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Land Use and Travel Behavior: Attitudes and Mobility PART II

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

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LAND USE AND TRAVEL BEHAVIOR: Attitudes and Mobility

Part II

Final Report

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1. Introduction

Ample evidence exists that land use and travel demand are strongly associated. Study after study has shown that household automobile ownership is correlated with residential density (Pushkarev & Zupan, 1977; Mogridge, 1985) and residential density has been found to be associated with public transit service level, household size and household income (Alonso, 1964; Muth, 1969). As a result, an urban area often exhibits a negative correlation between residential density and automobile use; residents in the central area tend to rely on public transit and non-motorized modes of travel, while suburbanites tend to live auto-oriented lifestyles. It has also been hypothesized that not only the intensity but the mixture of land uses is associated with travel demand as measured in terms of trip frequency by mode and travel distance (Levinson & Wynn, 1963; Pushkarev & Zupan, 1977; Goodwin, 1975; Cervero, 1989).

Based on the compelling evidence of association between land use and travel, we tend to conclude that travel demand can be affected by land use. In other words, we are inclined to infer causality on the basis of observed association, and conjecture that land use policies can be deployed to curb travel demand, in particular automobile use. The following question, however, is critical to that conjecture: Is the observed association between travel and land use real, or is it an artifact of the association between land use and the multitude of demographic, socio-economic, and transportation supply characteristics which also are associated with travel? High density in general means smaller housing units, lower automobile ownership levels, smaller household sizes, lower incomes, a mixture of land use types, higher accessibility to opportunities, and better transit service. An apparent association between land use and travel, therefore, may not imply that land use genuinely affects travel. Then one may ask: Can we really change travel behavior by changing land use characteristics? One could argue that certain types of land use patterns attract residents with certain demographic and socio-economic attributes, attitudes and values, and that these attributes of residents are the true determinants of their travel behavior. Spatial segregation of socio-economic classes and resulting relative homogeneity within each residential neighborhood are consistent with this view. If this is in fact the case, then altering land use characteristics by itself would not affect the residents' travel behavior; travel characteristics would change only after new residents are attracted by the new land use and move into the area while old residents who find the land use unsuitable eventually move out. In the case of new developments, given the increasingly unaffordable cost of single-family dwellings in major metropolitan areas, the demand for higher-density housing may be for many people due to its lower cost, not due to a lifestyle preference for a higher-density environment. If so, then selection of a home in a higher-density neighborhood may not be accompanied by the same travel characteristics that have historically been associated with such residential locations. That is, auto ownership and use may not be as low in the future for these types of developments as has been the case in the past. It is then unclear how effective or desirable it would be to attempt to manage travel demand through land use policy.

This study is an effort to analyze whether land use indeed affects travel and therefore whether properly formulated land use policies will serve to help control travel demand. Because of this orientation it is imperative for this study that the relationship between land use and travel demand be discussed within a comprehensive framework that takes all pertinent factors into account. The following have been identified in this study as such factors:

- demographic and socio-economic attributes,
- transit and highway accessibility,
- pedestrian/bicycle facilities,
- accessibility to opportunities,
- reasons for residential choice,
- perception of the quality of the residential neighborhood, and
- attitudes toward urban transportation, environment and other aspects of urban life.

Subjective factors as well as objectively measured variables are included in the analysis.

Since no data sets were readily available that contain these types of information, surveys of households were conducted at five selected neighborhoods in the San Francisco Bay Area. These neighborhoods, each approximately one-square-mile in area, were selected on the basis of residential density, land use mix and rail transit accessibility. Site surveys were conducted and supplementary data were collected to obtain detailed characteristics of each neighborhood. The resulting data set used for this study thus contains micro-scale measures of land use characteristics, roadway and transit service characteristics, and attitudinal and perception measures in addition to the more traditional census data, trip diary information and household demographics and socio-economics.

The resulting data set is used to examine the significance of the association between the variables from the above groups and travel demand, expressed in terms of: the number of trips, the number of transit trips, the number of non-motorized trips, the fraction of automobile trips, the fraction of transit trips, and the fraction of non-motorized trips. The individual, not the household, is used as the unit of analysis because attitudes and perceptions, which are considered as determinants of travel behavior, are associated with individuals. Linear regression models of these measures of travel demand are developed and effects of land use and other factors on travel demand are evaluated. Factor scores representing individuals' attitudes toward various aspects of urban life are then introduced into the model to evaluate how such subjective factors are associated with travel demand and to determine whether genuine association exists between land use and travel after attitudes and other factors are accounted for. Based on the results, inferences are made on the effectiveness of land use policy in shaping travel demand, and directions for future research are proposed.

This paper is organized as follows. In the next section, related recent studies in the literature are reviewed (a large body of literature exists on the subject of land use and travel; some of this general literature is reviewed in Hanson & Schwab, 1987, Giuliano, 1989, and Handy, 1992). The approach taken in this study is summarized in Section 3. The association between neighborhood characteristics and travel is discussed in Section 4. Attitudinal factors are introduced into the analysis in Section 5. Section 6 is a summary and recommendations.

2. Recent Related Research

There is a growing body of literature built around tests of the hypothesis that traditional neighborhood developments (TNDs), or similar land use patterns, lead to a reduction in vehicular trips and distance traveled. One study (Howard/Stein-Hudson Associates, 1993) involved modeling hypothetical scenarios for the Middlesex-Somerset-Mercer region of New Jersey. Year 2010 projected population growth was redirected to three types of configurations: transit-oriented, short-drive oriented, and walk-oriented. The outcome was that these higher-density configurations reduced vehicle use and increased transit use over the baseline case.

In another study (McNally & Ryan, 1993), two hypothetical transportation networks -- one representing a conventional community, the other a neo-traditional one -- were designed and their travel characteristics modeled. Holding activity levels constant, longer trips and greater congestion resulted from the conventional design. While small, this study is of interest in that densities and mixtures of land uses were not modeled -- the noted result is due only to the differences in configuration of the transportation network between the two types of communities (more cul-de-sacs and less connectivity in the conventional network).

Several studies have empirically compared existing travel behavior across different types of areas within the same region. A study of two neighborhoods in the City of Portsmouth, New Hampshire (White Mountain Survey Co., 1991) found that for the multi-use neighborhood, trip generation rates were considerably lower than the general averages contained in the ITE Trip Generation Handbook. Further, it appeared that a higher proportion of the trips that were generated remained internal to the study area than would normally be the case. These results did not hold for the second, primarily residential neighborhood, even though it also was considered to have "traditional" character.

Handy (1993) developed measures of local and regional accessibility to shopping opportunities for 34 superdistricts in the San Francisco Bay Area. Using the 1981 Metropolitan Transportation Commission travel survey data, she analyzed shopping travel by these geographic divisions, and concluded that high levels of either local and regional accessibility were associated with shorter trip lengths but not with fewer trips.

In Ewing, et al. (1994), trip records for six Palm Beach, Florida communities exhibiting a variety of land use configurations were examined for differences in trip frequency, mode choice, trip chaining, trip length, and overall vehicular travel. The "sprawling suburban" community generated almost two-thirds more vehicle hours of travel per person than the "traditional city" community, with the others falling in between these two endpoints. The authors observe that "[d]ensity, mixed use, and a central location all appear to depress vehicular travel" (p. 19).

Using a variety of techniques in a variety of regions, then, the literature is virtually unanimous in concluding that the higher densities and mixed land uses characteristic of traditional neighborhood developments are associated with reductions in vehicular travel. Whether TND configurations actually cause those reductions is seldom addressed explicitly but is generally implicitly assumed.

There is, however, at least one study that is critical of using land use strategies to reduce congestion and improve air quality. Wachs (1993) cites earlier aggregate studies (e.g. Newman and Kenworthy, 1989a, 1989b) finding that higher-density urban forms are correlated with lower energy consumption and greater use of transit, shared ride, and non-vehicular modes of travel. He argues, however, that the direction even in very high-density cities such as Hong Kong and New York is toward lower densities and greater use of the automobile and that it is unreasonable to expect to "reverse [that] steady, worldwide trend" (p. 9). Further, he points out that these higher-density cities, while achieving lower vehicular and energy use per capita, still experience higher levels of congestion in the aggregate precisely because they are higher density. Other studies (e.g. Gordon, et al., 1991) appear to support the hypothesis that "lower density development ... diffuses traffic and provides far less overall congestion..." (Wachs, p. 10). Also, he notes the inconsistency between policies supporting job - housing balance and those supporting rail transit development, which rely for their success on considerable imbalance between job and housing locations.

Finally, there is at least one study dealing with the association between personality characteristics and residential location and travel patterns. Prevedouros (1992) found that extroverts tended to make more non-work trips than introverts, that materialists tended to devote a higher proportion of their incomes to owning automobiles than utilitarian respondents, and that urbanites were more likely to live in higher-density areas than respondents having personality traits more commonly associated with suburban living. Although these findings were based on a relatively limited set of variables, they lend support to the premise of this paper, namely, that lifestyle choices are relevant to the selection of a residential neighborhood and to travel behavior.

3. Approach

The approach taken in this study is to collect micro-scale land use, roadway network, and public transit information in a set of carefully selected neighborhoods. This information is integrated with demographic, socio-economic, attitudinal, and travel behavior data collected through mail surveys of households in the same neighborhoods. The resulting database is used in multivariate statistical analyses to test various study hypotheses.

Because only a limited number of neighborhoods could be studied they were selected through a careful experimental design to yield the maximum amount of information. The selection procedure utilized the 700-zone land use data base for the nine-county San Francisco Bay Area supplied by the Metropolitan Transportation Commission (MTC). In addition, census data and geographical information available from land use maps, road maps, and other sources were used in the site selection to obtain data on neighborhood characteristics. Access to the Bay Area Rapid Transit (BART) system and land use mix were used as controlling factors in addition to median household income and residential density.

In order to gain a set of study sites that facilitates efficient statistical analysis, a strategy was set to obtain MTC zones that represent extreme values in terms of land use density and mixtures. On the other hand, zones with medium income ranges were desired to control for the effect of income on travel.

