MEMO

TO: Bert Granberg, WFRC.
FROM: Mark Bradley, Ben Stabler.
DATE: July 2, 2020
SUBJECT: Design and initial trip generation model results for the WFRC Bike Model

This memo specifies the design of the WFRC bike model and discusses next steps for creating the model.

Bike trip generation models

These models predict the number of bike trips generated per household in each microzone as a function of the number and types of households living in the microzone, as well as the land uses within various distance ranges of the microzones. Appendix A contains the list of variables currently on the WFRC microzone file.

Due to a lack of recent observed travel survey data on bike trips in the WFRC region, the generation models were generated using data collected in a 2018 household travel survey done by RSG for the Sacramento Council of Governments (SACOG). Households where adults owned smartphones (the majority of the sample) participated using RSG's rMove smartphone app, which collects GPS trace data on all trips and asks mode, purpose, travel party, and other details for each trip. The smartphone-based respondents were asked to participate for seven days, with the majority completing all seven days. Households where all adults did not own smartphones completed a more traditional one-day diary survey, with the travel day on a Tue, Wed or Thu. The sampling approach also included oversampling of urban areas where commute shares (based on ACS block-group data) for walk, bike, transit, and TNC were highest. The resulting sample is just over 4,000 households. The number of bike trips in the data is over 5,000, much higher than in most other household travel surveys. In addition, the smartphone app picks up all trips, including exercise/recreational trips that are often not reported in diary-based travel surveys. Descriptive analysis of the SACOG bike trip data (reported in a separate memo that will be combined into the final documentation) indicated that the trips fall into eight major purpose categories:

- Recreation/exercise, over 5 miles
- Recreation/exercise, under 5 miles with 2+ household members
- Recreation/exercise, other
- Work
- School- K-12
- School - University
- Maintenance (shopping/errands/meals/escort)
- Discretionary (social/entertainment/civic/other)

Also, the study area for the SACOG data analysis was limited to Sacramento, Yolo and Placer counties, as the other three counties in the SACOG region (Yuba, Sutter and El Dorado) have only a few bike trips in the data.

Trip generation model form and data

The model for each purpose p is estimated using linear regression:

> Y(mp) = a(p) + b(p) * X(md) + b(p) * X(ml)
>
> Y(mp) is the average number of bike trips per household-day made by households living in microzone m for trip purpose p.
>
> X(md) is a matrix of demographic measures d of the characteristics of households living in microzone m, along factors such as age, income, and lifecycle.
>
> X(ml) is a matrix of buffered land use measures of the attraction characteristics of microzones within three different buffers around microzone m, with variables such as employment by type, student enrolment for K-12 and university, number of parks, numbers of trailheads, and numbers of households.
>
> a(p), b(p) and c(p) are purpose-specific model parameters estimated based on the SACOG data, with a as the intercept term and b and c as vectors of coefficients related to the demographic and land use variables.

The demographic and land use explanatory variables used in the models are consistent with the microzone-level variables available in the WFRC database, listed in Appendix A. For the SACOG analysis, Census blocks were used to define microzones. The number of households in each microzone was derived by aggregating the most recent SACOG parcel database to the Census block level. The average household size, household income distribution, household lifecycle distribution, and person age distribution in each microzone were derived at the Census block group level from the most recent 5-year ACS data tables, and the block-group level distributions were used for each microzone (Census block) within the block group.

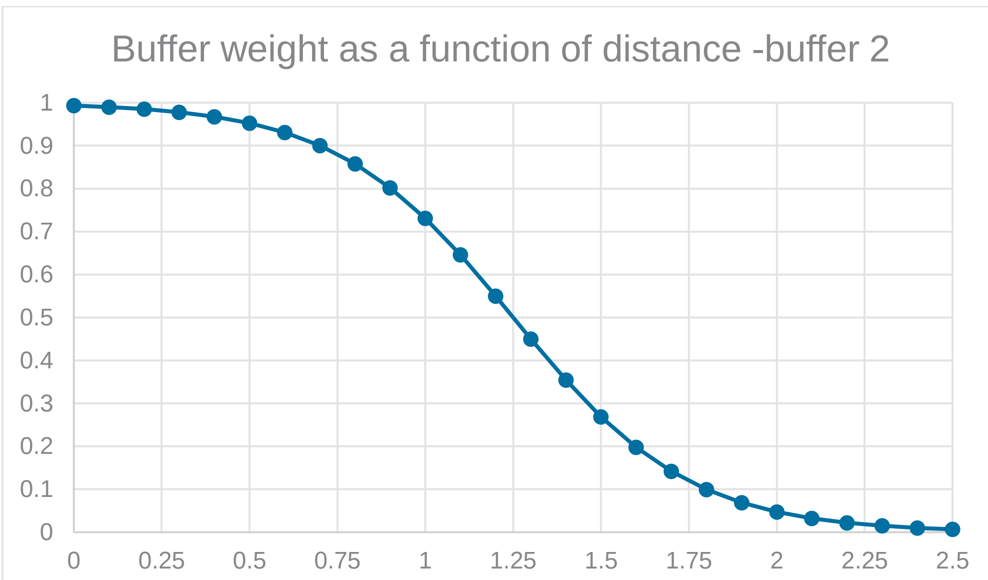
For the land use data, the SACOG parcel database was aggregated to the Census block level to derive the number of households, K-12 enrollment, university enrollment, number of jobs by 7 employment categories, the number and land area of public parks/open space areas, and the total land area within each microzone.

