Enhancing a Post Processing Application of Travel Demand Forecasts for Estimating Express Lanes Traffic and Variable Toll Rates

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Objectives, Motivations and Innovations

Florida DOT is looking to be more innovative when it comes to enhancing Florida's highway infrastructure. This includes evaluating some proposed projects as potential toll roads. Including this option as a build alternative means considering what the potential traffic forecast would be reduced to when a toll is applied to the road. A county or regional travel demand model is typically used to produce traffic forecasts for a Project Development and Environment (PD&E) study to determine the necessary capacity to support the expected traffic. This would also be the model used for producing a tolled traffic forecast. However, recent studies have required multiple scenarios to test various toll rates and project alternatives, especially when the project is a managed lanes facility located in an existing interstate highway corridor.

Travel demand models have become extremely complex over the years as computing power has improved and demand for more analyses output has been required to better evaluate project alternatives. This can add significant production time to a project that already has a large base model with long run times. Now, when considering current model run times have gotten extremely long due to complex coding and network size and projects usually require multiple analysis years and project alternatives, the amount of production time to complete all the model runs increases drastically. Furthermore, when you compound those project alternatives and analysis years with variations related to the project as a tolled alternative, the required number of runs is even higher, sometimes prohibitive to accomplish in the time allocated to complete the project. Then, add in all the additional resources to recode each toll alternative in each model forecast year, and you can have a major cost increase to the project if it's even feasible to complete all the requested tests in the project timeline. Florida’s Turnpike Enterprise (FTE) has developed a post travel demand model toll application that requires minimal run time and is very rich in data utilization, especially useful for evaluating complex managed toll lanes projects.

FTE wanted an application that could evaluate a tolled corridor with a competitive non-tolled alternative for multiple project alternatives by project section to produce among other things, an optimal toll rate but have a quick turnaround time for efficient production. The evaluation results desired included forecasted traffic volumes, speeds, and toll rates by project section and time of day. The original application development was successfully applied to a potential managed lanes project in Southwest Florida. This innovative approach allowed FTE to evaluate multiple toll policies, project alternatives, and years. The model runs were completed in a small fraction of the time it would have taken to use the travel demand model to complete the same number of runs.

FTE is currently evaluating three new corridors in Florida for potential managed toll lanes projects in existing Interstate Highway corridors. FTE is enhancing the existing structure of this Express Lanes Time of Day (ELTOD) application to provide better accuracy, more output detail and versatility to the input. The updates currently underway include a calibration update using available Florida managed lanes traffic data from I-95 in southeast Florida. Other enhancements are smaller time intervals (e.g. 15 minute Vs. 1 hour) for data output, Value of Time (VOT) updates based on the project study area supported by Stated Preference Surveys, and a corridor diversion option.

Methodology

The ELTOD procedure uses four primary sets of inputs:

1) Traffic estimates for the corridor (ideally, AWDT).
2) Distribution of total traffic within the corridor (by direction).
3) Geometric configuration of the facility: section length, free flow speed, lane capacity, passenger car equivalent factor (PCE), numbers of general use and express lanes.

4) Maximum/minimum toll rates ($/mile).

Currently, ELTOD holds the daily traffic and hourly distribution constant (i.e., does not reflect peak shifting) and estimates the split that will occur between general use and express lanes given those volumes. It does this by solving for the supply/demand equilibrium with both toll level and travel times for each hour. Diversion to alternative routes in this application is currently considered to be adequately represented from application of the travel demand model. The output from the travel demand model that is utilized as the final input to the time of day application is assumed to be traffic that would want to use the corridor and not divert out. This is concluded through an iterative process.

Output from the travel demand model is the necessary traffic origin-destination tables to the ELTOD analysis. Through the iterative process running the ELTOD and travel demand model for a selected project alternative, the rate per mile produced by the ELTOD using the demand model's input was compared to the constant rate used in the travel demand model. Once the ELTOD average rate by period (AM, PM, Midday, Night) for each project section was within a desired margin of error (difference), ELTOD was considered calibrated for use.

Supply Side

The supply side relationship between traffic volume and travel times is represented by Akcelik curves that estimate the section travel times separately for the general use and express lanes in each direction (1). These curves were developed based on queuing theory to more accurately represent congestion levels in over-capacity conditions. The Akcelik curves are calculated as:

\[
\text{Ratio of congested time to free flow time} = \frac{1}{S} + \frac{(0.25 \times T \times ((V/C - 1) + ((V/C - 1)^2 + (8 \times J \times (V/C)/(Q \times T)))^{0.5}))}{1/S}
\]

Where:
- \(T\) is the length of the time period in hours (default = 1)
- \(S\) is the free flow travel speed for the facility (mph)
- \(J\) is a facility-specific parameter
- \(Q\) is the facility capacity (veh/hr)
- \(V/C\) is the one-hour volume to capacity ratio

The result of these curves is that travel times equal the section length divided by the free flow speed for low volumes and increase dramatically as volumes approach or exceed the hourly capacity.

