October 7, 2015

# SANDAG Activity-Based Model Sensitivity Analysis

The SANDAG modeling staff conducted a series of sensitivity tests to demonstrate the effects of various inputs on vehicle miles traveled (VMT) and mode shares in the SANDAG ABM in response to requests by the California Air Resources Board (ARB). The tests included varying transit fare, transit frequency, and auto operating cost (AOC) by plus or minus 25 percent and 50 percent in 2012 scenarios. Staff also tested varying freeway general purpose lane and freeway to freeway connector capacity by reducing capacity 50 percent and increasing it 100 percent in year 2012. For land use density tests, SANDAG used 2035 revenue constrained network with alternative land uses.

All of the tests were compared to the elasticities identified in the CARB Senate Bill 375, *Research on Impacts of Transportation and Land Use-Related Policies*[1]. In each case, the results of the SANDAG tests were consistent with ARB research papers. For freeway capacity and auto operating costs the elasticity was derived as the change in VMT compared to the change in the relevant variable (Table 1). For transit operation, the elasticity was derived as change in boardings compared to the relevant variable (Table 2).

**Table 1 Summary of VMT and Elasticity of VMT to Freeway Capacity and AOC**

| Scenario | VMT | % of VMT Difference | Elasticity | Elasticity in CARB White Paper |
|---|---|---|---|---|
| 2012 baseline | 79,554,226 | | | |
| Reduce Freeway Capacity by 50% | 72,624,153 | -8.71% | 1.3 | 0.3 to 1.0 |
| Double freeway Capacity | 82,891,012 | 4.19% | 0.3 | |
| Increase AOC by 50% | 78,317,785 | -1.55% | -0.03 | -0.02 to -0.1 |
| Increase AOC by 25% | 78,781,407 | -0.97% | -0.04 | |
| Reduce AOC by 25% | 80,424,737 | 1.09% | -0.04 | |
| Reduce AOC by 50% | 81,525,803 | 2.48% | -0.05 | |

**Table 2 Summary of Transit Trips, Boardings and Elasticity to Frequency and Fare**

| Scenario | Transit Trips | % Diff of Transit Trips | Elasticity (Transit Trips) | Boardings | % Diff of Boardings | Elasticity (Boardings) | Elasticity in CARB White Paper |
|---|---|---|---|---|---|---|---|
| 2012 Baseline | 225,985 | | | 359,485 | | | |
| Reduce fare by 50% | 329,375 | 46% | -0.9 | 525,691 | 46% | -0.9 | -0.4 to -1.0 |
| Reduce fare by 25% | 271,859 | 20% | -0.8 | 432,605 | 20% | -0.8 | |
| Increase fare by 25% | 190,282 | -16% | -0.6 | 301,797 | -16% | -0.6 | |
| Increase fare by 50% | 161,681 | -28% | -0.6 | 255,684 | -29% | -0.6 | |

[1] Senate Bill 375 - Research on Impacts of Transportation and Land Use-Related Policies. <http://arb.ca.gov/cc/sb375/policies/policies.htm>

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Increase frequency by 50% | 287,526 | 27% | 0.5 | 493,718 | 37% | 0.7 | 0.5 |
| Increase frequency by 25% | 252,414 | 12% | 0.5 | 413,869 | 15% | 0.6 | |
| Decrease frequency by 25% | 210,624 | -7% | 0.3 | 328,012 | -9% | 0.4 | |
| Decrease frequency by 50% | 198,027 | -12% | 0.6 | 303,610 | -16% | 0.6 | |

In addition to VMT analysis, staff compared the mode shares from the simulated modules of the ABM: individual tour, joint tour, visitor, internal to external, Mexican resident cross border model and airport model. Tables 3 and 4 summarize mode shares and mode share differences between 2012 tests and baseline.

