Rapid Implementation and Validation of Dynamic Traffic Assignment in the Doyle Drive Corridor, the Southern Approach to the Golden Gate Bridge

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Doyle Drive is the 2-mile long southern approach to the Golden Gate Bridge. Carrying roughly 17,000 weekday transit riders and 127,000 weekday persons in cars, it is both the primary highway and transit link from San Francisco to the North Bay Counties, as well as an essential east-west connection for trips within San Francisco. Built over 60 years ago, Doyle Drive is also one of the most seismically unfit facilities in California and plans for a replacement facility have been underway since the 1970's. The final funding gap was closed by the American Recovery and Reinvestment Act of 2009 (ARRA) to facilitate the signing and certification of the final joint EIS/EIR. Accordingly, the construction time line has been significantly accelerated in order to meet ARRA requirements. This left the San Francisco County Transportation Authority (SFCTA), Caltrans and other local agency partners with little time to evaluate the traffic impacts from the construction of the new Doyle Drive Facility (to be named the Presidio Parkway). Recognizing the need to identify potential bottlenecks and queues as a result of the construction (and test possible solutions to these issues), SFCTA decided to implement Dynamic Traffic Assignment (DTA) for this quadrant of the city. This paper documents the rapid implementation of Dynameq DTA in the Doyle Drive Corridor, calibration challenges, validation statistics, and run times/computing resources. Additionally, because several of the construction scenarios are scheduled to occur by February 2010, the paper proposes a framework to evaluate the ability of this DTA to replicate field conditions.

Network Description

The Doyle Drive Corridor network is a portion of San Francisco County that extends from the west coast to Van Ness Avenue. Its northern boundary is the Golden Gate Bridge and its southern frontier is Fulton Street. It consists of 200 internal zones and 60 external zones with demand being on the order of 160,000 vehicles for the 3 hour PM peak period. There are approximately 3,000 nodes, 7,000 links, and 240 signalized intersections. This diverse network, shown coded in Dynameq below, consists of two limited access facilities (US 101, also known as Doyle Drive, as well as CA 1, also known as Park Presidio or Veteran's Boulevard), several rural park roads within the Presidio National Park, low volume stop-controlled city streets to the west, and high-volume city streets to the east with coordinated signals.

