to the extent feasible or possible.

At this time, the FSUTMS-Voyager Transit Model will use the PT single-path approach. The transit modeling system consists of modeling of transit demand and supply manifested in five areas: access to transit, the transit supply (network and system settings), path-building, mode choice, and assignment. Each one of these will be described in order executed in the model stream.

Time of Day
The evolution towards time of day (TOD) modeling reflects the recognition that choices are dependent on the congestion levels that vary over the course of the day. A quick review of existing transit models indicates peak and off-peak service is coded on all transit networks. This practice is formally adopted for the FVTM. Some areas have expressed a desire to develop three TOD networks. This should be encouraged, but also recognized that it has a high maintenance burden, as the survey data and networks (e.g., congested highway speeds, auto-egress connectors) must be prepared for modeling PM peak period travel.

The FTTM applies the constrained skims from a 24-hour highway assignment for HBW mode choice and free-flow skims for the HBNW and NHB mode choice. This assumes that HBW mode choice can be best represented using those conditions. Experience indicates that may no longer be an acceptable assumption. However, this practice is likely to continue in the near future. For models with TOD distribution, however, it is proposed that the mode choice model be run twice for each purpose, once for peak trips and impedances and another for off-peak trips and impedances.

Access to Transit
There are four elements to correctly determine transit accessibility: zonal access, walk-access connectors, drive-access connectors, and transfer connectors.

a) Zonal Access

Accurately reflecting transit access in transportation networks is directly related to the area of the traffic analysis zones. Many zone boundaries were originally developed in the early 1980s. Florida's high growth rates imply that a substantial amount of transit ridership would occur in future years in large zones (which could be upwards of five square miles). This reflects the fact that although transit service may directly service certain portions of the zone (via walk access), some of the zone may not be served at all. This mechanism is known as percent walk to transit or simply "percent walk".

These proportions are carried into the mode choice utilities, expressed as different access markets. Smaller zones with good transit service are likely to be "100% short walk", and therefore are likely for all activity have the ability to take transit. By contrast, large zones with isolated transit service are likely to be "25% long-walk", reflected in the mode choice model as 75% given only drive-transit and non-transit modes and 25% given a marginal chance of walking to transit and all other modes.

An ideal situation for travel demand modeling is to have zones as small as possible to minimize aggregation error. From a transit access standpoint, this means an average square zone with ¼ to ½ mile edges. While some areas have recently undertaken zone-splitting efforts, this document will assume that relatively large zones will be used in the near future in most models and that these zones will continue to absorb large quantities of activity. Consequently, the some zonal portioning methodology will need to be maintained and will be manifested in the computation of percent walks.

The zonal portioning methodology uses a simple "can/cannot walk" delimiter given that PT cannot effectively maintain the short/long-walk methodology without generating a set of paths for all access markets. Generating paths in this manner – one each for short access-short egress, short access-long egress, long access-short egress, long access-long egress, etc. – would be very time-consuming and of limited benefit.

b) Walk-Access Connectors

The FTTM utilizes an automated procedure, WALKCON, to develop walk-access connections between centroids and transit stops. WALKCON's logic assumes that the centroid connectors represent the best connection between the zone and the street grid if good transit service exists near the centroid connector node. But it created new connectors if the transit service and centroid connectors were on different sides of the zone. This ubiquitous access assumption is important, as it agreed with the assumptions of the percent walk calculations.

By contrast, PT's GENERATE creates walk access connectors by spidering along the highway network. This logic assumes that the centroid connectors are not only the best but the ***only*** connection between the zone and the street grid, an assumption that is inconsistent with the percent walk calculations. These differences have profound impacts on the calculation of percent walks (i.e., PCWALK file).

During development of the SERPM6 model, it was determined that PT's process generated more realistic connections (the most realistic scenario was no access for some zones) than the FTTM percent walk/WALKCON system. An additional procedure was developed to compare PT's walk connectors to the percent walks. The percent walks were adjusted depending on the type or existence of connection developed by PT. This seemed to produce viable results and is currently in use for SERPM6. A similar process will be used for other cities in Florida.