In addition to these variables within each microzone, buffered measures were created of the sum of each variable across all microzones within certain distance ranges. For the SACOG data, the buffering is based on straight line distance between microzone centroids. For the applied WFRC model, the buffering will use the generalized distance of the best bike path between each microzone pair. Using that buffering approach for the SACOG data would require too much additional all-streets and bicycle network processing for this project. For the WFRC application of the model, the advantage of using the best bike path is that the trip generation then becomes somewhat sensitive to improvements in the bike network by increasing the land uses accessible within the buffer.

For both regions, we use distance-decay buffering, using logistic curves centered around a specified inflection point where it is steepest. For each variable, three buffer measures were created: one with an inflection point at 0.5 mile, one with an inflection point at 1.25 mile, and another with an inflection point at 5 miles. In the modeling, the middle distance buffer variables have proven most significant. For buffering around microzone M1, the buffer weight for each microzone M2 is plotted in Figure 1 and the equation is:

Buffer weight(M1,M2) = 1 / (1 + EXP (4 * (Distance(M1,M2) – 1.25)))

Figure 1: Plot of buffer distance decay weights for buffer 2



.

The dependent variable for the model was created by calculating the number of valid complete household-days in the travel survey data for households in each microzone (Census block), and also counting up the number of bike trips for each purpose originating in each microzone, in order to calculate the number of bike trips generated per household-day by surveyed households in each microzone. Because non-home-based trips are difficult to explain in models, the number of non-home-based trips was reduced in two ways:

- Many recreation trips--particularly the longer ones—have intermediate rest stops that split a single trip into multiple trips in the smartphone-based data. Those stops were eliminated, and the partial trips merged into a single longer trip. This reduced the number of total recreation trips and also moved a small number into the recreation-long segment.

- For each non-home-based trip, the origin and destination location were compared to the home location, and if the closer of the two is within the same microzone as the home location, the trip is counted as a home-based trip with the closer trip end as the "home" end. Although not completely accurate, the model in practice will not be able to distinguish locations more accurately than the microzone, so no explanatory power is lost.

Treatment of weekend trips and non-home-based trips

(Note: This has changed substantially since the previous version of the memo)

Based on the SACOG survey data, Table 1 and Figure 2 show the distribution of trips for each purpose based on whether they are on weekdays and weekends and whether they are home-based or non-home-based. Overall, about 80% of trips are on weekdays and 20% on weekends. Only 3% of work and school trips are on weekends, so it is proposed to model trip generation for the other purposes separately for weekdays and weekends, but to only generate work and school trips on weekdays.

Table 1: Distribution of SACOG bike trips by purpose / day type / OD type

	Weekday-Home based	**Weekday-Non-home based**	**Weekend-Home based**	**Weekend-Non-home based**
recreation 5+ miles	44%	22%	16%	18%
recreation <5 miles 2+ HHM	31%	17%	40%	12%
recreation other	51%	30%	9%	9%
work	55%	42%	2%	2%
school- k-12	83%	14%	2%	1%
school- university	56%	42%	2%	1%
hh maintenance	55%	23%	16%	6%
discretionary	47%	15%	26%	13%
Total	**53%**	**27%**	**13%**	**7%**

On both weekdays and weekends, about two thirds of trips are home-based and one-third are non-home-based, with the highest fractions of non-home-based trips for the purposes of work or university, but substantial fractions for all purposes.

