BART @ 20 Series

Rail Access Modes and Catchment Areas for the BART System

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The University of California Transportation Center

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1. INTRODUCTION

To date, far more research has been conducted on the effects of the built environment on transit demand along mainline corridors than in the catchment zones surrounding transit stops. Pushkarev and Zupan (1977), for example, correlated transit ridership for the line-haul segment of trips as a function of residential densities, distance to downtown, and size of downtown; however, they ignored how access trips to transit stops were influenced by such factors. Seminal work by Meyer, Kain, and Wohl (1965) studied factors influencing bus and rail transit demand for three segments of trips — residential collection-distribution, line-haul, and downtown circulator — however, their work did not examine the direct effects of land-use variables. For example, in the case of access trips from home to rail stations, or what they call the residential collection-distribution segment, the number of "trip origins per city block" was used as the predictor of access demand. Standard trip generation rates were used to directly estimate access demand.

As part of the BART@20 study, this report studies the influence of the built environment on two aspects of transit demand: (1) modes of access to and from rail stations; and (2) the sizes and shapes of the ridership catchment areas. Variations in both modes of access and catchment area sizes are studied for different classes of stations, defined mainly in terms of the land-use environment. Also, both descriptive statistics and analytical models (ANOVA and regression) are used for examining these relationships.

2. WHY STUDY ACCESS TRIPS AND CATCHMENT ZONES?

It is important to study transit access trips and catchment areas for a number of reasons. One, in many suburban areas served by rail systems, the private automobile is predominantly used to reach stations. From an air quality standpoint, transit riding does little good if most people use their cars to reach stations. For a three-mile automobile trip, the typical distance driven to access a suburban BART park-and-ride lot, around 84 percent of hydrocarbon (HC) emissions and 54 percent of nitrogen oxide (NOx) emissions are due to cold starts (inefficient cold engines and catalytic converters during the first few minutes of driving) and hot evaporative soaks (Barry and Associates, 1991). That is, a sizeable share of the tailpipe emissions of the two main precursors to photochemical smog formation occur from turning the automobile engine on and off. Drive-alone access trips to rail stations, regardless how short they are, emit levels of pollutants that are not too much below those of the typical 10-mile solo commute. Rail trips that rely on park-and-ride access do very little to improve air quality.

It is clear that the built environment, along with parking provisions, has a significant influence on rail access trips, but to what degree remains unclear since little systematic work has been carried out to date on this question. In general, we know that as densities fall and distances to downtowns increase, people increasingly rely on mechanized means to reach stations. In downtowns, most people reach transit stops by foot. In 1992, for instance, over 60 percent of rail users walked to downtown BART stations (BART, 1993). As one leaves downtown stations and heads outward, the share of walk-on trips falls steadily, replaced by access trips made by some mechanized mode — normally, park-and-ride, kiss-and-ride, and bus-and-ride. In the case of BART stations, like Ashby and Glen Park, that lie in fairly built-up, urbanized areas but that have park-and-ride facilities, around 50 percent of customers reach stations by car, 8 percent ride a bus, and 37 percent arrive by foot. And at suburban stations, like Walnut Creek and Fremont, upwards of 85 percent of access trips by BART are by passenger car, and fewer than 5 percent are by foot or bicycle travel. Studies in greater Washington, D.C., metropolitan Toronto, and the Bay Area show that beyond one mile of a suburban rail station, around 60 to 80 percent of access trips are by automobile, with the share steadily rising with access distance (Stringham, 1982; JHK and Associates, 1986, 1989; Cervero, 1993; BART, 1993).

Creating places that are more conducive to pedestrain, bicycle, and bus transit access to rail stops would make environmental contributions beyond improving air quality. Reduced automobile access trips would also help reduce the emission of greenhouse gases and such precursors to acid rain as sulfur dioxide (SO2). More non-motorized access trips would also reduce energy consumption to the same degree they eliminate tailpipe emissions. The objectives of linking land development and transportation programs for the purposes of promoting national air quality, energy, and related environmental benefits are embodied in a series of recently adopted national legislative acts, including the 1990 Clean Air Act Amendments, the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), and the 1992 National Energy Policy Act.

The encouragement of alternatives to the automobile for accessing transit stops is also consonant with emerging community design concepts, such as traditional neighborhood development (TND) and "new urbanism." A growing legion of urban designers, such as Solomon (1992), Calthorpe (1993), and Katz (1993), call for designing new communities like those of yesteryear. They contend that encouraging more human-scale, compact development, returning to conventional gridiron street forms, narrowing street widths and building setbacks, and landscaping for pedestrian movements will reduce the dominance of the automobile and reduce dependence on it. The goal of linking transit facilities to community development is also embodied in the Liveable Communities program recently initiated by the Federal Transit Administration.

Overall, research that establishes relationships between built environments and modes of access could prove valuable in influencing future land planning, neighborhood and pedestrian facilities designs, and bus transit service deployment in the vicinity of rail stations. Recent laws and mandates have created a receptive policy environment for promoting stronger linkages between neighborhood development and transit services, making research in the areas all the more timely.

3. RESEARCH FOCUS

The following research questions are addressed in this study:

1. Modes of access to and from rail stations, and the shapes and sizes of ridership catchment areas, vary systematically by class of transit station area. Catchment areas increases in size and automobile access increases in shares in lower-density, more suburban areas. Station catchment areas increase as densities decline, park-and-ride facilities increase, distances from the CDB increase, and wherever a station is a terminus.
2. Station catchment areas are larger when surrounded by residential than by commercial/ office land uses. Mixed land use environments are associated with more compact catchment areas.
3. Walking is the dominant mode for access trips under 2,500 feet, or around one-half mile. Bus access is used most frequently for access trips 1.5 to 4 miles in length. Beyond one-half mile, the private automobile is the dominant access mode for stations with park-and-ride facilities.
4. For egress trips from stations in downtowns and highly urbanized areas, walking is the dominant mode up to a distance of around three-quarters mile. Beyond this distance, bus transit is the predominant egress mode.
5. The shares of non-auto access and egress trips to and from rail stations increase with density and levels of land-use mixture, controlling for other factors like parking supply.

The hypotheses tested on the effects of the built environment on the spatial dimensions of the catchment area is reflected by the drawing in Figure 1. In this figure, for a single class of station (such as suburban ones with no parking facilities, as suggested in Figure 1), the catchment radius for walk-access trips is thought to extend farther out as residential densities increase, the amount of non-residential activities increases, and the quality of the pedestrian environment rises.

The hypotheses on the effects of the built environment on the modal distributions of access trips are reflected by Figure 2. In both drawings, walk shares are presumed to drop precipitiously with distance. For access trips from residences to rail stations, park-and-ride access is assumed to eclipse walk access at distances of around one-half mile. In lower density settings, auto access might dominate at an even shorter distance, like one-quarter mile. These benchmarks are based on research by Untermann (1984) and others who have recorded the maximum distances Americans are willing to walk -- generally in the range of one-quarter to a half of a mile, though research shows acceptable walking distances can be stretched considerably (perhaps as much as doubled) by creating pleasant, interesting urban spaces and corridors. As an access mode, bus transit's market niche is thought to be primarily in the one- to 2.5-mile range. For

