Plan/Bay Area: Project Performance Assessment Travel Modeling Methodological Approach

Technical Paper

Metropolitan Transportation Commission with Parsons Brinckerhoff

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1 Introduction

To inform the Commission's Plan/Bay Area[1] investment trade-offs discussion (i.e. how should the region spend discretionary transportation funds), MTC performs a detailed assessment of proposed projects and programs. This project performance assessment had two primary components, a targets analysis and a benefit-cost computation[2]. The targets analysis qualitatively compared the expected outcome of each project/program to goals defined by the Commission for the Plan/Bay Area effort. The benefit-cost computation used the MTC travel model to support the quantification of project benefits, which were then compared to project costs.

The purpose of this technical paper is to describe the approach taken to use MTC's travel model, named *Travel Model One*, to support the quantification of project benefits.

Travel Model One is a complex simulation of individual travel behavior that relies on probabilistic models to predict travel-related outcomes. When used to assess the likely outcomes of scenarios[3] (i.e. a future year land use pattern paired with a future year transport system), the model is executed iteratively until an equilibrium is reached between supply and demand. This process can take 24 to 48 hours. The project assessment work required the analysis of over 100 projects in six weeks. If MTC used the model in the same manner it is used to analyze scenarios, the computing time alone would take over 14 weeks (24 hours * 100 projects / 24 hours per day / 7 days per week). MTC, therefore, needed to develop a strategy for using the model in a more efficient manner. The key question: how can MTC use aspects of *Travel Model One* to inform the assessment of 100 projects in six weeks?

In the remainder of this paper, three approaches are proposed and empirically evaluated. The paper concludes by recommending an approach that best meets the project performance assessment demands of providing robust information about the expected outcomes of a wide range of transportation projects within the time allotted for analysis.

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[1] Background information is available here: http://onebayarea.org/plan_bay_area/.

[2] Background information and additional details are available here: http://apps.mtc.ca.gov/meeting_packet_documents/agenda_1763/2_Project_Assessment_Memo___Attachments.pdf.

[3] An example application is described here: http://mtcgis.mtc.ca.gov/foswiki/pub/Main/Documents/2012_01_05_RELEASE_Second_Round_Travel_Model_Technical_Summary.pdf.

2 Possible Project Assessment Methods

In this section of the paper, a brief overview of the relevant design characteristics of the MTC travel model is first provided; the definition of potential methods follows this overview. Each potential method is discussed in detail below.

2.1 Relevant design characteristics of Travel Model One

Travel Model One is an activity-based micro-simulation model of household travel choices[4]; a schematic representation of the travel model is shown below in Figure 1 (the annotations on the figure are relevant to *2.2 Proposed methods*). During a typical "run" of the travel model, an initial trip table is first assigned to the roadway network to derive an initial estimate of roadway congestion (which, in turns, provides an initial estimate of bus travel speeds). The resulting level-of-service matrices (i.e., the time, cost, and other attributes required to move from one location in space to another) are then input into models of travel demand. In the demand models, individual agents (households and the persons which comprise households) are first sampled from a full synthetic population (i.e. a representation of all residents of the nine county Bay Area) and their choices are then simulated along a series of travel-related dimensions.

The first set of demand models simulate the so-called "long-term" decisions of the individual agents – specifically the number of automobiles each household should own and the work and school location of each worker and student in each household. Next, the agents make "short-term" decisions that form their daily travel behavior, including the frequency, destination, and time-of-day for travel tours (a tour is a sequence of trips that take a traveler from home or work, to a destination, and then back to home or work). After the tours are scheduled, the agents select a travel mode (e.g., drive alone, take the bus, walk, etc). Next, intermediate stops are scheduled and located (e.g., stop at a coffee shop on the way to work) and the best travel mode for each leg of the tour is determined (e.g., ride transit to the coffee shop, walk from the coffee shop to work). Finally, the demand for travel is aggregated across all individuals and assigned to the roadway network, thus creating a new estimate of roadway congestion. The model reaches convergence when the congestion levels upon which decisions are made are very similar to the congestion levels that result from those decisions. When analyzing scenarios, MTC typically repeats this process three times to achieve an adequate equilibrium between supply and demand.

