COMPLETING THE CYCLE:
INCORPORATING CYCLETRACKS INTO SF-CHAMP

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INTRODUCTION

Last year, recognizing the health and environmental benefits of bicycling for transportation as well as the increasing interest in high quality bicycle infrastructure, the San Francisco Board of Supervisors passed a resolution setting a goal of 20% bicycle mode share for all trips by 2020 (Supervisors 2010). In line with this particular resolution as well as our livability and environment goals for the San Francisco Transportation Plan (source), the San Francisco County Transportation Authority (the Authority) has been developing methods to robustly evaluate strategies to promote bicycle trip making within the framework of the San Francisco activity-based travel demand model SF-CHAMP (Outwater and Charlton 2006), which is the official tool to evaluate transportation investments and policies in San Francisco County.

Previous SF-CHAMP versions (i.e. the recent SF-CHAMP v4.1 *Harold*) have included rudimentary bicycle modal attributes (primarily distance) in the mode choice model but did not address the effect of bicycle infrastructure on cycling attractiveness. Updating the representation of bicycles in SF-CHAMP has been achieved in three phases: bike route choice data collection, route choice model development, and mode choice model development. In Phase I, the SFCTA developed CycleTracks, an application for GPS-enabled smartphones, in order to gather data on where cyclists ride in San Francisco and the Bay Area (Charlton, et al. May 2010). Phase II combined the revealed preference bicycle route data with network attributes to produce a bicycle route choice model. (Hood, Sall and Charlton 2011) describes the path-size logit model estimation with doubly-stochastic choice set generation. This paper describes the final phase: integration of the bike route choice model accessibilities into the bicycling utilities of the SF-CHAMP mode choice models.

The rest of this paper is organized as follows: First, the consideration of bikes in the SF-CHAMP v4.1 *Harold* is detailed. Second, existing advanced practices incorporating bicycling in travel demand models are reviewed. Third, the bike methodology implemented in the new SF-CHAMP *Fury* is described, followed by a discussion of the empirical results of the new mode choice model estimation. This paper concludes with a discussion of the initial performance and issues with the implementation of the described bicycle methodology in SF-CHAMP *Fury* and suggestions for future work.

CONSIDERATION OF BICYCLE MODE IN SF-CHAMP 4.1 *HAROLD*

SF-CHAMP is a tour-based regional travel demand model, which represents each individual bay area resident, worker and visitor's travel throughout the course of a typical weekday. This section describes how bicycles are considered for SF-CHAMP *Harold,* before the bike model development effort described in this paper was implemented.

Bicycle Skims: *Harold* assumes that cyclists will choose the shortest-distance route without regard to the quality of the facilities used (functional class, bike lanes, turns, etc). Distances are converted to bike travel times by assuming a constant cycling speed of 10 mph.

Tour Mode Choice: The tour mode choice model chooses the primary mode by which an individual gets from their home to their primary tour destination and back again. In *Harold*, tour mode choice is segmented by tour purpose and includes the following variables in the bike utility (bikability) function: bike time, number of stops in the tour, network topology, and urban vitality. The *network topology* variable is a subjective dummy variable that represents whether topological barriers exist (or don't) on the zonal street network (i.e. hills or freeways). The duality of this variable makes it impossible to represent incremental changes; furthermore, it is only accounted for at the tour destination zone, ignoring any features that are encountered along the path. The *urban vitality* variable is a similar dummy variable that subjectively represents pedestrian activity and pedestrian-oriented destinations. It suffers from the same issues of duality and subjectivity and is also only considered at the tour destination.

Trip Mode Choice: The trip mode choice model chooses the mode for a particular trip within a tour. The trip mode choice model is heavily influenced by the main mode chosen for the tour. The bike utility for the trip mode choice model in *Harold* is similar to the tour model, but for the exclusion of the topology dummy variable.

Tour Generation and Destination Choice: SF-CHAMP uses destination choice and tour mode choice logsums segmented by auto availability to represent the accessibility of and between places respectfully. The tour mode choice bike utilities, and the variables that they are comprised of, are thus considered in decisions affecting tour generation and destination choice. Thus in SF-CHAMP *Harold*, the only biking related variables that affect tour generation and destination choice are essentially distance and the two dummy variables for vitality and topology at the tour primary destination.