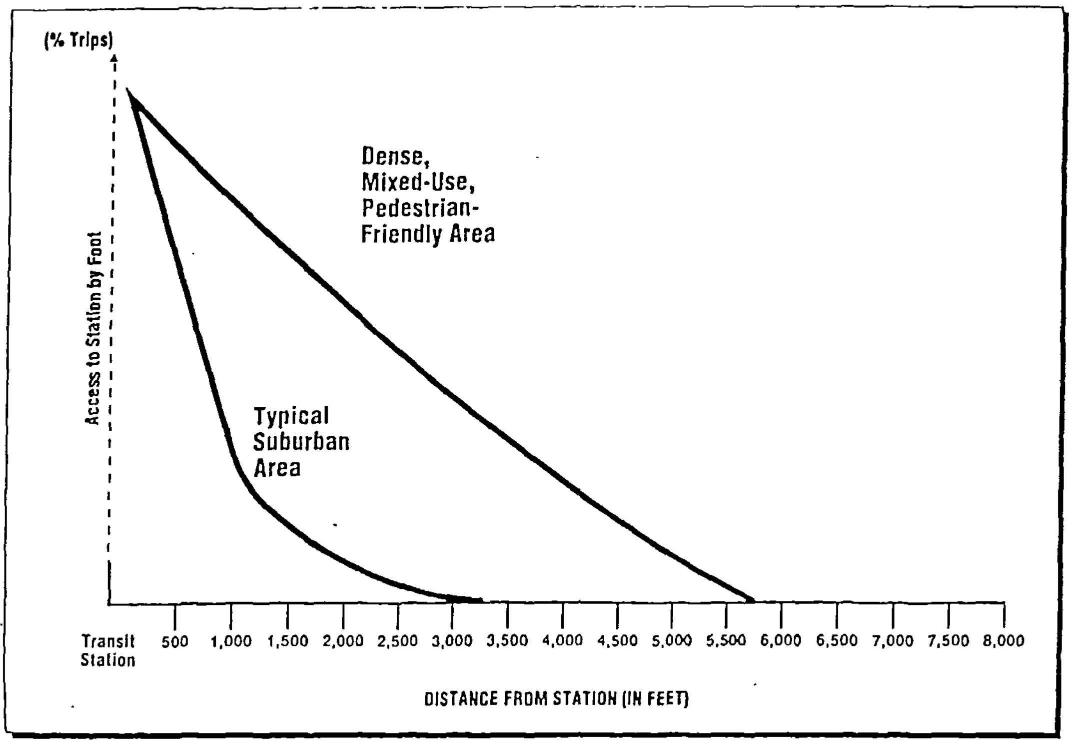


Figure 1. Hypothesized Effect of Neighborhood Design on Pedestrian Access to Stations

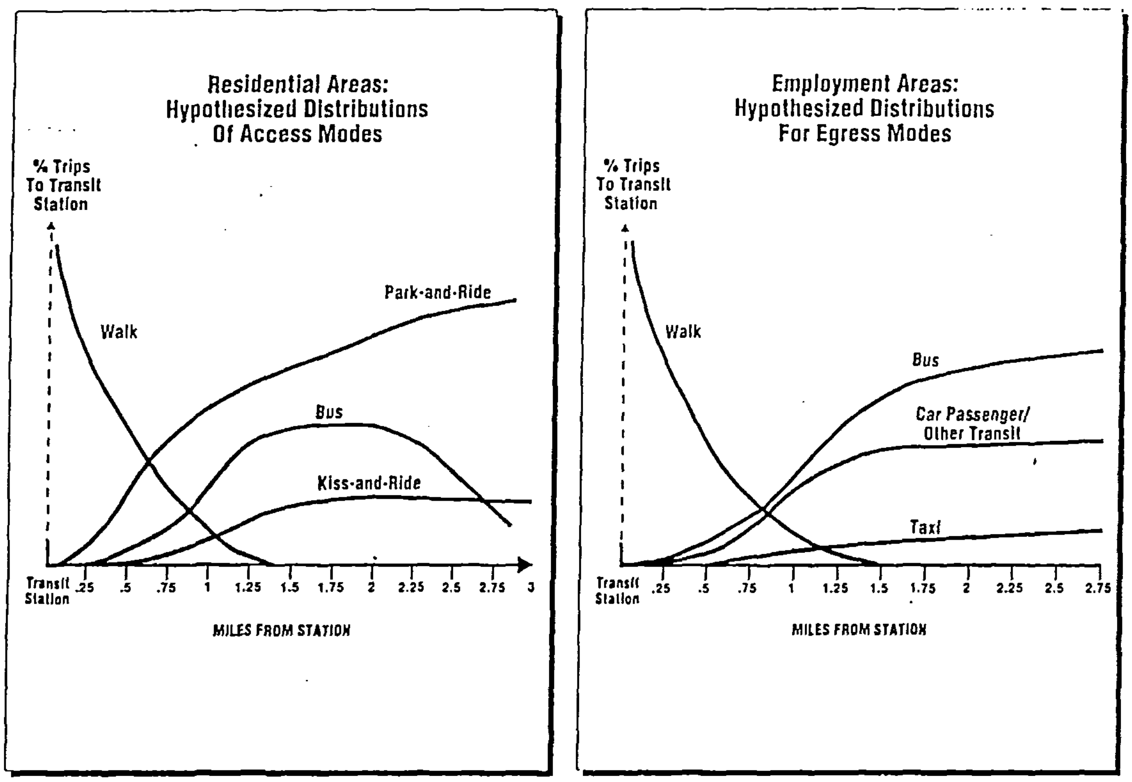


Figure 2. Hypothesized Distributions of Rail Station Access Modes
as a Function of Distance to Stations

egress trips from a rail station to one's work site, Figure 2 shows that bus transit or other surface modes are thought to predominate beyond three-quarters of a mile. The absence of private car accessibility at exit stations leaves many with few other options than to walk or take bus transit to their destinations.[1]

For the most part, these are original research questions which have not been systematically addressed to date. In a study of access trips to rail stations in Toronto and Edmonton, Stringham (1982) carried out the most in-depth work on these topics so far. Stringham found the "walking impact zone" to be as far as 4,000 feet from rail stations in Toronto, suggesting more compact, mixed-use urban environments are indeed associated with relatively large walk-on catchment areas. His work established that shares of access trips made by park-and-ride modes increased with distance. Stringham did not, however, study how access modes varied as a function of class of station area or directly as a function of land-use environments.

4. DATA SOURCES AND RESEARCH APPROACH

The primary data source used for carrying out this analysis was a survey of trips made by around 35,000 BART passengers, conducted in late-October 1992. The on-board passenger survey compiled data for individual BART trips, including the origin and destination station, trip purpose, time-of-day, fare paid, and various characteristics of the access trip. Information was available on the nearest street intersection where access trips to BART stations originated as well as the nearest intersection to which egress trips from BART stations ended. This fine-grain resolution of origin-destination data allowed fairly precise estimates of the straightline distance of access and egress trips to be estimated. Additionally, data on the modes, purposes, and times-of-day of access and egress trips were also available. For further information on the 1992 BART passenger profile survey, see BART (1993).

The principal land-use data used in this research was a 1990 digital inventory of dominant land uses within hecatre grid cells (100x100 meters), compiled by the Association of Bay Area Governments (ABAG) for the entire San Francisco Bay Area. Using the ArchInfo Geographic Information Systems (GIS) package, buffers were created to generate fairly precise estimates of the composition of land uses within a one-half-mile radius of all 34 BART stations.[2] While the ABAG inventory compiles data for over 40 individual land uses, these categories were collapsed into six major ones: residential, commercial, industrial/office, public, vacant, and other.

In testing the research hypotheses, several approaches were taken. BART ridership data supported the analysis of access and egress trips and from stations as functions of trip distance. For purposes of studying how access and egress trips varied by land-use environment, cluster analysis was used to classify stations with similar land-use characteristics, defined in terms of density and land-use composition. Residential and employment densities were estimated for block groups and census tracts surrounding each station, using 1990 census data from Summary Tape File (STF) 3-A and the Census Transportation Planning Package (CTPP) for the San Francisco Bay Area.[3] Land-use compositions were based on the 1990 ABAG inventories. These data were supplemented by other information compiled from various primary and secondary sources, such as the supply of parking at each station (from BART records) and whether stations were situated in freeway medians (supplied from field observations). Once stations were classified, differences in access modes were studied across classes of stations.