Unlike the FTTM, PT does not determine whether walking may be superior to the shortest "real" transit path. This necessitates developing "all-walk" connectors between every zone pair. These connectors will be compared to the transit skim. If the all-walk path is better than the transit skim, the transit skim values should be zeroed out before being processed by the mode choice model.

c) Drive-Access Connectors

The FTTM utilized the AUTOCON program to develop drive-access connections between centroids and park-and-ride (PNR) or kiss-and-ride (KNR) facilities. AUTOCON scans the network for available PNR or KNR facilities and develops a select number of connectors per origin zone. Its output is fully compatible with PT with some minor revisions to the source code.

The FTVM will use AUTOCON revised to be compatible with the PT format. It has also been changed to incorporate all aspects of the drive-access connector in the "cost" (i.e., perceived time). Specifically, the drive-access time is modified to reflect its equivalent to transit in-vehicle time and the station costs – in transit in-vehicle equivalent time – are added to the drive-access time on the connector. This will ensure that station cost is accurately accounted for in path-building.

d) Transfer Connectors

In the FTTM, transfer connections were represented using two sets of sidewalks. One was walk-able areas put in INET format, typically in or near Central Business Districts (CBDs). The other set was created by the SIDECON program, which generated a series of sidewalks near transit stations. Unfortunately, this system cannot be replicated in PT for a couple of reasons. PT is based on the leg concept, which requires all connections be between a centroid and transit stop or between transit stops. Intermediate links, such as those used in FSUTMS-Tranplan, are not allowable inputs. Also, PT's path-builder does not permit traversing consecutive non-transit legs.

Transit Network

The FVTM will take advantage of as many of PT's network coding features as possible. Some of these features eliminate the need for standard input files used in the FTTM and ease the coding maintenance burden. One such feature is the ability to code transit-only links directly into the highway network, making it more representative of a "transportation" network. Also, the STATDATA file inputs can be coded directly on the nodes of the highway network and scripted to an ASCII file during the model run.

Transit speeds are extremely important as they are the key determinant in computing user benefits. In the past, the default transit speed curves were typically accepted "as is" without any review for reasonableness. This task was admittedly made difficult with the awkward speed curve designations as well as auto speeds that were more reflective of highway assignment problems rather than actual travel time conditions. Surveys have recently been conducted in Jacksonville and Tampa to analyze the differences between auto and bus speeds on various facility and area type categories. Initial analysis indicates that changes are needed to the existing auto-bus speed delay curves.

The FTA has strongly encouraged the use of micro-coding fixed-guideway, park-and-ride and kiss-and-ride stations in recent months. The purpose is to reflect all the known attributes of travel in the network rather than relegating them to the utility bias constants. The station "floor" is a node on the highway network. The "platform" is connected to the "floor" by a transfer link with some small amount of travel time. Only the fixed-guideway system is able to access the "platform". Parking areas would be coded somewhere between the "floor" and "platform" and have separate connections to both. This system should be used for all stations. Micro-coding of fixed-guideway stations will be mandatory for all modeling efforts. A micro-coding process for PNRs will be finalized in the coming months.

Many other details related to transit network coding can be found in the companion "Application Framework" document.

Path-Building

In this country, the best path has historically been defined as the single shortest path between two zones. Headways are allowed to combine at similar boarding and alighting locations assuming similar travel times.

The number of transit paths will depend on the types of service and access offered and the quantity and quality of available data. Ideally, an on-board survey should be conducted and its results analyzed to determine the path structure. The following recommendations will generally hold:

- For areas with local transit service only, no park-and-rides and the most basic ridership data available, two paths – walk to all transit and drive to all transit – should only be required. All forms of transit will be available in this path.
- Areas with some local and express service and park-and-rides likely or those areas that need to test new modes would produce four paths: walk-bus, walk-premium/project, drive-bus, and drive-premium/project.
- Southeast Florida offers many different types of service. This area should build eight paths per period: walk-bus, walk-project, walk-MetroRail, walk-Tri-Rail, drive-bus, drive-project, drive-MetroRail and drive-Tri-Rail.