**Table 3 Mode Share for 2012 Tests and Baseline**

| Scenario | Drive Alone | Carpool | Transit | Walk & Bike | Other |
|---|---|---|---|---|---|
| 2012 Baseline | 42.02% | 42.93% | 1.91% | 11.74% | 1.39% |
| Reduce Freeway Capacity by 50% | 41.34% | 42.58% | 2.09% | 12.60% | 1.39% |
| Double freeway Capacity | 41.76% | 42.58% | 1.89% | 12.45% | 1.33% |
| Increase AOC by 50% | 41.56% | 42.28% | 2.08% | 12.68% | 1.40% |
| Increase AOC by 25% | 42.01% | 42.74% | 1.99% | 11.85% | 1.38% |
| Reduce AOC by 25% | 42.04% | 43.12% | 1.84% | 11.62% | 1.37% |
| Reduce AOC by 50% | 42.06% | 43.33% | 1.78% | 11.49% | 1.30% |
| Reduce fare by 50% | 41.74% | 42.54% | 2.79% | 11.63% | 1.30% |
| Reduce fare by 25% | 41.89% | 42.76% | 2.30% | 11.70% | 1.35% |
| Increase fare by 25% | 42.13% | 43.09% | 1.61% | 11.76% | 1.41% |
| Increase fare by 50% | 42.23% | 43.21% | 1.37% | 11.78% | 1.42% |
| Increase frequency by 50% | 41.69% | 42.73% | 2.43% | 11.76% | 1.39% |
| Increase frequency by 25% | 41.88% | 42.86% | 2.14% | 11.74% | 1.38% |
| Decrease frequency by 25% | 42.10% | 42.99% | 1.78% | 11.74% | 1.39% |
| Decrease frequency by 50% | 42.17% | 43.05% | 1.67% | 11.71% | 1.39% |

**Table 4 Mode Share Difference between 2012 Tests and Baseline**

| Scenario | Drive Alone | Carpool | Transit | Walk & Bike | Other |
|---|---|---|---|---|---|
| Reduce Freeway Capacity by 50% | -0.7% | -0.3% | 0.2% | 0.9% | 0.0% |
| Double freeway Capacity | -0.3% | -0.4% | 0.0% | 0.7% | -0.1% |
| Increase AOC by 50% | -0.5% | -0.6% | 0.2% | 0.9% | 0.0% |
| Increase AOC by 25% | -0.02% | -0.2% | 0.1% | 0.1% | -0.02% |
| Reduce AOC by 25% | 0.02% | 0.2% | -0.1% | -1.0% | -0.5% |
| Reduce AOC by 50% | 0.04% | 0.4% | -0.1% | -0.3% | -0.1% |

| | | | | | |
|---|---|---|---|---|---|
| Reduce fare by 50% | -0.3% | -0.4% | 0.9% | -0.1% | -0.1% |
| Reduce fare by 25% | -0.1% | -0.2% | 0.4% | 0.0% | 0.0% |
| Increase fare by 25% | 0.1% | 0.2% | -0.3% | 0.0% | 0.0% |
| Increase fare by 50% | 0.2% | 0.3% | -0.5% | 0.0% | 0.0% |
| Increase frequency by 50% | -0.3% | -0.2% | 0.5% | 0.0% | 0.0% |
| Increase frequency by 25% | -0.1% | -0.1% | 0.2% | 0.0% | 0.0% |
| Decrease frequency by 25% | 0.1% | 0.1% | -0.1% | 0.0% | 0.0% |
| Decrease frequency by 50% | 0.1% | 0.1% | -0.2% | 0.0% | 0.0% |

The 2035 revenue constrained network with Series 13 Regional Growth Forecast and alternative land use scenarios were tested to measure the impact of land use density on resident VMT (Table 5) and mode shares (Table 6). The Multiple Dense Core land use focuses forecasted housing and employment growth into four existing urban cores around high-quality transit fixed-route stops. The Smart Growth land use increases residential densities and employment intensities relative to the Series 13 Forecast within specified 2014 Smart Growth Opportunity Areas (SGOAs) identified on the SANDAG Smart Growth Concept Map. The total housing units and employment within the Smart Growth boundary or the Multiple Dense Core boundary compared to the baseline Series 13 Growth Forecast in year 2035 is show in Table 7 and Table 8.