In examining areas around which transit ridership is drawn, catchment areas were defined as contiguous census tracts which encompass the origins of 90 percent of all access trips to BART stations (or destinations of 90 percent of all egress trips from stations). Additionally, catchment areas for walk-on trips were defined as the contiguous census tracts encompassing the origins of 90 percent of all access trips made by foot. This second catchment represents, we believe, an area that corresponds to the zone of transit-oriented development around stations. The very fact that rail customers are willing to walk to stations from these areas suggests that, whether because of design, proximity, or a combination of the two, development is reasonably well-oriented to rail stations.[4] Defined catchment areas for each station are portrayed using GIS outputs. These outputs provide some understanding of how catchment areas vary in shape and size. Additionally, the average radius of catchment areas were estimated and compared across each class of station.[5]

Last, for testing the hypotheses on how built environments influence access trips, several regression equations were estimated that predict the percent of various access modes as functions of urban densities, land-use compositions, and various control variables (e.g., supply of parking, distance of station to downtown San Francisco, presence of freeway median). In estimating modes, cases consisted of BART stations and a data base was constructed using the various data sources described in this section.

5. STATION CLASSIFICATIONS

The analyses of how access modes and catchment areas vary relied on constructing a meaningful typology of BART station environments. The land-use settings of BART stations are not alike. Some are in dense, downtown areas, some are in predominantly residential suburban communities, some are in the medians of freeways, some include acres of parking, and some have no parking. At least in part, modes of access and egress to and from BART stations and the influences of distance on rail access trips will depend on features of the built environment around rail stops.

The process of classifying objects, be they rail station areas, cities, or insects, involves two steps: (1) selecting a set of variables which define the dimensions along which stations areas will be grouped (e.g., densities, parking supplies); and (2) applying a clustering algorithm. Each of these steps is discussed below.

5.1. Grouping Variables

Variables which defined the land-use and physical environments around BART stations were used for grouping stations into classes. Table 1 lists the variables initially considered. Land use variables gauged

Table 1. Candidate Variables for Classifying BART Stations

Land use characteristics	
Resdens	Residential density, in dwelling units per acre in 1990. Measured for census tracts and block groups that encompass a one-half-mile radius around station. Source: 1990 census STF 3-A.
Popdens	Population density, in population per acre in 1990. Measured for census tracts and block groups that encompass a one-half-mile radius around station. Source: 1990 census STF 3-A.
Empdens	Employment density, in employees per acre in 1990. Measured for census tracts and block groups that encompass a one-half-mile radius around station. Source: 1990 Census Transportation Planning Package, Part II, Metropolitan Transportation Commission.
Commercial	Proportion of land area in commercial use for one-half-mile radius around station. Source: 1990 Association of Bay Area Governments land use inventory.
Industrial	Proportion of land area in industrial or office use for one-half-mile radius around station. Source: 1990 Association of Bay Area Governments land use inventory.
Residential	Proportion of land area in residential use for one-half-mile radius around station. Source: 1990 Association of Bay Area Governments land use inventory.
Entropy	Index of land-use mixture. Relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i, and k = number of land-use categories; ranges between 0 and 1, where 0 signifies land devoted to a single use and 1 signifies all land area evenly spread among all uses.
Domlan	Dominant land use category: 1=residential, 2=commercial, 3=industrial/office, 4=public, 5=other. Source: 1990 Association of Bay Area Governments land use inventory and field observations.
Vclnd	Vacant/developable land within one-half-mile of station: 1=low (< 10 percent of land area, 2=medium (10-25 percent land area), 3=high (>25 percent of land area). Source: 1990 Association of Bay Area Governments land use inventory and field surveys.
Station Characteristics	
Fwypx	Freeway proximity, where limited-access freeway lies the following distances from stations: 1 = 0-0.5 miles, 2 = 0.5-1.0 miles, 3 = 1.0-2.0 miles, 4 = > 2 miles. Source: Thomas Brothers Maps, 1994.
Fwymd	Freeway median station location: 1=yes, 0=no. Source: Field observations.
Parking	Park-and-ride spaces at station, surface and structured. Source: BART Systemwide Parking Inventory, 1993.
Stnfn	Station function: 1=transfer, 2=terminal, 3=other. Source: BART system map.
Ridership Characteristics	
Dayexits	Average weekday exists, 1992 (January-December). Source: BART planning department.
BARTcm	BART commutes as a percent of total journeys-to-work made by employed-residents living within one-half-mile radius of station. Measured for census tracts and block groups that encompass a one-half-mile radius around station. Source: 1990 census STF-3A.
Neighborhood Characteristics	
Income	Annual household income for households within one-half-mile radius of station, 1990. Measured for census tracts and block groups that encompass a one-half-mile radius around station. Source: 1990 census STF-3A.
Redis	Redevelopment district encompasses station: 1 = yes, 0 = no. Source: interviews with local planning departments.
Speczone	Special zoning in station area: 0 = none, 1 = incentive zoning (e.g., density bonuses), 2 = restrictive zoning (e.g., downzoning of densities). Source: local planning departments.

the densities, compositions, and levels of mixture of activities, generally for a one-half-mile radius around stations. Other grouping variables measured characteristics of stations (e.g., parking supplies), ridership (e.g., rail modal splits), and neighborhoods (e.g., household incomes). Table 2 presents a matrix of data values for the grouping variables for each of the 34 stations.