Thus median zonal income was held relatively uniform across study sites while extremes were included in terms of population density and land use mix. Within each zone, however, income varies considerably across households, permitting the examination of the association between household income and travel behavior. This led to a candidate pool of twenty zones. Following the selection of the 20 candidate zones, a tentative set of study sites was selected and site visits were made to determine their individual suitability. Final selection was performed by examining the access to rail transit on zone maps. Five study sites in all were then defined using major streets as boundaries, each to cover an approximately one square mile area.

Site surveys were conducted at each of the five study sites to obtain micro-scale measurements of (a) street characteristics (street width, presence of sidewalks and bike lanes, speed limits and other traffic regulations, etc.), (b) public transit service (location of bus stops, service frequency, etc.), (c) location and types of commercial establishments, (d) parks and other public facilities, and (e) general observation of neighborhood characteristics. Table 1 summarizes the characteristics of the five study sites. Details can be found in Kitamura, et al. (1994).

Households in these study sites were randomly selected based on address listings and household members were surveyed by mail. The survey consisted of the following three phases:

1. Recruitment. Participation in the survey was solicited following several questions on basic household attributes.
2. Trip Diary and Household Survey. Three-day trip diaries were distributed to household members at least 16 years old along with a household questionnaire that collected information on perceived neighborhood characteristics as well as demographic and socio-economic attributes of the households.
3. Person Survey. Personal questionnaires were distributed to gain detailed information on individuals' commute trip alternatives, action space, attitudes towards various aspects of urban life, leisure activities and lifestyles.

Due to resource constraints, mail was the only feasible survey medium for the study. This led to a low response rate of 17.6% for the first survey phase. In the subsequent two phases, however, more than 60% of the respondents were retained.[1] The survey results were integrated with the results of site surveys, MTC land use data, census data and information from other sources to form the database used in the analyses described in the following sections.

Table 1
Study Site Characteristics Summary

Site Characteristic	NORTH SAN FRANCISCO	SOUTH SAN FRANCISCO	CONCORD	PLEASANT HILL	SAN JOSE
Density	High	High	Low	High	Low
Land Use	Mixed	Residential	Mixed	Mixed	Mixed
Street Pattern	Grid	Curved, rectilinear, grid	Radiating	Fragmented	Discontinuous, grid
Topography	Hills	Hill, Flat	Flat	Flat	Flat
Business Locations	Throughout the site	Monterey Blvd and near perimeter	Western end of site	Central near BART and Freeway	3 corners of site
Freeway Access	I-80 one mile east	I-280 to east	Hwy 242 1/2 mile west	I-680 transects site	Capitol Expressway on eastern boundary
BART Access	None	Southeast corner of site	West side of site	Center of site	None
Bus Lines	21 bus routes	One route	Three routes	Three routes	Five routes along perimeter
Main Street Name(s)	Geary, Divisadero	Portola Dr.	Galindo, Concord, Clayton, Cowell	Treat Blvd.	Branham
Main Street Direction	North-South and East-West	North-South	East-West	East-West	North-South
Bike Trails	None	None	Parallel to Contra Costa Canal and along Cowell Rd. No street markings	Parallel to Contra Costa Canal at southern boundary	None marked
Sidewalks	Wide	Narrow, Discontinuous	Missing, Discontinuous	Discontinuous	Missing
Walking	Common	Difficult	Hazardous	Hazardous	Hazardous

[1]This low response rate led to under-representation of individuals younger than 35 years old, individuals without college education, and households with annual incomes of less than $20,000 (see Kitamura, et al., 1994). This is not considered to present problems for this analysis because (a) hypotheses are tested and inferences are made in the study by modeling relationships among variables, not by tabulating descriptive statistics from the sample, and (b) measurements of individuals' perceptions and attitudes, which may be associated with the decision to participate or not to participate in the survey, are incorporated into the analysis.

4. Association Between Study Area Characteristics and Travel

This section focuses on the association between various measures of study area characteristics and selected measures of individuals' travel behavior obtained from the three-day travel diary. Both objective measures of neighborhood characteristics obtained by the research team and subjective measures reported by the respondents are included in the analysis. The objective of this section is to quantitatively assess how much land use characteristics, transit accessibility and other neighborhood characteristics are associated with travel demand, in particular vehicular travel demand.

Prior to the analysis, it is useful to review descriptive statistics of travel behavior from the five neighborhoods (Table 2). Because of the way the neighborhoods are selected they exhibit substantial differences in travel characteristics among themselves. North San Francisco is unique in its low vehicle ownership, high fractions of walk/bicycle trips and bus trips, and low fraction of auto driver trips. Concord and San Jose, on the other hand, have high levels of vehicle ownership and a more auto-dominated modal split. Like North San Francisco, South San Francisco shows a relatively low level of vehicle ownership. They both have substantially shorter mean trip lengths than those of the other three neighborhoods. The three neighborhoods with BART access, South San Francisco, Concord and Pleasant Hill, have higher fractions of rail trips. These statistics indicate the diversity that exists among the selected study sites ranging from the high-density, pedestrian-oriented neighborhood of North San Francisco to the suburban, auto-oriented neighborhood of San Jose.

The statistical analyses reported in the rest of this section focus on the following measures of mobility:

- total number of person trips,
- number of transit trips,
- number of non-motorized trips,
- fraction of automobile trips,
- fraction of transit trips, and
- fraction of non-motorized trips.

The distance traveled is not analyzed in this study because only reported trip distance is available while a rigorous analysis of person-miles traveled and miles traveled by mode would require geo-coding of trip ends.[1]

The individual, not the household, is chosen as the unit of analysis in this study because of the advantage that attributes specific to individuals can be incorporated into the analysis, in particular the attitudes toward transportation, environment, energy and other aspects of urban life. Note that the analysis of this study is for those individuals who were over 16 years old at the time of the survey and from whom trip-diary data are available.

Table 2
Vehicle Ownership and Trip Characteristics of the Five Study Sites

a. Number of Vehicles per Household†

	N	0	1	2	3	≥ 4	Total
North San Francisco	229	12.7	47.2	31.4	5.2	3.5	100.0
South San Francisco	284	1.1	27.5	52.8	14.1	4.6	100.0
Concord	259	1.2	18.1	49.8	18.5	12.4	100.0
Pleasant Hill	298	.3	38.9	44.0	13.1	3.7	100.0
San Jose	310	.0	7.4	52.3	27.1	13.2	100.0
Total	1,380	2.6	27.0	46.7	16.2	7.6	100.0

b. Number of Vehicles per Driver†

	N	0	< 0.5	< 1.0	= 1.0	> 1.0	Total
North San Francisco	220	12.7	22.7	6.8	50.5	7.3	100.0
South San Francisco	280	1.1	19.3	14.3	53.6	11.8	100.0
Concord	253	1.2	11.1	3.6	57.7	26.5	100.0
Pleasant Hill	292	.3	17.1	5.8	62.7	14.0	100.0
San Jose	306	.0	3.6	5.6	67.6	23.2	100.0
Total	1,351	2.6	14.3	7.3	59.0	16.9	100.0

Data missing for 29 cases.

†The table represents the distribution for individual respondents, not households. N is the sample size for each study area. The remaining Numbers are the percentages of N which fall into each category.

[1]Geo-coding of the trip data is among the tasks that would be desirable for future research.

Table 2
(Continued)

c. Reported Trip Distance (Miles)

	Mean	S.D.	N
North San Francisco	6.57	59.9	2,821
South San Francisco	6.73	21.6	3,476
Concord	8.90	25.3	3,162
Pleasant Hill	8.69	16.8	3,540
San Jose	9.09	56.8	3,763
Total	8.06	40.1	16,762

Data missing for 8 cases.

d. Distribution of Travel Modes

	N	Walk Bicycle	Auto Driver	Auto Pass.	Bus	Rail	Other	Total
North San Francisco	2,768	22.6	52.2	9.2	13.8	.7	1.6	100.0
South San Francisco	3,370	9.6	70.6	8.1	4.3	5.5	1.9	100.0
Concord	3,020	9.3	77.2	8.4	.7	4.3	.2	100.0
Pleasant Hill	3,492	7.9	77.8	6.5	.8	6.9	.1	100.0
San Jose	3,696	3.8	86.5	7.7	1.0	.1	.8	100.0
Total	16,346	10.1	73.8	7.9	3.7	3.5	.9	100.0

Auto driver includes motorcycle. Data missing for 424 cases.

Quantitative models are developed to explain the variations in, and predict the future values of, these mobility measures. These models use as explanatory variables demographic and socio-economic attributes of the sample households and their members, along with the following measures of neighborhood characteristics:

- study area dummies,
- macro-scale area descriptors,
- pedestrian/bicycle facility indicators,
- housing choice indicators,
- micro-scale accessibility indicators, and
- perceptions of the quality of the residential neighborhood.

Note that these measures are by no means independent of each other, but tend to represent similar or overlapping aspects of land use in different manners. Table 3 presents the definition of these variables.

Table 3
Neighborhood Descriptors Used in the Study

Study Area Dummies: 0-1 dummy variables that identify the study area in which each respondent lives

- North San Francisco (NSF)
- South San Francisco (SSF)
- Concord (CON)
- Pleasant Hill (PH)
- San Jose (SJ)

Macro-scale Area Descriptors: 0-1 dummy variables defined based on the factors considered during the site selection process

- BART Access (1 for SSF, CON and PH)
- Mixed Land Use (1 for NSF, CON, PH and SJ)
- High Density (1 for NSF, SSF and PH)

Pedestrian/Bicycle Facilities: 0-1 dummy variables based on responses to the survey questions: "Are there sidewalks in your neighborhood?"; and "Are there bike paths in your neighborhood?"

- Sidewalk
- Bike Path

Housing Choice Indicators: 0-1 dummy variables based on responses to: "Do you have a private backyard?"; "How many parking spaces are available exclusively for your household use? Include your garage and driveway"; and "Do you own your home?"

- Backyard
- Parking Spaces Available
- Own Home

Micro-scale Accessibility Indicators: Based on responses to: "How far away, to the nearest tenth of a mile, is the bus stop nearest your home?" etc.

- Distance to Nearest Bus Stop
- Distance to Nearest Rail Station
- Distance to Nearest Grocery Store
- Distance to Nearest Gas Station
- Distance to Nearest Park

Perceptions of Neighborhood Quality: 0-1 dummy variables based on responses to: "Given your current neighborhood situation, which of the following reasons may make you consider moving to a different area? (Check all that apply.)"; "Are the streets in your neighborhood pleasant for walking or jogging?"; "Is cycling pleasant in your neighborhood?"; "Is there good local public transit service in your neighborhood?"; "Is there enough parking near your home?" and "Are there problems of traffic congestion in your neighborhood?"

