

INCORPORATING A USER-BASED PERSPECTIVE OF LIVABILITY PROJECTS IN THE SF-CHAMP MODE CHOICE MODELS

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ABSTRACT

This paper presents the inclusion of path-based pedestrian environment factors in the SF-CHAMP model. These factors capture environmental determinants of utility beyond travel time and cost for walking and transit modes with a level of accuracy not previously exhibited in a major agency travel demand model. The paper describes the method for generating the environment factors, discusses which environment factors were found to be significant predictors of walking and transit use, and offers sample interpretations of estimated coefficients using actual livability projects in San Francisco.

INTRODUCTION

San Francisco has committed to ambitious policies to reduce greenhouse gas emissions and enhance livability (Brisson et al. 2011, MovesSmartSF.com 2012). Planners seeking to reach these targets need tools to study infrastructure investment scenarios and policy levers that aim to promote walking, biking, and transit. Among the most critical of these tools is a travel forecasting model that is sensitive to the broad range of factors that influence the attractiveness of non-driving modes and that can translate concrete changes in the built environment to travel behavior shifts.

Numerous studies find a spatial dependence in the utility of non-motorized modes. Cervero and Kockelman (1997) find measures of land use mixing and population and jobs density to be significant predictors of walk and bike mode share. Guo (2009) finds pedestrian friendly parcels, sidewalk quality, and crossing opportunities to be significant predictors of walking route choice. Ewing and Cervero (2001) in a meta-analysis of built environment travel literature find strong relationships between walking trips and land use diversity, intersection density, and number of close destinations as well as between transit use and street network design variables. Hood et al. (2010) find significant relationships between hills, protected facility treatments, and route indirectness and route choice by cyclists. A study (SANDAG 2010) comparing the performance of conventional (ITE) trip generation estimation methods and a method that applies an internal trip reduction based on spatial attributes in predicting travel to six TODs in San Diego found that the latter method much more accurately predicted trip generation (with conventional methods greatly overpredicting travel demand). . These and many other studies attest to the fact that traditional level of service variables such as travel time and cost do not by themselves adequately explain the attractiveness of non-motorized modes.

San Francisco's CHained Activity Modeling Process (SF-CHAMP) model previously incorporated zonal environment factors in the mode choice model at the origin and destination of trips. Limitations of these zonal environment factors included (A) subjectivity in translating changes in physical environment characteristics (e.g. addition of 100 jobs, reduction of 700 vph) to environment factor scores (B) the failure of origin and destination based scores to reflect conditions along an entire walking path, and (C) the introduction of cliff-effects from reduction of continuous variables describing the walking environment to simplistic scores.

This paper describes the incorporation of path-based environment factors in the tour mode choice model of SF-CHAMP. The paper first presents the method used to generate environment factors, then explains different specifications of walking and transit utility functions tested, and finally offers practical interpretations and example project applications of significant environment factors.

GENERATION OF PATH-BASED ENVIRONMENT FACTORS

SF-CHAMP's highway network file, which includes every street, alleyway, and path in San Francisco, was updated to include environment variables. SF-CHAMP's walking and transit skims were then modified to return pedestrian environment values. The walk and transit access/egress skims select a least generalized cost walking route along all roads where walking is permitted. Environment factor values for the entire walking path were computed as described in Table 1. For transit, the script returned separate values for the walk from the origin TAZ to origin station and for the walk from the destination station to destination TAZ. The quality of origin and destination walks was found to impact utility differently.

In constructing pedestrian and transit access/egress skims, one difficulty is ascertaining the true path that choicemakers used (or would have used for unchosen modes). This is not a new problem in mode choice data preparation: at a minimum, analysts must guess at the paths for all but one of the alternative paths. The problem is particularly acute for non-motorized modes. Unlike driving where the shortest path is usually a good guess, for walking and transit, many factors beyond distance influence route choice. In essence, the very reasons that motivate inclusion of environment variables in a mode choice model make it difficult to construct the path-based environment variables. The following methodology was used to try and identify true pedestrian route choices:

- Generate pedestrian environment factors using shortest-path route choice
- Estimate mode choice models using these environment factors
- Compute a perceived pedestrian distances using implied tradeoffs between walking time and significant walking factors from previous estimation
- Regenerate pedestrian environment factors using a perceived distance shortest-path route choice
- Re-estimate mode choice models using these environment factors.