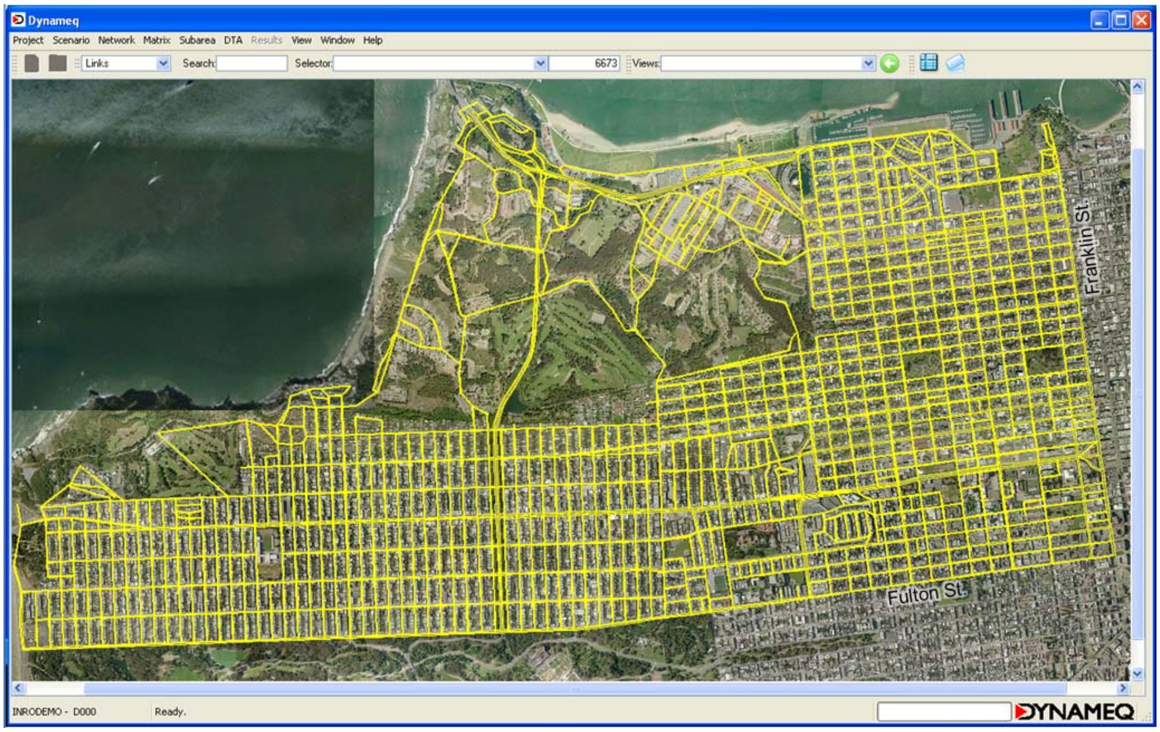

Figure 1. Doyle Drive DTA Network

Scenario Descriptions

The Doyle Drive team is primarily interested in assessing the network conditions that reflect two distinct stages of construction. Scenario 1 reflects the network condition between early 2010 and 2011, while Scenario 2 reflects the network condition between early 2011 through 2012 until the completion of construction. While the team evaluated other scenarios (such as a full weekend closure of Doyle Drive east of CA-1), these results are outside of the scope of this paper.

Changes from the base condition and Scenario 1 are outlined in Figure 2 below left. The changes are as follows:

- Ramp closed from Northbound CA-1 to Southbound US-101,
- Ramp closed from Northbound US-101 to Southbound CA-1,
- Portion of Lincoln Blvd Closed (as indicated in Figure),
- Crissy Field Avenue Closed,
- Construction traffic consistent with the average peak hour truck load added to and from the staging area (in the vicinity of the Lincoln Ave closure), and
- Response factor increased along the Doyle Drive facility to account for rubbernecking effect, essentially reducing the capacity to 1600 vehicles per hour per lane.

Figure 2. Doyle Drive Project Area – Scenario 1 (left) and Scenario 2 (right)

Changes between Scenario 1 and Scenario 2 are shown in Figure 2 above right and are:

- Northbound CA-1 to Southbound US-101 opened to traffic
- Traffic on US-101 east of CA-1 moved onto a temporary 5-lane detour facility,
- Halleck and Banks Streets are closed,
- Lincoln Blvd. is reopened to traffic,
- A temporary signal is installed to regulate traffic between Marina Boulevard and the new temporary detour facility, and
- Truck traffic increased to account for an increase in construction activity during this time.

In addition to these two primary scenarios, the team assessed network conditions with 15% more demand across the board, an increase that is consistent with the seasonal adjustment factor in this very tourist-heavy part of the city.

Demand Matrices

The 3-hour PM peak traversal matrices for cars and trucks were extracted from the 2005 base SFCTA regional travel demand model SF-CHAMP for the Doyle Drive study area. Origin-destination matrix adjustment was done in order to A) account for differences in demand that have happened between 2005 and 2009, and B) minimize differences in travel times and counts due to the demand matrices. While this process eliminates the direct connect between SF-CHAMP and the DTA model, it was necessary in order to meet the short time frame of the project. The matrix adjustment procedure used a variety of both mainline and turning traffic counts compiled by various studies over the past few years. Traffic counts were located on the perimeter of the study area and along key corridors. The location of traffic counts helped define the network boundaries. All were 15-minute counts: 74 mainline pcu counts covering the 3-hour PM-peak and almost 700 turn pcu counts covering 2 of the 3 hours. The demand matrices were adjusted in Emme travel demand forecasting software to better fit each of six 30-minute time slices of aggregate counts.

Calibration

The demand matrices, adjusted in Emme, were assigned in the Dynameq DTA software package to begin calibration. Network representation was refined and select-link analyses along key corridors enabled the analysts to understand why the assigned flows differed from the counts, due to demand inputs that were too high or low for specific O-D pairs, errors in the network representation, etc.

Analysis of used routes revealed an over-usage of alternating turns in reaching the Golden Gate Bridge and Doyle Drive. The congestion due to excessive turning movements led to a long period to clear the network. Left and right turns were penalized using a generalized cost DTA to account for drivers' tendency to choose simpler routes, particularly in dense grid networks as found in this scenario. Behaviorally, this can be explained by safety and reliability risks in drivers' perception of path cost. Empirically, this was supported by improved validation measures.