- No Reason to Move
- Streets Pleasant for Walking
- Cycling Pleasant
- Good Local Transit Service
- Enough Parking
- Problems of Traffic Congestion

Base models are first developed for the six measures of mobility using the demographic and socio-economic descriptors of the individual listed in Table 4.[2] The neighborhood descriptors from each variable group in Table 3 are introduced into these base models one at a time to examine the association between the mobility measures and these neighborhood descriptors. The intensity of the association between each variable group and the mobility measures is first examined. "Best" models are then

Table 4
Variables Used in the Base Regression Models of Mobility Measures

Household size
Number of persons over 16 years old
Number of vehicles
Number of vehicles per persons over 16 years old
Annual household income in $10,000
Square root of annual household income in $10,000
Number of years lived in the Bay Area
Driver's license holding
Age in years divided by 10
Square-root of age divided by 10
Female (0-1 dummy variable)
Employment (0-1 dummy variable)
Homemaker (0-1 dummy variable)
Student (0-1 dummy variable)
Professional (0-1 dummy variable)
Low education (up to high school diploma; 0-1 dummy variable)
College education (0-1 dummy variable)
High education (some graduate school or graduate degree; 0-1 dummy variable)
Graduate degree (completed graduate degree; 0-1 dummy variable)
High personal income (over $50,000 annually; 0-1 dummy variables)
Middle personal income (between $30,001 and $50,000; 0-1 dummy variable)
Apartment (0-1 dummy variable)
Single family home (including duplexes and triplexes; 0-1 dummy variable)

Note: The variables in the six explanatory variable groups discussed earlier in the section are shown in Table 3.

[2]For the dependent variables representing the fraction of trips by mode, models are developed using as the dependent variables the logit, $\ln(N_m/(N - N_m))$, where N is the total number of trips and N_m is the number of trips by mode m.

developed considering all the neighborhood descriptors as well as demographic and socio-economic variables. Genuine effects of neighborhood characteristics are inferred based on the results.

Base Models: Estimation results summarized in Table 5 indicate that the fraction of variation explained (R^2) varies substantially across the mobility measures, with number of person trips having the highest R^2 of 0.147 and number of non-motorized trips having the lowest, 0.0256.[1] Household

Table 5
Base Linear Regression Models of Mobility Measures

	Number of Person Trips		Number of Transit Trips		Number of Non-Motorized Trips	
	Coef.	t	Coef.	t	Coef.	t
Intercept	2.308		2.154		0.395	
Household Size	2.618	8.92	-0.059	-0.72	0.145	1.49
Persons Over 16 Yrs. Old	-2.966	-6.68	0.293	2.17		
No. of Vehicles			-0.526	-6.34	-0.302	-2.76
Vehicles per Person	-0.094	-0.17				
Driver's License	2.473	2.27	-0.740	-2.46	-0.189	-0.43
Age Divided by 10	-0.225	-2.53	-0.035	-1.41	-0.013	-0.35
Employment Dummy	0.369	0.59	0.309	1.59		
Professional Dummy			0.320	2.02	0.254	1.27
Student Dummy	3.565	2.77			-0.506	-0.95
High Education Dummy	0.658	1.31				
Graduate Degree Dummy			-0.408	-2.79		
Household Income (in $10,000)	-0.887	-2.53			-0.231	-1.61
(Household Income)$^{1/2}$	5.282	2.95			1.106	1.51
High Personal Income Dummy			0.384	2.53		
Years in Bay Area Divided by 10			-0.144	-4.05	-0.097	-1.88
R^2	0.1471		0.1184		0.0256	
F	13.37		10.30		2.305	
D.F.	10, 775		10, 767		9,789	
α	< 0.00005		< 0.00005		0.0147	

[1]The base models do not necessarily represent what one might consider "correct" specifications. Some insignificant variables are left in the model to facilitate the comparison of the variables' effects across the models.

Table 5 (Continued)

	Fraction of Auto Trips		Fraction of Transit Trips		Fraction of Non-Motorized Trips	
	Coef.	t	Coef.	t	Coef.	t
Intercept	-0.721		-1.200		-1.480	
Household Size			-0.222	-4.11	-0.068	-1.61
Persons Over 16 Yrs. Old			0.410	4.59		
No. of Vehicles			-0.353	-6.43	-0.057	-1.21
Vehicles per Person	0.636	4.14				
Driver's License	2.263	6.92	-0.936	-4.71	-0.674	-3.56
Age Divided by 10	0.007	0.28	-0.001	-0.01	0.023	1.45
Employment Dummy	0.069	0.37	0.093	0.73		
Professional Dummy			0.085	0.82	0.066	0.77
Student Dummy	0.185	0.49			-0.443	-1.93
High Education Dummy	0.073	0.49				
Graduate Degree Dummy			-0.307	-3.18		
Household Income (in $10,000)	0.142	1.36			-0.008	-0.14
(Household Income)$^{1/2}$	-0.704	-1.33			-0.058	-0.18
High Personal Income Dummy			0.227	2.26		
Years in Bay Area Divided by 10			-0.065	-2.77	-0.006	-0.28
R^2	0.0965		0.1319		0.0475	
F	10.39		11.66		4.38	
D.F.	8,778		10, 767		9, 789	
α	< 0.00005		< 0.00005		< 0.00005	

vehicle ownership (expressed as the number of vehicles and vehicles per person) and driver's license holding are significantly associated with these measures of mobility. As expected, vehicle ownership and license holding are both positively associated with vehicle use and negatively associated with the use of public transit and non-motorized modes. Notable is the result that vehicle ownership is not associated with number of person trips. Number of person trips generated by a household member is associated with household size and number of household members over 16 years old; the coefficient estimates for these two variables imply that a person from a larger household tends to make more trips, especially when there are members below 16 years old. The two income coefficients together imply a non-linear income effect which is concave and reaches its maximum at around an annual income of $90,000. The results also show associations between occupational categories and the mobility measures.

Neighborhood Descriptors: Contributions of the six groups of neighborhood descriptors to the goodness-of-fit of the base models are summarized in Table 6. It is evident from the table that these descriptors do contribute to the models' explanatory power; association between travel demand and land use and other neighborhood characteristics is not an artifact of the correlation between neighborhood characteristics and the residents' demographic and socio-economic attributes. Study area dummies,

Table 6
Contribution of Individual Neighborhood Descriptor Groups to the Fit of the Base Models of Mobility Measures

	Base Model	Area Dummy	Macro Descrip-tors	Ped/Bike Facilities	Housing Choice	Accessi-bility	Neigh-borhood Quality
Number of Person Trips	.1471	.1572 1.01%	.1544 .73%	.1479 .08%	.1613 1.42%	.1496 .25%	.1510 .39%
Number of Transit Trips	.1184	.1299 1.15%	.1287 1.03%	.1199 .15%	.1282 .98%	.1371 1.87%	.1271 .87%
Number of Non-Motorized Trips	.0256	.0473 2.17%	.0350 .94%	.0343 .87%	.0348 .92%	.0428 1.72%	.0292 .36%
Fraction of Auto Trips	.0965	.1397 4.32%	.1146 1.81%	.0979 .14%	.1271 3.06%	.1280 3.15%	.1190 2.25%
Fraction of Transit Trips	.1319	.1426 1.07%	.1418 .99%	.1324 .05%	.1420 1.01%	.1468 1.49%	.1396 .77%
Fraction of Non-Motorized Trips	.0475	.690 2.15%	.0611 1.36%	.0515 .40%	.0526 .51%	.0688 2.13%	.0523 .48%

The top number in each cell is an R^2 value and the bottom number represents the contribution of the variable group to the R^2 value (the absolute difference is shown in percent). The differences that are statistically significant at $\alpha = 5\%$ are underlined, and those significant at $\alpha = 1\%$ are double-underlined.

macro-scale area descriptors, and micro-scale accessibility indicators most often contribute to the models' fit. Pedestrian/bicycle facilities, on the other hand, are as a group significant only in the model for the number of non-motorized trips.

The neighborhood descriptors are most significant in the models of fraction of car trips and fraction of non-motorized trips. On the other hand only housing choice indicators are significant as a group in the model of total number of person trips. We may conclude that person trip generation is largely determined by demographic and socio-economic factors and is not strongly associated with land use characteristics. Generation of transit and non-motorized trips, and consequently modal split, however, is strongly associated with land use characteristics.

Analysis of Neighborhood Descriptors by Group: The coefficient estimates of the individual neighborhood descriptors are presented in Figure 1.[2] The coefficient estimates of study area dummies indicate that South San Francisco, Concord and Pleasant Hill are most transit oriented, both in terms of the number and the fraction of transit trips. San Jose, on the other hand, is least transit oriented. North San Francisco and South San Francisco have higher non-motorized trip generation, and these two study areas plus Pleasant Hill have significant positive coefficients in the model for fraction of non-motorized trips. Quite notable is the result that North San Francisco has a significant coefficient estimate in the model of total number of person trips. This may be due to the high non-motorized trip rates shown by the respondents from this study area.

The coefficient estimates of macro-scale area descriptors indicate that BART access is associated with higher transit trip generation and higher fractions of transit trips. High density is found to be associated with more person trips, non-motorized trips, lower fractions of auto trips, and higher fractions of non-motorized trips. There is no indication from this study that mixed land use is associated with travel. This, however, may be due to the ambiguity inherent in the term; whether a household resides among mixed land uses depends on how the neighborhood is geographically defined. The micro-scale accessibility indicators of this study may be considered as more suitable measures of land use mix.