**Table 5 Resident VMT and VMT Difference in 2035 Land Use Density Tests**

| Scenario | Resident VMT | Resident VMT Difference | % Difference |
|---|---|---|---|
| Baseline - Series 13 Growth Forecast | 60,989,959 | | |
| Alternative Land Use - Multiple Dense Core | 59,833,247 | (1,156,711) | -1.9% |
| Alternative Land Use - Smart Growth | 60,647,442 | (342,517) | -0.6% |

**Table 6 Mode Share Summary for 2035 Land Use Density Tests**

| Scenario | Drive Alone | Carpool | Transit | Walk & Bike | Other |
|---|---|---|---|---|---|
| Baseline - Series 13 Growth Forecast | 39.5% | 42.3% | 3.1% | 13.3% | 1.7% |
| Alternative Land Use - Multiple Dense Core | 39.3% | 42.4% | 3.1% | 13.5% | 1.7% |
| Alternative Land Use - Smart Growth | 39.0% | 42.5% | 3.3% | 13.6% | 1.7% |

**Table 7 Housing Units and Employment in 2035 in Smart Growth Alternative Boundary**

| | Baseline Series 13 Growth Forecast | Smart Growth Alternative |
|---|---|---|
| Housing Units in Smart Growth Alternative Boundary | 393,681 | 422,815 |
| Employment in Smart Growth Alternative | 689,457 | |

| | | |
|---|---|---|
| Boundary | | 732,680 |

**Table 8 Housing Units and Employment in 2035 in Multiple Dense Core Alternative Boundary**

| | Baseline Series 13 Growth Forecast | Multiple Dense Core Alternative |
|---|---|---|
| Housing Units in Multiple Dense Core Alternative Boundary | 1,008,114 | 1,042,264 |
| Employment in Multiple Dense Core Alternative Boundary | 1,376,761 | 1,426,114 |

To examine the impact of changing household income to VMT and mode share, instead of creating population composition of alternative household income and conducting sensitivity tests, staff used the cross-sectional analysis adopted by Metropolitan Transportation Commission (MTC) to explore the relationship between VMT and household income. The cross-sectional approach examines outputs from a single model simulation. The simulated travelers with different income and from different neighborhood based on the synthetic population comprise the sample for the cross-sectional analysis.

Using a year 2012 baseline simulation of SANDAG ABM, staff regressed typical weekday VMT against household income for full- and part-time workers. Figure 1 shows a scatter plot of logarithm 10 of VMT for full- and part-time workers in relationship to logarithm 10 of household income. Staff also conducted regression on typical weekday VMT against household income for all simulated travelers with a sample size of 2.37 million. Both the regression results show a positive relationship between income and VMT.