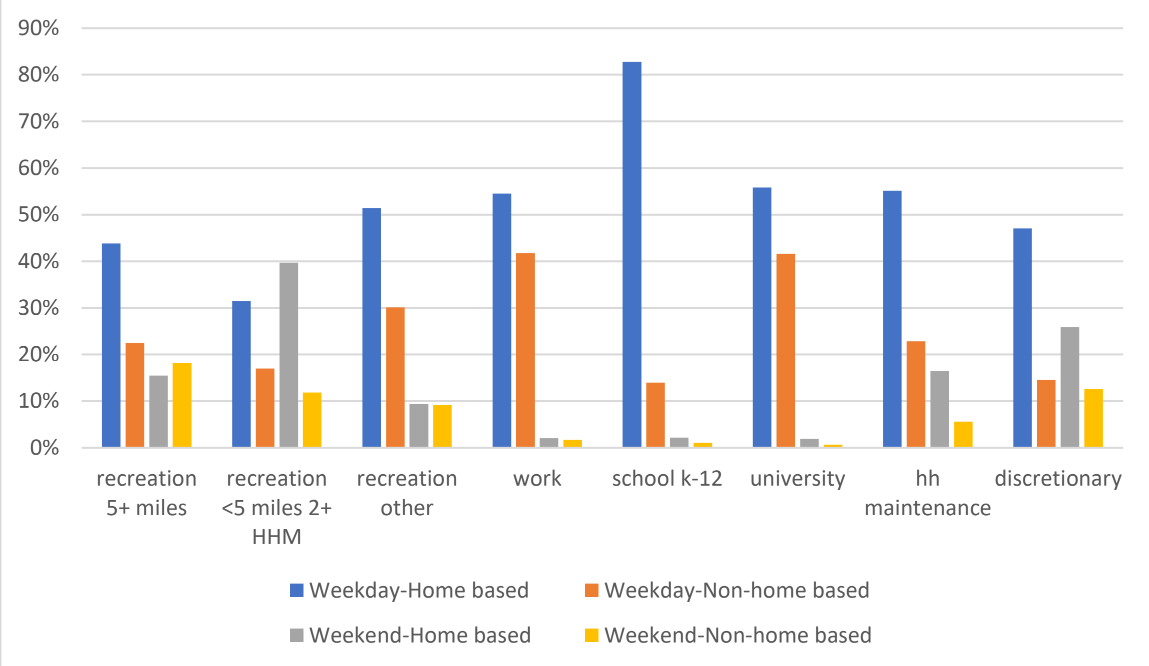
We propose to handle non-home-based trips as follows:

- Generate <u>both</u> home-based and non-home-based trips from the home microzone.using the trip generation models.

- Assuming that the fractions of home-based and non-home-based trips stays constant using the fraction in Table 1, first distribute the home-based trips for each purpose using a production-attraction format. (Each home-based trip is simulated as going from the home microzone to the destination microzone and then back home again.

- For each purpose, run the distribution model a second time from each home-based trip destination to simulate non-home-based trips.

Figure 2: Distribution of SACOG bike trips by purpose / day type / OD type



In equation form:

HB(h,d,p) = G(h,p) * DCFraction(h,d,p)

HB(h,d,p) is the number of home-based (round)trips with production microzone h and destination microzone d for purpose p.

G(h,p) is the number of home-based (round) trips generated from production microzone h for purpose p

DCFraction(h,d,p) is the destination choice fraction of home-based trips from microzone h going to microzone d for purpose p (destination choice models are described below)

NHB(m,p) = sum over h [HB(h,m,p)] * Non-home-based trip factor(p)

NHB(m,p) is the number of non-home-based trips with origin m for purpose p.

Non-home-based trip factor(p) is the number of non-home-based trips generated for each home-based trip for purpose p, from Table 1 above.

NHB(o,d,p) = NHB(o,p) * DCFraction(o,d,p)

NHB(o,d,p) is the number of non-home-based trips with origin microzone o and destination microzone d for purpose p.

DCFraction(h,d,p) is the destination choice fraction of non-home-based trips from microzone o going to microzone d for purpose p (destination choice models are described below)

This approach is somewhere between a trip-based and tour-based approach. The non-home-based trips are generated from the home location and then distributed from non-home locations, but they are not simulated as full, consistent tours. The aggregate O-D patterns will be essentially the same as from a tour-based model, but without the complexity of predicting and simulating intermediate stops on tours.

Note that this approach for non-home-based trips can be supplemented to include bike-share trips of O-D data for such trips is available. Many of the non-home-based trips are work-based or university-based, which is also true for many trips using bike-share bikes.

