

9.2 Facility and Mileage Based Pricing

One of the major changes from SACSIM15 to SACSIM19 was the implementation of facility and user fee-based pricing. In order to integrate pricing, major SACSIM overhauls include:

- DAYSIM calibration
- DAYSIM distribution of value-of-time (VOT)
- VOT bins during highway assignment
- Network Skimming
- Dynamic tolling adjustment algorithm during highway assignment
- Reconfiguration of Path loading by mode
- New Mileage Based User Fee spatial and temporal inputs
- New priced roadway network identification attributes and cost inputs
- Model equilibrium, population sampling, and global iterations

This section will not discuss calibration or model structure details for all topics above and instead focuses on SACSIM19's user fee or roadway pricing functionality. For model structure adjustments, see Chapter 3 on Model Structure and Chapter 12 on Calibration and Validation.

9.2.1 Facility Pricing

To incorporate effects of roadway pricing, travel choice components must be considered such as trip generation, distribution, time-of-day, congestion, mode choice, and routing. The concept is based off the *Strategic Highway Research program C04: Improving Our Understand of How Highway Congestion and Pricing Affect Travel Demand, 2012*. Consistent with the SHRP2 C04 report, SACSIM19 implements the utility-based function in Equation 9-1 to model the effects of pricing and congestion to travel.

Equation 9-1 Utility-based function to model the effects of pricing on travel¹²

$$U = \Delta + a_1 Time \times (1 + a_2 Dist + a_3 Dist^2) + b [Cost / (Inc^e \times Occ^f)] + c STD / Dist$$

(1)

Where:

- Δ = Alternative-specific “bias” constant for priced facilities
- a_1 = Travel time coefficient, estimated as a random parameter to capture unobserved user heterogeneity
- $Time$ = Average travel time
- a_2, a_3 = Coefficients reflecting the impact of travel distance on perception of travel time
- $Dist$ = Average travel distance
- b = Coefficient on travel cost
- $Cost$ = Cost of travel including tolls, parking, and auto operating costs
- Inc = Household income of traveler
- e = Coefficient reflecting the impact of income on the perception of cost
- Occ = Occupancy of vehicle
- f = Coefficient reflecting the impact of auto occupancy on the perception of cost
- c = Coefficient reflecting the impact of travel time (un-)reliability
- STD = Day-to-day standard deviation

SACSIM19 does not implement all congestion pricing recommendations from the SHRP C04, but builds off the key concepts for functionality of SACSIM’s existing modules and structure. SACSIM does incorporate congestion as its primary proxy for reliability, a difficult input for Demand modeling, with time factors that range from 10.05 to 1.80 based on traffic conditions. Table 9-2 compares key concepts from SHRP C04 pricing recommendations and how they are implemented into SACSIM19.

Table 9-2 SACSIM19 Implementation of SHRP C04 Concepts

ID	Recommendations	Built into SACSIM19
1	Random coefficient on travel time to reflect unobserved user, such as a truncated lognormal distribution curve constrained as negative ensuring logical negative utility with respect to travel time.	Adjusted distributed travel time sensitivities based from a lognormal distribution with standard deviation of 0.85. Higher standard deviation shifting majority trips to lower initial VOT bin.
2	Travel time sensitivity should be a function of distance with short distances and longer distance decreasing sensitivity factors to travel time.	Not implemented due to contradictory findings from other studies.
3	Scaling travel cost coefficient by a function of household income and auto occupancy.	Already built into previous versions of SACSIM
4	Utility function include standard deviation of travel time, scaled by distance as a measure of reliability. Suggest congestion a proxy for reliability with time factors that range from 1.05 to 1.80 traffic conditions.	Cost of delays built in with time factors from 1.05 to 1.80 during highway assignment.

