Travel Time Feedback Review and Recommended Model Development Guidance

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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 travel time feedback. Travel time feedback is the process of equilibrating the travel times used in the demand model with the travel times obtained from highway assignment. The purpose of feeding back the travel times resulting from the assignment step is to ensure consistency between the input model assumptions and the model outcome. That is, the travel times that informed the demand model (in particular trip distribution and mode choice), should be equal to the travel times "caused" by the trip forecast. FSUTMS does not apply travel time feedback; instead, the demand model is always exposed to the input free-flow times. This assumption may be accurate in rural areas, but usually does not apply to even moderate urban and suburban areas, where some level of congestion is observed during peak periods. Moreover, free-flow travel times may not be representative of peak or off-peak travel conditions in future years in rapidly growing areas of the state.

Highway travel times affect transit trip forecasts in two ways. First, bus speeds are computed as a function of both highway speed and stop dwell time; erroneous highway times will then lead to incorrect bus speeds and a misrepresentation of the transit level of service. Second, highway travel times determine, among other factors, the level of service for the main transit competition – the highway system. If the highway times are assumed to be faster than expected for the forecasted demand levels, the model will over-estimate the highway utility and therefore under-estimate the relative attractiveness of transit. To avoid these problems, most urban regional travel models employ a travel time feedback method. The purpose of this memorandum is to describe a proposed feedback methodology for FSUTMS.

2 Time of Day Stratification

Travel time feedback is typically, though not always, applied in conjunction with time of day segmentation. Figure 2-1 shows the current and proposed FSUTMS time of day stratification. The purpose of the time of day stratification is to better estimate travel time conditions during peak periods, rather than assuming average conditions throughout the entire day. Travel time feedback works in tandem to ensure that the travel times forecasted by the model are commensurate with the demand levels, and that the demand levels are commensurate with the forecasted travel times.

As described in the Time of Day Segmentation memorandum, the proposed FSUTMS and CRTPA prototype model time of day periods are:

- 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

Note however that the demand models –trip generation through mode choice—are applied only for peak and off-peak periods, as is customary in a trip-based model. The AM peak travel times are assumed to be representative of the 'peak' demand conditions, while the Midday travel times are assumed to be representative of the 'off-peak' demand conditions. As such, it is necessary to feed back two sets of highway times, the AM Peak times and the Midday times.

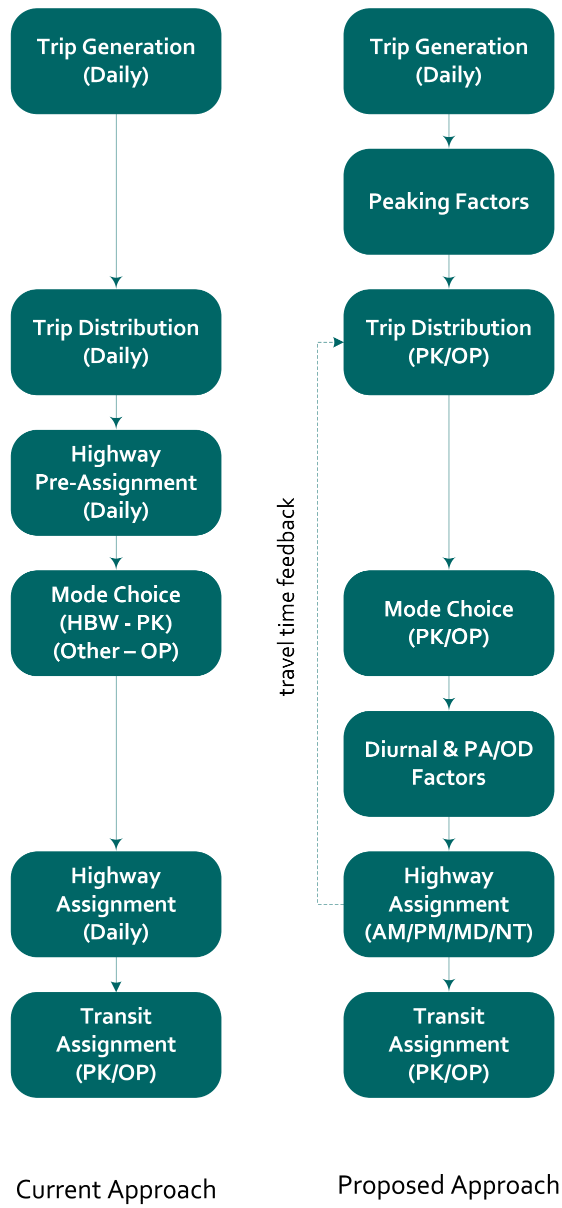

Figure 3-1: Current and Proposed Time of Day Stratification

3 Feedback Implementation

As shown in Figure 2-1, travel time feedback is an iterative process—the travel times forecasted by the highway assignment are fed back to the top of the model chain; the demand model is executed again, and a new set of travel times is obtained, which is subsequently fed back to the top of the model chain. It is important to choose a feedback method that converges, and preferably one that converges quickly (meaning, in relatively few iterations). Convergence means that the travel times computed in one iteration are equal (or nearly equal) to the travel times computed in the previous iteration.

As such, implementation of feedback consists of two separate but related decisions: how to combine the travel times obtained during the current and previous iterations to form the estimate for the next iteration, such that convergence to a unique solution is guaranteed, and how to measure convergence.

The only feedback method that has been shown to guarantee convergence in travel demand equilibration is the method of successive averages (MSA). MSA employs a decreasing step to average the current iteration link flows with all previous iterations' link flows. The feedback travel time is obtained by applying the model volume-delayed functions to the averaged volumes. If k is the current iteration, then the average link volume is calculated as:

$$Vol^{k+1} = \left(1 - \frac{1}{k}\right) \times AvgVol^{k-1} + \frac{1}{k} \times Vol^{k}$$

As the number of iterations increases, the contribution of the last iteration's time decreases. Eventually the travel time will converge because the next iteration travel time is nearly identical to the previous iteration travel time, by definition.

Compared to other ad-hoc methods, MSA converges relatively slowly. Although the convergence of other methods is not guaranteed, often they do converge. In particular, there is empirical evidence that constant step sizes sometimes result in faster convergence than MSA. However the results have not been generalized, and for this reason MSA remains the most widely adopted feedback methodology employed in the United States.

Note that it is incorrect to average the travel times to obtain the next iteration's time. This is because the volume-delay functions are not linear; the average of the function values (times) is not equal to the function applied to the average volume.

The uniqueness of the MSA solution is guaranteed only in the case of a single class assignment. For multi-class assignments, as implemented in FSUTMS, the uniqueness of the solution cannot be proven mathematically.

Many different measures of convergence or gap have been proposed. They measure relative changes in link flows, or relative changes in total travel costs. An additional measure of convergence is the relative change in OD trips. These convergence measures are generally satisfactory, provided that the threshold or maximum gap value chosen is small enough for practical purposes. Oftentimes tests with different gap values are required to arrive at a good solution – a small enough gap achieved relatively quickly.

In addition, it is recommended that a maximum number of feedback iterations be established in the application. A typical value is between 5 and 10 iterations, which often guarantees or nearly guarantees convergence. The gap measure between iterations should be reported, so that the analyst is able to establish the convergence history, and decide whether additional iterations are required. A model that takes a large number of iterations to converge may exhibit an improperly specified MSA function, a large assignment equilibration gap, other implementation errors, or unrealistic demand vs. capacity assumptions.

The convergence method proposed for FSUTMS measures the change in link flows. The contribution of each link to the global convergence is weighted by its volume, so that changes in small flows contribute less than changes in large flows.