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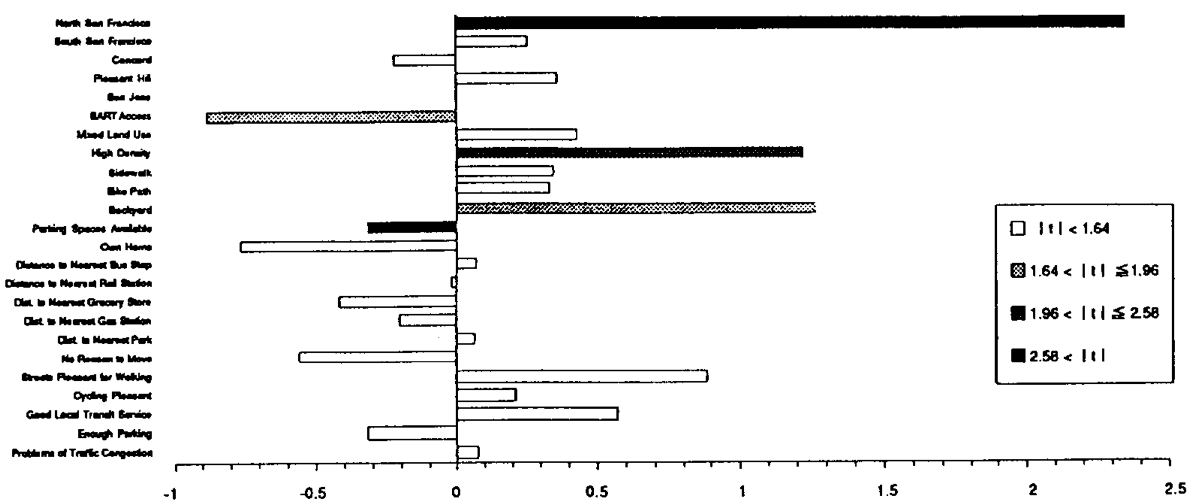
[2]Recall that these coefficient estimates are obtained by introducing the descriptor groups into the base models one at a time. Because the descriptors are not uncorrelated across the groups, the coefficient estimates may reflect the association between the mobility measures and neighborhood descriptors from other groups.

Figure 1
Coefficient Estimates of Neighborhood Descriptions in Models of Mobility Measures

Total Number of Person Trips



Number of Transit Trips

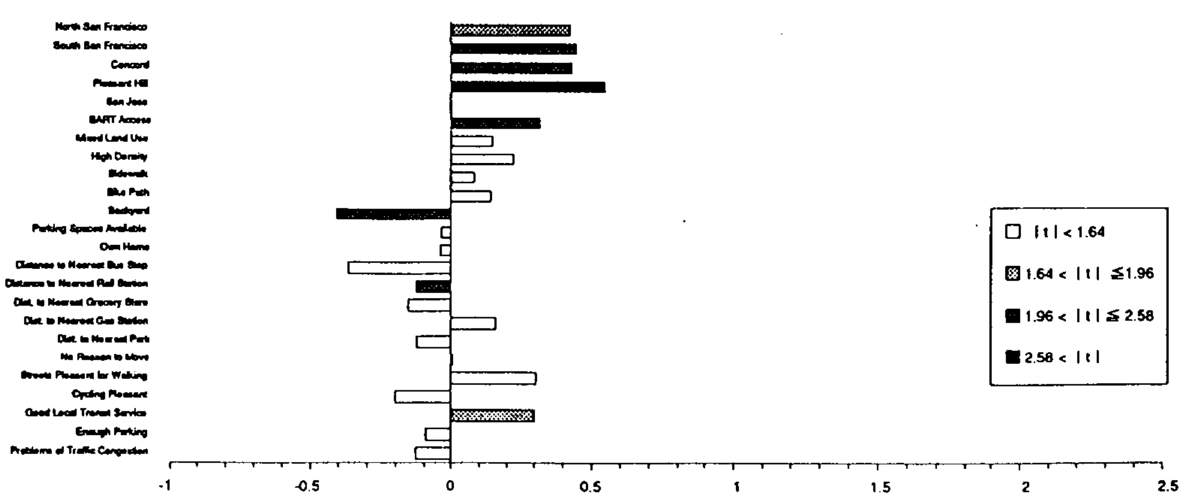
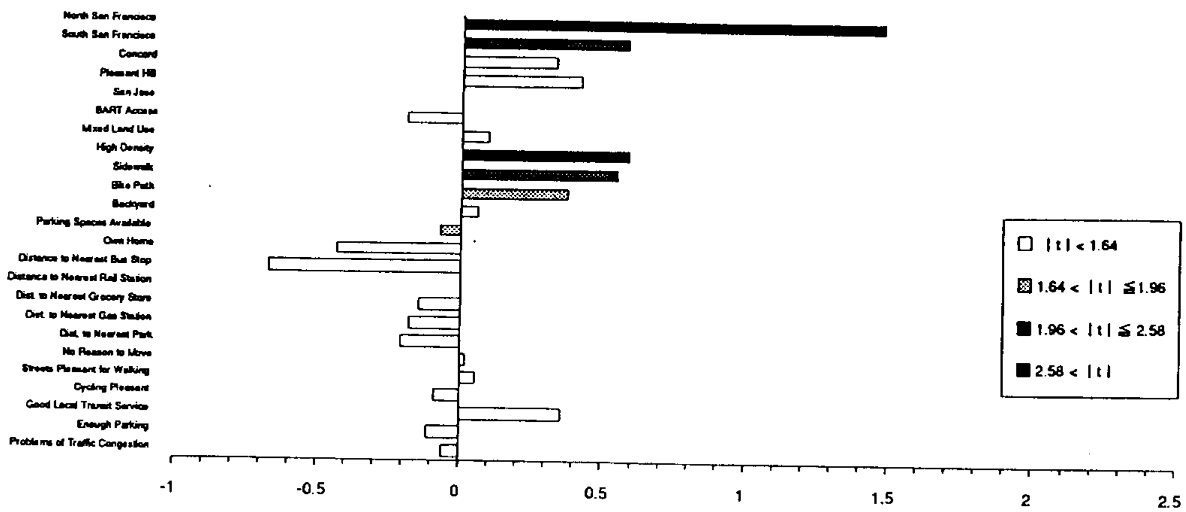


Figure 1
(continued)
Coefficient Estimates of Neighborhood Descriptions in Models of Mobility Measures

Number of Non-Motorized Trips



Fraction of Car Trips

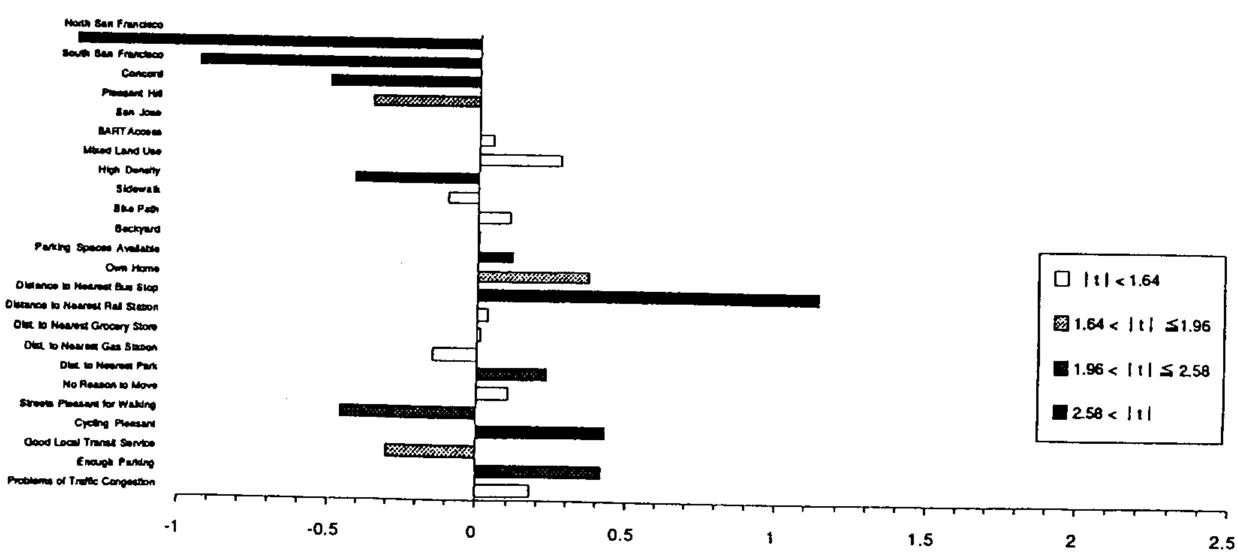
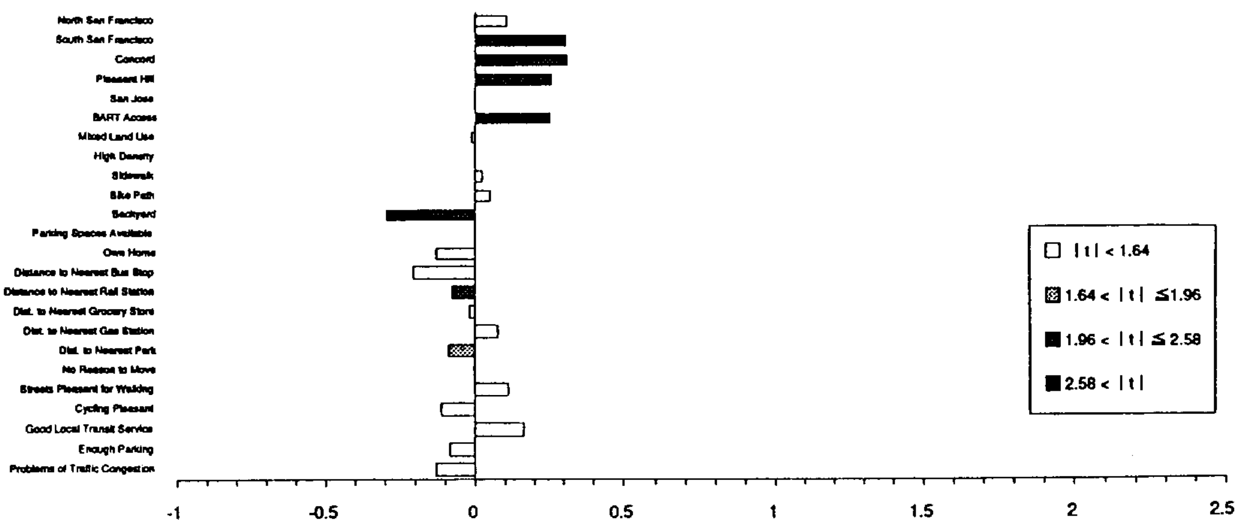
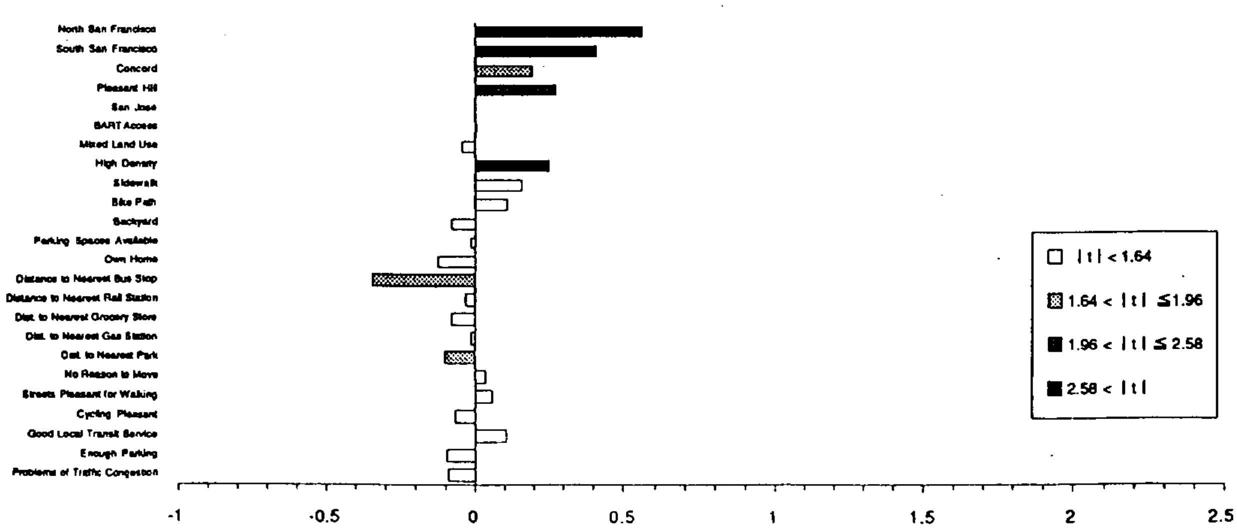