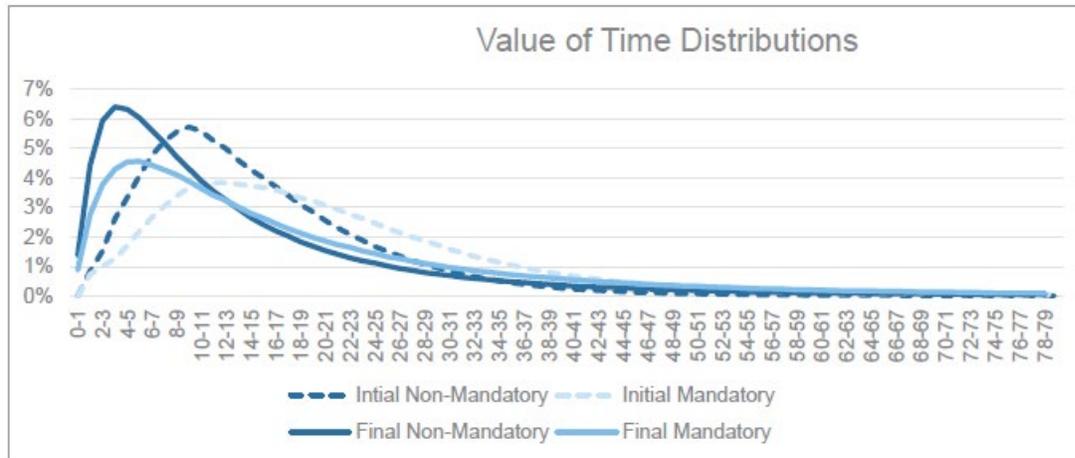
Source: SACOG 2020

9.2.1.1 Valuation of Time

Per RSG Travel demand Model Toll Enhancements¹², SACSIM uses distributed travel time sensitivities that are drawn from a lognormal distribution whose shape is controlled by the user. In the initial model, the values-of-time (VOT) for mandatory and non-mandatory SACSIM trips were drawn from log normal distributions with standard deviations equal to 0.24 and 0.15 respectively. Comparison of the resulting distributions of value-of-time with that of other regions collected by RSG indicated the need for increasing the standard deviation for SACSIM trips. Several trials were run with different values of standard deviation and compared against the other regions’ distributions. A standard deviation of 0.85 was selected for both mandatory and non-mandatory trips in the current version. Figure 9-2 shows the initial and final value-of-time distributions for trips by tour type (mandatory versus non-mandatory). As shown in the plot, the new distributions use a higher standard deviation and therefore shift trips to the left (more trips with lower value-of-time than the initial distributions). These plots more closely match the results of several Stated Preference surveys conducted by RSG over the past several years¹.

¹² RSG *Travel Demand Model Toll Enhancements Technical Memorandum* for SACOG, September 20, 2018

Figure 9-2 Initial Versus Final Value of Time Distributions



Source: Research Systems Group (RSG) 2018

9.2.1.2 Auto Value-of-Time Bins

Per RSG’s toll modeling enhancements memo¹², the initial model setup used one value-of-time to determine path choice for all trips in the model. In the new model setup, three VOT bins were created for highway skimming and assignment. The bins were created using 33rd, 66th and 90th percentile values of the values-of-time for all trips. The corresponding dollar amount of the percentiles were \$7.25, \$16.85 and \$38.80 respectively. These bins were used to group all trips into three VOT classes; low (1), medium (2) and high (3). The resulting cube script skims time, distance, and toll cost for three occupancy groups (drive alone, shared ride-2 and shared ride 3+) and 9 time periods for each of the three VOT classes. The total number of skim matrices thus produced is 243. A generalized cost function, shown below in Equation 9-2, was used to find the shortest path that considers both time and cost.

Equation 9-2 Generalized cost roadway utilization function with VOT and toll pricing¹²

$$\text{cost} = \text{time} + (\text{AOC} + \text{toll}) * \text{VOT}_i$$

Where:

- cost is the generalized cost on the link in minutes
- time is the congested time on the link returned by the volume-delay function
- AOC is the auto operating cost on the link, in dollars
- VOT_i is the value-of-time on the link, in minutes per dollar.
- The VOTs used for the three classes are:
 - Low VOT bin: 60/7.25 = 8.28 min/\$
 - Medium VOT bin: 60/16.85 = 3.56 min/\$
 - High VOT bin: 60/38.80 = 1.55 min/\$

