Transit Modeling Update

Time of Day Stratification Review and Recommended Model Development Guidance

Contents

1 Introduction

The purpose of the Transit Modeling Update project is to specify, within FSUTMS and associated support systems, the changes necessary to improve the preparation of transit demand forecasts to a point consistent with federal expectations, and to incorporate state of the practice techniques and tools through a prototype model application. The Tallahassee Capital Region Transportation Planning Agency (CRTPA) model was chosen as the prototype FSUTMS model application.

This memorandum offers guidance on time-of-day stratification. FSUTMS does not apply time of day stratification, in the usual sense of allocating trips among peak and off-peak periods. Instead, FSUTMS applies the classical assumption that all home-based work travel corresponds to peak period travel conditions and all non-work travel corresponds to free-flow conditions. This assumption is no longer accurate – while the majority of work trips do occur during peak periods, one-third of these trips are observed during the off-peak; conversely, nearly half of all non-work trips occur during peak periods. Moreover, free-flow travel times may not be representative of off-peak travel conditions in urban areas of the state, nor will be representative in future years in rapidly growing areas of the state.

The FSUTMS Tallahassee implementation uses another time-of-day simplification--it applies free-flow travel conditions to distribute all trips, work and non-work alike. Even if valid for today's conditions, this assumption may not apply in 30 years' time, and therefore its suitability for long range planning is questionable.

Regional travel demand models introduce time-of-day stratification in two places: after trip generation, to split productions (Ps) and attractions (As) into peak and off-peak Ps and As separately for each trip purpose, and then prior to highway assignment, to allocate auto trips into 3 to 5 or more time periods for assignment. In these schemes, the AM peak and PM peak assignment periods are typically from 2 to 4 hours long. Peak and off-peak skims developed from these assignments are input to trip distribution and mode choice. More recently, some models stratify the highway assignment into shorter time periods (1 hour long), usually with the goal of modeling peak period conditions in greater detail.

The state of the practice for time-of-day stratification in regional models is the use of factors that are invariant to level of service attributes. This practice has come under scrutiny due to interest in variable time-of-day pricing and other congestion mitigation strategies. Concurrent with this transit modeling guidance, efforts are underway at FDOT to develop a time-of-day model for FSUTMS that provides the required sensitivity to variable travel time and roadway prices[1]. For the purpose of transit modeling, it is recommended that the FSUTMS time-of-day stratification be based on fixed diurnal factors. This recommendation is consistent with current best practices for transit modeling, and also consistent with FTA guidance related to the use of constant person trip tables. The recommendation does not preclude the eventual adoption of a choice or incremental model, once this model is fully developed and tested.

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[1] Technical Memorandum: Incorporating Time of Day Modeling into Florida Standard Urban Transportation Model Structure. Phase II. Time of Day Choice/Peak Spreading Sub-Model Interim Report (Draft). June 1, 2011.

2 Time of Day Stratification

2.1 Proposed Approach

Figure 2-1 shows the current and proposed FSUTMS time of day stratification. The proposed approach is to introduce time of day stratification in two places in the model chain: after trip generation (peaking factors), and after mode choice (diurnal factors). The peaking factors simply stratify trip productions into two time periods, peak and off-peak. Trip attractions would be stratified as well, by default, since they get balanced to productions. The trip distribution and mode choice models would then be stratified into peak and off-peak segments, with appropriate skims used for each time period. After mode choice, the diurnal factors further stratify the peak auto trips into AM and PM peak period trips, and the off-peak auto trips into Midday and Night time trips. The transit trips will continue to be stratified simply into peak and off-peak period trips. This recommendation is consistent with current best practices for transit modeling.