The predicted flows matched counts closely from 4-5pm, but were low from 5-6pm. Local judgment indicated that speeds were too high and congestion was clearing too quickly. Free flow speeds were reduced in the main corridors from 30mph to 27.5mph, and driver's reaction times were increased. This improved the fit of the flows to the counts from 5pm to 6pm.

The calibrated DTA converged to a maximum 4% relative gap among all 15-minute departure intervals, and a mean relative gap of 2.4% (Figure 3), indicating that the assignment was acceptably close to a dynamic equilibrium. The calibrated flows matched the mainline and turning counts closely with slope 1.00 ± 0.03 and R^2 between 92% and 95%.

Validation

Observed travel times from SFCTA's April 2009 Level of Service Monitoring were compared with simulated speeds for 27 routes for multiple departures from 4:30pm to 6pm. The average length of these routes is 1.5 miles. The average observed travel time was compared to the simulated travel time. The regression for all 27 routes had slope 0.96 with an R^2 of 91% (Figure 5), and along the key corridors affected by the upcoming construction the slope was 0.98 with an R^2 of 92% (Figure 6).

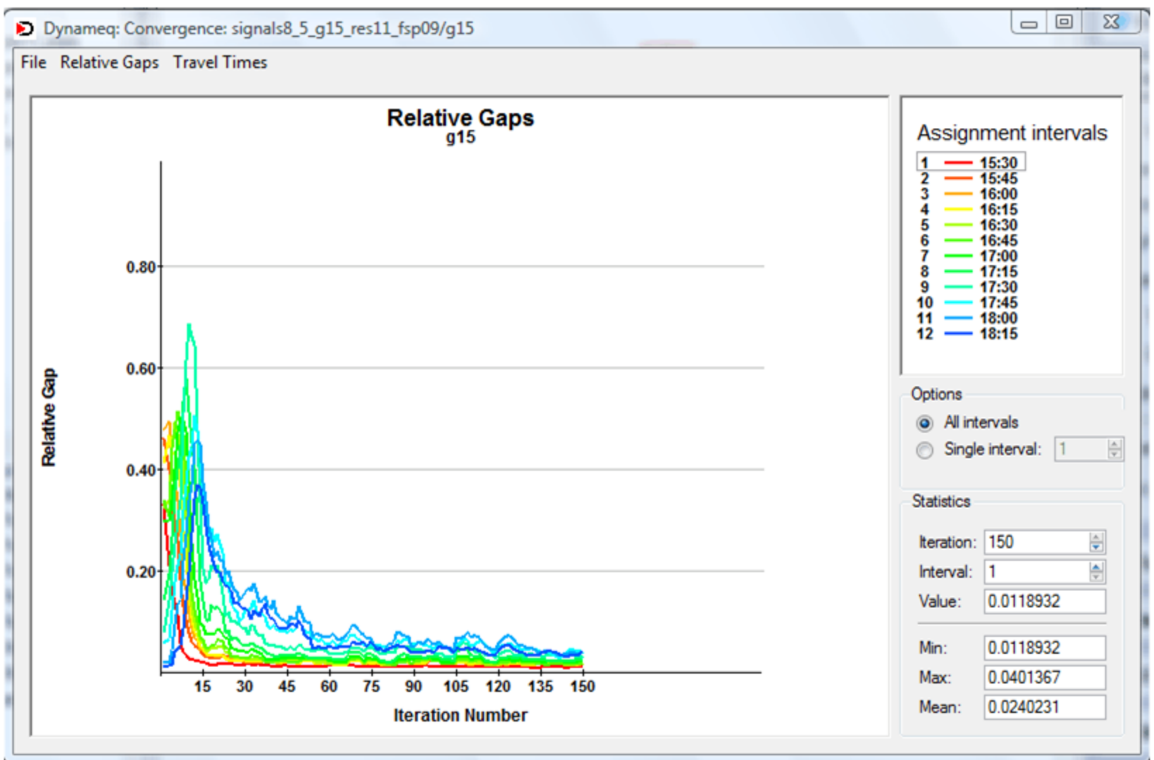

Figure 3. Relative Gaps

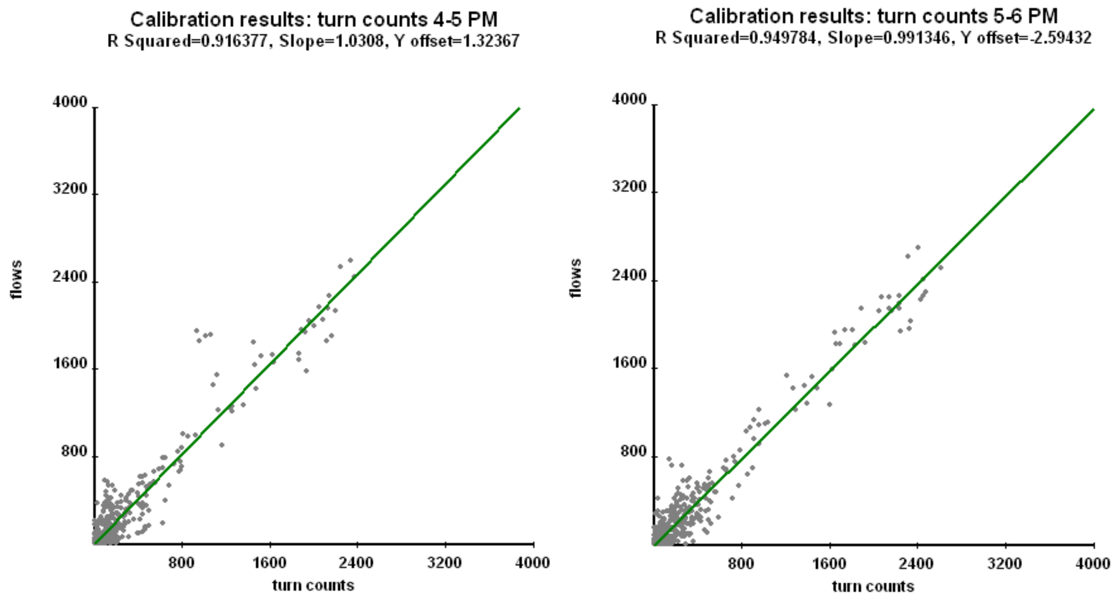

