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The San Francisco County Transportation Authority (SFCTA) received a grant from the Federal Highway Administration's Value Pricing Program in 2006, to study the feasibility of implementing congestion pricing in downtown San Francisco. Congestion pricing is the charging of user fees for drivers on congested routes or in congested areas, with goals of reducing congestion for those who choose to pay the fee, and improving alternatives to driving during peak periods for those who choose not to.

A major component of the technical analysis for this study is a comprehensive revision to the Authority's existing activity-based travel model, in order to make the model more sensitive to the various pricing schemes being tested. The original design of the model did not anticipate answering policy questions such as time-of-day shifts, destination shifts due to tolls, or toll/non-toll path choices. And notably, the original model was relatively insensitive to changes in travel behavior by nonresidents of San Francisco, obviously a major shortcoming when analyzing the trip patterns of Bay Area residents traveling into the city.

This paper seeks to outline the enhancements made to the SFCTA activity-based model such that it can be used to credibly test the policies described above. Further, it presents the results of scenario tests with the enhanced models to illustrate the behavioral response that can be expected from such a model.

Modeling Approach

The starting point for modeling the above policies was SF-CHAMP, an activity-based model that has been used in practice for several years. SF-CHAMP offers the standard advantages over classical trip-based models, including the chaining of trips, and the maintenance of detailed traveler information through a micro-simulation application. These features make well-suited to model congestion pricing because the structure can be easily adapted to track payment history throughout the day, and to capture variations in preferences across individuals.

The model enhancements were implemented in three phases. In the first phase, a generalized cost equation was introduced in highway assignment to allow the model to consider congestion prices in path choice. The existing model was somewhat limiting for congestion pricing applications, however, primarily because it was originally designed and implemented to model travel for only San Francisco County residents, and relied on the Metropolitan Transportation Commission's (MTC's) trip-based model for non-resident travel. According to 2000 Census data, approximately 45% of the workers in San Francisco county reside outside the county, and San Francisco is also well known for attracting recreational trips throughout the Bay Area. These non-San Francisco resident travelers were not be covered by the activity-based model, yet would be affected by pricing policies.

To overcome this limitation, SF-CHAMP was extended to cover all nine Bay Area counties in the second phase of enhancements. This extended model is termed the 9-County Regional Planning Model (RPM-9). Concurrently, the model was enhanced to explicitly consider the choice of whether or not to pay the congestion pricing toll, via sub-nests on the auto modes in both the tour and trip mode choice models. This extension of mode choice also makes the destination choice models sensitive to tolling in a consistent manner because the destination choice models use mode choice logsums.

Through this enhancement, it is possible to represent the choice of driving around the pricing area for free, or paying a toll to take advantage of time savings offered by reduced congestion in the pricing area.

The RPM-9 model was also enhanced to use continuous value-of-time distributions, rather than a single value of time for each of three income groups. This is implemented by drawing a value of time for each individual in the simulation from a distribution, where the mean of the distribution is a function on their household income. In this stage of analysis, the value-of-time distributions were asserted based on the information from previous work, but they will be estimated in the next phase. This particular enhancement allows for a much greater range of variability across individuals, and is very well suited to models implemented in a micro-simulation framework.

A recently-conducted stated-preference survey will be used to analyze the elasticities of mode and time-of-day choice to pricing policies and transfer those elasticities to RPM-9 in the third phase of model enhancements. In addition, the following structural changes will be made to model structure:

- Destination choice for non-work tours will be moved up in the model chain so that chosen destinations can inform time-of-day choice (work destination choice already precedes time-of-day choice), and
- A detailed half-hourly trip time-of-day choice model will be added to the end of the model chain, specifically to model peak spreading for auto trips.

Results

A number of scenario tests of the model system were performed in order to demonstrate its enhanced sensitivities and reasonableness of results. One of the initial runs involved the testing of a cordon pricing scheme. In this test, travelers were charged $4.00 (in 2015 $) every time they used an auto during the AM peak or PM peak periods to cross a cordon line that encompassed much of downtown San Francisco and South of Market. The results demonstrated the model's sensitivities to changes in overall tripmaking, destination choice, mode choice, and assignment.