In the project performance assessment application, a set of metrics is extracted from the travel model results. These metrics are used to inform the benefit-cost calculation and include estimates of such quantities as vehicle-miles traveled, emissions, delay, and transit vehicle boardings. When determining a preferred method for applying the travel model for the project performance assessment application, the accuracy of these metrics (relative to the expected outcomes of projects/policies) is of primary importance, sitting ahead of the need to meet the six week schedule.

[4] Additional background information on the travel model is available here: http://mtcgis.mtc.ca.gov/foswiki/Main/Development.

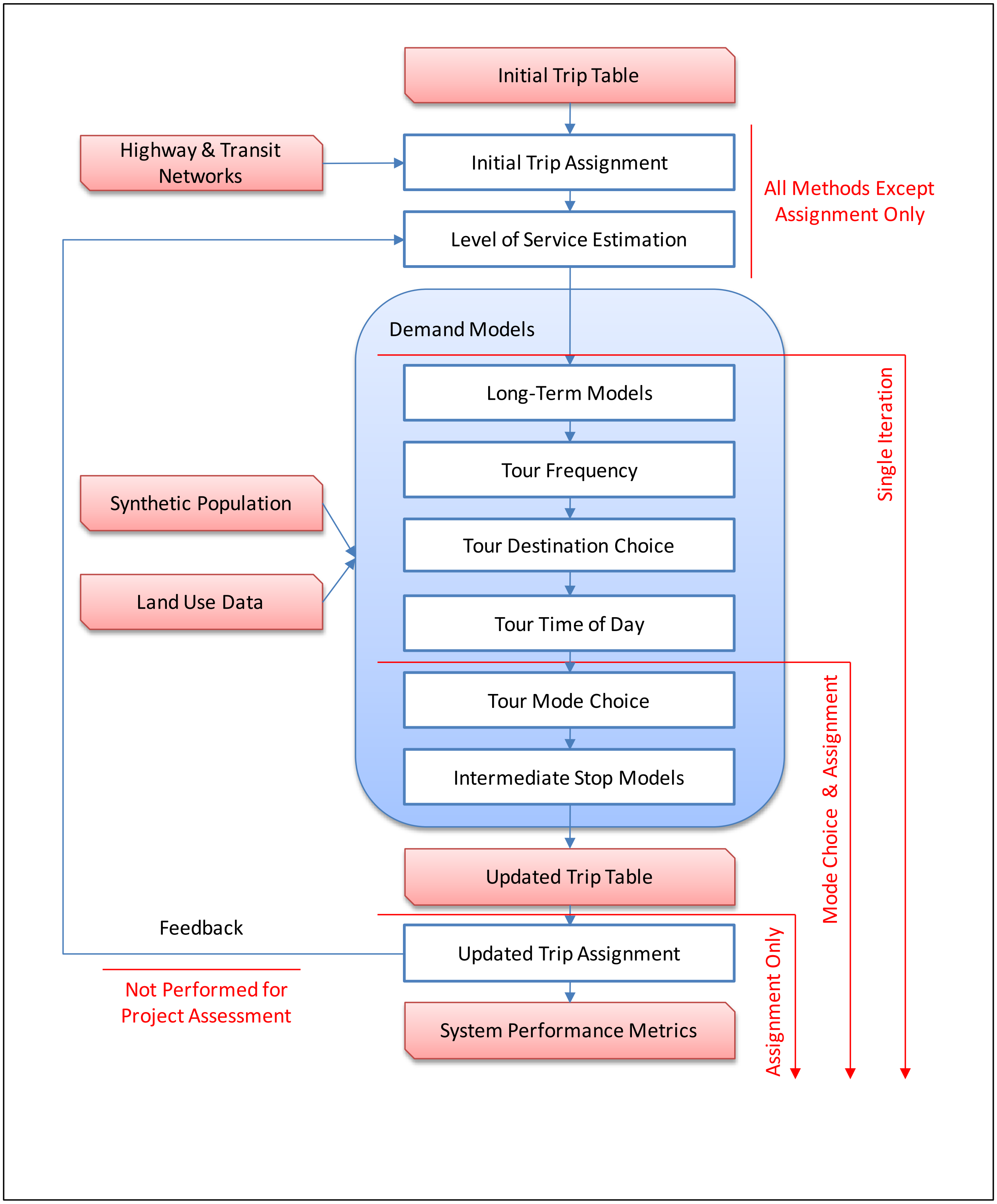

Figure 1: Structure of Travel Model One and Tested Modifications

2.2 Proposed methods

Beginning with the application approach taken for scenario analysis as described above, the following three strategies are available to reduce the travel model's execution time:

i. Reduce the number of iterations through the demand models (three are typically used in scenario assessments);
ii. Reduce the number of households sampled from the synthetic population (a 50 or 100 percent sample is typically used in scenario assessments, depending on the nature of the application); and/or,
iii. Assume certain outcomes remain unchanged across projects and skip select demand sub-models.

The projects/programs considered in the project assessment are different from the system-wide changes considered in scenario analysis. In the scenario analysis, large scale changes in land use patterns and transport systems are considered. Here, the land use pattern is kept constant and a single project is coded into the transport system on top of a "no build" network (which includes existing plus committed infrastructure[5]). The scope of the change from the no build scenario is, therefore, quite limited and unlikely to create a significant disequilibrium between supply and demand after a single iteration of the demand models. As such, the first strategy considered for the project assessment work is to execute a single iteration of the demand models (reduced from the three typically used in scenario assessments); this strategy is referred to henceforth as **single iteration**. A 100 percent sample is used in the **single iteration** method.

The second strategy we examined skipped the demand step all together and simply measured the impact of projects on route choice. This method, referred to henceforth as **assignment only**, assigns the demand from the no build condition to the build condition roadway and transit networks.

The third and final strategy attempts to find a middle ground between the **single iteration** approach and the **assignment only** approach. This approach, referred to henceforth as **mode choice**, keeps the results from the long term choices, tour frequency models, and tour destination choice models fixed from the no build condition and simulates the tour mode choice, stop frequency, stop location, and trip mode choice decisions prior to assigning the roadway and transit networks.

The annotations on Figure 1 attempt to graphically depict these three strategies over the model flow schematic. Through experimentation not documented here, the results from the **mode choice** strategy did not vary when reducing the sample rate from 100 to 50 percent. As such, the **mode choice** approach used a 50 percent sampling rate.

In the next three sub-sections, each of these three methods is described in more detail. Table 1 summarizes the key characteristics of each approach.

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[5] Details on the Plan/Bay Area's committed policy are available here: http://apps.mtc.ca.gov/meeting_packet_documents/agenda_1645/tmp-4006.pdf.

2.2.1 Single iteration method

The **singe iteration** method begins with an initial estimate of congestion, which comes from a scenario assessment model run for the no build scenario, meaning a full three iterations through the demand models. The trip tables that result from this run are used as the input demand to the **single iteration** assessment. Importantly, the no build project must also be run through the **single iteration** assessment to ensure that an "apples to apples" comparison is made between the project-specific outcomes and the no build outcomes.

The benefits of the **single iteration** approach are as follows:

- *Excellent accuracy* (relative to a scenario assessment or "full" model run). Because all of the demand models are being executed, the changes in supply dictated by each project will affect all household decisions, including each of the model elements depicted in Figure 1. And, since the changes in each tested project should be small relative to regional demand, a single iteration of the models should not produce demand that is far enough out of equilibrium with supply to require running the model with feedback.
- *Minimal stochastic simulation variance*. By simulating decisions for 100 percent of the synthetic population, stochastic simulation variance is minimized (within the single iteration paradigm).
- *Unbiased*. The method should not bias (relative to the full model) either roadway or transit projects because changes in supply motivate increases in demand (from changes in route, mode, scheduling, tour frequency, and stop frequency). Roadway projects, therefore, suffer from new users and transit projects benefit from new users.
- *Low risk*. Implementing this method requires only minor changes to the application tools used for scenario assessment model runs. As such, the implementation mechanics should be very straightforward.

The drawbacks of the **single iteration** approach are as follows:

- *Run time*. Executing a single iteration of the model with a 100 percent sample takes over 24 hours (even a 50 percent sample takes ~18 hours), which, as noted previously, does not allow for 100 projects to be analyzed in six weeks.