Figure 4. Turn Counts versus Flows

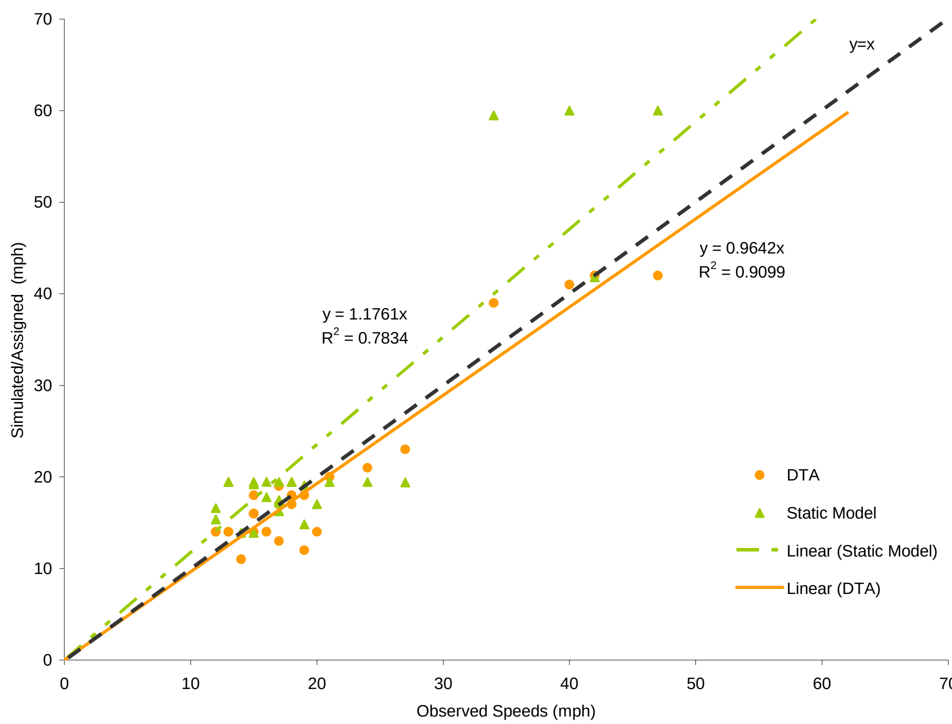

Figure 5. Simulated and Assigned versus Observed Speeds for Routes in Study Area

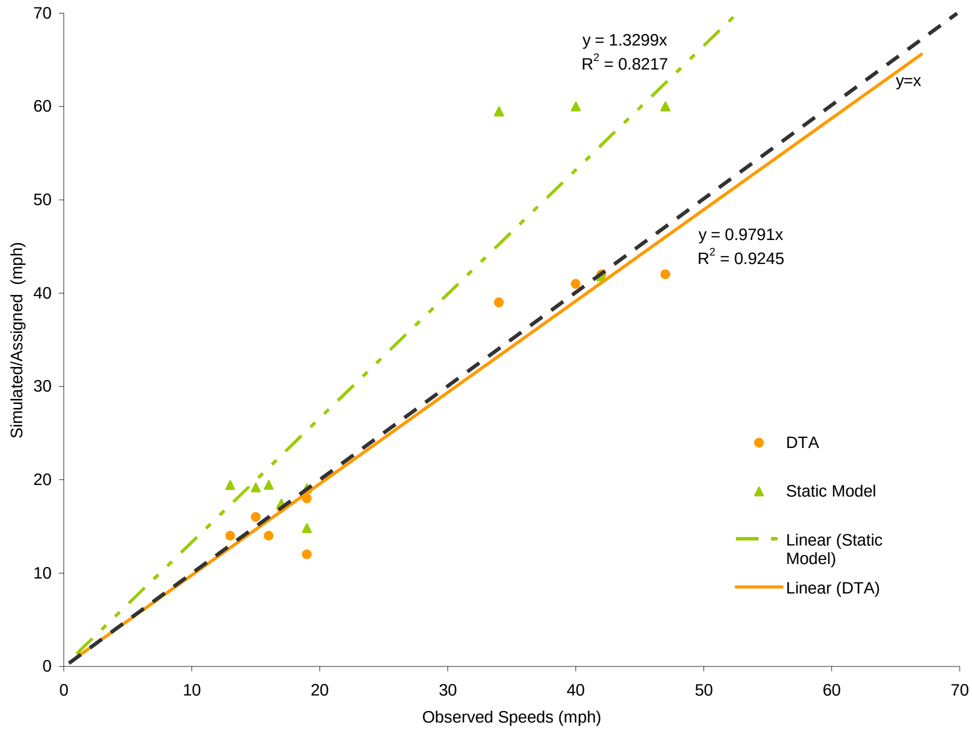

Figure 6. Simulated and Assigned versus Observed Speeds for Key Routes in Study Area

In addition to the performance of the DTA model, the above figures also compare the computed speeds of SFCTA's existing static assignment algorithm along these same corridors. This comparison was done using the same (adjusted) PM peak period trip table that was used in the DTA assignment and an identical network (with the exception that the DTA uses a lot more network variables). The static assignment was run to a relative gap of 0.004. On the whole, speeds reported in the static model were higher than observed speeds resulting in a slope of 1.18 for all routes and 1.3 for key routes. R-squares for the static model, 78% and 82%, are also not as good as the DTA model.

Resources

Project Timeline and Level of Effort
This section will provide some data points that will hopefully be useful to other practitioners. One of the most defining characteristics of this study is that the entire effort from network conversion through running scenarios was done in just two months from August 20th to October 20th, including the calibration