RESULTS

This section summarizes different specifications tested and presents final model estimates for select tour purposes. Table 1 defines the pedestrian environment variables tested and indicates the tour purposes and modes for which each variable was found to have a significant relationship to the utility of choosing that mode. Table 2 shows the complete work and other tour models.

DISCUSSION

This section offers practical interpretations of estimated coefficients on pedestrian environment variables.

Elevation gain is significant for transit work tours (~16 mins in vehicle time/100 ft) and walking other tours (~24 mins in vehicle time/100 ft). These results suggest that investments in transit service oriented towards commuters to workplaces in hilly areas may be ill-founded. Similarly, travelers who must contend with hills on their way to shop or recreate may choose not to walk, even if the walking time alone is not unreasonably long.

Employment density along a path (in log form) is a significant predictor of walking and transit utility for most tour purposes (see Table 1). Figure 2 graphs the implied tradeoff with in vehicle time for a range of job densities encountered in the Bay Area. The graph indicates diminishing returns to density. Hence, a move from job densities such as those encountered in a purely residential area like San Francisco's Outer Sunset to job densities in a residential and retail neighborhood like the Mission District (~5 jobs/acre to ~50 jobs/acre) dramatically reduces perceived travel times; a move to high job densities like the Financial District on the other hand (~500-900 jobs/acre), offers little additional travel time reduction benefit. The decreasing returns are consistent with the idea that beyond ground floor uses additional density contributes little in the way of pedestrian amenities. The highest job densities likely represent business parks and office towers that do not offer greater pedestrian amenities than a moderate density neighborhood.

Average capacity “exposure” (in log form) is a significant predictor of walking disutility for work and other tours when transformed by a logarithm and interacted with the walking time. This form implies that pedestrians grow less willing to tolerate high vehicle throughput roads as their walk increases in length. A further implication is that above roughly 1000 vph and for tours shorter than roughly 3 mi, pedestrians are fairly insensitive to average roadway capacity. Figure 3 depicts the implied *added* in vehicle time for walking work tours for typical average roadway capacities and tour lengths.

Indirectness was a significant predictor of walking utility for commute, grade school, and high school tours and transit utility for other tours. For commute tours for instance, every 10 percent further out of the way from crows’ flight distance that a traveler must walk is worth 1.5 minutes of in vehicle time. Randall and Baetz (2001) find that indirectness ranges from 1.4-1.48 for traditional, streetcar suburbs to 1.63-1.88 for more contemporary, automobile era suburbs. Using these ranges, the effective tradeoff with in vehicle time from moving to a regular street grid to suburban street network is 2.25 to 7.5 minutes.

EXAMPLE PROJECT APPLICATIONS

This section discusses what the pedestrian environment factors coefficient estimates imply for project application.

Transit Oriented Development

The Hunters Point Shipyard in southeastern San Francisco is slated for redevelopment. The project calls for a final build out that will increase the average job density along a walk path from the end of the Muni 19-Polk to the center of the development area from 1.2 jobs per acre to 14.9 jobs per acre. Given the implied rates of substitution between travel time and a walking environment with employment and shopping opportunities, this job density increase is equivalent to travel time reductions of 35-45 minutes of in vehicle time (or 7-8 minutes of destination walking time, which is perceived as more onerous than in vehicle time) for commute and other tours.

Road Diet

Valencia Street in the Mission District was reconfigured in March 1999 from a four-lane street to a two-lane street with a two way left turn lane and bicycle lanes. The project halved the roads vehicle capacity from 2400 vph (bidirectional) to 1200 vph. The changes, which were motivated by a community desire to improve safety for cyclists and pedestrians, precipitated an increase in bicycle traffic volumes and decrease in pedestrian and injury collisions. A 1 mile walk tour along Valencia St. from 16th St. to 24th St. would see an equivalent reduction in travel time of 2-3 minutes of in vehicle time (or 0.75-1 minute of walking time) for commute and other tours. The perceived savings in walk time represents 2-3 percent of the actual walk time (36 minutes round trip).

CONCLUSIONS

The addition of path-based environment variables to the SF-CHAMP model offers several important lessons. First, of the types of environment variables tested, measures of vitality most consistently bore a significant relationship to walking and transit utility. Employment density, in particular, is significant across nearly all tour purposes. Measures of topography and network connectivity (the absolute elevation gain and path indirectness) also entered in as significant in several tour purposes.