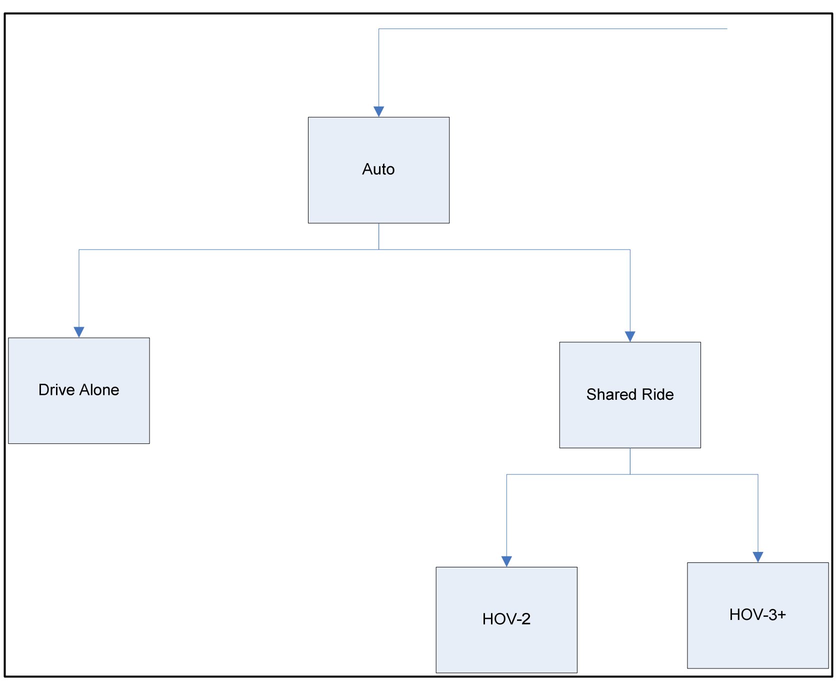
Including fares in the path-building criteria has been done in models across the country. Technically, they should be included (via an appropriate value of time factor) to have the path-builder and mode choice utilities fully consistent. In practice, however, fares are very difficult to determine until the entire path is known due to software limitations and/or complex fare policies. Some research will have to be conducted to verify that PT can evaluate the correct fare regardless of the system used. Paths should not reflect fares until that time.

Mode Choice Model

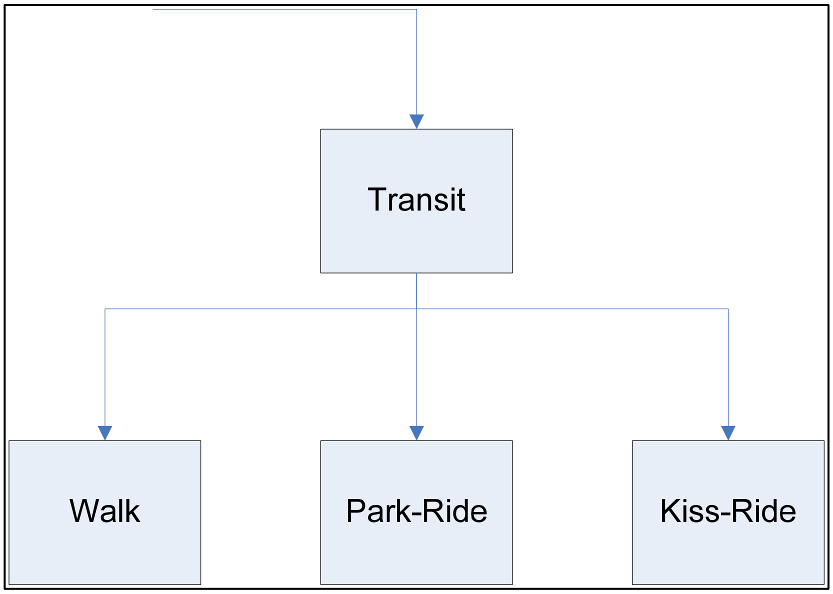
The FTTM maintains the "highway-only" mode choice in the DISTRIB step and uses the "nested logit" structure in the MODE step. This process should probably be maintained in the FVTM as long as the overall FSUTMS model stream remains unchanged.