and demand adjustment, which took only 3 weeks. Total person time on the project is estimated to be two FTEs for the duration. Clearly more time could have been spent refining the calibration; however, ground was broken on the Doyle Drive Construction in November and therefore time was critical. Follow up work will be done to see if more time/effort will be able to improve the calibration.

Computer Resources
The scenarios runs were run on a 3.3 Ghz Nehalem Xeon processor computer. Table 1 summarizes the scenarios and their respective Dynameq DTA runtimes for 150 iterations. Scenarios 1a and 2a had 15% more vehicles in the simulation, which resulted in runtimes approximately 11% higher. Scenarios 1 and 2 took just over 3% longer to run than the base scenario due to added network congestion.

Table 1. Dynameq Computing Time Comparisons

Vehicles	Scenario	Average Relative Gap	Maximum Relative Gap	Runtime (min)	Runtime per Iteration (min)
160,946	Base	2.5%	5.1%	279	1.9
160,946	1	3.4%	6.3%	288	1.9
185,030	1a	5.5%	10.2%	319	2.1
160,946	2	3.4%	5.8%	289	1.9
185,030	2a	6.1%	10.9%	319	2.1

For reference, static highway assignment with the same demand tables and network took just over 15 minutes for 24 iterations (38 seconds / iteration) to achieve a relative gap of 0.004 using an AMD 2.50 GHz Opteron.