Figure 1
(continued)
Coefficient Estimates of Neighborhood Descriptions in Models of Mobility Measures

Fraction of Transit Trips



Fraction of Non-Motorized Trips



As noted earlier, the variables representing pedestrian/bicycle facilities are not significant in these models, except for the model of number of non-motorized trips. Housing choice indicators in general exhibit an association between housing choice and mode use. Members of households which reside in housing units with larger numbers of parking spaces tend to make more auto trips, while those who make more transit trips tend to live in housing units without a backyard. Another indication of the association between housing choice and travel is given by the coefficient of parking spaces available in the model for total number of person trips, which is highly significant and negative. This is counter-intuitive. One interpretation is that those with more parking spaces tend to use the automobile and make fewer trips than those who use non-motorized modes. The latter individuals may make more short trips.

Micro-scale accessibility indicators have no significant coefficients in the model of total number of person trips. Consistent with the earlier result, person trip generation appears to be independent of accessibility or land use. This group of variables indicates that transit trip generation and fraction of transit trips are both associated with the distance to the nearest rail station (but not significantly with the distance to the nearest bus station), while fraction of car trips is associated with the distances to the nearest bus stop and the nearest park. The result with car trips suggests highly auto-oriented travel patterns of residents of exclusively residential neighborhoods.

Perceptions of the quality of the neighborhood are in general insignificant. The only exception can be found in the model for fraction of car trips. The perception that streets are pleasant for walking is associated with smaller fractions of auto trips, while the perception that cycling is pleasant in the neighborhood is associated with larger fractions of auto trips. The latter may represent the higher safety standards of neighborhood streets which are typically found in recently developed suburban subdivisions.

Best Models: The above analysis by variable groups have offered many findings on the association between neighborhood characteristics and travel. Based on these results, models of the mobility measures are developed again considering all neighborhood descriptors shown in Table 3 and the demographic and socio-economic variables of Table 4. Results are summarized in Table 7.

Table 7
Best Models of Mobility Measures

	Total Number of Person Trips		Number of Transit Trips		Number of Non-Motorized Trips	
	Coef.	t	Coef.	t	Coef.	t
Intercept	2.022		2.858		-0.149	
Socio-Demographic Variables						
Household Size	2.835	9.62				
Persons Over 16 Yrs. Old	-3.013	-7.07	0.258	2.42		
Number of Vehicles			-0.476	-5.75		
Driver's License	2.805	2.66	-0.650	-2.20		
Age Divided by 10	-0.232	-2.64				
Professional (0-1)			0.395	2.79		
Student (0-1)	3.260	2.56				
Graduate Degree (0-1)			-0.417	-2.90		
High Personal Income (0-1)			0.370	2.47		
Household Income (in $10,000)	-0.979	-2.81				
(Household Income)$^{.8}$	5.791	3.27				
Years in Bay Area Divided by 10			-0.139	-3.97		
Neighborhood Descriptor Variables						
North San Francisco	1.863	2.39			1.494	4.43
BART Access					0.662	2.90
Sidewalk					0.584	2.29
Backyard			-0.593	3.13		
Parking Spaces Available	-0.261	-2.73				
Distance to Nearest Rail Station			-0.141	-3.01		
Distance to Nearest Park			-0.211	-2.52		
R^2	0.1622		0.1386		0.0306	
F	16.69		112.34		8.376	
D.F.	9, 776		10, 767		3, 795	
α	< 0.00005		< 0.00005		< 0.00005	

Table 7 (Continued)

	Fraction of Auto Trips		Fraction of Transit Trips		Fraction of Non-Motorized Trips	
	Coef.	t	Coef.	t	Coef.	t
Intercept	-2.064		-0.728		-1.633	
Socio-Demographic Variables						
Household Size					-0.094	-2.51
Persons Over 16 Yrs. Old			0.203	2.86		
Number of Vehicles			-0.335	-6.09		
Vehicles per Person	0.504	3.31				
Driver's License	2.224	7.08	-0.919	-4.68	-0.698	-3.80
Professional (0-1)			0.099	1.05		
High Education (0-1)	0.117	0.83				
Graduate Degree (0-1)			-0.306	-3.20		
High Personal Income (0-1)			0.195	1.96		
Middle Personal Income (0-1)					0.195	2.32
Years in Bay Area Divided by 10			-0.039	-1.67		
Neighborhood Descriptor Variables						
High Density					0.260	3.15
Backyard			-0.489	-3.88		
Parking Spaces Available	0.119	4.28				
Distance to Nearest Bus Stop	0.880	3.31			-0.418	-2.23
Distance to Nearest Rail Station			-0.084	-2.70		
Distance to Nearest Park	0.239	2.77	-0.140	-2.52	-0.132	-2.46
R^2	0.1429		0.1415		0.0664	
F	21.67		12.64		9.28	
D.F.	6, 780		10, 767		6, 783	
α	< 0.00005		< 0.00005		< 0.00005	

The model for total number of person trips includes the North San Francisco and parking spaces available dummies from the neighborhood descriptor pool. The former reflects the uniqueness of the study area which has dense and mixed land uses and is strongly pedestrian oriented. The model of number of transit trips indicates that transit trip generation increases with the accessibility to rail stations (as indicated by the negative coefficient estimate of distance to nearest rail station) and is associated with residential density (as indicated by the coefficient estimates of backyard and distance to nearest park).

The model for the number of non-motorized trips comprises three neighborhood descriptors alone: North San Francisco, BART access, and sidewalk. Age and other demographic variables which may have been hypothesized as determinants of non-motorized trip generation, turned out to be insignificant in this study. The coefficient estimates again indicate the pedestrian orientation of North San Francisco. Respondents from study areas with BART access tend to make more non-motorized trips. This may not be exclusively due to the characteristics of these study area neighborhoods, but may imply that the use of BART for commuting tends to generate non-motorized trips both at the work and home ends. The significant coefficient of sidewalk in this model is important. This study offers statistical evidence that the presence of sidewalks is positively associated with the number of non-motorized trips.

The neighborhood descriptors that appear in the model for fraction of auto trips (parking spaces available, distance to nearest bus stop, and distance to nearest park) indicate the auto-dominated modal split in residential suburbs. Those in the model for fraction of transit trips indicate that residential density (as represented by backyard), rail accessibility (distance to nearest rail station), and mixed land uses (distance to nearest park) are associated with transit modal split. Residential density (high density), bus accessibility (distance to nearest bus stop) and mixed land uses are associated with fraction of non-motorized trips.

The best models confirm the earlier results that neighborhood characteristics are associated with residents' travel. With the extensive range of variables used in this study, vehicle ownership and other attributes of residents vary greatly across the five study areas. Differences in their travel, however, cannot be explained solely by the differences in demographic and socio-economic attributes; differences in neighborhood characteristics -- in particular residential density, public transit accessibility, mixed land use (as represented by the distance to the nearest park) and the presence of sidewalks -- are significantly associated with trip generation by mode and modal split. Finally, North San Francisco, with its dense and highly mixed land uses, emerged as a neighborhood which is extremely pedestrian oriented.

5. Association between Attitudes and Travel

This section addresses the possibility that the apparent association between land use and travel is a fallacy. That is, attitudinal factors, which are typically not included in studies of land use effects, are correlated with land use characteristics and produce the apparent association between land use and travel; the true determinants of travel, however, are attitudes. If this is the case, then changing land use characteristics through land use policy will not alter travel behavior unless either land use policy or resulting land use characteristics can change attitudes. This section presents an initial attempt to address this issue.

To measure respondents' attitudes toward various aspects of urban life, a total of 39 questions are included in the survey, each presenting a statement and soliciting a response on a five-point agree-disagree semantic scale. These questions are divided into eight groups: (1) private automobile, (2) ridesharing, (3) public transit, (4) urban transportation, (5) time, (6) environment, (7) housing and (8) economy. Responses to these questions are discussed in detail in Kitamura et al. (1994).

Factor analysis was applied to the responses to these attitudinal questions with the intent of reducing their dimensionality. The first eight factors, which collectively explain 43.3% of the total variation in the data, are discussed here. Statements that principally define each factor are listed in Table 8.