2.2.2 Assignment only method

The **assignment only** method is very simple to implement. Here, the demand from a single iteration of the no build scenario is assigned to roadway and transit networks modified from the no build per the assessed project's definition. As shown in Figure 1, the **assignment only** method skips the demand models altogether; demand is held constant across the no build and each project run.

The benefits of the **assignment only** approach are as follows:

- *Run time*. Executing the assignment routines takes less than two hours, meaning 100 projects could be analyzed over the course of two weeks.
- *Low risk*. The mechanics of this approach are simple and could be easily implemented.

The drawbacks of the **assignment only** approach are as follows:

- *Poor accuracy*. Per this method, changes in supply (e.g., widening a roadway) will not result in changes in demand. The number of trips will remain constant; the mode share will remain constant; origin/destination patterns will remain constant. This approach will only reveal changes in congestion and transit route choice.

- *Biased*. This method should favor highway projects and disfavor transit projects. Highway projects generally increase capacity on the roadway network in an effort to reduce congestion. Some of this increase in capacity is quickly consumed by travelers who change routes, modes, and/or time-of-day in response to the reduction in congestion. The benefits of the project, therefore, will be overstated if increases in demand do not accompany the changes in supply. Conversely, improvements in transit service are, often, made to increase the number of riders served in a corridor – particularly in under-served corridors. In this approach, the number of transit riders in the project corridor would be held constant, thus underestimating the project's likely benefits.

2.2.3 Mode choice method

The **mode choice** method attempts to find a middle ground between the **single iteration** and **assignment only** methods. The first step in this approach is to use the **single iteration** approach for the no build project. When the simulation is complete, the long term, tour frequency, destination, and scheduling choices will be stored in memory. Next, the trip table used to seed the no build project with an initial estimate of congestion (taken from the full model run for the no build scenario) is assigned to the project-specific roadway networks. This assignment generates an estimate of congestion levels from which project-specific level-of-service matrices can be generated. Then, the project-specific level-of-service matrices are used in the simulation of tour mode choices, the frequency and destination of which remain unchanged from the no build condition. Intermediate stops on these tours are then scheduled and located, the modes of individual trips are determined, and the new trip tables are assigned to the project-specific roadway and transit networks.

The benefits of the **mode choice** approach are as follows:

- *Good accuracy*. This approach captures changes in travel mode motivated by changes in roadway and/or transit supply. Roadway projects will therefore encourage travelers to change routes, tour modes, stop frequency, and stop location – many of the expected behaviors. Transit projects will motivate similar behavioral changes. This approach will fall short of the **single iteration** approach by not simulating changes in tour destination (e.g., workers deciding to change jobs because of transport infrastructure changes) or automobile ownership.
- *Run time*. This approach takes about eight hours, meaning 100 projects would take about five weeks of computer time, which is within the six week budget.
- *Unbiased*. This approach should not significantly bias roadway or transit projects, as mode choice decisions are being simulated.
- *Small stochastic simulation variance*. By simulating decisions for 50 percent of the synthetic population, stochastic simulation variance is not minimized (within the single pass paradigm) but should be small.

The drawbacks of the **mode choice** approach are as follows:

- *High risk*. The mechanics for this approach have not yet been tried, thus introducing risk to how effectively this process can be implemented over 100 projects.
- *Run time*. While the run time of eight hours is reasonable, it is still much longer than the two hours offered by the **assignment only** approach.

Table 1: Summary of Potential Approaches

	Approach			
	Scenario-assessment	**Single iteration**	**Mode choice**	**Assignment only**
Runtime	48 hours	19 hours	8 hours	2 hours
Sampling rate	100 percent	100 percent	50 percent	n/a
Bias	None	None	None	Favors roadway projects
Risk	None	Low	High	Low
Stochastic variation	Minimized	Minimized	Low	n/a

3 Empirical Approach

The discussion in section 2 *Possible Project Assessment Methods* suggests the **mode choice** approach likely offers the best compromise between run time and accuracy (relative to the **single iteration** approach). To determine the veracity of this claim, tests were conducted comparing the performance results for three hypothetical projects across the three potential project assessment methods.