Table 2. Station Characteristics: BART System

Station	Res-density	Fwy-px	Fwy-md	Stnfn	Day-exits	BART-cm	Dom-lan	Park-ing	Yclnd	Emp-density	Popden-sity	Redis	Pec-zone	Com-mercial	Indus-trial	Resi-dential	Entropy
Rockridge	8.6	1	1	3	4,016	10.7	1	889	3	7.0	18.0	0	2	0.0900	0.0604	0.7162	0.5456
MacArthur	8.1	1	1	1	4,407	9.5	1	609	3	5.5	18.9	0	0	0.1808	0.0687	0.5467	0.7524
W. Oakland	5.5	2	0	3	3,722	8.5	1	424	2	2.4	15.9	0	0	0.2010	0.1519	0.2365	0.9033
19th St. Oak.	7.9	1	0	3	7,855	15.2	3	0	3	64.8	11.5	0	0	0.3429	0.1004	0.3829	0.8029
Oak. City Ctr.	7.3	1	0	1	9,534	6.6	3	0	3	52.2	20.4	1	0	0.3032	0.1164	0.2753	0.9257
Lake Merritt	12.1	1	0	3	3,549	11.5	3	205	3	23.4	21.8	0	0	0.3637	0.1312	0.2669	0.8723
Fruitvale	5.0	1	0	3	5,741	7.7	2	1,103	3	4.4	18.1	0	0	0.3405	0.0903	0.5118	0.6349
Coliseum	3.6	1	0	3	5,571	3.5	3	1,059	2	2.6	12.5	0	0	0.2289	0.0848	-.3252	0.9013
N. Berkeley	10.1	3	0	3	3,181	10.0	1	840	3	7.7	20.8	0	2	0.1523	0.0601	0.7274	0.1533
Berkeley	14.1	4	0	3	10,055	10.8	2	0	3	24.4	23.0	0	0	0.1534	0.1862	0.6443	0.5304
Ashby	11.3	3	0	3	3,104	9.5	2	626	3	4.1	23.4	0	2	0.1762	0.0525	0.7259	0.4905
San Leandro	6.0	2	0	3	3,937	9.9	3	1,295	3	4.8	12.1	1	0	0.1233	0.0732	0.4480	0.7133
Bay Fair	6.3	2	0	3	5,247	7.2	1	1,903	3	3.5	14.7	0	0	0.2063	0.1005	0.6136	0.6250
Hayward	4.1	3	0	3	4,890	3.7	2	1,061	2	7.2	10.4	1	0	0.2084	0.1266	0.5912	0.6241
S. Hayward	4.0	3	0	3	2,845	9.5	1	1,307	3	1.1	14.2	0	0	0.1294	0.0992	0.4252	0.7332
Union City	2.2	4	0	3	3,807	1.1	3	1,218	2	2.1	6.5	1	0	0.0933	0.0521	0.4587	0.7899
Fremont	4.9	4	0	2	5,674	4.9	5	2,494	2	1.5	12.7	0	0	0.2221	0.1585	0.3399	0.7530
Pleas. Hill	4.8	1	0	3	6,088	16.9	1	3,245	1	4.1	8.6	1	1	0.1391	0.0671	0.7477	0.4548
Concord	2.8	2	0	2	7,730	13.0	1	1,975	3	1.6	7.6	1	0	0.1993	0.1211	0.6325	0.5911
Walnut Creek	5.3	1	0	3	5,308	13.7	3	1,518	3	19.0	9.0	0	0	0.2517	0.0392	0.6017	0.6105
Lafayette	0.7	1	1	3	3,179	13.6	1	1,521	3	0.5	1.7	0	0	0.1027	0.0482	0.5633	0.6494
Orinda	2.0	1	1	3	2,951	5.3	1	1,380	3	0.2	4.2	0	0	0.0334	0.0148	0.5058	0.5854
Richmond	5.9	2	0	2	2,704	10.7	1	796	1	4.3	17.7	1	1	0.1777	0.0909	0.6453	0.5686
EC del Norte	4.9	1	0	3	7,387	14.4	1	2,516	3	2.2	12.3	1	0	0.1089	0.1474	0.6318	0.6455
El Cerrito (EC)	6.6	2	0	3	3,769	15.6	1	795	3	4.9	14.1	1	0	0.1153	0.1303	0.6834	0.5774
Embarcadero	11.4	2	0	3	26,966	2.4	3	0	3	156.0	20.3	0	0	0.4456	0.0438	0.2046	0.7953
Montgomery St.	4.8	2	0	3	28,080	2.3	3	0	3	234.0	9.7	0	0	0.4109	0.0361	0.2489	0.7967
Powell St.	23.6	2	0	3	17,413	4.8	3	0	3	86.0	46.9	0	0	0.4503	0.0492	0.2105	0.7705
S.F. Civic Ctr.	42.1	2	0	3	12,931	6.0	3	0	3	75.0	75.7	0	0	0.4406	0.0382	0.2414	0.7537
Mission 16th St.	22.0	2	0	3	5,963	15.2	2	0	3	22.6	53.2	0	2	0.2548	0.0402	0.4685	0.7287
Mission 24th St.	21.6	2	0	3	8,659	12.0	1	0	3	16.1	63.6	0	2	0.1154	0.0445	0.7226	0.5529
Glen Park	10.3	1	0	3	5,795	15.4	1	55	3	2.4	27.4	0	2	0.0320	0.0276	0.8036	0.4319
Balboa Park	8.5	1	0	3	10,001	13.5	1	0	3	4.4	26.7	0	2	0.0440	0.0772	0.8067	0.4167
Daly City	7.8	1	0	2	10,250	8.7	1	2,228	2	2.5	28.6	0	0	0.0895	0.1328	0.5941	0.6828

Sources: BART, Thomas Bros. Maps, 1990 US Census, ABAG, MTC.

5.2. Classification

The grouping of the 34 BART stations into homogenous classes was carried out using cluster analysis. The process involved combining cases into clusters on the basis of their "nearness" to each other when expressed as squared Euclidean distances.[6] Using the technique of agglomerative hierarchical clustering, clusters were sequentially formed by grouping cases into even larger clusters until all cases were members of a single cluster.[7]

A number of combinations of variables were attempted in creating decipherable and intuitive appealing clusters. Because of high collinearity among variables, employing all variables would have introduced unnecessary redundancy and overemphasized certain variables. The most satisfactory results were obtained by using the following variables:

- Employment density (workers/acre)
- Residential density (households/acre)
- Percent of station area devoted to residential land uses
- Entropy index of land-use mixture

- Parking supply, based on an ordinal scale of 0 to 4.
- Annual household income, in $1,000s
- Percent of commutes by station-area employed-residents by rail

All of these variables were drawn directly from the data base shown in Table 2 except for the variable measuring parking supply. Because of the large variation in parking supplies, with around one-third of stations having no parking and some stations having several thousand spaces, the use of original parking variable dominated all other variables in the formation of clusters.[8] The revised ordinal parking variable was scaled as follows: 0 = no parking, 1 = 1 to 1,000 spaces, 2 = 1,001 to 2,000 spaces, 3 = 2,001 to 3,000 spaces, and 4 = > 3,000 spaces.

The results of the cluster analysis are summarized in the hierarchical graph, called a dendogram, show in Figure 3. This shows the clusters being sequentially combined and the normalized values of the