Attitude Factors: The first factor is primarily defined by responses to statements concerning the environment such as: "Environmental protection costs too much" (negative loading), "Environmental protection is good for California's economy," and "Environmentalism hurts minority and small businesses" (negative loading). This factor represents the respondents' environmental orientation and is named "pro-environment."

The second factor can be termed "pro-transit" and reflects the individual's orientation towards ridesharing as well as public transit. The third factor will be called the "suburbanite" factor. It is primarily defined by responses to: "I need to have space between me and my neighbors," "I would only live in a multiple family unit ... as a last resort," "It's important for children to have a large backyard for playing," and "High density residential development should be encouraged" (negative loading). This factor thus represents an individual's orientation toward the consumption of land for his/her living space.

Table 8
Primary Variables that Define Eight Attitude Factors

Statement for Agree/Disagree Semantic Scale	
Factor 1: Pro-Environment	
Environmental protection costs too much.	-
Environmental protection is good for California's economy.	+
Environmentalism hurts minority and small businesses.	-
People and jobs are more important than the environment.	-
Stricter vehicle smog control laws should be introduced and enforced.	+
We should raise the price of gasoline to reduce congestion and air pollution.	+
Vehicle emissions increase the need for health care.	+
Using tax dollars to pay for public transportation is a good investment.	+
We should provide incentives to people who use electric ... vehicles.	+
Whoever causes environmental damage should repair the damage.	+
Factor 2: Pro-Transit/Ridesharing	
Buses and trains are pleasant to travel in.	+
I can read and do other things when I use public transportation.	+
Public transportation is unreliable	-
Ridesharing saves money	+
I am not comfortable riding with strangers	-
The rideshare car or van is often late	-
I like someone else to do the driving	+
Too many people drive alone	+
It costs more to use public transportation than ... to drive a car	-
Factor 3: Suburbanite	
I need to have space between me and my neighbors.	+
I would only live in a multiple family unit as a last resort.	+
It's important for children to have a large backyard for playing.	+
High density residential development should be encouraged.	-
Factor 4: Automotive Mobility	
Driving allows me to get more done.	+
Driving allows me freedom.	+
I would rather drive an electric vehicle than give up driving.	+
Factor 5: Time Pressure	
Getting stuck in traffic doesn't bother me too much.	-
I would like to have more time for leisure.	+
I feel that I am wasting time when I have to wait.	+
Traffic congestion will take care of itself because people will adjust.	-
Factor 6: Urban Villager	
Having shops and services within walking distance ... would be important.	+
Too much valuable agricultural land is consumed to supply housing.	+
I use public transportation when I cannot afford to drive.	+
Factor 7: TCM	
I would be willing to pay a toll to drive on an uncongested road.	+
More lanes should be set aside for carpools and buses.	+
We need to build more roads to help decrease congestion.	+
Factor 8: Workaholic	
I like to spend most of my time working.	+
When ... busy at work, I get more done by cutting back on personal time.	+
... I would be willing to give up a day's pay to get a day off work.	-

The fourth factor represents the individual's orientation toward the ubiquitous mobility provided by the automobile and shall be named "automotive mobility." The fifth factor is defined principally byresponses to: "Getting stuck in traffic doesn't bother me too much" (negative loading), "I would like to have more time for leisure," and "I feel I am wasting time when I have to wait." This can be appropriately called a "time pressure" factor.

Responses to "Having shops and services within walking distance of my home would be important to me," and "Too much valuable agricultural land is consumed to supply housing" are the primary determinants of the sixth factor. Individuals with high ratings on this factor would be inclined toward a pedestrian-oriented, high-density urban environment, leading lifestyles where work may not be the primary concern. This will be thus named the "urban villager" factor.

The dominant variables that define the seventh factor are responses to: "I would be willing to pay a toll to drive on an uncongested road," and "More lanes should be set aside for carpools and buses," followed by "We need to build more roads to help decrease congestion." Other variables that define this factor (but are not shown under this factor as they are load more heavily on other factors) include: "We should provide incentives to people who use electric or other clean-fuel vehicles," and "Stricter vehicle smog control laws should be introduced and enforced." People with high values on this factor would tend to believe in transportation control measures and regulations to resolve transportation and other urban problems. However they would also tend to be positive about the expansion of facilities and tend not to have reservations about urban expansion. Based on its primary constituents, this factor will be termed a "TCM" factor. The final factor is defined by responses to: "I like to spend most of my time working," "When things are busy at work, I get more done by cutting back on personal time," and "Occasionally, I would be willing to give up a day's pay to get a day off work" (negative loading). This can be unequivocally named a "workaholic" factor.

Comparison of Attitude Scores across the Study Neighborhoods: Differences in respondents' attitudes across the five study areas are summarized in terms of the means and standard deviations of scores on these factors in Table 9. Factor scores are normalized to have means of zero and variances of unity across the entire sample.

Table 9
Means and Standard Deviations of Attitude Factor Scores by Study Site

		North San Francisco (141)	South San Francisco (199)	Concord (195)	Pleasant Hill (214)	San Jose (235)
Factor 1: Pro-Environment	μ	.340	.251	-.262	-.019	-.092
	σ	1.022	.963	.969	.945	1.053
Factor 2: Pro-Transit	μ	-.238	-.088	.204	.238	-.054
	σ	1.003	.972	.991	.902	1.082
Factor 3: Suburbanites	μ	-.466	-.247	.425	-.216	.281
	σ	1.113	.955	.834	1.063	.859
Factor 4: Automotive Mobility	μ	-.134	-.027	-.042	-.014	.144
	σ	1.090	1.093	.885	.920	.961
Factor 5: Time Pressure	μ	.136	.030	-.015	.089	-.118
	σ	1.016	.925	1.014	1.068	.988
Factor 6: Urban Villager	μ	.186	.105	.001	-.098	-.048
	σ	1.077	.899	.890	1.078	.961
Factor 7: TCM	μ	.352	.159	-.195	-.129	-.189
	σ	.818	.966	1.015	.942	.951
Factor 8: Workaholic	μ	-.223	.058	-.005	.038	.108
	σ	1.076	1.026	.931	1.014	.909

As hypothesized earlier, attitude factor scores vary substantially across the five study areas in ways that tend to be consistent with the travel patterns associated with them. North and South San Francisco both have high mean pro-environment factor scores while Concord has the lowest mean score on this factor. The two communities embracing BART stations, Concord and Pleasant Hill, exhibit the highest pro-transit factor scores while, unexpectedly, North San Francisco has the lowest mean score on this factor. The result suggests that being pro-environment may not automatically imply being pro-transit and vice versa. That the North San Francisco site is not served by rail while the available bus service may be of lesser quality due to traffic congestion in the densely developed area, also suggests that attitudes are formed interactively with experience.

Concord happens to score the highest on the suburbanite factor followed by San Jose. As expected, North San Francisco has the lowest score. Automotive mobility and time pressure have relatively small variations in their means across the five neighborhoods. The former exhibits the same tendency as modal split; San Jose is most auto-oriented and North San Francisco is least auto-oriented. Interestingly, the least auto-oriented North San Francisco scores highest and San Jose scores lowest on the time pressure factor.

The urban villager and TCM factors split between the high density neighborhoods of North and South San Francisco, and the more suburban Concord, Pleasant Hill and San Jose, with the former group containing more positive scores on both factors. The workaholic factor, on the other hand, does not exhibit the same split. On this factor, North San Francisco again stands alone, having a negative mean score while scores for the other five areas are either positive or (for Concord) essentially zero.

This comparison of mean factor scores across the five neighborhoods has shown that attitudes vary reflecting neighborhood characteristics and that there are clear associations between the factor scores and travel patterns. Examined next is the hypothesis that given the attitudes of an individual, neighborhood characteristics do not offer additional explanation of his/her travel.

Association between Attitude Factors and Travel: Measures of personal attitudes are not often used in the analysis of travel demand. There are several reasons for this. Among the most important reasons are the various difficulties encountered when measuring and forecasting attitudes. Also important is the view that attitudes are, like travel behavior itself, elements that are to be explained, but not to be used to explain behavior. In fact there are competing hypotheses regarding the relationship between attitudes and behavior: attitudes are formed through experience as a result of behavior; attitudes prompt certain types of behavior; and interactive, two-way relationships exist between attitudes and behavior (Tardiff, 1977; Dobson, et al., 1978; Tischer & Phillips, 1978; Lyon, 1984; Pendyala, 1993).

In the rest of this section, the analysis of the previous section is extended by introducing the attitude factors into the model as explanatory variables. The intent here is not to identify causal relationships that may exist between attitudes and behavior. Rather, the purpose is to assess the relative intensity of the relationship between attitudes and travel behavior. If attitudes dominate neighborhood characteristics in explaining travel behavior, then it would lend support to the notion that land use policy would not alter travel demand unless it can change residents' attitudes. If, on the other hand, neighborhood characteristics are associated with travel beyond the association between attitudes and travel, then it could be interpreted as evidence that travel demand can be modified by changing land use characteristics. In either case, if attitude factors are significantly associated with travel, then further analysis is warranted into causal relationships that involve attitudes.

The eight attitude factor scores are introduced into the best models for the six mobility measures. The contributions of the attitude factors to the models' goodness-of-fit are summarized in Table 10. The coefficient estimates of the attitude factors are summarized in Figure 2.[1] The best model re-estimated for the subsample of the attitude analysis and the model with the attitude factors are summarized in Table 11 for the fraction of auto trips, the mobility measure for which the attitude factors are most significant.

A quick inspection of Table 10 indicates that these attitude factors are strongly associated with the mobility measures. They are highly significant as a group as the F-statistics indicate, and they substantially improve the "best" models' R^2s (the R^2 values of the base models of Table 6 and those of the best models of Table 7 are repeated in Table 10 for comparison purposes). Although the neighborhood descriptors introduced into the best models do improve the models' fit, the contributions of the attitude factors are in general greater than those of the neighborhood descriptors in the best model. Note that the improvements made by the attitude factors are in addition to those

[1]Models are estimated with approximately 640 respondents for whom complete factor scores are available. No elaborate techniques are employed in this study to account for the missing data problem.

made by the neighborhood descriptors. It is evident that individuals' attitudes are tightly linked to their travel behavior as represented by the mobility measures of this study.