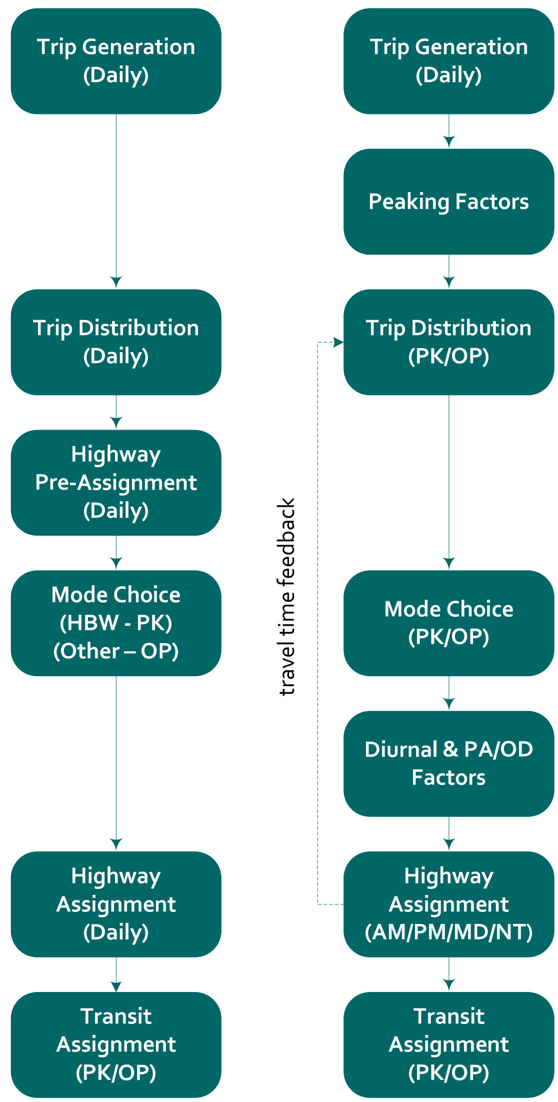

Figure 2-1: Current and Proposed Time of Day Stratification

It is recognized that this proposed approach may fail to completely capture important time-of-day differences in transit demand or levels of service, such as variations in frequency within the AM peak period, or variations in frequency and/or travel time between the AM peak and the PM peak. These issues can be addressed by using higher time-of-day resolution. Supporting such levels of stratification implies additional effort spent in transit network coding, and additional model run time required for skim building and mode choice. The additional coding effort is not limited to coding the right frequencies or routes, but also the directionality of the drive access connectors. For example, drive access connectors in the AM should be coded only from the centroid to the pnr stop, to accommodate the vast majority of travelers in the morning who are moving from home, but preventing travelers from using auto as an egress mode in the morning. If a skim or assignment is done in the PM, this scheme is reversed. Also, when implementing separate AM and PM transit networks, care must be taken in mode choice to associate the skims to the correct 'home' end of the trip. A simple way to maintain this consistency is to transpose the PM transit skims for use by the mode choice model.

2.2 Time of Day Periods

As is the case with other market segmentation strategies used in trip-based models, the goal is to stratify the market into periods expected to exhibit approximately constant travel conditions. These conditions include not just highway travel times and the duration of congestion, but also transit levels of service. Both of these conditions can be highly variable from region to region, and for this reason each region should be allowed to establish its own peak periods.

The diurnal trip pattern for Florida is shown in Figure 2-2. It exhibits the expected bi-modal shape, with the AM peak occurring between 7:00 AM and 8:00 AM, and the PM peak occurring between 5:00 PM and 6:00 PM. The diurnal pattern for the CRTPA region, also shown in Figure 2-2, follows a similar pattern, with the notable exception of a peak around noon. It may be that the relative lack of congestion in and around Tallahassee, relative to the more urbanized areas of the state, encourages people to travel for lunch and other errands during the midday. It should be noted however that the CRTPA pattern is based on a relatively small number of trip observations, and therefore this noon peak may simply be an artifact of the small sample size.