In contrast, measures intended to capture the threat or discomfort from automobiles rarely were significant predictors of walking and transit mode share. Intuitively, high traffic roadways are difficult to cross and unpleasant to walk along, yet capacity and speed were only significant for a handful of purposes. In part, this may be attributable to the difference between the measures tested (capacity and free flow speed) and the actual traffic volumes perceived by pedestrians. Another reason for the failure to find significant relationships may be the use of shortest-path based walk skimming and the high dependence of these measures on the exact path chosen. Measures of level of amenities, topography, and network connectivity are generalizable to the neighborhood level so even if skimming indirectly predicts users paths by a block (or several blocks), the values assumed for employment density or indirectness are likely not substantially different from the true values. The capacity and speed values, on the other hand, can differ greatly from one street to the next. The failure to find significant relationships may reflect measurement error rather than the lack of a causal relationship between traffic volumes and pedestrian utility. Absent knowledge of actual walk paths, it is difficult to know the true average capacity or vehicle speed, though innovations in travel survey data collection using GPS may overcome this barrier.

Overall, the models presented here indicate that walking and transit trips that are actually the same length, but that take place in dramatically different walking environments, are perceived as having substantially different travel times. A move from low to moderate job densities is effectively worth 60 to 80 minutes of in vehicle time for work and other tours (and more for work-based tours). These differences are considerable and suggest that travel demand modelers greatly discount the importance of the built environment if they fail to account for it in mode choice prediction.

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TABLES AND FIGURES

Table 1: Definition of Environment Factors and Specifications Tested

Variable Group	Variable	Definition	Specifications Tested	Significant Relationships [Tour Purpose (Mode)]
Topography	Rise	Elevation gain minus elevation drop* [00 ft]	L, Q, A, S	
	Percent Rise	Rise divided by walk path distance	L, Q, A, S	
	Absolute Rise	Elevation gain* [00 ft]	L [#] , Q, A, S	Work (TrnD) Other (Walk)
	Percent Absolute Rise	Absolute rise divided by walk path distance	L, Q, A, S	
Convenience	Indirectness (SF)	Ratio of network distance to Euclidean distance	L [#] , Q	Work (Walk) GSchool (Walk) HSchool (Walk) Other (TrnO)
Safety from automobiles	Capacity (SF)	Average (bidirectional) roadway capacity ** [vph]	L, Q, LN, WT, LN+WT [#]	Work (Walk) Other (Walk)
	Free Flow Speed (SF)	Average (bidirectional) free flow speed ** [mph]	L, Q, LN	
	Number Lanes (SF)	Average (bidirectional) number lanes **	L, Q, LN	
Vitality	Population Density	Average population density***[ppl/acre]	L, LN [#]	Work (TrnO)
	Employment Density	Average density of jobs *** [jobs/acre]	L, LN [#]	Work (Walk & TrnD) GSchool (TrnO) HSchool (TrnD) College (Walk & TrnD) Other (Walk & TrnD) Work-based (Walk, TrnO, & TrnD)
	Entropy	Average of entropies (measure of land use mixing) computed for all one-half mile radius neighborhoods surrounding each of a census tract's actively developed hectares.	L	
	EntropyNW	Average of non-work entropies (computed for all one-half mile radius neighborhoods surrounding each of a census tract's actively developed hectares), where non-work entropy depends only on four distinct use types (i.e., residential, commercial, public, and parks and recreation).	L	

* = summed over walk path; ** =distance-weighted average of links in walk path; *** = distance weighted average of TAZs of links along walk path; [#] = best fit functional form; L = linear; LN = logarithmic; Q = quadratic; A = interacted with age; S = interacted with dummy variable indicating 65+ years of age; WT = interacted with walk time; TrnO = origin end of transit tours (home to station walk), TrnD = destination end of transit tours (station to destination walk); SF = only enters utility function of walk or transit access/egress paths entirely within San Francisco due to low resolution street network outside of city.