Table 10
Contributions of Attitude Factors to the Goodness-of-Fit of the "Best" Models of Mobility Measures

		Number of			Fraction of		
		Person Trips	Transit Trips	Non-Motorized Trips	Auto Trips	Transit Trips	Non-Motorized Trips
Base Models of Table 6	R^2	.1471	.1184	.0256	.0965	.1319	.0475
	k	10	10	10	10	10	10
Best Models of Table 7	R^2	.1622	.1386	.0306	.1429	.1415	.0664
	k	9	10	3	6	10	6
Best Models Re-estimated with Attitude Data	R^2	.1433	.1503	.0340	.1350	.1287	.0656
	k	9	10	3	6	10	6
Best Models with Attitude Factors	R^2	.1718	.2110	.0946	.2125	.1916	.1308
	k	17	18	11	14	18	14
F of Attitude Factors		2.73	6.10	5.37	7.87	6.17	6.00
d.f.		8, 636	8, 635	8, 642	8, 639	8, 635	8, 639
Significance (* = 5%, ** = 1%)		**	**	**	**	**	**

k = number of slope coefficients in the model.
The base models of Table 6 and the best models of Table 7 are not nested.

The coefficient estimates of these attitude factors summarized in Figure 2 indicate that attitudes and behavior in fact form coherent relationships. For example, in the model for number of transit trips the coefficient of the pro-transit factor is positive and significant (α = 1%) while that of the automotive mobility factor is negative and significant (α = 1%). The pro-environment factor and pro-transit factor both have positive and significant (α = 1%) coefficients and that of automotive mobility is again negative and significant (α = 1%) in the model for number of non-motorized trips. Similar consistent results can be found for the models of fraction of auto trips, fraction of transit trips, and fraction of non-motorized trips. In the last model, the urban villager factor and the pro-environment factor both have significant (at α = 5%) positive coefficients. The results indicate that making walking and cycling trips is strongly and consistently associated with the attitudes one has toward the environment, public transit, and the door-to-door mobility provided by the automobile. Quite interestingly the pro-environment factor is not associated with transit use.

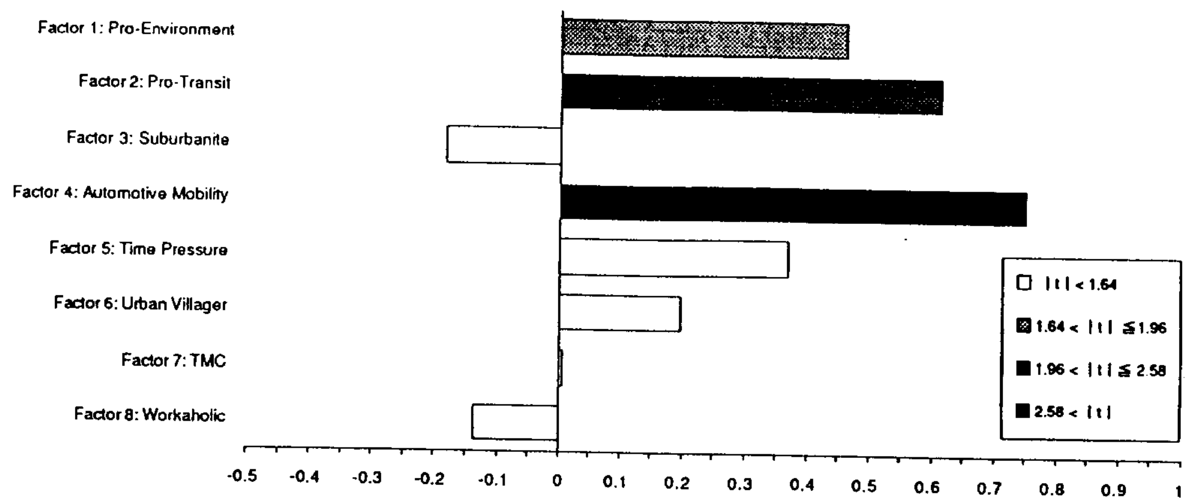
Table 11
Relative Effects of Socio-Economic Factors, Neighborhood Descriptors, and Attitude Factors in the Model for Fraction of Auto Trips

	1. Best Model of Table 7 (re-estimated)		2. Neighborhood Descriptors Excluded		3. Socio-Economic Factors Excluded		4. All Factors	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Intercept	-2.169		-1.005		0.726		-1.611	
Cars per Person	0.551	3.15	0.453	2.64			0.387	2.26
Driver's License	2.275	6.13	2.004	5.45			2.005	5.54
High Education Dummy	0.118	0.77	0.156	1.02			0.138	0.91
Parking Spaces Available	0.104	3.52			0.111	3.70	0.098	3.33
Distance to Nearest Bus Stop	1.137	3.31			0.823	2.39	0.765	2.28
Distance to Nearest Park	0.259	2.61			0.193	1.94	0.224	2.31
Factor 1: Pro-Environment			-0.217	-3.01	-0.166	-2.26	-0.148	-2.05
Factor 2: Pro-Transit			-0.230	-3.32	-0.235	-3.34	-0.222	-3.25
Factor 3: Suburbanite			0.157	2.22	0.062	.85	0.075	1.04
Factor 4: Automotive Mobility			0.472	6.53	0.519	7.14	0.445	6.23
Factor 5: Time Pressure			-0.146	-2.07	-0.115	-1.62	-0.138	-1.98
Factor 6: Urban Villager			-0.145	-1.98	-0.163	-2.18	-0.120	-1.65
Factor 7: TCM			-0.008	-0.11	0.021	0.29	0.027	0.38
Factor 8: Workaholic			0.130	1.79	0.112	1.52	0.120	1.67
R^2	0.1350		0.1818		0.1612		0.2125	
Standard Error of Estimation	1.829		1.785		1.808		1.756	
F	16.83		12.97		11.22		12.32	
D.F.	6, 647		11, 642		11, 642		14, 639	
α	< 0.00005		< 0.00005		< 0.00005		< 0.00005	
F of the Excluded Group	7.87		8.37		13.88		-	
D.F.	8, 639		3, 639		3, 639		-	
Significance (* = 5%, ** = 1%)	**		**		**		-	

The relative effects of the base demographic and socio-economic factors, neighborhood descriptors, and attitude factors are examined using the model for fraction of auto trips for which the attitude factors as a group are most significant. The purpose of this analysis is to show that the neighborhood descriptors do have their own contributions to the model's explanatory power. Yet, their relative effects may be limited.

Figure 2
Coefficients of Attitude Factors

Number of Trips



Number of Transit Trips

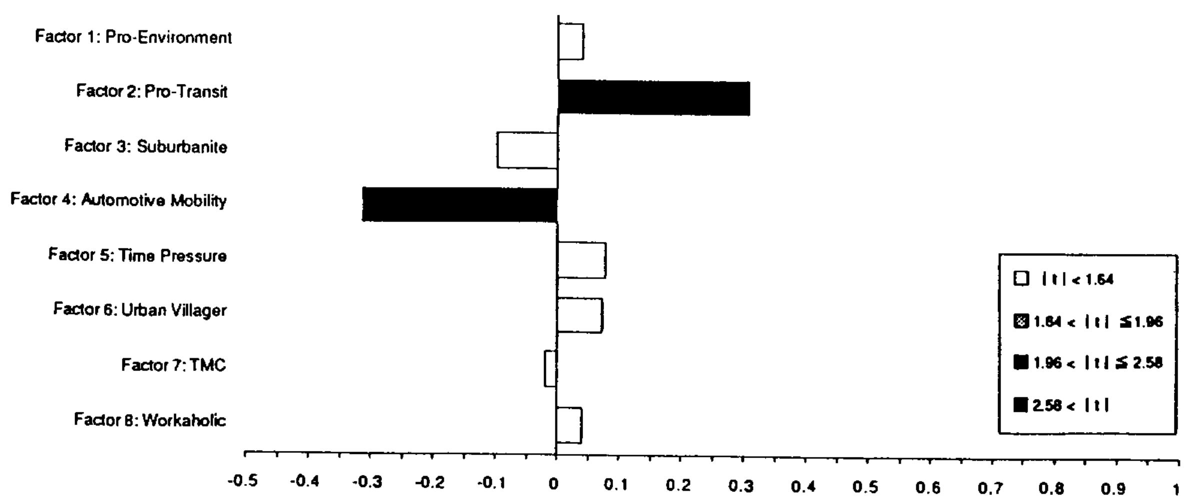
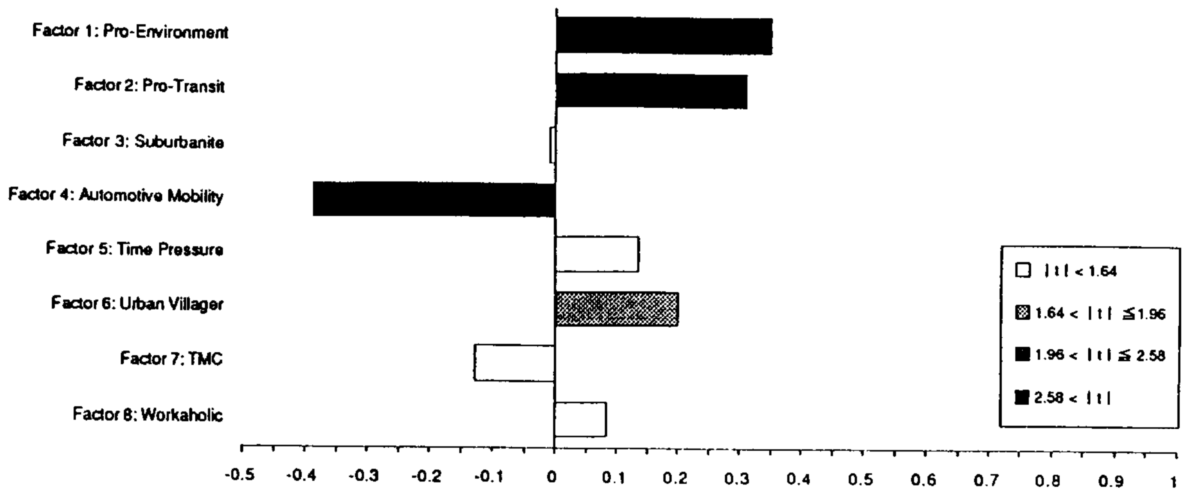