Bicycle Link Volumes: At the end of the final global iteration of SF-CHAMP *Harold*, the final trip tables for autos and transit are assigned to the network. Non-motorized trips are generally not (although hypothetically could be) assigned to the network because the only variable affecting their route choice in *Harold* is distance, and so the model is ignorant of most of the reasons affecting how or why people choose a particular route for walking or biking.

REVIEW OF EXISTING METHODS

SF-CHAMP *Harold* summarizes a typical approach used by agencies that model bicycle trips within a regional travel demand model. While the details of the zone-based "environment factors" at the origin and destination may vary across models, the weaknesses are generally the same: these factors are mostly subjective, they do not represent actual transportation investments or policy, they are not granular enough, and they ignore attributes along the path of travel.

A new breed of network-based bicycle representation in regional models has emerged in recent years. These models attempt to relate the attractiveness of the path between the origin and destination to actual infrastructure and characteristics of the *path*. While network-based route choice models for bicyclists are not a new concept to researchers (see literature review in Hood et al 2011), very few have made it into practice. Metro, Portland is one such agency that is currently incorporating the utility of the "best bicycle route" into their mode choice models (Stein May 2011). The "best bicycle route" is calculated based on a bicycle route choice model (Broach, Gliebe and Dill 2011) estimated from revealed preference GPS data. Metro did not re-estimate their mode choice models, but recalibrated them to reflect the observed mode share. One problem with the approach of only including the "best bicycle route" is that if a bicycle facility is added parallel to an existing one, it is not reflected in the overall perceived bicycle accessibility unless it is superior to the original route. The other issue with only using a "best route" is that it is unlikely to reveal any bike ridership on secondary facilities thus underestimating the value of such facilities, and so bike assignment will over assign bikes to the 'best' facilities.

ENHANCED BIKE MODEL IN SF-CHAMP *FURY*

The San Francisco bike route choice model estimated using CycleTracks data considers bicycle facilities, travel distance and slope among other attributes. By incorporating the bike route choice model, SF-CHAMP *Fury* will be sensitive to the factors that CycleTracks users revealed to increase bicycle utility and will be able to represent more realistic bicycle trip making. Due to the greater degree of confidence associated with the bicycle trip table and route choices, *Fury* also assigns bicycle volumes to the network. Because of this added functionality, SF-CHAMP *Fury* will be able to offer insights into the benefits of building bicycle infrastructure by forecasting changes in bicycle trip making and resulting citywide impacts to traffic, transit crowding, and greenhouse gases. The following sections detail how SF-CHAMP *Fury* incorporates the San Francisco Bicycle Route Choice Model.

Bicycle Skims: The path size logit model estimated from the CycleTracks revealed bike route choice data showed the following variables to have significance in choosing a bicycle route (Hood, Sall and Charlton 2011):

- Route distance
- Turns per unit distance
- Proportion of the route going the wrong way on a one-way street
- Proportion of the route on dedicated bike facilities (Class I)
- Proportion of the route on bike lanes (Class II)
- Proportion of the route on bike routes – sharrows or streets with signage (Class III)
- Average up-slope

In order to evaluate the zone to zone bicycle accessibility as a skim, bicycle facilities and elevation information were added to each link of the San Francisco roadway network so that the bike route choice model could be executed. Several measures of bike accessibility were considered for inclusion as the skim variable into the model, such the maximum utility of the chosen bike routes, the average utility, and the logsum. However, the maximum utility does not encapsulate the benefit of having a multitude of high quality bike route options for a given origin/destination, and would therefore undervalue an extensive bicycle network. The average utility would be subject to decreases if lower-grade bicycle facilities are added to the network and included in the choice set. Thus, the development team chose to include the bicycle route choice logsums. Figure 1 maps the logsums using the Ferry Building (a landmark near to downtown) as a fixed origin and destination. Bicycle facilities and elevation contours are also included, and the effects of both can be seen in the logsums. Since the Ferry Building is on low elevation, the slope effects are especially visible in the map with the Ferry Building as its origin. Since bicycle infrastructure data was not readily available for road links outside of San Francisco, distance-based skims were also calculated (as per SF-CHAMP *Harold)* and used for trips with origins or destinations outside of the city.