Trip generation model results

The generation models presented in Table 2 are for weekday travel (Mon-Fri). Similar generation models for five of the eight purposes will be estimated for weekend trips.

Table 2 shows the weekday regression results for the eight trip purposes. A log-llinear form was used where instead of using Y(m,p) as the dependent variable (definition repeated below), the dependent variable is LN(1 + Y(m,p)).

> *Y(m,p) is the average number of bike trips per household-day made by households living in microzone m for trip purpose p.*

The log-linear form prevents the predicted number of generated trips from becoming negative, and it also improved the model fit for most of the model purposes. The addition of 1 in the dependent variable avoids taking the log of 0, since some microzones with survey households produce 0 surveyed bike trips for some purposes.

The r-squared values are quite low, which could be expected for a model estimated at the Census block level. A disaggregate model estimated using household and person data for the specific survey respondents would give a better model fit and more significant variables, but would not be appropriate for application at the microzone level.

A Yolo county dummy variable (mainly the city of Davis) is positive and significant in each model, since Davis has the highest bike mode share of any city in the US for reasons that are not captured in the other variables. (This variable will not be used in application.)

The variables used in the models are in Appendix A, with the exception of two calculated variables:

- Average household size is the number of people divided by the number of households in each microzone.

- The mixed use measure in a buffer is equal to the product of households times total jobs divided by the sum of households plus total jobs. It reaches a maximum when the two are equal and goes to 0 when either one is 0.

*Mixed use(buffer 2) = [Households(buffer 2) * Total jobs(buffer 2)] / [Households(buffer 2) + Total jobs(buffer 2)]*

The variable for number of parks in the buffer is related to the “Park Score” variable in the WFRC database, although not equivalent. Some method for buffering that variable in the WFRC data should be considered. The number of parks may also be related to the presence of Class 1 bike paths, which are often located in or near parks.

Although variables for the 10-mile buffer 3 were tested for the recreation-long model, none were significant, so it is not necessary to buffer out to that distance in the WFRC model. Variables for smallest buffer 1 were tested in several models, but the buffer 2 measures were consistently more significant.

It is interesting that in the SACOG data, bike trip generation for most purposes is highest in microzones with income distribution skewed either toward the lowest quartile or the highest quartile relative to the middle income quartiles. Although most of the low-income variables are not statistically significant, they all have positive values. If cycling is more of a low-income phenomenon in other regions compared to SACOG—e.g. due to low car ownership—then these variables can be used for calibration.

Table 2: Weekday regression model results for aggregate trip generation at the microzone level (home-based plus non-home-based)

Models for weekday trips	recreation-long	recreation-family	recreation-other	work	grade school	university	mainte-nance	discretion-ary/ other
R-squared	.014	.004	.035	.100	0.016	0.069	0.058	0.055
Constant	.012	-.007	.016	.123	-.010	-.041	-.029	.001
t-statistic	*1.0*	*-1.0*	*1.2*	*0.6*	*-0.8*	*-3.8*	*-1.3*	*0.3*
Yolo county (will not be used in application)	.022	.011	.065	.123	.047	.030	.103	.094
t-statistic	*4.5*	*2.6*	*8.5*	*8.3*	*5.9*	*5.3*	*9.9*	*9.3*
Average household size	-.009					.026		
t-statistic	*-3.1*					*6.8*		
Fraction HH with income under $35,000	.019	.012	.015	.015	.007	.031	.107	.077
t-statistic	*1.3*	*1.0*	*0.7*	*0.4*	*0.3*	*2.9*	*3.6*	*2.6*
Fraction HH with income over $100,000	.033	.011	.022	.071	.048		.124	.092
t-statistic	*2.5*	*1.0*	*1.1*	*1.9*	*2.2*		*4.5*	*3.4*
Fraction HH with children under 18 (LC2)			-.069					
t-statistic			*-3.6*					
Fraction HH with adults age 65+ (LC3)						-.015		
t-statistic						*-1.1*		
Fraction people under age 18 (AG1)				-.160		-.167	-.142	-.167
t-statistic				*-2.4*		*-5.9*	*-2.8*	*-3.4*
Fraction people age 65+ (AG3)				-.068			-.047	-.047
t-statistic				*-1.5*			*-1.4*	*-1.4*
Total jobs in buffer 2								
t-statistic								
Education & government jobs in buffer 2				1.81E-05				
t-statistic				*5.1*				
Medical jobs in buffer 2				2.96E-06				
t-statistic				*1.5*				
Office jobs in buffer 2				-1.49E-05				
t-statistic				*-1.5*				
Industrial jobs in buffer 2				-7.73E-06				
t-statistic				*-1.4*				
Total households in buffer 2	8.58E-07							