The three projects are as follows: (i) no build; (ii) urban bus rapid transit (BRT) project; and, (iii) suburban high-occupancy vehicle (HOV) lane addition. Because this testing occurred prior to the final definitions of specific projects, hypothetical rather than "real" projects were used for testing. This applies to the no build project as well. *The results from this testing should not be compared to MTC's published project assessment findings,* as they are based on different networks and different inputs, nor should they be generalized to characterize the performance of BRT projects or HOV lane additions. The purpose of this exercise is limited to supporting or refuting the hypothesis that the **mode choice** approach offers an appropriate mix of efficiency and accuracy.

The outcomes examined in this approach are based on those expected, at the time of testing, to be utilized in the benefit-cost analysis and include person trips by travel mode, vehicle miles traveled (VMT), transit boardings, average travel time (per trip), and non-recurring delay (a highly sensitive measure whose computation is based on the travel model's assigned roadway network).

Descriptions of the hypothetical projects are described below.

3.1 No build

The no build project consists of infrastructure that either exists, is in construction, or whose funding is committed per MTC's committed project policy. At the time of testing, this definition had not been finalized and, as such, a draft no build was used for these tests. To generate the project assessment metrics for the other projects, the no build network was modified to include either the hypothetical urban BRT project or the hypothetical suburban HOV lane addition project.

The purpose of the empirical tests is to compare the no build project to each of the two build projects within each method. This exercise involves comparing the no build to each build project when using the **single iteration** method; comparing the no build to each build project when using the **mode choice** method; and, comparing the no build to each build project when using the **assignment only** method. This is how the benefit-cost assessment will be performed: by comparing the change a project causes from a no build condition. Cross method comparisons, e.g., comparing the urban BRT outcomes from the **mode choice** method to the urban BRT outcomes from the **assignment only** method are less useful.

3.2 Hypothetical urban bus rapid transit (BRT) project

The urban BRT project converts a general purpose travel lane to a bus-only lane and improves bus headways from about five minutes to about three minutes in a heavily utilized bus corridor (approximately 50,000 boardings per day in the no build condition) in close proximity (five to ten miles) to a central business district. The speeds at which buses travel through this corridor are improved by the dedicated travel lane. Travelers therefore benefit by having to wait a shorter time for buses to arrive and, once on board, reaching their destinations faster. The **single iteration** and **mode choice** methods should show minor shifts from automobile to transit travel as well as slightly faster transit travel; the **assignment only** approach should only reveal slightly faster transit travel times. The key question is the extent of the similarity of the **single iteration** and **mode choice** approaches (i.e. can we save run time without reducing accuracy).

3.3 Hypothetical suburban high-occupancy vehicle (HOV) lane addition

The suburban HOV lane addition project widens a roadway by a single lane which is designated as an HOV lane during the morning and evening commute periods. The roadway segment extends an existing HOV lane in a moderately congested suburban corridor. The project should allow all travelers to move through the corridor slightly faster and encourage driving (due to the moderate congestion levels, the amount of new carpool formation should be small). The **single iteration** and **mode choice** methods should show minor shifts from transit to automobile travel as well as slightly faster travel times; the **assignment only** approach should reveal faster automobile travel times. Again, the comparison between the **single iteration** and **mode choice** approaches are of primary interest.

4 Empirical Results

To evaluate the relative performance of the project assessment methods, each of three projects described in 3 *Empirical Approach* are analyzed by each of the three assessment methods described in 2 *Possible Project Assessment Methods*. Results are discussed relative to the no build project for the hypothetical urban BRT and the hypothetical suburban HOV lane addition below.

4.1 Urban bus rapid transit project

Table 2 compares, separately, the no build project results to the urban BRT project results for each of the three assessment methods. Again, the quantities of interest are the changes from the no build, and comparing those changes (or "deltas") across methods.

Per the hypotheses in the previous section, the **single iteration** and **mode choice** methods revealed a change in transit person trips; the **assignment only** method did not. The **single iteration** method did show a larger shift to transit from automobile (as measured by transit person trips). In both methods, transit boardings increase slightly more than transit trips, meaning travelers are willing to take a feeder bus and transfer to the BRT route. The change in vehicle miles traveled, regardless of method, is negligible.