Figure 2
(continued)

Number of Non-Motorized Trips



Fraction of Auto Trips

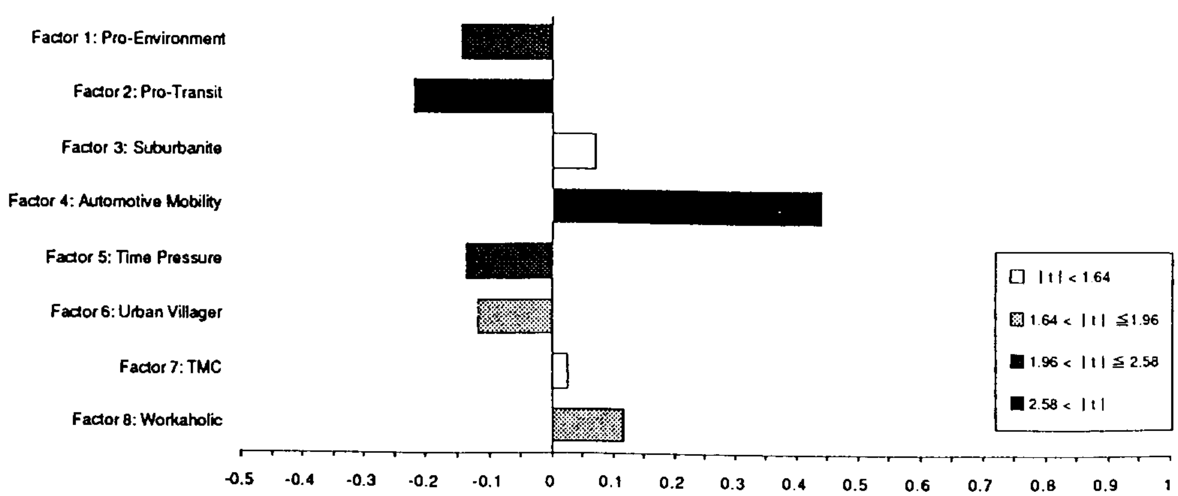
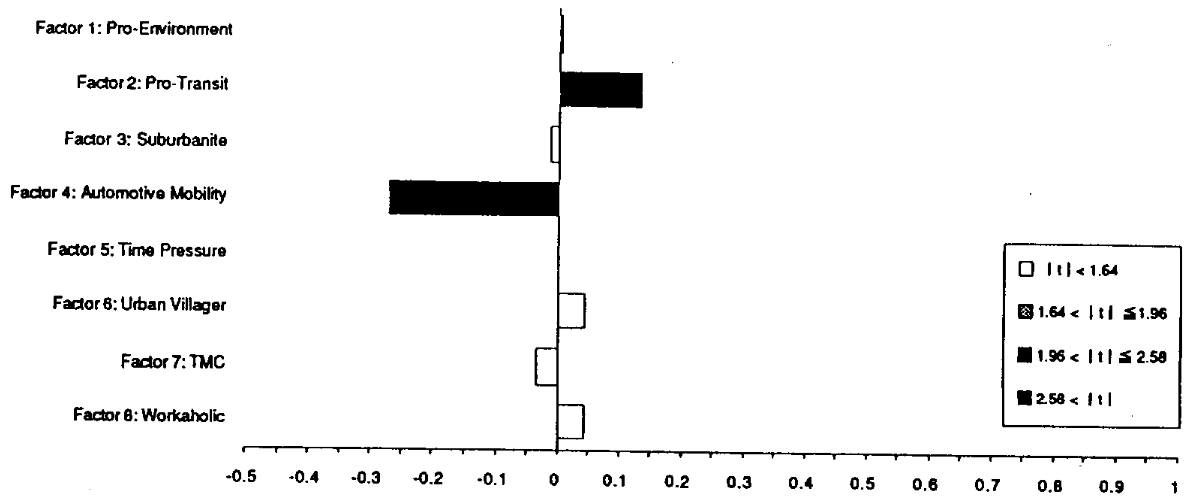
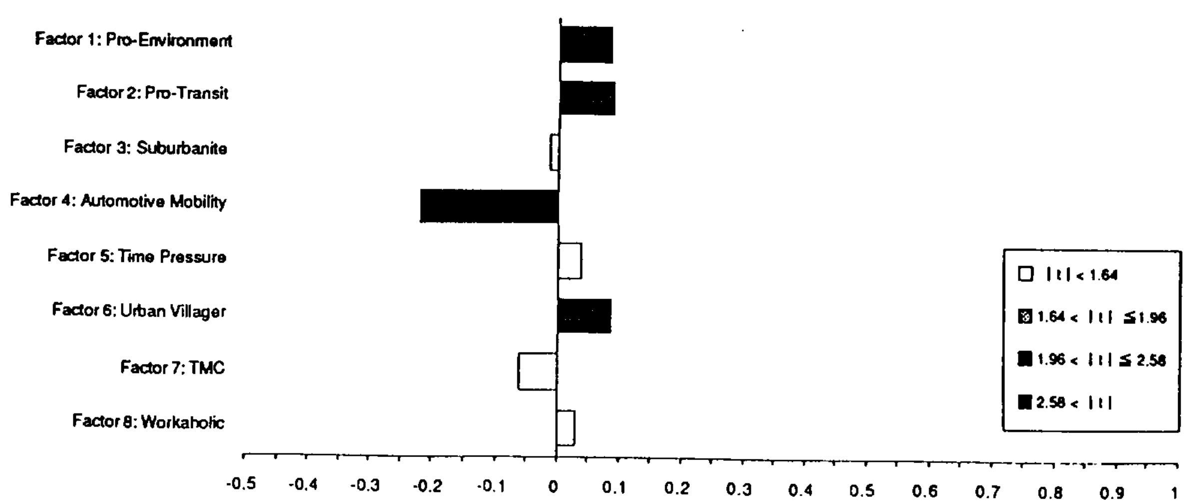


Figure 2
(continued)

Fraction of Transit Trips



Fraction of Non-Motorized Trips



The F-statistics obtained by dropping one variable group at a time from the model with all factors (the last columns) indicate that the socio-economic attributes, the neighborhood descriptors, and the attitude factors are each significant as a group. The explanatory power of the neighborhood descriptors, however, is relatively small. Comparing Model 1 and Model 2 indicates that the neighborhood descriptors account for a much smaller portion of the total variation than do the attitude factors. Comparing Model 2 and Model 3 indicates that the socio-economic variables of the best model account for a larger fraction of variation than do the neighborhood descriptors. Neighborhood descriptors do have their own association with the mobility measure, but the strength of the association is weak relative to that of socio-economic attributes or attitude factors.

The analyses here have made it evident that attitude factors are strongly associated with the travel demand measures used in this study. They contribute significantly to the models' explanatory power in addition to the demographic, socio-economic and neighborhood characteristics variables that are in the best models of Table 7. In particular, the number of trips by travel mode and modal split are both strongly associated with factors that represent individuals' attitudes toward the environment, public transit, automotive mobility, urban forms, and time.

Land use characteristics as represented by the neighborhood descriptors are associated with mobility and offer some explanation of the variation in the mobility measures in addition to that offered by the attitude factors. Their associations with the mobility measures, however, tend to be weaker compared with the associations shown by the attitude factors. One may conclude that attitudes are at least more strongly, and perhaps more directly, associated with travel than are land use characteristics.

6. Summary and Conclusions

This study examined the effects of land use and attitudinal characteristics on travel behavior for five diverse San Francisco Bay Area neighborhoods. The data collected for this project form a rich basis from which these types of effects can be explored. A number of items on the surveys used, not discussed here, relate to lifestyle and activity choices that are likely to be associated with travel behavior and possibly residential location. Other items relate to reasons for using or not using modes other than driving alone to commute to work, reasons for choosing the current residential location, and type of location preference. The travel diary database, which in this study was analyzed with respect to numbers of trips and distributions of trips across modes, can be further analyzed with respect to vehicle-miles traveled, and distribution of trips across purpose, time of day, and geographical location. This paper has reported the results of initial analyses of this rich data base. They can be summarized as follows.

First, socio-economic and neighborhood characteristics were regressed against number and proportion of trips by various modes. The best models for each measure of travel behavior confirmed earlier studies' findings that neighborhood characteristics are statistically associated with amounts of travel and mode split, and add significant explanatory power when socio-economic differences are controlled for:

- Parking availability was negatively associated with the total number of person trips.
- Having a backyard and the distances to the nearest rail station and park were negatively correlated with both the number and fraction of transit trips.
- Access to BART and having sidewalks were positively associated with the number of non-motorized trips.
- High density was positively, and distances to the nearest bus stop and park were negatively, correlated with the fraction of non-motorized trips.
- Parking availability and the distances to the nearest bus stop and park were positively associated with the fraction of auto trips.

In two of the six best models, those for number of person trips and number of non-motorized trips, a dummy variable for the North San Francisco neighborhood was significant and positive, indicating the unique nature of this area. For the most part, these relationships are consistent with prior hypotheses.

Second, 39 attitude statements relating to urban life were factor analyzed into eight factors: pro-environment, pro-transit, suburbanite, automotive mobility, time pressure, urban villager, TCM, and workaholic. Scores on these factors were introduced into the six best models discussed above. The relative contributions of the socio-economic, neighborhood, and attitudinal blocks of variables were assessed. While each block of variables offers some significant explanatory power to the models, the power of the attitudinal variables was the strongest, i.e. they explained the highest proportion of the variation in the data.

It may be concluded that attitudes are certainly more strongly, and perhaps more directly, associated with travel than are land use characteristics. This suggests that land use policies promoting higher densities and mixtures may not alter travel demand materially unless residents' attitudes are also changed. It will be important in the future, then, to determine:

- how these attitudes are formed,
- how they interact with travel experience,
- how they are related to the choice of residential and job location, housing unit, and vehicle ownership,
- how the observed associations between attitudes and neighborhood characteristics are formed, and
- how attitudes can be affected by land use policy.

The questions raised above are not all new. Yet the analytical results of this study point to the urgent need to revisit these issues for a more thorough understanding of the relationship between land use and travel. Such an understanding is central to the formation of effective land use policy directed toward the improvement of the environment and mobility.

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