t-statistic	*1.8*							
Students enrolled in K-12 in buffer 2		1.49E-06			1.72E-06		2.22E-06	
t-statistic		*2.1*			*1.3*		*1.2*	
Students enrolled in university in buffer 2						2.08E-06		
t-statistic						*6.6*		
Number of parks/open space parcels in buffer 2			.002	.003				
t-statistic			*2.8*	*2.8*				
Mixed use measure in buffer 2				6.17E-06			2.24E-06	3.13E-06
t-statistic				*2.0*			*2.0*	*2.9*

Bike trip destination choice models

The destination model uses a formulation somewhat similar to a gravity model:

> Util(o,d,p) = LN(Size(d,p)) + GC(o,d,p)
>
> *Util(o,d,p) is the logit model utility for destination microzone d for purpose p, from origin microzone o*
>
> *Size(d,p) is the attraction size function for destination microzone d for purpose p. It is typically a function of various land use variables for the destination microzone.*
>
> *GC(o,d,p) is the generalized distance function from origin microzone o to destination microzone d for purpose p.*

For estimation on the SACOG data, the generalized distance function includes variables based on centroid-to-centroid straight line distance, allowing different distance impedance for weekend trips relative weekday and non-home-based trips relative to home-based. For application, we propose using the more comprehensive generalized distance function currently being applied for the City of Los Angeles DOT Accessibility Platform project (see Appendix B), as compared to the simpler function already implemented and applied for AMBAG bike model (see Appendix C).

The estimation for the SACOG data used the full system of 25,757 microzones in the 3-county study area as alternatives. For each trip, the available alternatives were limited to those within a maximum distance of 5 miles from the origin. The exception is the "recreation-long" segment, where the minimum distance is 5 miles and the maximum was set at 50 miles (one-way). No random sub-sampling of destination alternatives was used in estimation, and we do not recommend using random sampling in application either. The distance limitation of 5 miles as well as the pre-calculation of best paths should ensure that run times are reasonable without restricting the choice set.

Table 3 shows the estimation results for the eight trip purposes. Because the sensitivity to distance was allowed to vary between home-based vs. non-home-based and weekday vs. weekend trips, but the size variable attraction function is assumed to be the same for all trips for a given purpose.

The distance sensitivity is the highest for grade school trips, short family recreation trips, and maintenance and discretionary trips, and lowest for the long recreation trips. An intra-microzone constant was also estimated, and is highly positive for the grade school and short recreation trips, many of which remain within the same microzone.

The size functions generally make sense for each purpose. For most recreation trips, the land area of the microzone is the strongest attraction variable, and even stronger when the land area is in parks/open space areas.

Note that the recreation-long purpose is qualitatively different from the others in that it considers microzoe pairs over a much wider radius, so may want to use much simpler route choice functions in application that are more oriented to following recreational trails and paths (or popular road biking routes). Also, many of these trips are non-home-based, relying on a previous bike or auto trip to the start of the recreational route. In practice, an "origin" choice model may be better suited for this trip purpose, rather than the approach recommended above for non-home-based trips for other purposes.

Table 3: Logit model results for disaggregate trip destination choice at the microzone level (home-based plus non-home-based)