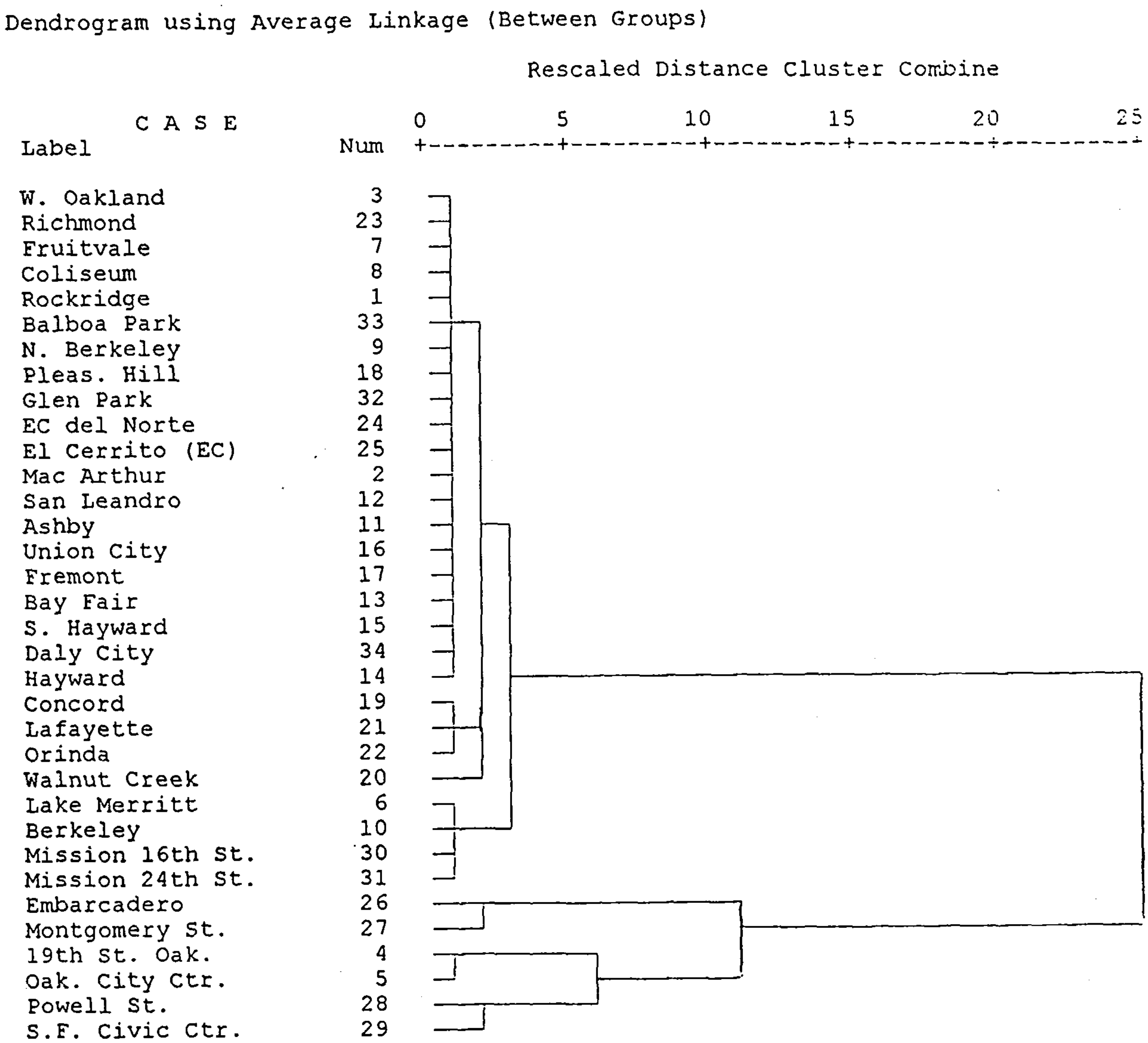


Figure 3. Dendogram for Classifying BART Stations by Land-Use Environment

coefficients (i.e., squared Euclidean distances) at each step. The judgemental part of cluster analysis is deciding at what stage to stop joining clusters. This is normally done when the distance coefficients dramatically increase from on agglomeration to another, or when an intuitive number, normally 4 to 6, of clusters have been formed. For this analysis, six station classes were considered to be the maximum acceptable. Six classes were formed between the 24th and 25th stages of merging clusters. This provided an intuitive and interpretative grouping of stations. The following six station classes were formed, with the BART stations that grouped into each class also listed:

San Francisco Office Center: Embarcadero and Montgomery
San Francisco Commercial/Civic Center: Powell and Civic Center
Downtown Oakland: City Center (12th Street) and 19th Street
Urban Districts: Lake Merritt, Berkeley, Mission 16th Street, and Mission 24th Street
Suburban Centers: Lafayette, Orinda, Walnut Creek, Pleasant Hill,[9] and Concord
Low-Density Areas: MacArthur, West Oakland, Rockridge, Fruitvale, Coliseum, San Leandro, Bay Fair, Hayward, South Hayward, Union City, Freemont, Ashby, North Berkeley, El Cerrito Center, El Cerrito del Norte, Richmond, Glen Park, Balboa Park, and Daly City.

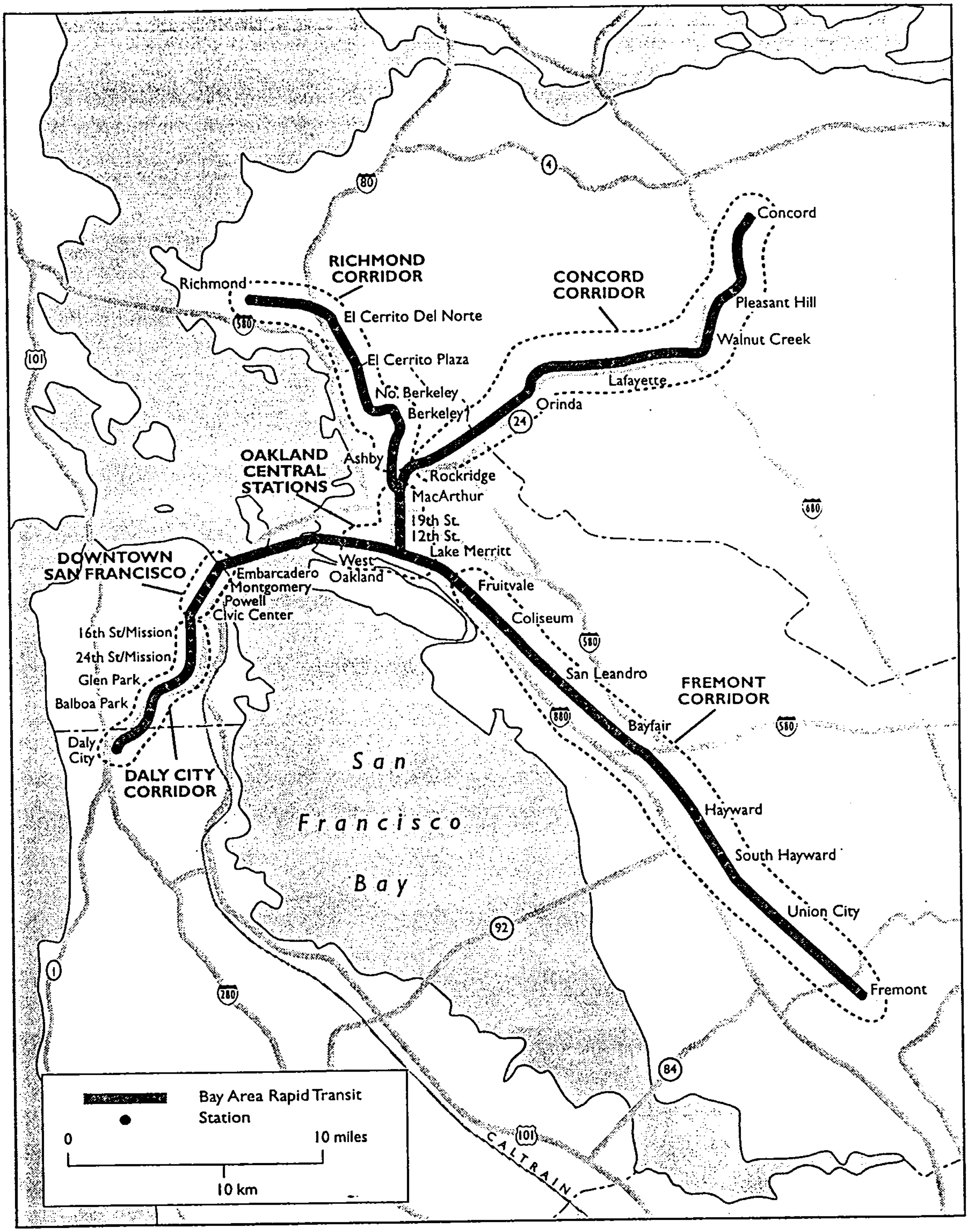
(See Map 1 for a map showing the locations of each station on the BART system.)

Table 3 suggests why these particular titles were chosen for describing the six station classes; it presents the means, standard deviations, and low-to-high ranges of the seven variables used in forming clusters. The homogeneity of cases in each cluster is reflected by the low standard deviations relative to means (i.e., low coefficients of variation) for most variables. The distinctiveness of clusters is reflected by the relative large differences in means for variables across the six groups.[10]

5.3. Station Classes

The following six station classes are presented in hierarchical order based on their level of urbanization. Level of urbanization is perhaps best reflected by the descending employment densities across these station classes. Other distinguishing land-use features of each station class are also highlighted in this section.

- San Francisco Office Center: These two stations — Embarcadero and Montgomery — serve the heart of downtown San Francisco's high-rise office and financial district, surrounded by the tallest buildings in the Bay Area. They are characterized by extremely high employment densities, with relatively little housing nearby (reflected by the low percentage of residential land area). The relatively modest residential densities reflect relatively few dwelling units per gross acre. (On a net residential acreage basis, densities would be fairly high.) They have a moderate level of mixed uses owing to the presence of some restaurants and retail services in the area. Average household incomes within a half mile of the stations are fairly high. These stations have no parking; however, they have the highest levels of connecting transit services, including diesel and trolley buses, cable cars, light rail transit, trams, and ferry services. Relatively few employed-residents in the area commute by rail in large part because many can walk to their jobs.