Converting mode choice models to Voyager script should be done only when the running time impacts are minimal. Running scripted mode choice models increases run time. In some cases, the difference may be substantial for medium- and large-cities. A simple scripted mode choice model might work effectively for small cities. Newer, multiple-core machines are making longer run times less of a concern for these areas. Larger cities will likely want to continue using FORTRAN programs as time-of-day highway assignments will already consume large amounts of run time.

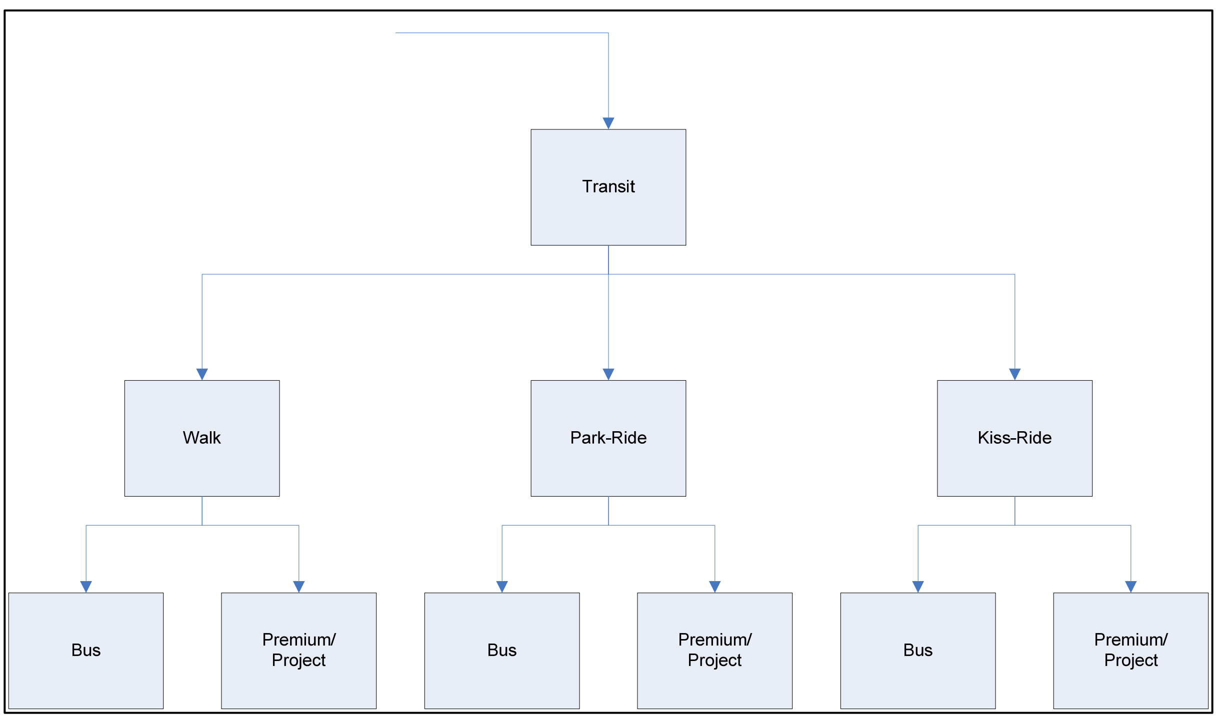
The mode choice model will continue to use a nested logit structure reflecting the paths produced in path-building. The standard SOV/HOV and HOV-2/HOV-3+ nests in the auto branch will be maintained (shown below).