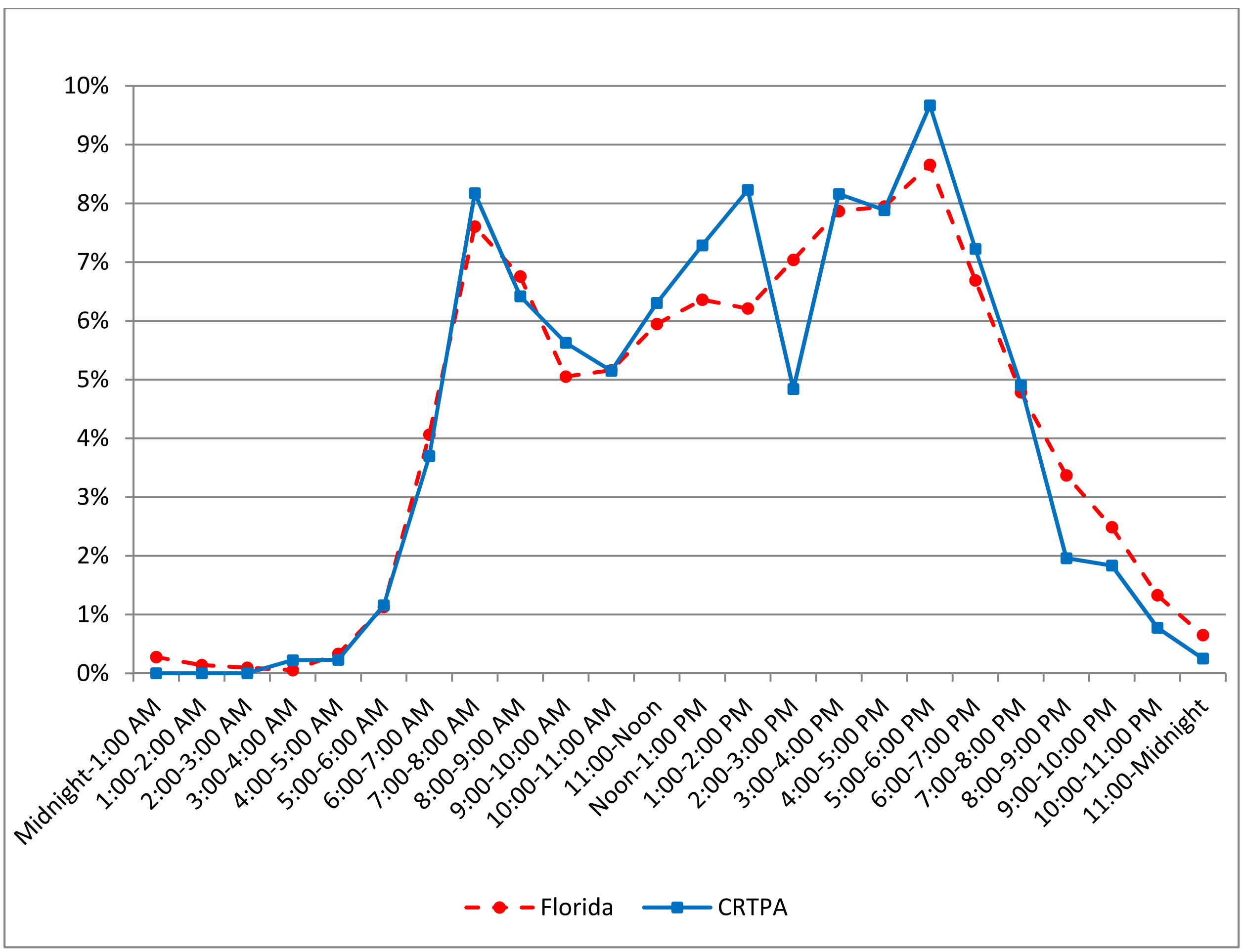

Figure 2-2: Trip Diurnal Distribution

The CRTPA HBW diurnal pattern shows this region peaking nearly an hour earlier in the evening than the rest of the state combined (Figure 2-3).

