Discussion-piece #3
Evaluation of Highway Capacity Congestion Relief Benefits
Federal Transit Administration
June 6, 2006

1. Motivations. FTA recognizes that the impacts of major transit projects include reductions in highway congestion and, consequently, greater mobility for highway users. Therefore, FTA defined the New Starts measure of mobility benefits – Transportation System User Benefits – to capture mobility improvements accruing to both transit and highway users. The measure captures impacts on both groups of users because it obtains information on mobility differences between alternatives from the denominator of the logit mode choice model – that quantifies the mobility of all travelers, regardless of mode. Consequently, the user-benefits measure as it is currently defined (in FTA regulations) and implemented (in FTA-distributed software "Summit") is able to credit projects with both the direct improvements in transit service caused by the transit project and the indirect improvements in highway conditions caused by the diversion of some auto travelers to the transit system. Congress has expressed support for the inclusion of congestion relief among the measures of benefits generated by New Starts projects and, in the FY2005 transportation appropriation, directed FTA and FHWA to study how highway congestion relief benefits could be incorporated into the New Starts ratings process.

2. Difficulties and responses. Unfortunately, initial results for projects whose sponsors attempted to capture the benefits of highway congestion relief suggested that these benefits are not predicted reliably in current models – in both their magnitude and their geographic location with respect to the transit project. Because of those problems, FTA has elected to consider only direct transit benefits in rating proposed projects and to sponsor research on the prediction of highway-congestion impacts in hopes of correcting the difficulties. The research effort was designed to (1) confirm the existence and magnitude of unreliability problems, (2) diagnose the source(s) of unreliability, (3) propose solutions to the problem(s), and (4) prepare recommendations on how project sponsors could proceed to develop reliable estimates of highway congestion-relief benefits.

3. Nature and sources of the problems. The apparent unreliability of congestion-relief estimates came to FTA's attention through Summit-generated reports and graphics that appeared to show a wide range of highway-side impacts that were largely unexplainable as consequences of the underlying transit project. Unexplainable results might have been caused by a wide range of potential causes including undetected problems in the transit portions of the model. To substantiate that the problem was caused by the highway congestion elements of the model, initial tests focused on estimates of highway congestion relief benefits generated by two models previously reviewed by FTA and found to be generally capable of forecasting transit ridership impacts. The forecasts in these two cases – a relatively modest-sized project with limited region-wide impacts and a very large project with large regional impacts – produced vehicle trip tables that had appropriate reductions in auto trips that were strongly related to the underlying transit project in both magnitude and location. However, highway assignments of vehicle trips from the baseline and build projects (using the local model's calibrated equilibrium assignment approach) generated both positive and negative congestion

impacts on trip-ends throughout the entire region. These patterns gave the appearance of "randomness" and suggested that corresponding estimate of user benefits rested entirely on the net difference between the sums of the (apparently "random") positive and negative outcomes. A similar pattern was evident in plots of the differences (build versus baseline) in assigned vehicle hours of travel by link, as illustrated in Figure 1. These findings led to conclusions that (1) estimates of highway congestion relief user benefits were not reliably estimated in the two test cases and (2) the underlying cause appeared to be related to instability in the highway assignment process that rendered meaningless any comparison of highway-side changes between two transit alternatives.

4. Test of solution #1: elimination of integer bucket rounding. Both models generated the vehicle trip tables for assignment using integer bucket rounding techniques. Since these techniques move fractions of trips from cell to cell in response to minute changes in mode shares, both models were converted to generate (1) un-rounded integer trips in 100ths where 0.01 trips was represented as 1 trip in the trip table, (2) single precision real numbers, and (3) double precision real numbers. The resulting highway assignments showed a slight reduction in random noise but left most of the problem unresolved.

5. Test of solution #2: fixed iteration weights. To eliminate possible instability caused by the different weights dynamically derived in equilibrium highway assignments for the baseline and build alternatives, the iteration weights for the build assignment were fixed to equal the weights derived for the baseline assignment. The test resulted in no observable improvement to the assignment stability for the two test-case models.

6. Test of solution #3: tighter closure criteria. The assignment closure criteria for both models were typical of common practice: Model 1 was set to cease iterations when the gap fell below 1 percent; and Model 2 was controlled with a closure gap of 0.1 percent and a maximum of 15 iterations. Tighter closure criteria – a closure gap of 0.001 percent and no maximum on the number of iterations – produced substantially more stable estimates in both models of the change (build versus baseline) in link-level VHT. The tighter closure required thousands of iterations to achieve and increased execution times by many hours. However, the results represented the first apparently reasonable estimates of the impacts of changes in vehicle trips on underlying traffic congestion for the two projects.