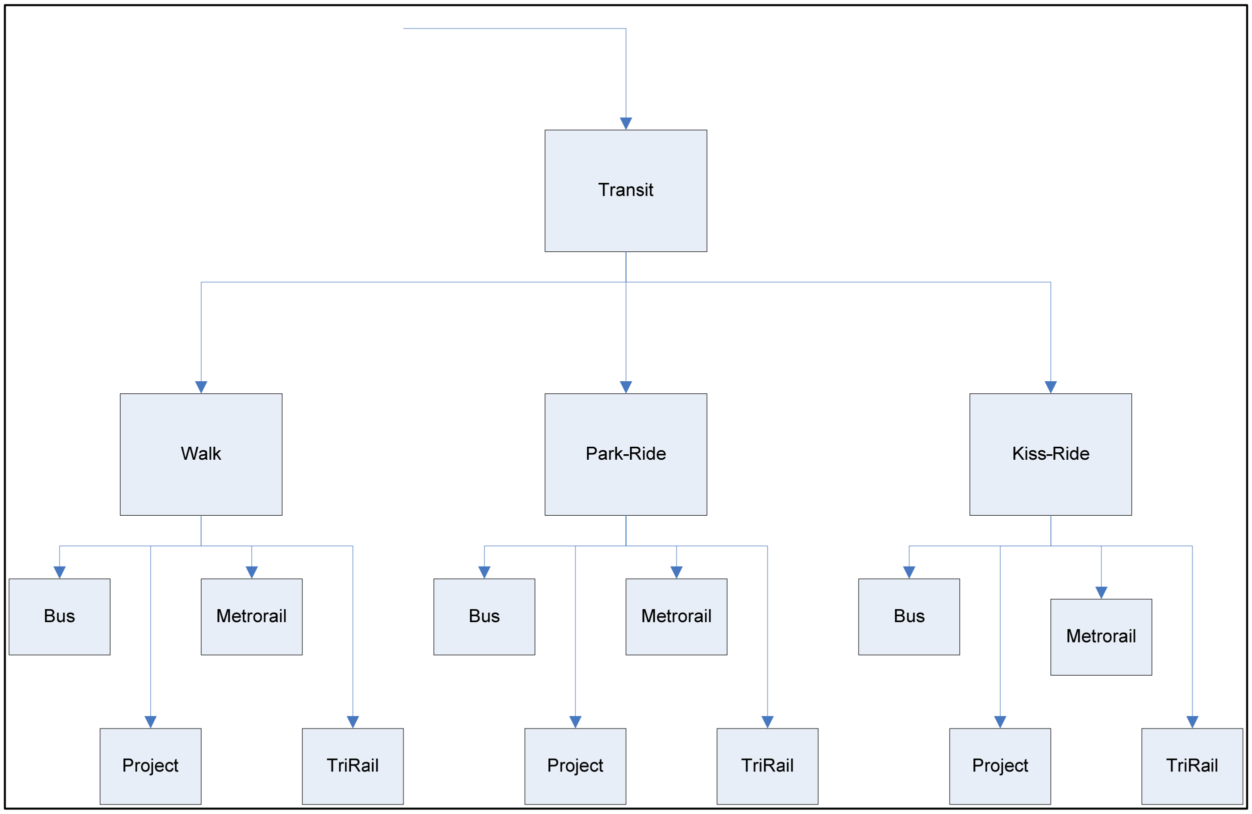
For the transit nests, areas pulling two access paths per period should use the simplified structure shown below. The walk-transit path is used in the walk-transit nest. The drive-path is used in both the park-ride and kiss-ride nests.



Areas producing three paths for each period will need to expand the access modes accordingly. The walk-, park-ride- and kiss-ride-transit paths will reside in the same transit nest. This structure is shown below. As before, the drive-transit paths will be used in the park-ride and kiss-ride nests.



The mode choice structure for the Southeast region will reflect its eight paths, having separate branches for Metrorail and TriRail. This allows the mode choice mode to determine whether commuter rail or a non-commuter rail mode is used, and the access mode of that mode. This structure is shown below.



The FTTM used coefficients taken from other areas rather than derived from local data. This was, in part, a reflection of the extensive time and cost required to produce them. The current FTA position is that enough work has been done across the country to justify using the mid-range of previously completed coefficient estimations. It is proposed to use core coefficients (e.g., in-vehicle time, out-of-vehicle time, fare) recently proposed by the FTA for New Starts quality control analysis. They represent the mid-range of national experience and have solid inter-relationships. In most cases they are similar to what has historically been used in Florida.