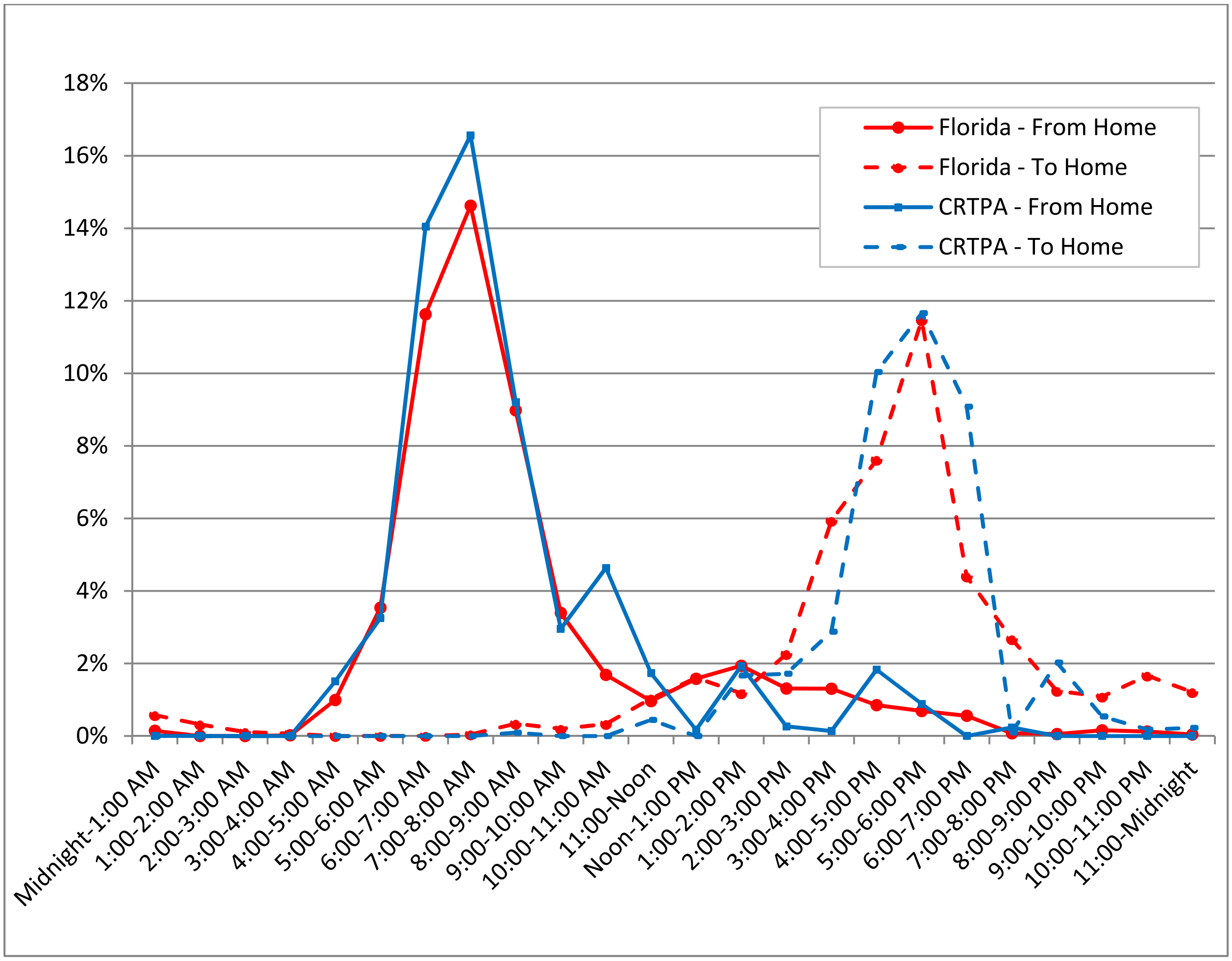

Figure 2-3: HBW Diurnal Trip Distribution

Based on the statewide and CRTPA diurnal distributions, the following definition of time periods is recommended for FSUTMS and for the CRTPA prototype model:

- AM Peak: 6:00 AM to 8:59 AM
- Midday: 9:00 AM to 2:59 PM
- PM Peak: 3:00 PM to 6:59 PM
- Night: 7:00 PM to 5:59 AM

Establishing the period boundaries should be based on both an understanding of times during which congestion is present, and when transit operations may change between a peak and off-peak condition in terms of fare, route structure and/or service headways.