7. Test 4: an incremental assignment approach. An incremental approach is an entirely different strategy for improving the reasonableness of the change in link-level VHT. The incremental test used a 1-iteration all-or-nothing method to assign the change in vehicle trips (build minus baseline) onto the congested network from conventional equilibrium assignment of vehicle trips in the baseline alternative. (Since the software packages did not allow assignment of negative trips, the change in the vehicle trip table was separated into two tables of positive number – one for increases in vehicle trips and the other for decreases. Each table was assigned separately and the sign of the incremental trips was addressed during the reporting process.) This approach also resulted in highway assignments results (build versus baseline VHT) that appeared reasonable and highly correlated with the underlying transit project. The execution time for this approach was not substantially different from the original assignments.

8. User benefits from Tests 3 and 4. Detailed review of the estimated user benefits from the incremental approach (#4) suggested that the strategy removed large numbers of trips from the shortest highway paths and did not allow for the backfill in traffic volumes that would surely occur. Therefore, the highway travel time savings were evidently too high for the primary routes most directly affected by the project and too low for the facilities carrying spillover traffic that would – in part – be diverted back to the primary routes by their now-lower traffic volumes. Further, the incremental approach would be difficult to apply in cases where the baseline and build highway networks are different from each another. For these reasons, further consideration of the incremental technique was abandoned. A review of the highway user benefits from the tighter closure criteria (#3) suggested that, while this strategy produces much more reasonable VHT results, it does not correct the largely random patterns of positive and negative highway user benefits.

9. Internal inconsistencies. Much additional research into the remaining problem (unstable highway user benefits even with reasonable underlying highway assignments) identified the root cause to be inconsistencies in the impedance weights used in different model components. Specifically, the highway path building procedures included weights on components of time and cost that were difference from the relative weights on those same characteristics in the mode choice model. (This inconsistency enables the pathfinder to find a "better" path in the build alternative that the mode choice model then evaluates as being worse, rather than better, because it has a different opinion on the relative importance of times and costs.) Test runs using impedance weights set identically in all model components substantially reduced (improved) the random appearance of the computed benefits accruing to highway users. As with many insights about travel forecasting, this finding was not surprising in retrospect: it is *identical* to the early (2002) finding on the need for consistency between weights in mode choice and transit pathbuilding derived from initial reviews of Summit reporting of ridership changes and associated user benefits for New Starts projects.

10. Possible implementation of findings. Taken together, these research results suggest that it may be possible to derive meaningful estimates of the congestion-relief benefits of New Starts projects. Useful forecasts might be possible from model sets that (1) hold trip tables in sufficiently precise formats – hundredths of trips or better; (2) iterate highway assignment procedures to sufficiently stable closure – at least for "official" New Starts submissions; and (3) employ consistent impedance weights "across the board" in transit pathbuilding, highway pathbuilding, and mode choice. Implementation of the first condition requires relatively minor effort and most travel models are already migrating to software packages that hold table information in real numbers. Implementation of the second condition is dependent on the locally implemented software package but requires minor effort (though lots of computer time) to prepare comparable highway assignment results for pairs of baseline and build transit alternatives. Implementation of the third conditions is a potentially significant effort because it would require recalibration of highway pathbuilding/assignment procedures, the mode choice model, and/or both model components.

11. National consistency. The approach sketched in item 10 addresses only the conditions necessary to produce potentially comparable highway assignment results for a pair of transit alternatives. Pair-wise comparability of predicted congestion levels is necessary for local evaluation of the potential congestion-relief benefits of a major transit project. That

condition does not, however, begin to address two other issues necessary to the usefulness of congestion-relief benefits in New Starts project ratings. The first issue is whether or not the estimated highway travel times are "reasonable" within individual metropolitan areas. In order to properly estimate highway user benefits, a detailed assessment of the reasonableness of free flow speeds, capacities, and volume-delay functions would be required before any outcome could be used for project evaluation. The second issue is whether or not sufficient consistency exists (or could exist) across metropolitan areas to support meaningful national comparisons of congestion-relief benefits. Since model structures, parameters, and other characteristics vary widely across the United States, the possibility exists that equally "reasonable" – but different – approaches to highway assignment could generate significantly different estimates of highway congestion relief benefits. These changes could be sufficiently large to affect project ratings in ways that are not related to the relative performance of the many projects that are proposed nationally.