Table 2: Final Work and Other Tour Mode Choice Models

Variable Group	Coefficient	Work Tours		Other Tours	
		Estimate	Ratio to IVT	Estimate	Ratio to IVT
Travel Time	In Vehicle	-0.0105*	--	-0.0087*	--
	Wait (Initial and Transfer)	-0.0234*	2.2	-0.0230*	2.6
	Origin (OTAZ-station) Walk	-0.0192*	1.8	-0.0156*	1.8
	Dest Walk (station-primary DTAZ)	-0.0566*	5.4	-0.0461*	5.3
	Transfer Walk	-0.0782*	7.4	-0.0800	9.2
	Bike	-0.0269*	2.6	-0.0340*	3.9
	Walk	-0.0283*	2.7	-0.0327*	3.7
Convenience & Reliability	Number of Transfers	-0.0815*	7.8	-0.0524	6.0
	Bike Logsum	0.2430*	-23.1	0.3960*	-45.4
	Drive to Transit Access Ratio	-0.8380*	79.8	-1.0900*	124.9
	Drive Distance WVC>0.8	-0.0224*	2.1	-0.0352*	4.0
	Drive Park Availability Index	-0.2400*	22.9	-0.2440*	27.9
Demographics	Drive Alone Age	0.0202*	-1.9	0.0150*	-1.7
	Drive Alone Senior	--	--	-0.6120*	70.1
	Shared Ride Junior	--	--	0.2330*	-26.7
	Bike Age	-0.0097***	0.9	-0.0222*	2.5
	Bike Child	--	--	-1.1100*	127.1
	Transit Child	--	--	-0.6550*	75.0
	Shared Ride 2 HHSIZE1	-1.2500*	119.0	-1.3900*	159.2
	Shared Ride 2 HHSIZE2	-0.3130*	29.8	--	--
	Shared Ride 3+ HHSIZE1	-2.1000*	200.0	-2.7600*	316.2
Shared Ride 3+ HHSIZE2	-1.5000*	142.9	-2.0300*	232.5	
Walk Environment Factors	Walk Ln(EmpDen)	0.1930*	-18.4	--	--
	Walk AbsRise (00 ft)	--	--	-0.2160*	24.7
	Walk Ln(AvgCap) * WalkTime	-0.0008**	0.1	-0.0010*	0.1
	Walk Indirectness	-0.1560	14.9	--	--
Transit/Taxi Environment Factors	Trn Dest End Walk AbsRise (00 ft)	-0.1710**	16.3	--	--
	Trn Origin End Walk Ln(PopDen)	0.0778*	-7.4	--	--
	Trn Origin End Walk Indirectness	--	--	-0.0873	10.0
	Trn Dest End Walk Ln(EmpDen)	0.1390*	-13.2	0.1310*	-15.0
	Taxi Origin Ln(EmpDen)	0.0814	-7.8	0.3240	-37.1
Stops in Tour	Drive Alone	0.0000	0.0	0.0000	0.0
	Shared Ride 2	0.4450*	-42.4	0.1410*	-16.2
	Shared Ride 3+	0.6190*	-59.0	0.1810*	-20.7
	Bike	-0.2520*	24.0	-0.0392	4.5
	Walk	-0.2570*	24.5	-0.0875*	10.0
	Walk to Transit	-0.0680*	6.5	-0.1370*	15.7
	Drive to Transit	0.0201	-1.9	0.0747***	-8.6

*= significant to 0.01 level, ** = significant to 0.05 level, *** =significant to 0.10 level, Distance VC>0.8 = distance of driving mode tours over V/C = 0.8, Senior = age 65+, Junior = under 16 years of age, Child = under 10 years of age,