Results

The following section discusses some of the results that we extracted from the DTA model. Please note that all results presented here are preliminary.

Travel time impacts to the far east of the corridor and the south of the corridor are presented below in Figures 7 and 8. On average for the PM period, vehicles in Scenario 1 experience 3 minutes more travel time than the base and those in Scenario 2 experience 6 minutes more. The differences in travel time increase as time moves forward and more vehicles are loaded on to the network

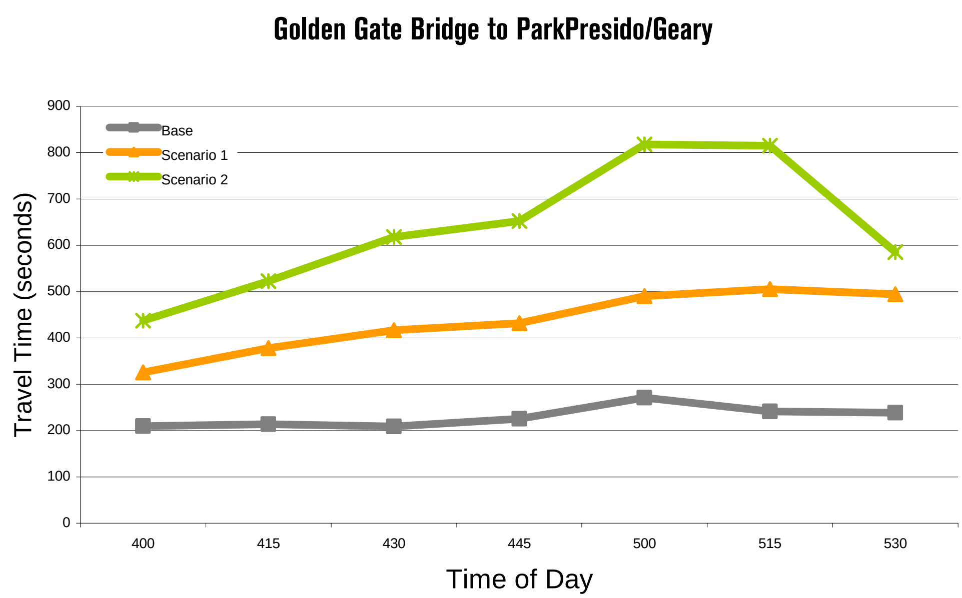

Figure 7. Travel Time Differences from the Golden Gate Bridge to Park Presidio and Geary

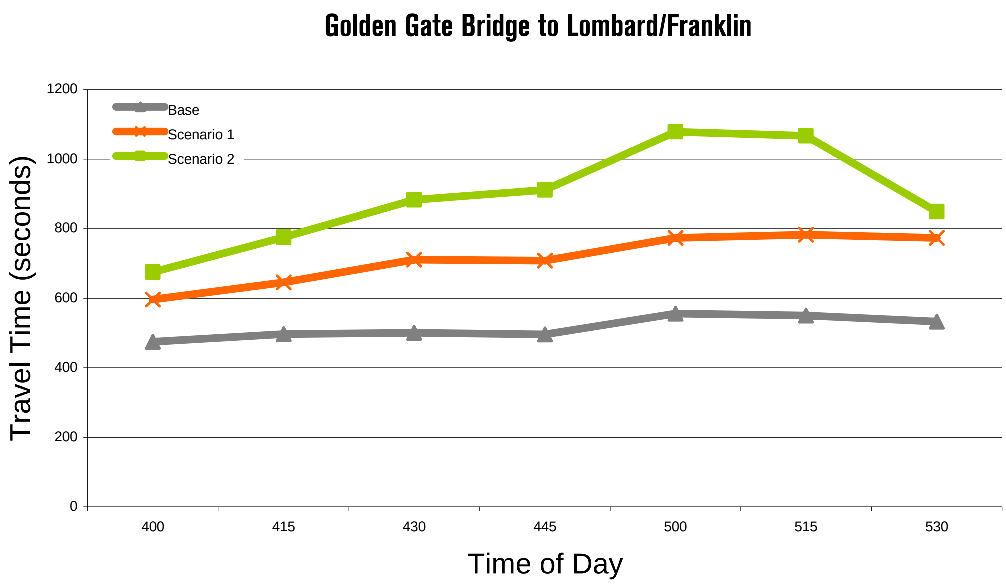

Figure 8. Travel Time Differences from the Golden Gate Bridge to Lombard/Franklin

In addition to general concerns about travel time impacts, the Doyle Drive construction stakeholders have three very specific concerns that are addressed in this paper: (1) are too many vehicles going to cut through the Golden Gate Bridge visitor parking lot? (2) When the detour is opened (in Scenario 2), there is a signal to turn left on to Marina Blvd. How does this signal operate? (3) Are transit operations on Geary Blvd (a major east-west transit line) adversely affected by traffic diverted from Doyle Drive?