Map 1. Map of the BART System

Table 3. Characteristics of the Six BART Station Classes

	Class of BART Station					
	San Francisco Office Center	San Francisco Commercial/ Civic Center	Downtown Oakland	Urban Districts	Suburban Centers	Low-Density Areas
Density						
Employment Density (workers/acre)						
Mean (std. dev.)	195.0(58.2)	80.5(7.8)	58.5(8.9)	21.6(3.8)	5.1(7.9)	3.9(1.9)
Range	156.0-234.0	75.0-86.0	52.1-64.8	16.1-24.4	0.2-18.9	1.1-7.7
Residential Density (dwelling units/acre)						
Mean (std. dev.)	8.1(4.7)	32.8(13.1)	7.6(0.5)	17.4(5.1)	3.1(1.9)	5.7(2.7)
Range 4.8-11.4	23.6-42.1	7.2-7.9	12.1-21.9	0.7-5.3	2.2-11.3	
Land Use						
Percent Land Area Residential						
Mean (std. dev.)	22.7(3.1)	22.6(2.2)	32.9(7.6)	52.6(20.3)	61.0(9.1)	57.5(16.1)
Range	20.5-24.9	21.0-24.1	27.5-38.3	26.7-72.3	50.6-74.8	23.6-80.7
Mixture of Use (relative entropy[1])						
Mean (std. dev.)	.796(.001)	.762(.011)	.864(.087)	.671(.168)	.578(.073)	.647(.139)
Range	.795-.796	.753-.771	.803-.926	.534-.872	.454-.649	.417-.903
Other Characteristics						
Parking Spaces at Station						
Mean (std. dev.)	0(0)	0(0)	0(0)	51(103)	1928(770)	1116(725)
Range	0-0	0-0	0-0	0-205	1380-3245	0-2516
Annual Household Income ($1000, 1990)						
Mean (std. dev.)	39.4(5.6)	31.0(4.2)	15.1(1.4)	20.2(3.6)	37.4(7.1)	22.4(7.8)
Range	35.4-43.5	28.2-34.1	14.4-15.7	16.8-25.3	26.4-44.1	9.2-35.1
Percent Residents Commuting by BART, 1990						
Mean (std. dev.)	2.38(.16)	5.42(.85)	10.90(6.07)	12.36(1.98)	12.49(4.32)	9.16(3.98)
Range	2.27-2.50	4.82-6.01	6.61-15.20	10.82-15.16	5.26-16.88	1.11-15.60

[1]relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i, and k = number of land-use categories; ranges between 0 and 1, where 0 signifies all land devoted to a single use and 1 signifies all land area evenly spread among all uses.

- San Francisco Commercial/Civic Center: These two stations — Powell and Civic Center — represent the remaining downtown San Francisco stations, serving the region's major shopping district (Powell) and institutional-cultural complex (Civic Center). They have relatively high employment densities (though much lower than the Office Center stations) and by far the highest residential densities of all station classes. Still, relatively little land area around these stations is devoted to housing. As part of the downtown, these stations rate fairly high in terms of the levels of mixed uses. They have no parking but like the Office Center enjoy high levels of surface transit connections.

- Downtown Oakland: These two stations — City Center (12th Street) and 19th Street — serve the Bay Area's second-tier urban center, downtown Oakland. Employment densities in downtown Oakland fall below those of downtown San Francisco, but are considerably above those of the remaining Bay Area. Downtown Oakland is less segmented than downtown San Francisco, with office, retail, and services intermingled; this is reflected by the high relative entropy index, signifying a rich mixture of land uses. Compared to downtown San Francisco, downtown Oakland has more housing in the immediate vicinity, though average household incomes are low. The City Center station lies in a redevelopment district; the redevelopment authority has recently used tax increment financing and other incentives to attract new development, including a mixed retail-office plaza with attractive landscaping that ties directly into the station and a large federal building complex. These stations have no parking, but are the major terminuses of buses operated by AC Transit, which serves the urbanized parts of Alameda and Contra Costa Counties in the East Bay.

- Urban Districts: These four stations — Berkeley (downtown), Lake Merritt, Mission-16th Street, and Mission-24th Street — lie outside of the region's two big CBDs, but are in highly urbanized areas. In the urban hierarchy, they represent third-tier centers. They are mature districts, with considerable numbers of jobs (in low- to mid-rise buildings) and significants amounts of housing. Among all station classes, they have the highest gross residential densities and relatively high shares of land devoted to residential uses. These station areas are also most balanced in terms of jobs and housing. Retail is prominent around all except the Lake Merritt station. Downtown Berkeley has the most mixed office-retail-residential development. The Lake Merritt station area is predominantly a government employment district surrounding by mid-rise housing and a sprinkling of retail uses. Oakland's Chinatown, cultural complex, and Laney College also flank the Lake Merritt station. The two Mission stations, serving the traditional Hispanic district of San Francisco, feature very similar mixes of small, independently owned retail outlets interspersed by moderate-income housing. Only the Lake Merritt station has parking (just 205 spaces that cost a quarter per day to park), and all four stations are well-served by bus transit connections. Relatively high shares of residents around these stations commute by rail transit.
- Suburban Centers: These five stations — Orinda, Lafayette, Walnut Creek, Pleasant Hill, and Concord — are surrounded by fourth-tier commercial centers in the eastern suburbs of the Bay Area. As shown in Figure 4, they are also aligned along the Concord corridor serving Contra Costa County. The three outermost stations — Walnut Creek, Pleasant Hill, and Concord — are surrounded by mid-rise office towers, while the Orinda and Lafayette stations flank commercial-retail districts with relatively few offices nearby. All five stations have apartments nearby (especially Pleasant Hill, which has over 1,600 apartment units within a quarter-mile of the station); middle- and upper-middle-income single-family detached housing generally lies beyond these apartments. Overall, gross residential densities are fairly low in these station areas and average household incomes are comparatively high. In general, household incomes and rent gradients decline along the Concord corridor as one travels outward from the Orinda station — Orinda being a fairly well-to-do community and Concord having much larger shares of moderate-income households. What most distinguishes these stations are the large volume of park-and-ride spaces — ranging from 1,380 at Orinda to 3,245 at Pleasant Hill.[11] Large shares of residents living within one-half mile of these stations commute to work by rail transit — on average, around 12.5 percent. This reflects the relatively high shares of residents in Orinda and Lafayette working in downtown San Francisco. All five stations lie near a freeway; both Orinda and Lafayette stations lie in the median of Highway 24, thus inhibiting development immediately at the station. The Pleasant Hill station is distinguished from the other stations for being in an unincorporated area and being part of a redevelopment district. The formation of a redevelopment district in the early-1980s at the Pleasant Hill station has helped leverage over 1.5 million square feet of new office space construction and five large apartment complexes within a quarter-mile of the station in the past seven years (see Cervero, Bernick, and Gilbert, 1994).
- Low-Density Areas: The remaining 19 BART stations form a station class of low-density development. What most distinguishes these station areas is their comparatively low

employment and residential densities. All lie in low-rise, suburban-like settings. Most are surrounded by predominantly residential development (e.g., Glen Park and Balboa Park neighborhoods in San Francisco), though some have prominent retail districts nearby (e.g., Rockridge in Oakland and Bay Fair in San Leandro) and others are surrounded by industrial and vacant land uses (e.g., Coliseum in Oakland and South Hayward). In general, these areas have relatively low levels of land-use mixing. Most stations in this class have moderate supplies of parking, ranging from none at Balboa Park in San Francisco to 2,516 at the El Cerrito del Norte station on the Richmond line. Bus transit connections tend to operate at lower service levels at these stations, except at the MacArthur station in Berkeley which functions as a transfer station between the three East Bay BART lines. Several of the stations on the Richmond line (El Cerrito, El Cerrito del Norte, and Richmond) and the Fremont line (San Leandro, Hayward, and Union City) lie within redevelopment districts. The most significant redevelopment activities have been near the El Cerrito del Norte station, where new housing and retail projects have opened in recent years (see Cervero, Bernick, and Gilbert, 1994). Five of the station areas — Rockridge, North Berkeley, Ashby, Glen Park, and Balboa Park — are notable for the restrictive zoning introduced after BART was opened, aimed at limiting preserving the single-family residential characters of these neighborhoods.