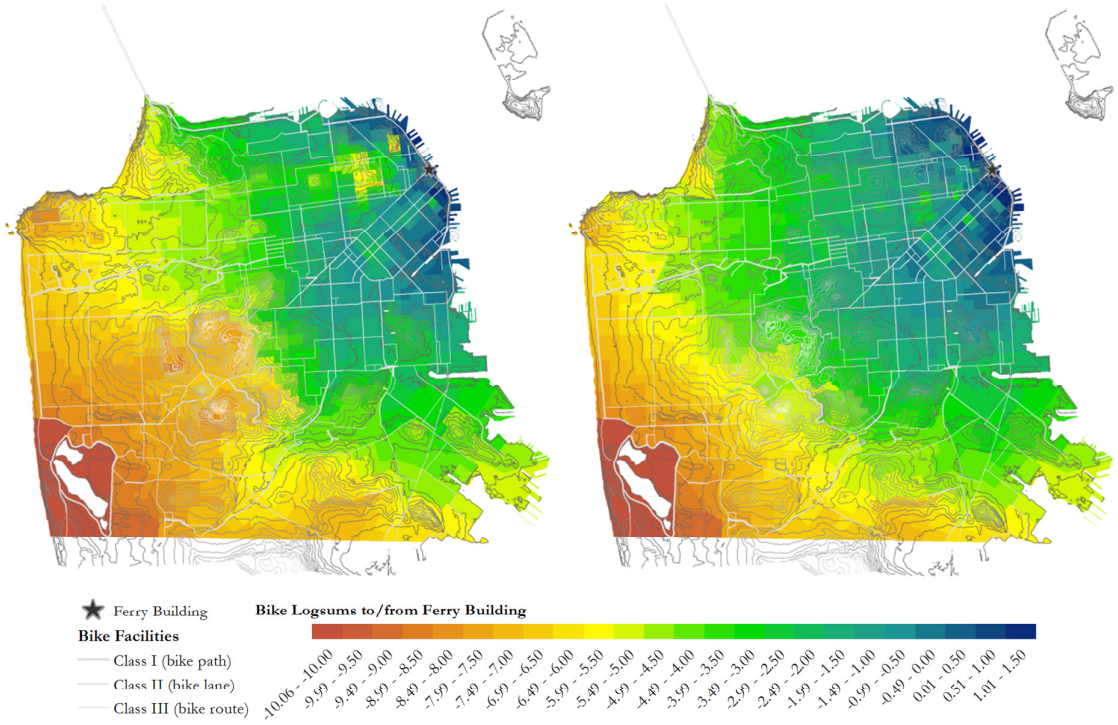


Figure 1 Bike logsums *from* the Ferry Building (starred) at left, *to* the Ferry Building at right.

Since an important goal for model development was to enable the Authority to study the effects of bicycle infrastructure changes, the bike route choice model needed to take additional care to ensure that the bike skims would be directly comparable between a no-build scenario and a scenario with a bike project implemented. This required the development team to ensure that random seeds were fixed appropriately across scenarios. Since the double-stochastic method of route choice generation randomizes both the variable coefficients as well as link variables, random seeds are generated using indices into both of those sets of variables. Figure 2 shows the change in the bike logsum using the same destination (the Ferry Building), from before and after the 1999 Valencia Street road diet, which included striping bicycle lanes.