12. Recommendation. The research accomplished in response to the Congressional instructions regarding congestion relief suggests that current practice in travel forecasting may have the fundamental tools necessary to produce useful insights. However, the research also suggests that major efforts would be needed – by project sponsors and by FTA – to refine the details of current practice sufficiently to make such an outcome possible. Necessary local efforts would likely include substantial recalibration of existing model sets, collection of data on highway speeds, refinement of coding procedures for highway networks, and adjustments (or wholesale replacement) of methods used to load traffic on those networks and estimate congested speeds. Even more consequential, perhaps, might be the impact of these changes on existing findings of conformity with national air-quality standards and any additional work to bring air-quality-related work into alignment with substantially revised travel models. Necessary FTA efforts would include quality control on both the reasonableness and the consistency of predicted congestion relief benefits (to ensure, for example, that transit projects with similar ridership impacts in settings with similar congestion levels would be evaluated with similar congestion-relief predictions). Because of the potentially large local burden and the likely requirement that FTA take a substantial role in efforts to improve forecasts of highway performance, FTA has recommended to Congress that evaluations of New Starts projects continue to be done with transit user benefits (and that FTA continue to make general allowances in cost-effectiveness ratings for the absence of highway user benefits).

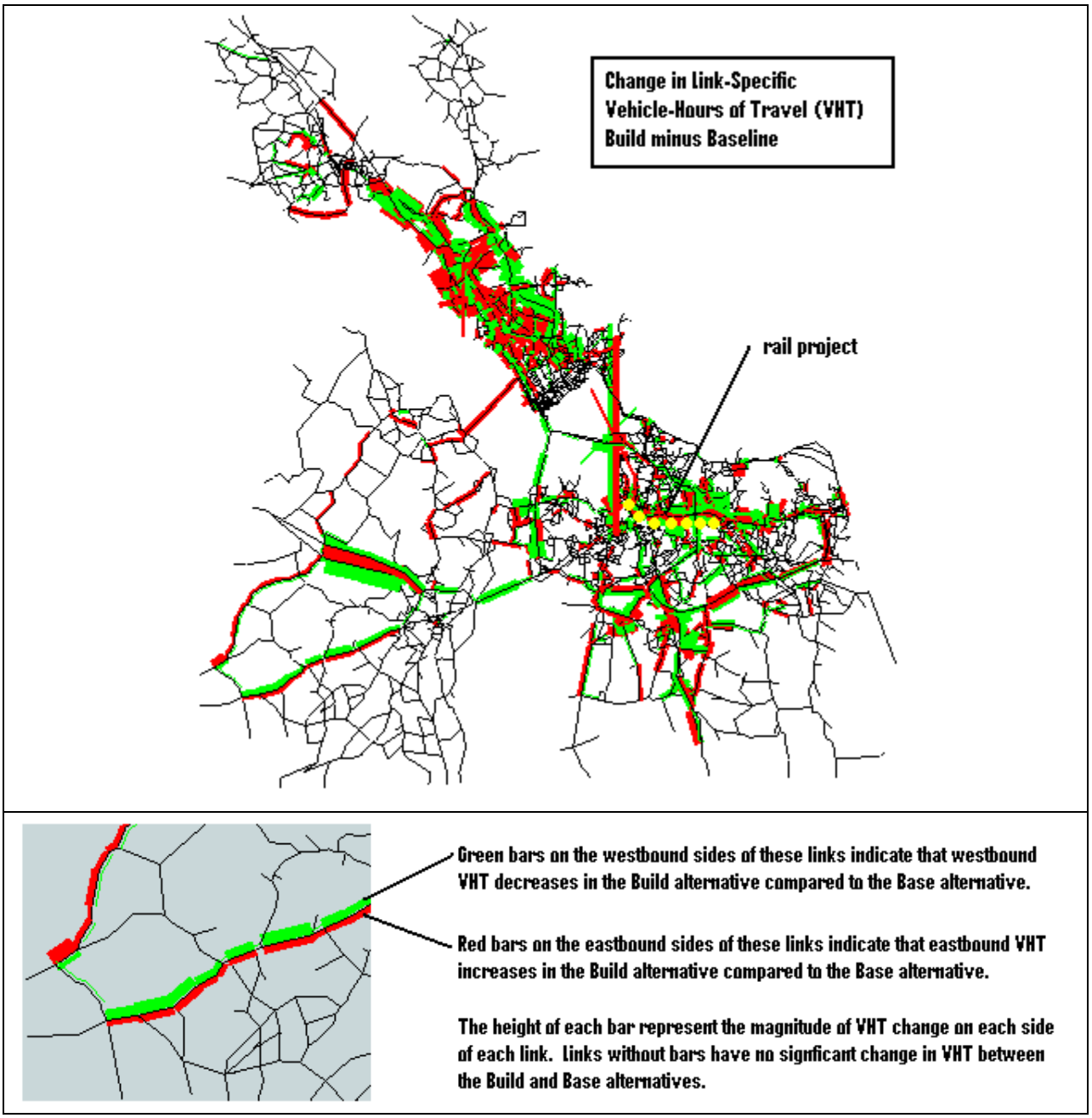

Figure 1. Display of Predicted VHT Changes for a Rail Project in a Medium-Sized Area