2.3 Representative Skims

2.3.1 Peak Period Skims

For the peak period, a question arises as to whether the most representative conditions for trip distribution and mode choice are the AM peak or the PM peak skims. The classical assumption is to use AM peak skims as the peak period skim, partly out of convenience (it corresponds with the PA trip format used in distribution and mode choice), and partly because no significant differences were observed between AM and PM travel times and prices. Again, this assumption has come under renewed scrutiny because in many urban areas the PM peak lasts longer than the AM peak, and in some cases higher levels of congestion are observed during the evening commute than during the morning commute. Portland Metro, for example, uses PM conditions as the representative peak period skim.

An emergent approach is to use a blended skim to represent peak period conditions. The blended skim is a weighted average of AM and PM skims, where the AM skim weight is the share of peak period trips that occur in the AM period, and the PM skim weight is the share of peak period trips that occur in the PM period. In this way, the peak period skims –and therefore the peak period distribution and mode choice models- are sensitive to changes in AM and PM levels of service.

The blended skim approach however has some drawbacks. First, it might create some inconsistencies between mode choice and transit assignment, particularly if there are large differences between the AM and PM transit service. For example, if the mode choice model allocates transit trips to an OD pair that has no transit service in the AM, but some service in the PM, the assignment will be unable to load the trips onto the network, because it uses only the AM transit network. Obviously, where there are large differences in levels of service across times-of-day, then some degree of inconsistency is unavoidable, regardless of the approach taken, unless a high time-of-day resolution approach is adopted. A second drawback is the increase in model run time, since this approach requires developing AM and PM skims at each feedback loop, instead of only AM skims. Another drawback is related to the blending weights. The most consistent approach is to vary the weights with the trip purpose, to represent the varying peaking patterns of each purpose. To economize on model output storage, the blended skims are not saved to disk; instead they are created 'on-the-fly', that is, as the distribution and mode choice models execute. This approach can be confusing to the end user, because the skims saved to disk are not quite the values applied to each OD pair.

2.3.2 Off-Peak Period Skims

Oftentimes free-flow conditions are used to represent off-peak conditions. The danger of building this assumption into the model is that, in 30 years' time, demand levels during the midday can be high enough that free-flow conditions may no longer be an appropriate assumption. A more consistent approach is to develop off-peak skims by assigning the midday trips, and perform the necessary feedback convergence loops. An option could be built into the model to skip the midday assignments for short range planning applications.

In summary, the recommended approach for FSUTMS is to use AM peak skims for the peak period, and midday skims for the off-peak period.

3 Peaking and Diurnal Factors

Peaking factors based on the NHTS 2008 data are shown in Table 3-1; diurnal factors are shown in

Table 3-2 and

Table 3-3 for all of Florida and the CRTPA model area, respectively.   In these tables the column heading "PA" refers to the direction from production to attraction (i.e., from home to primary activity for home-based trips, or from work to activity for non-home-based work trips). The column heading "AP" refers to the direction from attraction to production (i.e., from the activity to home for home-based trips, or from the activity back to work for non-home-based work trips).