The Golden Gate Bridge parking lot connects to a tunnel underneath the bridge toll plaza which leads to Lincoln Blvd. It is one of the many possible cut-throughs once the intra-San Francisco ramps are closed. However, traffic detouring through the parking lot is concerning for two reasons: (1) the parking lot is the site of a lot of pedestrian activity, and (2) because there is little (if any) storage area, any queuing in the parking lot would quickly spill back and affect mainline operations on U.S. 101. The preliminary analysis using the DTA shows that the overall volume cutting through this parking lot will *not* change as a result of Doyle Drive Construction, and the hourly volumes in the results for this link remain in the range of 15 vehicles per hour for each direction. The reason that this link is not taken as a detour route is that other detour routes have sufficient capacity to carry demand.

The analysis team examined the queue capacity at the new temporary signal on the Doyle Drive detour with Marina Boulevard by summing up the total queue lengths for the left turn and comparing them to the total queue length capacity of the pocket lane (823 feet). Figure 9 below shows that the Southbound U.S. 101 queue waiting to turn left on to Marina Boulevard never approaches the storage capacity of 823 feet. However, it should be noted that this analysis is for the PM peak period and Southbound U.S. 101 traffic peaks in the AM period. Further analysis at this signal will be done when an AM calibration is completed.

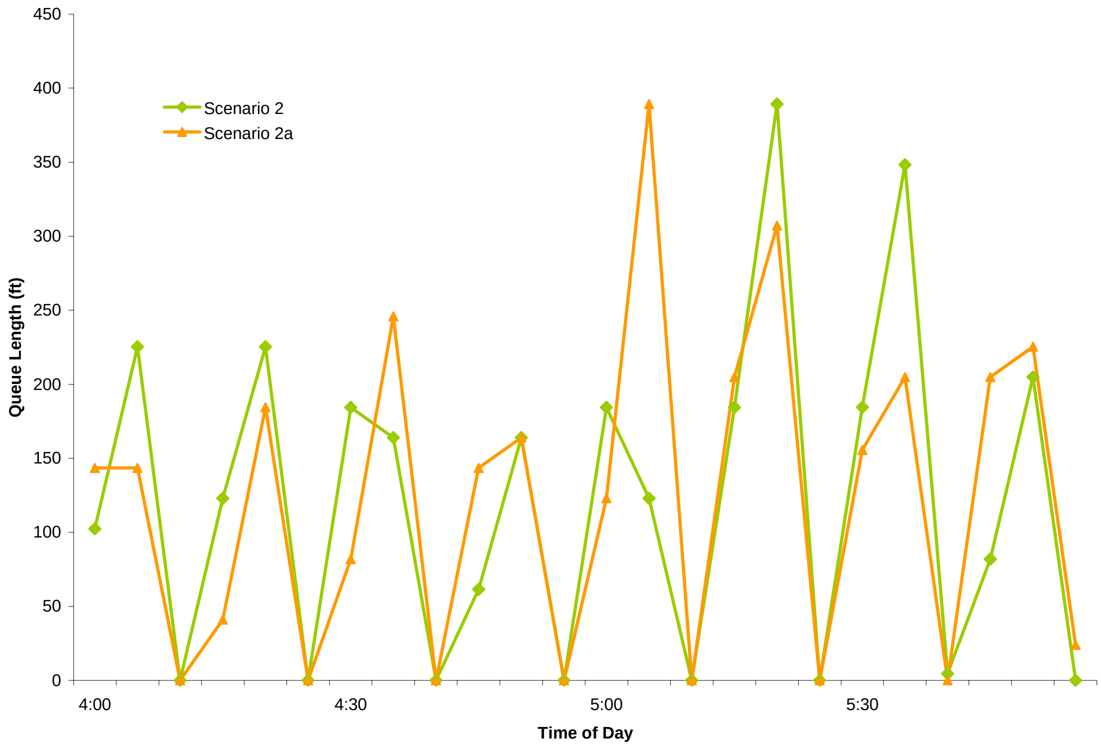

Figure 9. Southbound Left Turn Queue Length at Temporary Signal on Doyle Detour