Models for weekday trips	**recreation-long**	**recreation-family**	**recreation-other**	**work**	**grade school**	**university**	**mainte-nance**	**discretion-ary/ other**
Observations	91	193	458	1134	291	301	648	792
Rho-squared	.168	.279	.180	.192	.591	.419	.259	0.115
Distance (centroid-centroid straight line, miles)	- .302	-2.00	-.791	-.780	-1 46	-1.10	-2.02	-1,53
t-statistic	*-9.0*	*-9.0*	*-14.5*	*-15.3*	*-11.2*	*-9.5*	*-18.8*	*-19.4*
Additive distance term for non-home-based trips	.051	-.388	.401	-.208	.550	-1.29	.278	.205
t-statistic	*1.0*	*-1.4*	*4.5*	*-2.2*	*1.9*	*-4.2*	*1.3*	*1.3*
Additive distance term for weekend trips	-,193	,440	-.447				-,079	-.133
t-statistic	*-2.0*	*1,8*	*-3.4*				*-0,4*	*-1.0*
Destination is same microzone as origin	n/a	2.19	3.0	-.160	3.08	-1.58	.479	.385
t-statistic		*6.0*	*(constr.)*	*-0.6*	*6.6*	*-3.4*	*1.9*	*1.3*
Size function variables								
Total jobs in destination MZ				1.0				
t-statistic				*(base)*				
Education & government jobs in destination MZ			1.0	2.69	0.31	4.13		0.35
t-statistic			*(base)*	*8.4*	*-6.2*	*12.1*		*-8.8*
Retail jobs in destination MZ							1.0	1.0
t-statistic							*(base)*	*(base)*
Office jobs in destination MZ							0.07	
t-statistic							*-10.8*	
Medical jobs in destination MZ							0.02	
t-statistic							*-7.9*	
Other (service) jobs in destination MZ							0.29	0.55
t-statistic							*-5.4*	*-2.6*
Food/accommodation jobs in destination MZ	1.0							
t-statistic	*(base)*							
Total households in destination MZ		0.79					0.09	0.20
t-statistic		*(-0.8*					*-12,2*	*-9.2*

Students enrolled in K-12 in destination MZ		1.0			1.0		0.11	
t-statistic		*(base)*			*(base)*		*-15.0*	
Students enrolled in university in destination MZ						1.0		
t-statistic						*(base)*		
Number of parks/open space parcels in destination MZ		55.9	4.77					
t-statistic		*14.3*	*8.0*					
Land area in destination MZ (square miles)	69.6		234.6					
t-statistic	*12,0*		*17.4*					
Area of of parks/open space parcels in destination MZ	11.6							
(square miles) *t-statistic*	*1.0*							

Bike trip assignment / routing

The bike assignment / routing algorithm will find the best path with the lowest generalized cost between each O-D microzone pair for which there are trips, and will assign trips to the links along the path. The assignment / routing module will search for routes up to a user specified max cost in order to reduce runtime. The assignment / routing module will be based on the Python code implemented for the AMBAG bike model and will be modernized to improve ease-of-use, maintenance, support for Python 3, and support WFRC specific needs.

The bike assignment / routing algorithm will expect the network specified by the generalized distance function used for the City of Los Angeles DOT, which is shown in Appendix B. This node-link network requires the following attributes:

- Link length
- Link is bike lane
- Link is bike boulevard.
- Link is bike path
- Link proportion of slope based on elevation data (see Appendix B)
- Link auto average daily traffic (ADT) bins (see Appendix B)
- Node control (uncontrolled, stop, or signal)

The assignment model will be validated to the extent possible based on local count data and Strava bike data. The validation data will be compared at the daily weekday level. The long recreation trip segment in particular will benefit from the use of Strava data.

The table below is our recommended correspondence between the facility types coded in the WFRC network and the Broach model used for the LA DOT route choice function.

Code values	**Route choice model**
1A, 1B, 1C, 1 - Cycle track	Bike path
2A, 2B, 2 - Bike lane	Bike lane
3A - Shoulder bikeway	Bike lane
3B, 3C- Marked shared roadway	Bike boulevard
3- Other bike route, unspecified	None
PP- Parallel paved path	Bike path or Trail
PU- Parallel unpaved path	Trail
UN- Unknown category	None

There is a type called “trail” which is not in the LA DOT model. For the recreation-long purpose segment, we propose to not use the LA DOT route choice function, but to instead pre-designate a set of possible routes in the network that include trails and unpaved paths, as well as popular road biking routes. Unpaved paths that aren’t currently in the network could be added in a simple way, as straight lines with various “destinations” (turn around points/nodes) that are in different microzones.

Appendix A: List of variables in WFRC microzone database

Households: Number of households (residential units that are occupied)
Residential: Number of residential units
Population: Total population
jobs1: Number of Accommodation, Food Services Jobs
jobs3: Number of Government and Education jobs
jobs4: Number of Health Care jobs
jobs5: Number of Manufacturing jobs
jobs6: Number of Office jobs
jobs7: Number of Other Jobs (non-typical commuting/travel patterns)

jobs9: Number of Retail Trade jobs
job10: Number of Wholesale, transport jobs
jobsT: Total number of jobs

ENROL_ELEM: Elementary school enrollment / population
ENROL_MIDL: Middle school enrollment / population
ENROL_HIGH: High school enrollment / population
ENROL_UNIV: University enrollment / population