The **assignment only** method, by construct, shows no change in person trips or transit person trips; travelers are not permitted to change travel mode in this approach, only transit route. The only metric which is informed by the **assignment only** approach is the reduction in average travel time (this metric is overestimated relative to the **single iteration** metric). The bias of the **assignment only** approach towards transit renders this method unacceptable for the project performance assessment work.

Table 2: Difference between the No Build and Urban Bus Rapid Transit Projects across Assessment Methods

Project	Assessment method	Person trips	Transit person trips	Transit boardings	Average transit trip travel time (minutes)	Non-recurring delay (hours)	Vehicle miles traveled
No Build	Single Iteration	31,258,602	2,044,464	2,865,889	39.3	200,592	184,042,840
	Mode Choice	30,951,816	2,074,648	2,902,876	39.1	199,534	183,014,433
	Assignment	30,935,444	1,930,680	2,855,415	39.0	197,742	185,942,475
Urban BRT	Single Iteration	31,257,764	2,052,802	2,878,006	39.1	200,737	184,047,181
		0.00%	0.41%	0.42%	-0.40%	0.07%	0.00%
	Mode Choice	30,934,266	2,075,728	2,906,595	39.0	199,887	183,037,001
		-0.06%	0.05%	0.13%	-0.21%	0.18%	0.01%
	Assignment Only	30,951,816	2,074,648	2,855,101	38.9	197,742	185,942,475
		0.00%	0.00%	-0.02%	-0.29%	0.00%	0.00%

4.2 Suburban high occupancy vehicle lane addition

Table 3 compares, separately, the no build project results to the suburban HOV lane addition project results for each of the three assessment methods. Again, the quantities of interest are the changes from the no build, and comparing those changes across methods.

Generally speaking, the results are similar across the **single iteration** and **mode choice** only assessment approaches. The lack of congestion in the corridor results in fairly minor changes in behavior and outcomes.

The **assignment only** method results are similar and show small reductions in delay for both single- and high-occupant vehicles.

Table 3: Difference between the No Build and Suburban High Occupancy Vehicle Lane Addition Projects across Assessment Methods

Project	Assessment method	Single-occupant vehicle (SOV) person trips	High-occupant vehicle (HOV) person trips	Transit person trips	Average SOV trip travel time (minutes)	Average HOV trip travel time (minutes)	Vehicle miles traveled
No Build	Single Iteration	13,957,406	11,597,940	2,044,464	13.6	11.0	184,042,840
	Mode Choice	13,697,464	11,418,834	2,074,648	13.7	11.1	183,014,433
	Assignment	13,718,156	11,495,528	1,930,680	13.5	11.1	183,014,433
Suburban HOV Lane Addition	Single Iteration	13,954,464	11,600,238	2,044,612	13.6	11.0	184,074,432
		-0.02%	0.02%	0.01%	0.00%	0.00%	0.02%
	Mode Choice	13,693,726	11,418,056	2,069,844	13.7	11.1	183,041,821
		-0.03%	-0.01%	-0.23%	-0.01%	0.06%	0.01%
	Assignment Only	13,718,156	11,495,528	1,930,680	13.5	11.1	183,029,964
		0.00%	0.00%	0.00%	-0.00%	-0.05%	0.01%

5 Recommendations

Of the three reviewed methods for using the travel model to support the benefit-cost portion of the project performance assessment, the **single iteration** approach is the most accurate (relative to the "full" travel model). However, the execution time of this approach (at least 18 hours per project depending on the sampling rate) is not compatible with the schedule (evaluate 100 projects in six weeks). The **mode choice** method adequately replicates the **single iteration** results while requiring only a fraction of the run time (about eight hours per project). This method is risky, however, as it would require a mechanical intervention into the model system not previously attempted. The **assignment only** method is faster still (about two hours per project), but does not adequately reflect the **single iteration** results and is biased against transit projects.

The **mode choice** method offers the best trade-off between run time and accuracy and is, therefore, recommended for the project performance assessment task.