Travel time differences for major transit lines in the study area were minimal across all alternatives, alleviating concern that the ramp closures would have a significant impact on transit. The bus lines on Geary were of particular concern as Geary is projected to be a popular route choice for those diverted due to the ramp closures. Figure 10 shows that bus travel times within the study area essentially remain the same or improve in the Scenario 1 and 2 DTA model. As expected for the PM period, travel times on the 38-Outbound bus line are higher than the 38-Inbound by about 5 minutes.

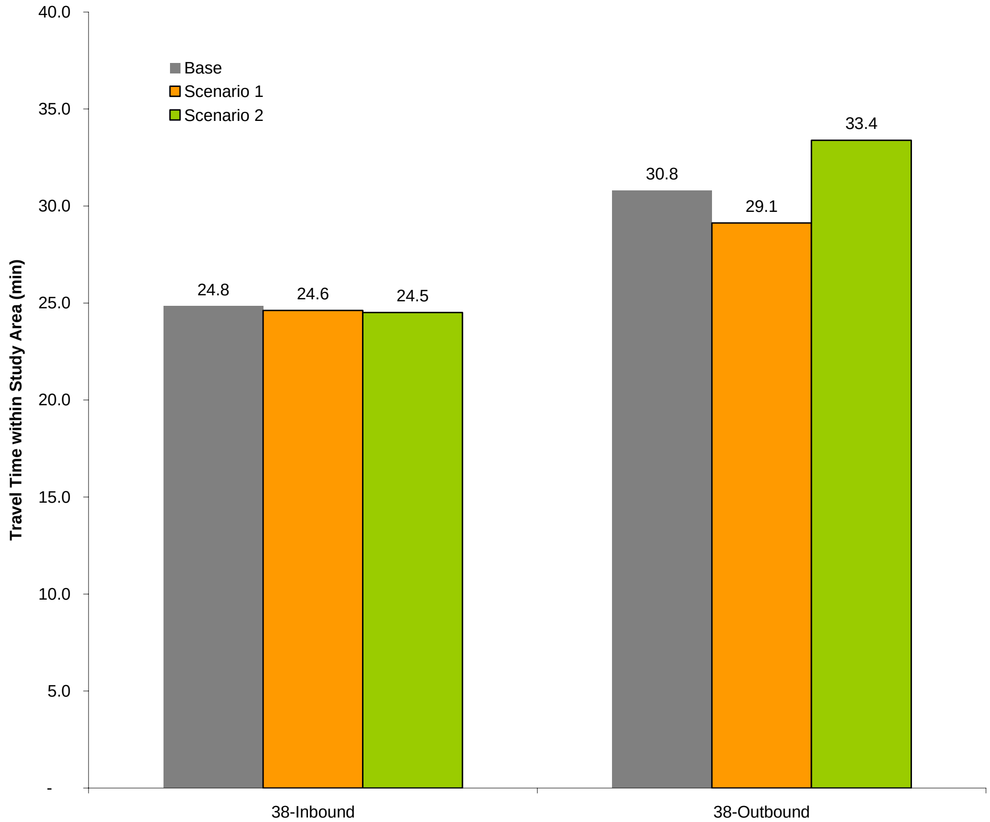

Figure 10. Travel Time Impacts on the Geary-38 Bus Lines

Next Steps

As of the deadline for this paper, additional results were being compiled to address all stakeholder concerns. This study will be extended to validate the results of the scenario tests with field data. Field data is expected to be collected throughout the project and will be ready for Scenario 1 this winter. Aside from counts, validation data is expected to include observed travel times as well as transit travel times.

Conclusions

In conclusion, we have shown that it is feasible to implement and apply a DTA model of this size in a matter of months. More importantly, SFCTA was able to use this appropriate tool to address Doyle Drive stakeholders' questions and concerns. The stakeholders were brought along in the model development process and briefed along the way in order to get buy-in for the results. The rapid model development complete, SFCTA can work with the stakeholders to quickly develop and test remedies for several of the areas that will experience congestion as a result of construction.