POP_LC1: Total Population LC1 (households with no children and seniors)
POP_LC2: Total Population LC2 (households with children and no seniors)
POP_LC3: Total Population LC3 (households with seniors and may have children)
HHSIZE_LC1: Mean household size LC1 (households with no children and seniors)
HHSIZE_LC2: Mean household size LC2 (households with children and no seniors)
HHSIZE_LC3:Mean household size LC3 (households with seniors and may have children)
PCT_INC1:Household Percentage INC1 (Under $35,000)
PCT_INC2:Household Percentage INC2 ($35,000-$49,999)
PCT_INC3:Household Percentage INC3 ($50,000-$99,999)
PCT_INC4:Household Percentage INC4 ($100,000 or more)
PCT_AG1:Population Percentage AG1 (Children - 0 to 17)
PCT_AG2:Population Percentage AG2 (Adults - 18 to 64)
PCT_AG3:Population Percentage AG3 (Seniors - 65 +)
PARK_SCORE: Presence of desirable park spaces. 1) Acreage > 10, 2) 5 < Acreage < 10, 3) Acreage < 5
TRAIL_HEAD: Presence of a trailhead or other common ride starting point 1) yes, 0) no
LIGHT_RAIL: Presence of a light rail station 1) yes, 0) no
COMM_RAIL: Presence of commuter rail station 1) yes, 0) no

Appendix B: Generalized distance function used for the City of Los Angeles DOT, based on the dissertation work of Joseph Broach of Portland State University.

Length Adjusted Metric	Length Multiplier*	Variable Name	Notes
distance	1.0	distance	
bike boulevard	-0.108	bike_blvd_penalty	OSM: cycleway="shared" OR LADOT: bikeway=("Route" OR "Shared Route")
bike path	-0.16	bike_path_penalty	OSM: highway="cycleway" OR (highway="path" & bicycle="dedicated") OR LADOT: bikeway="Path"
prop link slope 2-4%	0.371	slope_penalty	upslope for forward direction, downslope for backward direction
prop link slope 4-6%	1.23	slope_penalty	upslope for forward direction, downslope for backward direction
prop link slope 6%+	3.239	slope_penalty	upslope for forward direction, downslope for backward direction
no bike lane (10-20k)	0.368	no_bike_penalty	OSM: cycleway=(NULL OR "no") OR OSM: bicycle="no" AND LADOT: bikeway=NULL
no bike lane (20-30k)	1.4	no_bike_penalty	OSM: cycleway=(NULL OR "no") OR OSM: bicycle="no" AND LADOT: bikeway=NULL
no bike lane (30k+)	7.157	no_bike_penalty	OSM: cycleway=(NULL OR "no") OR OSM: bicycle="no" AND LADOT: bikeway=NULL

Fixed Distance Metric	Addt'l Distance (m)*	Variable Name	Notes
turns	54	turn_penalty	assume additive ped turn penalty and scale other penalties based on the ratio of the coefficient to the original bike turns coefficient
stop signs	6	stop_penalty	(LADOT: stop/yield)
traffic signal	27	signal_penalty	(LADOT: signalized intersection)
cross traffic (5-10k)	78	cross_traffic_penalty_ls	left or straight only
cross traffic (10-20k)	81	cross_traffic_penalty_ls	left or straight only
cross traffic (20k+)	424	cross_traffic_penalty_ls	left or straight only
cross traffic (10k+)	50	cross_traffic_penalty_r	right only
parallel traffic (10-20k)	117	parallel_traffic_penalty	left only
parallel traffic (20k+)	297	parallel_traffic_penalty	left only

*Multipliers and distances inspired by Broach (2016)

Generalized Cost	Formula
gen_cost_bike:link	distance + distance * (bike_blvd_penalty + bike_path_penalty + slope_penalty + no_bike_penalty)
gen_cost_bike:left	turn_penalty + stop_penalty + signal_penalty + cross_traffic_penalty_ls + parallel_traffic_penalty
gen_cost_bike:straight	stop_penalty + signal_penalty + cross_traffic_penalty_ls
gen_cost_bike:right	turn_penalty + stop_penalty + signal_penalty + cross_traffic_penalty_r

Appendix C: Generalized distance function used for AMBAG Bike model, based on models estimated by Jeffrey Hood based on route choice data from the Bay Area

(Separate versions are available for work and non-work trips)

```
route_varcoef_bike:
    d0: 0.858 # distance on ordinary streets, miles ( bike_class == 0 and lanes > 0 )
    d1: 0.387 # distance on bike paths ( bike_class == 1 )
    d2: 0.544 # distance on bike lanes ( bike_class == 2 )
    d3: 0.773 # distance on bike routes ( bike_class == 3 )
    dw: 3.449 # distance wrong way ( bike_class == 0 and lanes == 0 )
    riseft: 0.005 # elevation gain in feet
    turn: 0.094 # number of turns
    dne2art: 1.908 # additional penalty for distance on an arterial without bike lane
    bike_exclude: 999.0 # bikes not allowed ( link_type in ['FREEWAY'] )
```

Appendix D: Recommendations for a next phase of updates (written October 12, 2020)

This appendix contains a number of suggested changes for further updates to the model in a subsequent work phase.