The FVTM will maintain the practice of assigning the drive portion of auto-access transit trips. Also, the Voyager software allows decimalized matrices. At this time, it seems reasonable to recommend two-decimal precision for trip tables. Future testing may show that single- or double-precision may be necessary to avoid bucket-rounding issues.

The “Lifestyles” trip generation procedures employed in several models across Florida offer the possibility of making the key socio-economic variables available to the mode choice model. One such example is using income-based stratifications rather than the auto-based ones used today. Nationally, there has been a trend toward using income-based stratifications rather than auto-ownership in mode choice utilities. The basis for this is the observation that households with similar incomes make comparable choices. In FSUTMS, migrating toward income-based stratifications has not been possible since the ZDATA sets do not include the required income variables. This issue will requires further exploration.

Transit Assignment

Transit assignment follows the same general methodology as path-building. An assignment module will be needed for every transit path created in path-building. PT assignments are decimalized, a key difference from the integer-based assignments in the FTTM.

Summarizing transit assignments requires a program as PT or TRNBUILD do not create similarly-styled reports as used in the FTTM. A new program named TAREPORT has been produced for this purpose.

Calibration/Validation

Highway model calibration in Florida has been historically accomplished by adjusting the speed/capacity lookup table. One downside to this technique is a distortion in the auto speeds (free-flow and/or congested). The transit speeds are consequently impacted, and subsequent re-calibration efforts will produce relationships that cannot be observed or validated. In addition, the mode choice model becomes impaired in its evaluation of distorted auto speeds and questionable transit travel times. The model's sensitivities to these imprecise speeds also come into question. The resulting bias constants reflect this error and translate this into erroneous user benefit results.

Artificially altering auto speeds also mutates the trip distribution process in an unpredictable manner and, although the regional average trip lengths can be maintained, the market of eligible transit trips can greatly impact the mode choice model's ability to reliably forecast a change in transportation supply. The best remedy is to avoid altering the speed/capacity table without first investigating issues with other areas of the model.

It is proposed to expand beyond simple trip targets and ridership totals for validating transit models. The FTA has found that validating only aggregate (i.e., regional) numbers can mask substantial problems and impair a model's ability to properly forecast ridership. It is recommended to use a twofold effort for general modeling efforts and a four-pronged effort for validating transit models for New/Small Starts analysis.

The linked trip and ridership elements reflect the current state of the practice in Florida and should be maintained for general modeling use. Linked trips are calibrated within the mode choice model, typically at the lowest nest level. Boardings should be validated by mode and operator to verify the travel patterns and transfer rates.

New/Small Starts efforts should also review trip distribution and bus travel times during the calibration process. Trip distribution is very critical to effective transit modeling as this determines the eligible travel markets. Transit supply is temporally- and directionally-oriented, so it is crucial to have the correct number of trips in their proper direction and period. It is recommended to check the work trip distribution by comparing it to a district-to-district comparison of CTPP journeys to ensure the modeled travel patterns reflect observed behavior. A review of the end-to-end travel times for all transit lines is also proposed as correct travel times are the most important element in computing user benefits.

Uncertainties

It should be noted that there are still uncertainties in accepting this approach. The FVTM approach is different from the existing FSUTMS transit modeling methods because of changes in techniques in recent years and increasing federal scrutiny of New/Small Starts projects. The approach requires more expertise and technical skill. There is more focus on observed data and consistently good transit network coding. It is reliant on good highway modeling practice, especially highway network coding, distribution and auto speeds.

This approach was developed to avoid as many theoretical and application issues as possible, with extensive beta testing and coordination with Citilabs and the FTA. However, experience has proven that there is no substitute for real application. It is hoped to set up a proto-type model before finalizing this approach, with its validation as it undergoes the New Starts process. It is recommended that these standards be re-visited in 3-5 years as these recommendations and improvements to the overall model stream (i.e., time of day, distributive processing) are put into practice.