Toll rates are computed for each hour and direction based on the express lane’s volume to capacity ratio using power curves (Power curves rather than splines or other piecewise linear forms are used to avoid discontinuities that could prevent convergence of the equilibration process). As illustrated later in this paper, power curves can be used to represent a wide range of tolling policies, from those that increase tolls gradually as traffic increases throughout the range to those that are intended to “protect” a certain level of service and thus increase rapidly as the limits of that level of service are approached. The rates are set so that they fall within a specified minimum to maximum toll range, with a shape determined by a specified power curve exponent. Figure 1 displays a sample of TollEXP values with a minimum of six cents and a maximum of $1.40 set at a LOS D threshold.
Figure 1 Toll Rate Examples (TollEXP shown @ 4-8, 10, 20)

**Demand Side**

The demand side is presented by a binary logit-based toll route choice model. The general form of this model is shown below.

\[ P(EL) = \frac{1}{1 + e^{\theta(\alpha(TT_{GU} - TT_{EL}) - \beta(TOLL))}} \]

Where: EL and GU represent the express lanes and general use lanes, respectively
\( \theta \) is a scale parameter
\( \alpha \) is an estimated travel time coefficient
\( \beta \) is an estimated toll coefficient

The model determines the hourly toll (express lane) share based on the difference in travel times between the general use and express lanes and on the toll amount. Coefficients for the logit equation (or choice model) were taken from a 2006 stated preference survey and choice model estimation project conducted in Lee and Collier Counties of southwest Florida. The time and cost coefficients from that study reflect a value-of-time of just over $17/hour.

The logit model scale (\( \theta \)) was adjusted so that it replicated the observed 1999 time-of-day distribution on the SR-91 facility in southern California (2). The scale of a logit model affects the steepness of the logit curve which in turn reflects variance of the utility function's error term. By convention, the logit model's variance parameter is set arbitrarily to 1.0 but in practice the variance depends on the degree to which travelers' behaviors are affected by random factors other than those that are explicitly included in the utility function. For the choice between general use and express lanes, the variance is likely quite low because travel time differences can be easily discerned and there is little else other than time and cost that distinguishes the two types of lanes. A higher scale parameter implies lower variance and results in higher shares being allocated to the alternative with the highest utility. This is reflected in the ELTOD model by a
scale parameter of 15, which results in relatively low shares being allocated to the express lanes during off-peak periods, consistent with experience from SR-91.

Because the supply and demand functions are both highly non-linear, the simultaneous solution of these functions is most conveniently found using an iterative method.

The current calibration of ELTOD was done using available data from California's SR-91 Express Lanes facility. Recalibration of the ELTOD is planned using data from a current I-95 Express Lanes project in southeast Florida. The data was recently acquired so it will reflect current conditions comparable to the validation years of the travel demand models being used.

The new updates for the ELTOD to provide more details of the managed toll lanes in an existing interstate corridor will be completed to support the travel demand modeling efforts for current and upcoming Managed Lanes Projects. One of the project corridors includes reversible lanes in the future network plans for the study area; therefore, this will be an added feature to ELTOD. This will increase the versatility of the application to use it on projects that may have reversible lanes as an alternative as well. Another update to the network features of the application includes provision of an additional facility for representation of surface street diversion. Currently, ELTOD only has the ability to model the limited access corridor (non-tolled and tolled lanes). This means that the network is a closed system and traffic only has two choices, toll or non-toll highway lanes in the corridor, no matter how congested the facility may be. This option will now allow the vehicles to divert off the highway should there not be adequate capacity based on the input parameters. With this in mind, an update to the time periods is also being done. The current design distributes the input volumes by predefined percents of the total input volume for each study segment for each predefined time intervals. Therefore, if the segment volume is higher than the capacity defined by the input parameters, it continues to degrade thus creating the potential for high volume to capacity ratios. To resolve this potential problem, a peak spreading component will be incorporated into the application to handle this should it occur. It will be an input selection which can be turned off if desired. The time intervals will also be updated to smaller increments. Currently they are set to one hour. They will be changed to 15 minute intervals now over 24 hours. The input traffic volume features are going to be modified so they can be input as one to four Origin-Destination (O-D) matrices. The selected number of matrices will cover a full 24 hour period but be defined based on the range of each time period input to ELTOD.

**Expected Major Results**

These improvements are expected to provide more accurate model application results with greater output details. With these updates, the sensitivity of changes to the inputs such as toll rates, VOT, and corridor alternatives should be more noticeable and give the ability to better determine which ones could be eliminated or be further investigated. The additional details included with the updates to the application will increase the level of confidence from the analysis results. The projects under review are being investigated due to shortfalls in funding Florida's future transportation infrastructure. It is anticipated that these evaluations will provide insight as to what level of contribution tolls could make in funding these projects. The various toll structures and project alternatives to be tested will produce a number of options for construction including possible phasing of the project over time. This will also allow the determination of when the highest expected revenue intervals could be expected based on the time of day. That means a more realistic revenue stream could be realized by capturing additional revenue that otherwise would not have contributed to the total or possibly identify where the project's shortfall may be.
Contributions to State of the Practice

Coleman et al used Florida's I-95 Managed Lanes project data and a Stated Preference Survey from the Dulles Toll Road to update their model for an Express Lanes project in Fredericksburg, Virginia. The model is a four period travel demand model with updated volume/delay functions, reliability, and full mode choice implementation. However, there is no mention of detailed toll rate optimization potential components like the ELTOD application has.

Bradley et al reviewed choice dimensions including route, mode, auto occupancy, and time-of-day, at a trip and tour level for the SHRP2 C04 Project (3). Revealed Preference-based findings for willingness to pay tolls as well as the impact of travel time and reliability research could be useful components to work with for improvements to an application such as ELTOD. The research includes many potential parameters that could be evaluated using an application such as ELTOD.

Oryani et al are working on updating a model for six counties in Southern California to evaluate various pricing scenarios. Updates include mode choice, route choice, and time of day. They examined multiple trip purposes to incorporate more details in the model based on available data. They also considered peak spreading and propensity to pay a particular toll based on travel time. They have a very detailed time of day choice model. The ELTOD could be used in conjunction with their updated model to enhance their ability to optimize their toll rate structure for a managed lanes project.

REFERENCES