6. ANALYSIS OF MODES OF ACCESS ACROSS STATION CLASSES

This section examines differences in modes of access across these six classes of BART stations. Access trips to and egress trips from classes of BART stations are also stratified as either home-end (going from or to home) or work-end (going from or to a workplace). Thus, four submarkets of access trips are examined:

1. Home-end access trips: trips from home to a BART station.
2. Home-end egress trips: trips from a BART station to home.
3. Work-end access trips: trips from a workplace to a BART station.
4. Work-end egress trips: trips from a BART station to a workplace.

For the typical commute, the first and fourth trips would occur in the morning and the second and third would occur in the afternoon/evening. In general, modal splits should be similar for the two home-end trips and the two work-end trips. What is expected to differ most as a function of land-use environment are differences in home-end trips versus work-end trips. Accordingly, this section emphasizes differences in modes of access and egress (combined) between home-end and work-end travel.

To the degree that land-use environments vary among station classes, modal splits for access and egress trips should also vary among the classes, as postulated by the research hypotheses. In this section, Analysis of Variance (ANOVA) results comparing differences among station classes in the mean percentages of access and egress trips by modes are presented. Automobile access trips are first examined, followed by access trips by kiss-and-ride and then access and egress trips by transit and walking (at both the home- and work-ends).

Table 4 shows the ANOVA results for home-end access trips by automobile, revealing statistically significant differences among station classes. (Results for home-end egress trips were virtually identical, indicating symmetry in modal splits of access to and egress trips from home; also, few work-end access or egress trips are by automobile, so these submarkets are not examined.) As expected, few home-end access trips to BART's downtown stations are by automobile, indicating that dense, mixed-use settings, along with the absence of park-and-ride facilities, discourage auto access. As station areas become more suburban-like in character, automobile access shares increase. Percentages of home-end access trips by auto seem strongly related to densities and even more strongly related to parking supplies.[12] Suburban centers, with the largest average parking supplies and comparatively high average incomes in surrounding households, average the highest share of park-and-ride trips. Thus, while land-use environments clearly seem to influence auto access trips, so do non-land-use factors, particularly parking supplies.

Table 4. ANOVA in Percent of Home-End Access Trips by Automobile Across Station Classes

Dependent Variable: Percent of Home-End Access Trips by Automobile

Station Class	Mean	Standard Deviation	Summary Statistics: F Statistic	Summary Statistics: Probability
San Francisco Office Center	1.5	0.71	26.22	.000
San Francisco Commercial/ Civic Center	5.0	1.41		
Downtown Oakland	9.0	1.41		
Urban Districts	15.5	12.02		
Suburban Centers	71.2	11.97		
Low-Density Areas	53.9	13.49		
TOTAL	42.9	26.24		

Tables 5 and 6 break down home-end automobile access trips by the two major types: drive-alone and kiss-and-ride (passenger drop-off). Relationships for drive-alone trips were very similar to those of total automobile trips: virtually no one reaching downtown stations from home drive alone, only around 7 percent of those going to urban district stations (which also have few parking spaces) drive alone, and between one-third and one-half of those going to all remaining stations (all of which have low densities) drive alone. Table 6 shows that for the entire BART system, only around one of ten home-end access trips are by kiss-and-ride; for access trips to suburban centers and low-density station areas, around 13-14 percent are by kiss-and-ride.

The ANOVA results for home-end access trips by transit are shown in Table 7.[13] No strong patterns are evident. While San Francisco's Commercial/Civic Centers had the largest share of transit access trips, the nearby San Francisco Office Center had the lowest share. Transit service levels, which were not used to classify stations,[14] as well as density probably explain some of the differences in home-end access trips. San Francisco's Commercial/Civic Center stations receive intensive feeder bus, street-car, and cable car services, and thus average high share of transit access trips. While San Francisco's

Table 5. ANOVA in Percent of Home-End Access Trips by Drive-Alone Automobile Across Station Classes

Dependent Variable: Percent of Home-End Access Trips by Drive-Alone Automobile

Station Class	Mean	Standard Deviation	Summary Statistics F Statistic	Probability
San Francisco Office Center	1.00	0.00	14.65	.000
San Francisco Commercial/ Civic Center	2.00	0.00		
Downtown Oakland	2.50	1.29		
Urban Districts	7.05	7.07		
Suburban Centers	49.20	12.32		
Low-Density Areas	33.84	12.56		
TOTAL	27.03	29.58		

Table 6. ANOVA in Percent of Home-End Access Trips by Kiss-and-Ride, Across Station Classes

Dependent Variable: Percent of Home-End Access Trips by Kiss-and-Ride

Station Class	Mean	Standard Deviation	Summary Statistics F Statistic	Probability
San Francisco Office Center	0.50	0.71	26.68	.000
San Francisco Commercial/ Civic Center	2.00	1.41		
Downtown Oakland	5.55	0.57		
Urban Districts	6.47	3.53		
Suburban Centers	13.80	1.30		
Low-Density Areas	13.32	2.58		
TOTAL	10.65	4.99		

Table 7. ANOVA in Percent of Home-End Access Trips by Transit, Across Station Classes

Dependent Variable: Percent of Home-End Access Trips by Transit

Station Class	Mean	Standard Deviation	Summary Statistics F Statistic	Probability
San Francisco Office Center	8.00	0.00	1.55	.207
San Francisco Commercial/ Civic Center	23.50	9.19		
Downtown Oakland	12.50	2.12		
Urban Districts	16.00	6.27		
Suburban Centers	12.20	7.46		
Low-Density Areas	20.16	9.68		
TOTAL	17.53	9.05		

Office Center stations also enjoy intensive feeder services, the area is so dense and compact that most nearby residents can more easily reach the station by foot. Many suburban stations have higher transit modal splits for home-end access trips than more urbanized ones. Similarly insignificant results were found for the share of work-end egress trips by transit. Table 8 shows low-density areas averaged more work-end egress trips by transit than downtown stations. Overall, it appears transit plays a relatively modest feeder role in more urbanized station settings, partly because destinations can be more easily reached by foot. Its role as an access and egress mode is most vital in low-density station areas, where many origins and destinations are beyond a convenient walk.

Table 8. ANOVA in Percent of Work-End Egress Trips by Transit, Across Station Classes

Dependent Variable: Percent of Work-End Egress Trips by Transit

Station Class	Mean	Standard Deviation	Summary Statistics: F Statistic	Summary Statistics: Probability
San Francisco Office Center	12.00	2.82	2.07	.098
San Francisco Commercial/ Civic Center	16.50	4.95		
Downtown Oakland	12.50	6.36		
Urban Districts	18.00	7.48		
Suburban Centers	16.60	9.02		
Low-Density Areas	27.42	12.23		
TOTAL	22.29	11.63		

These results are reinforced by the ANOVA results, shown in Tables 9 and 10, on market shares of home-end access and work-end egress stations by walking. Shares of pedestrian access and egress are highest in the densest, most mixed-use settings. Around nine of ten access trips from home to San Francisco Office Center stations (ostensibly as part of a reverse commute) are by foot. For suburban center and low-density station areas, fewer than one of five BART users walk from their homes to stations. Higher shares of those going to and from low-density station areas walk than their counterparts using suburban center stations, ostensibly because suburban center stations have the most generous supplies of parking.