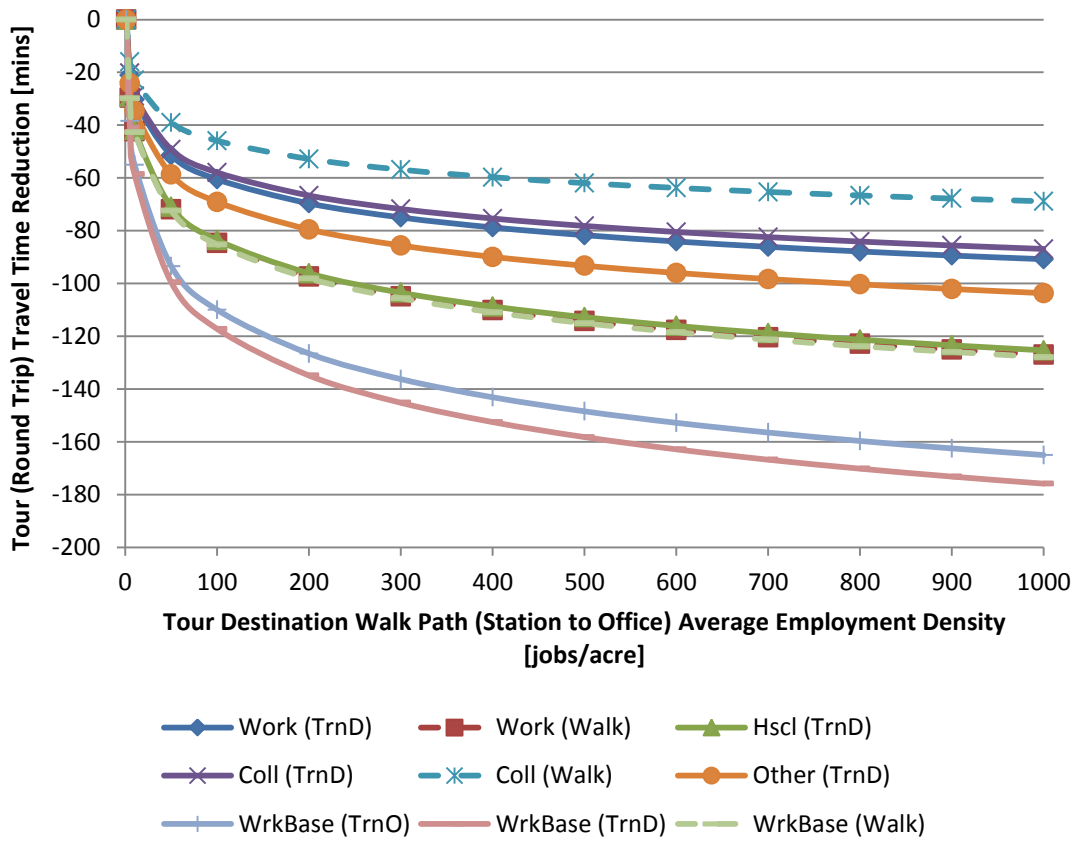


Figure 2: Effective reduction of in vehicle travel times due to employment density [Purpose (Tour Mode)]

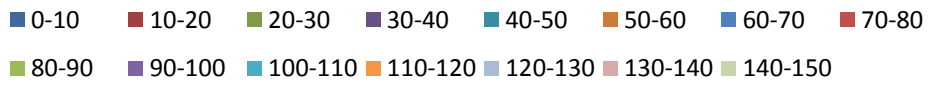
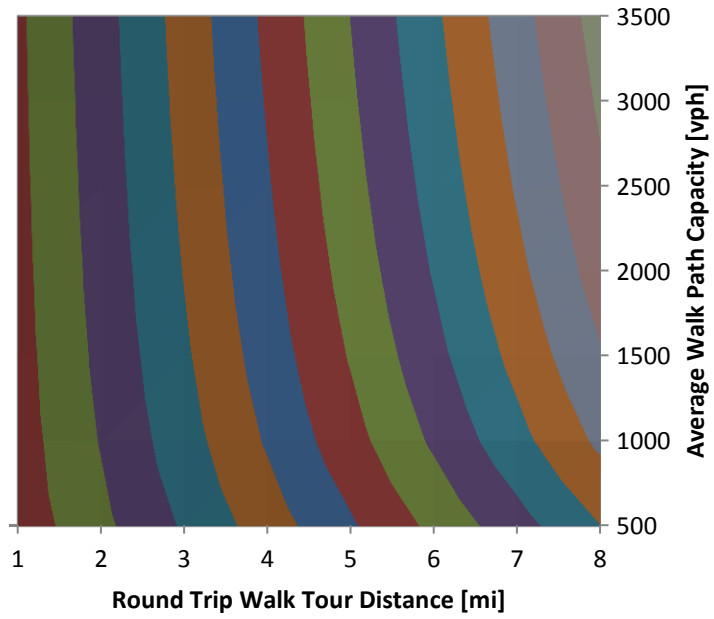


Figure 3: Effective added in vehicle minutes due to roadway capacity