Table 1 shows the distribution of regional trips in the baseline. The model simulates a total of 32 million regional trips. Approximate 1.2 million of these trips have at least one trip end in the area delineated by the cordon. Table 2 illustrates the changes in regional trips resulting from the imposition of the $4.00 cordon toll. Regionally, overall tripmaking is virtually unchanged – there are 4,800 fewer trips out of 32 million.

Table 2 also illustrates the changes in the distribution of trips. With the imposition of the toll, there are approximately 25,700 fewer trips with at least one trip end within the cordon area, a reduction of about 2% in trips to or from the cordon area. Table 2 also illustrates that, while trips to or from the pricing area are reduced slightly, trips entirely within the pricing area and trips entirely within the rest of San Francisco increase slightly, indicating the choice of destinations that reduce the need to cross the cordon. This is consistent with a cordon pricing scheme, where travelers are charged every time they cross the cordon (as opposed to an area pricing scheme where travelers would pay a single fee once a day for the privilege of entering or leaving the pricing area).

Table 1. 2015 Baseline Daily Bay Area Trips

	Pricing Area	Rest of SF	Bay Area	Total
Pricing Area	198,900	364,700	136,800	700,400
Rest of SF	361,100	2,208,300	493,900	3,063,300
Bay Area	140,400	490,100	27,674,000	28,304,500
Total	700,400	3,063,100	28,304,700	32,068,200

Table 2. 2015 Cordon Pricing Alternative: Changes in Daily Trips

	Pricing Area	Rest of SF	Bay Area	Total
Pricing Area	3,400	-10,100	-4,400	-11,100
Rest of SF	-9,700	12,500	-4,800	-2,000
Bay Area	-4,900	-4,300	17,500	8,300
Total	-11,200	-1,900	8,300	-4,800

Tables 3 illustrates changes in mode for trips with at least one end within the pricing area. This table indicates that the imposition of the toll reduces auto person trips to/from the pricing area by 10%, while increasing transit person trips by 6%. These results are consistent with the expected behavioral response to the imposition of the toll.

Table 3. Changes in Trips by Mode To/From Pricing Area

	Base	Cordon Toll	Diff	% Diff
Auto	540,900	487,800	-53,100	-10%
Transit	344,200	363,400	19,200	6%

The changes in the distribution and trip modes were reflected in transportation network performance. A key goal of the policy is to reduce traffic congestion in the pricing area. Table 4 shows, for a few selected links in the pricing area, how imposition of the $4 toll increases speeds and reduces congestion

Table 4. Congested Speeds on Selected Links in the Pricing Area

Name	**From**	**To**	**Travel Dir**	**2015**	**2015 $4**
1st Street	Market	Harrison	S	10.9	12.4
2nd Street	Market	Brannan	N	7.9	11.5
	Brannan	Market	S	7.7	11.3
3rd Street	Terry Francois	Market	N	14.2	15.1

In addition to providing estimates of transportation network performance improvements, model outputs can be used to estimate revenues associated with new tolls. Table 5 indicates the estimated revenues based on the volumes assigned to the roadway network at the cordon locations. In this scenario test, tolls were only charged during the peak periods. Table 5 shows that the model estimates that over one-half million dollars will be generated every weekday with the imposition of cordon pricing.

Table 5. Daily Toll Revenue (2015 $)

Time Period	Estimated Revenue (2015 $)
Early AM	$0
AM Peak	$221,867
Midday	$0
PM Peak	$351,257
Evening	$0
Daily	$573,125

Conclusions and Future Work

While the final phases of the model development are still in progress at the time of this white paper's writing, it is already clear that the new model is significantly more robust than the original model. Questions regarding the myriad effects of toll variation by time-of-day and geography can now be answered with a level of confidence appropriate for this feasibility study. Further, the model system now gives consistent results for both SF residents and non-residents.

It should be noted that the model does provide different results than were developed for previous toll studies in the Bay Area; notably, travelers are now predicted to be slightly more sensitive to new and increased tolls than previous models suggested. The validity of this finding will not be revealed until the project implementation stage.

The phase 3 enhancements have not been completed at the time of writing this paper. However, the SP estimation is nearly complete, and we will be making the model structural changes within the next few weeks. We expect to demonstrate time-of-day sensitivities to pricing policy with the phase 3 models shortly thereafter.