Table 3-1: Florida and CRTPA Peaking Factors

Purpose	Florida		CRTPA	
	Peak	Off-Peak	Peak	Off-Peak
HBW	0.684	0.316	0.764	0.236
HBCU	0.515	0.485	0.581	0.419
HBSC	0.773	0.227	0.816	0.184
HBSH	0.396	0.604	0.409	0.591
HBSR	0.455	0.545	0.401	0.599
HBO	0.544	0.456	0.565	0.435
NHBW	0.479	0.521	0.436	0.564
NHBO	0.383	0.617	0.435	0.565
All	0.496	0.504	0.512	0.488

Table 3-2: Diurnal Factors, Florida Statewide

Purpose	AM 6:00AM-8:59AM		MD 9:00AM-2:59PM		PM 3:00PM-6:59PM		NT 7:00PM-5:59AM	
	PA	AP	PA	AP	PA	AP	PA	AP
HBW	0.516	0.005	0.339	0.206	0.050	0.429	0.167	0.287
HBCU	0.550	0.003	0.333	0.328	0.191	0.255	0.004	0.335
HBSC	0.680	0.001	0.126	0.730	0.018	0.302	0.021	0.123
HBSH	0.128	0.038	0.346	0.366	0.318	0.517	0.079	0.209
HBSR	0.148	0.038	0.285	0.194	0.452	0.362	0.124	0.397
HBO	0.354	0.094	0.408	0.322	0.199	0.352	0.088	0.183
NHBW	0.055	0.317	0.469	0.411	0.547	0.082	0.076	0.045
NHBO	0.111	0.111	0.422	0.422	0.389	0.389	0.078	0.078

Table 3-3: Diurnal Factors, CRTPA Region

Purpose	AM 6:00AM-8:59AM		MD 9:00AM-2:59PM		PM 3:00PM-6:59PM		NT 7:00PM-5:59AM	
	PA	AP	PA	AP	PA	AP	PA	AP
HBW	0.524	0.005	0.474	0.169	0.039	0.432	0.221	0.136
HBCU	0.752	0.007	0.155	0.745	0.002	0.239	0.017	0.083
HBSC	0.662	0.000	0.148	0.820	0.007	0.331	0.000	0.032
HBSH	0.146	0.023	0.367	0.401	0.248	0.582	0.045	0.187
HBSR	0.047	0.057	0.294	0.198	0.496	0.401	0.162	0.346
HBO	0.343	0.045	0.388	0.290	0.192	0.420	0.059	0.263
NHBW	0.015	0.258	0.472	0.466	0.678	0.049	0.062	0.000
NHBO	0.119	0.119	0.451	0.451	0.381	0.381	0.049	0.049

The CRTPA HBW AM diurnal factors were slightly adjusted because the NHTS data show 0% trips in the AP direction. A share of AP trips equal to the Florida share was asserted. The CRTPA HBCU diurnals were also adjusted because the NHTS data shows 0% trips in the NT period. The CRTPA peaking and diurnal factors may be adjusted during the validation of the highway assignment. Similarly, it is anticipated that peaking and diurnal factors computed for any Florida region may need to be adjusted during each region's model validation.

The diurnal factors were calculated for highway trips only, since the recommendation is to continue performing peak and off-peak transit assignments. If diurnal transit trip factors are desired, their calculation would need to be based on on-board survey data or transit ridership counts, due to the small size of the NHTS transit sample.

4 Model Application

As shown in Figure 2-1, the peaking factors are applied to the trip productions prior to trip distribution. The diurnal factors are applied to the peak and off-peak highway trip tables after mode choice. The diurnal factors allocate peak trips between the AM peak and the PM peak, and off-peak trips between the midday and the night time periods. The diurnal factors also simultaneously perform the PA to OD trip conversion. For example, to create the AM highway trip tables the following formula is applied:

$$OD\ Trips_{AM} = PA\ Trips_{PEAK} \times fac_{AM}^{pa} + PA\ Trips_{PEAK}^{transposed} \times fac_{AM}^{ap}$$

where $PA\ Trips_{PEAK}$ is the highway trips out of mode choice, and fac_{AM}^{ap} and fac_{AM}^{ap} are the AM diurnal factors for the PA and AP direction, respectively. Since the diurnal factors are expressed relative to the peak and off-peak periods, the sum of the AM and PM factors must be 1.0, and the sum of the MD and NT factors must be 1.0

Note that after mode choice the peak and off-peak trips are always kept separate, that is, they are not combined to create the diurnal trip tables.