9.2.1.3 Dynamic Roadway Pricing Loop

The toll optimization algorithm was incorporated to allow dynamic roadway pricing in SACSIM19. In order to maximize travel time savings from a priced facility, the priced facility volume must continue to flow. Therefore, the price must increase or decrease based on demand to maintain the facility at an optimal level of service. The toll optimization algorithm does this at link level by comparing the travel time savings of a toll segment to the adjacent “free” or general-purpose lane. The toll price is then calculated by multiplying the time savings by the average value-of-time the highway assignment takes place. This toll value is then applied to the vehicle pathloading impedance function represented as part of the cost as describe above in Equation 9-2 to determine the demand and person who will use the priced facility. If the V/C ratio of any link in a defined toll segment exceed the optimal level of service, currently set to 0.8, or LOS D, the toll increase reducing the attractiveness, by increase the value in the impedance function. Ideally, this process continues until the facility has converged to an optimal price based on demand. In practice, this process of running the optimization loop is rather time consuming and is set to beak each toll loop when the maximum toll changes (new toll - previous toll) for any segment is less than \$0.05 or 5 toll optimization loops have been run.

9.2.1.3.1 Sequential Steps of Toll Optimization Algorithm:

1. Start the toll optimization loop.
2. Read initial tolls for each segment from the tolls.csv file.
3. Calculate the travel time on the toll segments and the corresponding gp segments.
4. Calculate the time savings in the toll segment ($\text{tollseg_time} - \text{gpseg_time}$)
5. Multiply the time savings by the average VOT to get the current toll.
6. If the v/c ratio in any link of the toll segment is greater than 0.8, multiply the current toll by 2 (or any other factor).
7. Calculate new toll by taking an average of the previous toll and the current toll.
8. Apportion the segment toll to each link in the segment.
9. If the maximum change in tolls from the previous step is less than 50 cents, break the loop.

9.2.2 Mileage Based User Fee

A mileage-based fee, known as a pay-as-you-go, or PAYGO fee, was added into SACSIM19 path building utilization cost function. The fee is defined as:

- Combination of state and federal fuel tax per mile traveled, based on the inflation-adjusted cost of fuel taxes on a per mile basis; or
- PAYGO or mileage-based fees assumed to replace part or all of the fuel taxes in future scenarios

Within the Cube® script used to run SACSIM19, a user would set the “direct” costs of fuel, maintenance and tires on a per-mile basis for the “AOC” variable described below, and the fuel tax or PAYGO fee per mile for the “mileagefee” variable as described below.

This allows SACSIM19 new functionalities described above for travel time sensitivity distribution curves and three VOT bins for highway skimming to also be sensitive to a dynamic mileage-based fees. The fee can also vary by defined geography and time periods to represent potential fee increases based on congestion around denser land use areas or peak commute travel times. Similarly, allow fee reductions for non-congestion areas, due to off peak travel times or locations requiring longer mandatory trips to job and service areas such as rural and agricultural areas.

The generalized cost function described in Equation 9-2 for shortest path during skimming and assignment is now updated to consider not only time, costs outlined above but also, mileage-based user fees. Equation 9-3 and Equation 9-4 show the mileage-based fee integration into the cost equation.

Equation 9-3 Generalized Cost Function with Mileage Based User Fee (Equation 2 update)

$$\text{cost} = \text{time} + (\text{AOC} + \text{toll} + \text{mileagefee}) * \text{VOT}_i$$

Where:

- cost is the generalized cost on the link in minutes
- mileagefee is the mileage-based fee applied on the link, in dollars

Equation 9-4 Mileage Based User Fee

$$\text{mileagefee} = (\text{imilagefee} * \text{spatialfactor}) + \text{congestionfee} + \text{feediscount}$$

Where:

- imilagefee is the initial mileage-based fee applied on the link, in 2000 dollars (typically as a fraction of cents)
- spatialfactor is a multiplicative factor spatial adjustment by regional analysis zone (RAD) applied on the link level, in 2000 dollars, for “flat fee” spatial factor is set to one.
- congestionfee is a mileage-based fee increase applied on the link based on time period, in 2000 dollars, for “flat fee” congestionfee is set to zero.
- feediscount is a mileage-based fee decrease (negative value) applied on the link based on time period, in 2000 dollars, for “flat fee” feediscount is set to zero.