U.S. Department of Transportation

DEVELOPMENT OF TRUCE-ST FROM TRUCE 3.0

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TRUCE Version 3.0 is a sketch planning tool for evaluating on-freeway congestion pricing in urban areas. Capabilities include the prediction of revenue generation, toll collection costs, and impacts on greenhouse gas emissions and fuel consumption. For comparison with toll collection costs, the model also includes a worksheet for estimating the costs of collecting revenue for highway spending through existing instruments such as fuel taxes and vehicle registration fees. The principal source of traffic data for TRUCE 3.0 is the TTI Urban Mobility Report series. Since that source provides data for 85 urban areas, but not at the state level, development of the state-level version of TRUCE, TRUCE-ST, necessitated a reliance on state-level data on traffic volume and lane miles from the FHWA *Highway Statistics*. TRUCE-ST contains equations that predict average speed on the urban highways of a state, for arterials and freeways, separately as a function of these data from Highway Statistics. In addition, TRUCE-ST contains several improvements which have yet to be incorporated into TRUCE 3.0. These model enhancements and the mechanisms for predicting average speeds are described below.

Division of the peak period between congested and uncongested portions

TRUCE 3.0 uses data for the peak period as defined in the TTI Urban Mobility Report (UMR), 6-10 am and 3-7 p.m. The model predicts an average congestion charge per mile for this entire eight-hour period.

TRUCE-ST incorporates from the UMR the division of the peak-period into congested and uncongested portions, and assumes that congestion charges apply only during the congested portion. In the UMR data for 2005, the only area for which TTI estimates the entire peak period to be congested (at least somewhere on the system) is Los Angeles. For other areas, the data indicate that a portion of the peak period (toward the beginning or the end) is uncongested. The UMR also uses an equation to predict the percent of daily VMT that travels within the congested peak, for which the maximum value is 50 percent, the estimated percent of daily VMT that travels within the 8-hour peak period. Except for Los Angeles, the estimated share of daily VMT that travels within the congested portion of the peak is less than 50 percent. The UMR equation for estimating this share uses a Roadway Congestion Index (RCI). Appendix A to the 2007 Urban Mobility Report contains only a graph of this equation, which is piece-wise linear, but the algebraic version was obtained from TTI for this study. Appendix A to the 2007 report also contains the equation for calculating the RCI; TRUCE-ST performs this calculation using data on the annual VMT and lane-miles on the urban freeway and principal arterials in a state. Annual VMT are converted to daily figures by dividing by 365.

Estimation of the average value of travel time

TRUCE-ST follows the TRUCE 3.0 approach to estimating a weighted average value of travel time per vehicle-hour (averaged across vehicle types and trip purposes). The only difference is in interpretation: TRUCE 3.0 treats the average as the mean, whereas TRUCE-ST takes it to be the median. As a result of this and the assumed properties of the distribution of the value of time, the implied mean value of travel time is higher in TRUCE-ST than in TRUCE 3.0. Given the considerable uncertainty that surrounds the average value of travel time, it is hard to judge which is the more appropriate interpretation. The interpretation of the average as the median has been incorporated into TRUCE-ST for computational convenience. In the application of the model to the case study state, the median and mean values of auto travel time are estimated respectively at $23.77 per hour (cell C53, "Values of Time" worksheet) and $32.53 per hour (cell C177, "Analysis" worksheet). Users of the model who regard these values as too high or too low can alter them by making adjustments in the "Values of Time" worksheet.

Prediction of the average speeds

Estimates of average speeds during the congested peak were obtained from a study HDR recently prepared for USDOT on the costs of congestion.[1] These were average speeds in each of the 85 urban areas covered by the UMR, measured separately for freeways and arterials. Speeds were measured for this purpose exclusive of the effects of incident delay: the speeds reported in Appendix A of the 2007 UMR were adjusted to exclude incident delay using the incident delay ratios also reported in that appendix. For development of TRUCE-ST, we ran a linear regression of these average speeds against the ratio of daily VMT to lane-miles. TRUCE-ST uses the fitted equation to predict the average speeds for each state (urban areas only).

Estimation of the distribution of freeway VMT by level of congestion

Given the average freeway speed excluding incident delay, TRUCE-ST calculates the distribution of peak congested VMT between travel under normal congestion and travel under hyper-congestion. In terms of the TTI categories, our “normal” congestion includes the categories with congestion no worse than “heavy” (i.e., uncongested, medium, and heavy), while hyper-congestion includes the categories of severe and extreme congestion. In calculating the distribution of VMT between these two broad levels of congestion, (hyper versus normal), we used estimates of average speeds at each level for the Los Angeles area (unpublished tabulations provided by TTI). These speeds are 55.8 mph (normal congestion) and 37.0 mph (hyper-congestion). To illustrate the calculation, if the average speed predicted for a state’s urban freeways is, say, 50 mph, then the estimated distribution of VMT by broad congestion level is 71 percent normal and 29 percent hyper-congested. (With this percent split, the average speed is 50 mph). Within these broad congestion categories, the percent split by congestion level is assumed to be the same as in the Los Angeles area.