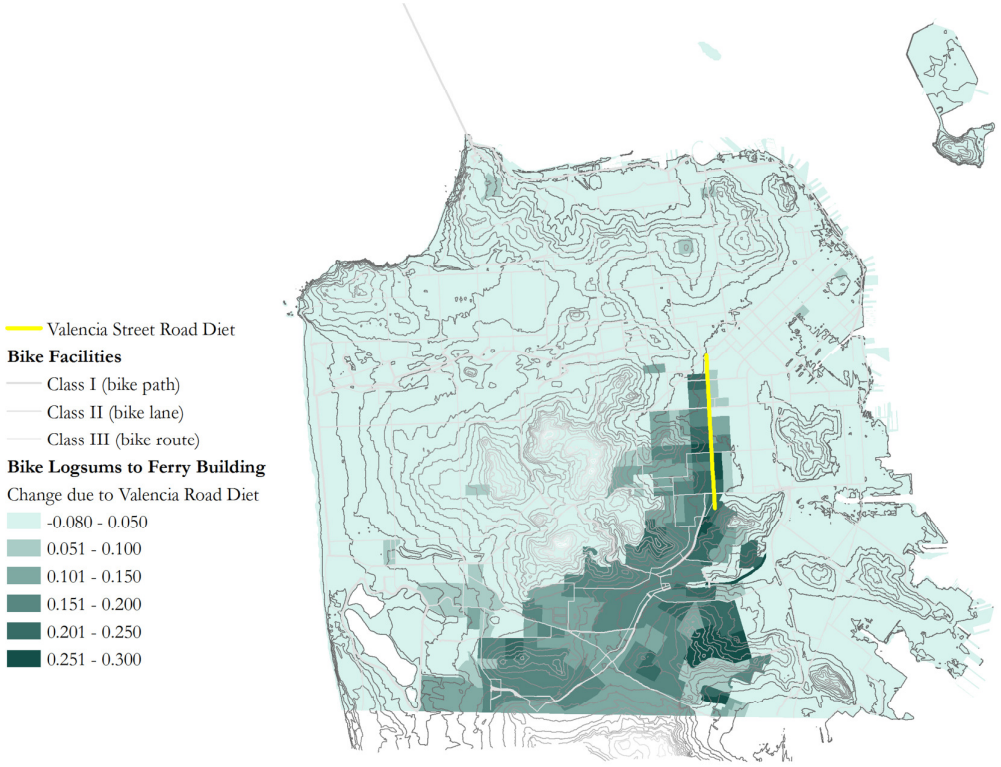


Figure 2 Change in Bike logsum to the Ferry Building, before and after Valencia Street Road diet

Tour Mode Choice

The development team re-estimated the SF-CHAMP tour mode choice model using the Bay Area Travel Survey 2000 in order to incorporate the new bicycle accessibility variable (logsum), the results of which are shown in Table 1. The "Bike Logsum" variable is only used for those bike trips with an origin and destination within San Francisco, while the "Bike Mode Time" variable is used for the remaining trips. This is to account for the fact that the network is much sparser outside of San Francisco County and could unduly influence the bike route choice model. Both variables are significant and have the correct sign for commute and other tour purposes. The bike mode time variable had to be fixed for the College tour purpose due to high standard errors that resulted from the small sample size.

Table 1. Tour Mode Choice coefficients for bike-related variables in the Enhanced Model.

	Work Tours			Other Tours			College Tours		
	Value	Std err	t-test	Value	Std err	t-test	Value	Std err	t-test
BikeLogsum	0.243	0.022	11.000	0.398	0.042	9.470	0.131	0.052	2.540
BikeModeTime	-0.027	0.002	-12.190	-0.034	0.003	-11.230	-0.030	fixed	0.000
BikeStops	-0.252	0.053	-4.790	-0.041	0.041	-1.010	0.073	0.128	0.570
BikeAge	-0.010	0.005	-1.930	-0.024	0.004	-5.840			
BikeAge < 10				-1.070	0.224	-4.770			
Constant: Autos==0	1.600	0.326	4.900	0.911	0.294	3.100	1.970	0.908	2.170
Constant: Autos<Workers	1.570	0.302	5.220	-0.424	0.221	-1.920	-0.286	0.537	-0.530
Constant: Autos>Workers	0.670	0.265	2.530	-1.550	0.191	-8.080	-0.378	0.302	-1.250

Trip Mode Choice

Likewise, the Trip Mode Choice model was re-estimated with the new variables. However, the Bike Mode Time coefficents were fixed as a multiple of the in-vehicle-time coefficients, using the multiplier consistent with the tour mode choice estimation.

Bike Trip Assignment

In SF-CHAMP Fury, the final bicycle trip table is assigned to the network using the San Francisco Bicycle Route Choice Model. A validation of bicycle volumes is forthcoming and will be compared to the validation performed in Hood et al 2011, which used SF-CHAMP *Harold* trip tables that were derived without the benefit of the bike route choice model logsums in mode choice. This resulted in too many bike trips taking undesirable routes over hills. In theory, SF-CHAMP *Fury* should mitigate this issue by predicting bicycle trips for tours more hospitable for biking.

DISCUSSION & CONCLUSIONS

These enhancements to SF-CHAMP *Fury* constitute a vast improvement over the existing SF-CHAMP, enabling the Authority complete the cycle begun with CycleTracks development and data collection. With these enhancements, the Authority will gain insight into the effects of changes in bicycle infrastructure on bicycle trip making and facility use based upon the attributes revealed by cyclists as affecting their route choice: number of turns, bicycle facility type, and slope. Future work will include bicycle volume validation from a complete model run (including feedback), such as a comparison of the bike model results on Valencia Street before and after the road diet with the observed data from that period.

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