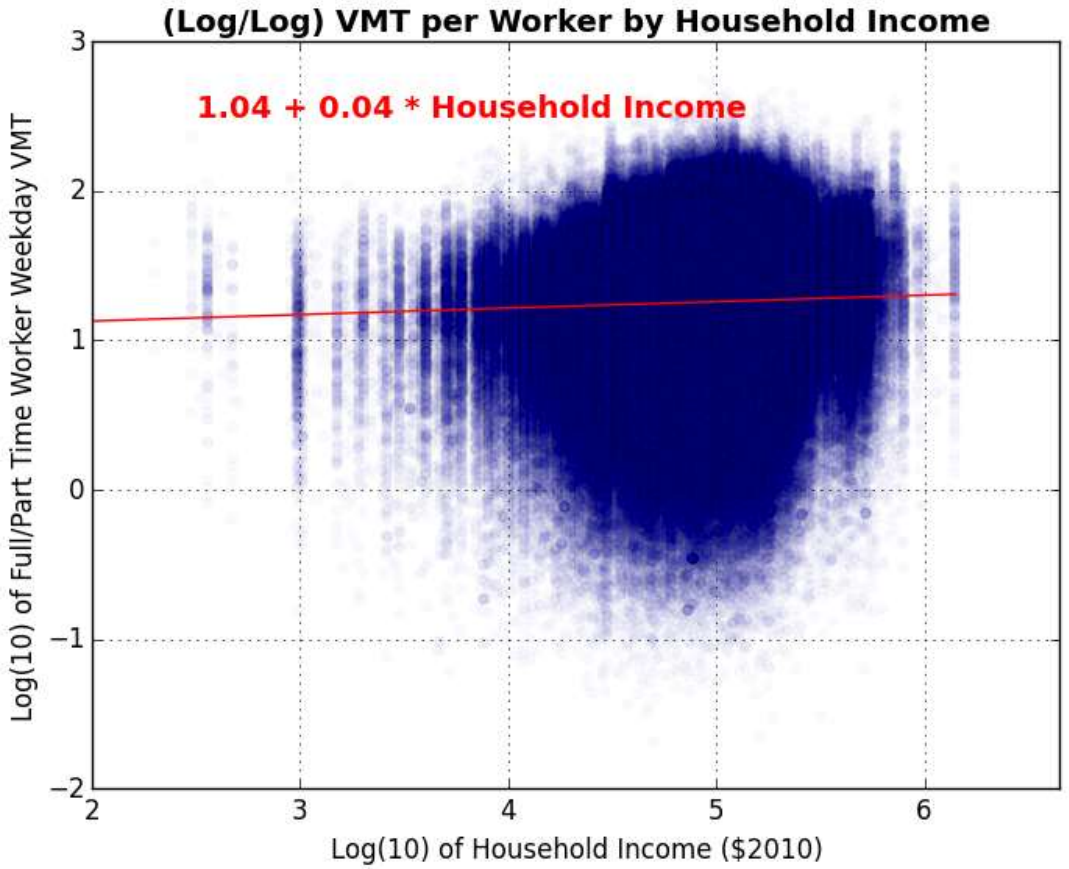


**Figure 1 Typical Weekday Workers' VMT by Household Income**

Table 9 below includes the relevant quantities for the VMT to household income elasticity calculations.

**Table 9 VMT for All Travelers to Household Income Elasticity Calculations**

| Quantity | Units | Value |
|---|---|---|
| Mean vehicle-miles traveled for all travelers | Vehicle-miles | 20.94 |
| Mean household income | Year 2010 dollars | 98955 |
| Regression coefficient on household income | Veh-miles/Year 2010 dollars | 2.16e-05 |
| Elasticity – VMT to household income | -- | 0.102 |

**Description of Test Input Changes**

Freeway Capacity: The time of day capacities for freeway general purpose lanes and freeway to freeway connectors were updated by reducing 50 percent or increasing 100 percent in the highway network build process.

AOC: The parameters of fuel and maintenance were set to be 25 percent less, 50 percent less, 25 percent more, or 50 percent more of the corresponding values in the 2012 baseline scenario.

Transit Fare: In the transit route attribute table of each scenario, the fares by route were set to be 25 percent less, 50 percent less, 25 percent more, or 50 percent more of the corresponding values in the 2012 baseline scenario. The zone based fare for commuter rail was updated in the same way as the route based fare assumption.

Transit Frequency: In the transit route attribute table of each scenario, the frequencies by route were set to be 25 percent less, 50 percent less, 25 percent more, or 50 percent more of the corresponding values in the 2012 baseline scenario.

Land Use Density: The MGRA based land use input file, the synthetic population, and household files based on 2035 Series 13 Regional Grow Forecast and alternative land use scenarios of Smart Growth and Multiple Density Cores were used to run the SANDAG ABM with the 2035 revenue constrained network.