Users of TRUCE-ST can override the distribution of VMT with data more specific to their state by drawing on the Highway Performance Monitoring System (See TRUCE-ST User’s Guide). This would be necessary to analyze the scenario for moderate congestion pricing for states for which TRUCE-ST predicts an average freeway speed greater than 55.8 mph. In such cases, the above-described method for distributing VMT between

[1] HDR 2009, ***Assessing the Full Costs of Congestion on Surface Transportation Systems and Reducing Them through Pricing*** **prepared by HDR for the Office of Economic and Strategic Analysis, US Department of Transportation.**

travel under normal and hyper-congested conditions will not work because even with all the VMT falling in the normal category, the predicted speed will be 55.8 mph.

Prediction of the average congestion charge

To predict the average congestion charge during the congested peak period (the charge is zero outside that period), TRUCE-ST first estimates the average speeds on freeways and arterials during that period. The average congestion charge is predicted from the willingness-to-pay (WTP) distribution discussed in the technical report on TRUCE 3.0. That version of TRUCE applied this willingness-to-pay approach only for aggressive congestion pricing in Los Angeles. From the result of that one application, a factor was derived to adjust the model's raw predictions of the average congestion charge. (The raw predictions were based on an estimated average willingness-to-pay without consideration of the dispersion around that average). TRUCE-ST dispenses with the adjustment factor by creating for each state an estimated distribution of willingness-to-pay (i.e., the per mile willingness to pay for traveling on freeways rather than arterials).

As explained in Appendix A of the technical report, the WTP distribution is assumed log-normal (which ensures that the WTP is always positive). Unlike the normal distribution, for which mean=median, the log-normal distribution has a skew to the right, so mean exceeds median. For autos, the USDOT formula for valuing personal travel time is based on median household income, so we treat the calculated value of time for auto travel as the median. For the case study state, the median value of auto travel time is $23.77 per vehicle-hour (cell C55, 'Values of Time' worksheet), while the mean is $32.53 per vehicle-hour (cell C177,'Analysis' worksheet).

Benefit-cost calculations

TRUCE Version 3.0 calculates two of the elements needed for a benefit-cost analysis of on-freeway congestion pricing: (1) the total annual savings in travel time for travel still taken with congestion charges in effect, and (2) the annual amortized cost of the electronic system of congestion charge (toll) collection. TRUCE-ST values the annual savings in travel time at the average value of time among highway travelers, which is based on the USDOT formula. In addition, TRUCE-ST calculates the loss of consumer surplus from the reduction in the amount of road travel during the congested peak period (the reduction needed to achieve the speed target in the congestion pricing scenario).

For travel diverted to the unpriced arterials, the calculation is based on the willingness-to-pay distribution. The average congestion charge is the willingness-to-pay of the "marginal traveler" at the relevant percentile in the WTP distribution (the percentile determined by the percent reduction in freeway traffic due to pricing). To calculate the loss of consumer surplus due to diversion from freeways to arterials, TRUCE-ST calculates the average WTP on the portion of the distribution from that percentile on down. This "reverse conditional mean" (i.e., the mean on the lower tail of the WTP distribution) is calculated in the ‘Analysis’ worksheet cells C172:C191 (and again in cells C206:C225).

As a rule, TRUCE-ST (as well as TRUCE Version 3.0) will predict that a substantial majority of the congested-peak travel priced off the freeways will shift to the arterials (though users can substitute their own predictions; see TRUCE-ST User’s Guide). The rest of the travel priced off the freeways may shift to other times of day (outside the congested peak), to carpooling or transit, or simply be eliminated through consolidation of trips or other adjustments. For such trips, TRUCE-ST assumes the loss of consumer surplus per trip (i.e., per ten miles traveled) to be the same as for the trips that divert to arterials.

Calculation of average speeds including incident delay

For development of TRUCE 3.0, HDR obtained unpublished UMR estimates of average speed by level of congestion on Los Angeles area freeways. Estimates were obtained for speeds including and, alternatively, excluding the effects of incident delay. For the base case, TRUCE 3.0 assumed the same speeds for all urban areas. TRUCE-ST, on the other hand, generalizes in this way only for speeds excluding incident delay. To convert from these speeds to speeds including incident delay, TRUCE-ST uses the incident delay ratios reported in the UMR. The ratios, which are treated as constants, equal the amount of incident delay to the amount of recurrent delay (due to causes other than incidents, both measured in vehicle-hours). Users of the model need to calculate an appropriately weighted average of the ratios for urban areas fully or partly within the state being considered. The model then calculates the average peak congested speed for this state on urban freeways and arterials. At each level of congestion, excluding the category for absence of congestion, the results will vary across states because of differences in the incident delay ratio for freeways (for arterials, TTI uses a uniform ratio of 1.1). For the uncongested category, recurrent delay is absent; since the incident delay ratios are constants, this implies that incident delay is also absent.

In reality, some amount of incident delay will occur even without any recurrent congestion, but the primary data source of traffic data for TRUCE, the UMR, provides no means of estimating the amount of such delay. On the plus side, the incident delay ratios in the UMR provide a means of estimating the effect of congestion pricing on the amount of incident delay via reductions in recurrent delay. This linkage is generally absent from models of congestion pricing, which focus on recurrent delay.