1. **Factoring trip generation from an average weekday to an average day of week**

This can be done very simply based on the observed trip frequency by day of week in the SACOG survey data. The table below is derived from Table 1 above. The model currently predicts the trips generated on an average weekday for each purpose. To factor those trips to the number of trips generated on an average day, including weekends, multiply the number of generated trips by the factor in the righthand column below. For recreation, and discretionary, the trips are generally factored up, and for work and school they are factored down.

Purpose	% of trips on Weekdays	% of trips on Weekends	% of trips on each Weekday	% of trips on each Weekend day	% of trips on an average day of the week	Factor to go from average weekday to average day
recreation 5+ miles	66%	34%	13.2%	17.0%	14.3%	1.082
recreation <5 miles 2+ HHM	48%	52%	9.6%	26.0%	14.3%	1.488
recreation other	81%	19%	16.2%	9.5%	14.3%	0.882
work	97%	3%	19.4%	1.5%	14.3%	0.736
school- k-12	97%	3%	19.4%	1.5%	14.3%	0.736
school- university	98%	2%	19.6%	1.0%	14.3%	0.729
hh maintenance	78%	22%	15.6%	11.0%	14.3%	0.916
discretionary	62%	38%	12.4%	19.0%	14.3%	1.152

2. **Adjusting the trip distribution model for the recreation-long purpose**

The recreation long purpose can access new zones that are outside the regularly modeled area. (These are the “spider legs” that run up into the canyons.) For each of these zones, a new zonal attribute called “recreation long attractiveness” should be specified, and this attribute should be given a coefficient of 1.0 in the Recreation long destination choice equation, and a coefficient of 0 for all other purposes (and should have a value of 0 for all zones within the regular study area). For each zone that is only relevant for long recreation trips, this attractiveness value can be used as a calibration value to get the right number of trips ending and turning around at that point.

There may also be an adjustment for non-home-based long recreation trips. For most purposes, the origin of non-home based trips is set using the destinations of home-based trips for the same purpose. For long recreation trips, however, many trips begin at trailheads that are reached by car trips rather than bike trips. The origins of non-home-based long recreation trips can be adjusted to begin more often at trailhead/recreational route parking locations.

3. Using different route choice functions and distance ranges for different purposes

It is recommended to use three different route choice functions to find the best path between any given zone pair, and to determine which zone pairs are possible destinations:

A. For the Work purpose, calculate the best path for all zone pairs out to a maximum straight line distance of 8 miles, and use the route choice function for Work trips, as estimated by Broach and adjusted for this project. (That is the function that is currently being used for all purposes.)

B. For the Recreation-long purpose, calculate the best path for all zone pairs with a straight line distance of 5 miles or more. Use the same route choice function as for the work purpose, but with the Slope parameters set to 0.

C. For all other purposes, calculate the best path for all zone pairs out to a maximum straight line distance of 5 miles, and use route choice function estimated by Broach for non-work trips, and make any similar adjustments for facility type that were made for the work route choice model.

Currently, the calculation of best paths takes by far the most run time in the model, and is done twice—one to use in trip generation and distribution, and then again to assign the O/D trips to specific links. Run time could be reduced substantially by storing the set of links on the best path for each zone pair for each relevant purpose type, and then simply reusing those paths in the assignment step.

4. Adding additional buffered values to use in trip generation (and possibly trip distribution)

The original models were based on data available for the SACOG region. Some additional values may be useful to buffer for the WFRC models. These include:

- Buffering on parks using "park score"
- Buffering of distance of specific types of bike infrastructure, particularly separate bike paths.
- Buffering of trailheads and any other indicators of popular designated bike routes.
- Buffering of transit stations, particularly those that tend to attract bike "park and ride".

To use these buffer measures in the models at first, it would be necessary to assert coefficient values and adjust them for calibration. When new travel survey data is available (likely in 2022) new models can be estimated.