Overall, the ANOVA results support the research hypotheses. Dense, urban station areas have relatively high shares of walk access trips. Stations in suburban settings are reached mainly by private automobiles. The land-use environment appears to have the weakest influence on transit access and egress. Transit service levels are likely more important (see next section).

Table 9. ANOVA in Percent of Home-End Access Trips by Walking, Across Station Classes

Dependent Variable: Percent of Home-End Access Trips by Walking

Station Class	Mean	Standard Deviation	Summary Statistics F Statistic	Summary Statistics Probability
San Francisco Office Center	89.50	0.71	39.27	.000
San Francisco Commercial/ Civic Center	70.00	11.31		
Downtown Oakland	70.50	10.61		
Urban Districts	71.75	6.61		
Suburban Centers	15.40	4.82		
Low-Density Areas	18.84	11.81		
TOTAL	35.76	26.87		

Table 10. ANOVA in Percent of Work-End Egress Trips by Walking, Across Station Classes

Dependent Variable: Percent of Work-End Egress Trips by Walking

Station Class	Mean	Standard Deviation	Summary Statistics F Statistic	Summary Statistics Probability
San Francisco Office Center	86.50	3.54	32.73	.000
San Francisco Commercial/ Civic Center	87.00	5.65		
Downtown Oakland	78.00	0.00		
Urban Districts	76.00	7.81		
Suburban Centers	19.60	7.26		
Low-Density Areas	28.05	12.89		
TOTAL	42.73	26.56		

7. PREDICTORS OF ACCESS AND EGRESS MODES

This section builds upon the previous one by presenting regression models which directly predict the influences of land-use variables as well as other factors (e.g., parking supplies) on the percentages of access and egress trips by different modes. Stations and their surrounding one-half mile areas served as the cases for estimating regression models — 34 cases in all.[15]

Table 11 presents a multiple regression model that predicts the percentage of access trips (home-end and work-end combined) to BART stations by automobile. The hypotheses postulated in the research are supported by these results. Market shares of automobile access trips fall with both employment and residential densities and mixed land uses around stations, and rise with park-and-ride spaces. The model suggests, for instance, that an increase in station-area residential densities of 10 households per acre lowers the share of access trips by automobile by 10 percent, ceteris paribus. From the coefficient on the entropy

Table 11. Regression Model for Predicting Percentage of Access Trips to BART Stations by Automobile

Dependent Variable: Percent of Access Trips by Automobile

Variable:	Coefficient	Standard Error	Probability
Employees/acre within one-half mile of station	-0.198	0.064	.003
Households/acre within one-half mile of station	-1.00	0.311	.003
Percent of land area within one-half mile of station in commercial use	-0.729	0.304	.023
Percent of land area within one-half mile of station in residential use	-1.029	0.339	.005
Entropy index of land-use mixture within one-half mile of station[1]	-85.334	33.894	.032
Park-and-ride spaces at station	0.014	0.003	.000
Constant	169.691	45.058	.001

Summary Statistics:
R2 = .869
F = 29.88, prob. = .000
No. of cases = 34

Note:
[1]Relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i and k = number of land-use categories ranges between 0 and 1, where 0 signifies land devoted to a single use and 1 signifies land area evenly spread among all uses.

variable, we see that a station area that has an even distribution of acreage among land uses could be expected to have 85 percent fewer access trips by automobile than a station area with just one use, like offices, assuming all other characteristics of the station areas, including densities, were identical. Parking supply, on the other hand, induces automobile access — every 100 spaces is associated with 1.4 percent more access trips by automobile, all other things held constant. Overall, the model predicts around 87 percent of the variation in access trips by automobile for the 34 stations.

In the case of egress trips from BART by transit, Table 12 shows, consistent with the ANOVA results, that land-use variables exerted a relatively weak influence. Transit modal shares increased as station-area densities declined, especially residential densities. This is consistent with the ANOVA findings that suburban center and low-density area stations averaged the highest transit access and egress modal splits. Far more significant in explaining transit egress modal splits is transit service levels, measured in route miles per 1,000 households within one-half mile of stations. Where bus feeder connections are good and densities are low, transit egress modal splits tend to be high. The exceptions, again, are the downtown stations, where most destinations are close enough to stations that most egress trips are by foot, despite the very high quality of transit connections to downtown stations in San Francisco and Oakland. Overall, the model shown in Table 12 explains two-thirds of the variation in transit egress modal splits. (The model for transit access modal splits was nearly identical, and is thus not presented.)

The models for access versus egress walking trips varied somewhat; thus both are shown. Table 13 reveals that the percent of access trips by foot rises sharply with densities (especially residential densi

Table 12. Regression Model for Predicting Percentage of Egress Trips from BART Stations by Transit

Dependent Variable: Percent of Egress Trips by Transit

Variable:	Coefficient	Standard Error	Probability
Employees/acre within one-half mile of station	-0.157	0.029	.000
Households/acre within one-half mile of station	-0.669	0.174	.000
Transit service levels, in route miles per 1,000 households within one-half mile of station[1]	4.984	0.707	.000
Constant	12.482	2.611	.000

Summary Statistics:

R^2 = .667
F = 20.11, prob. = .000
No. of cases = 34

Note:
[1]Route miles of all surface transportation, including bus transit, streetcar trams, light rail transit, and cable car services, within one-half mile of rail station, excluding BART services.

Table 13. Regression Model for Predicting Percentage of Access Trips to BART Stations by Walking

Dependent Variable: Percent of Access Trips by Walking

Variable:	Coefficient	Standard Error	Probability
Employees/acre within one-half mile of station	0.330	0.057	.000
Households/acre within one-half mile of station	1.130	0.314	.001
Percent of land area within one-half mile of station in residential use	0.532	0.312	.100
Entropy index of land-use mixture within one-half mile of station[1]	55.746	35.308	.127
Park-and-ride spaces at station	-0.020	0.004	.000
Transit service levels, in route miles per 1,000 households within one-half mile of station[2]	-3.121	1.099	.009
Terminal or near-terminal station (0=no, 1=yes)[3]	19.569	6.886	.009
Constant	-18.664	42.474	.664

Summary Statistics:

R^2 = .887
F = 29.30, prob. = .000
No. of cases = 34

Notes:
[1]Relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i, and k = number of land-use categories. Ranges between 0 and 1, where 0 signifies land devoted to a single use and 1 signifies land area evenly spread among all uses.
[2]Route miles of all surface transportation, including bus transit, streetcar trams, light rail transit, and cable car services, within one-half mile of rail station, excluding BART services.
[3]Near-terminal represents stations toward the end of the line that function like terminals because they are closer to freeways than the actual terminals and thus serve a larger catchment area. BART's near-terminal stations, El Cerrito del Norte and Pleasant Hill, have larger supplies of parking than terminal stations since they are easier to reach by freeway.

ties) and mixed land use levels, and declines as substitutes to walking are more plentiful — i.e., lots of parking and good transit connections. According to the model, an increase in residential densities of 10 households per acres is associated with an 11.3 percent increase in the share of access trips by walking, controlling for parking supplies and other explanatory variables. Interestingly, Table 13 shows that once parking supplies and other factors are controlled for, terminal and near-terminal stations tended to have higher levels of access trips by foot, despite their freeway and highway orientations. This finding largely reflects the presence of several large apartment complexes in the vicinity of the two near-terminal stations, Pleasant Hill and El Cerrito del Norte, yielding high shares of walking-access trips to these two stations. Overall, the model shown in Table 13 produced the best-fitting model of all the regression models estimated, explaining around 89 percent of the variation in walk-access modal splits.

Table 14 shows that the relationships for explaining walk egress trips were fairly similar, though land-use variables exerted an even stronger influence in this model. Controlling for densities, parking supplies, and other factors, for instance, Table 14 suggests that a station area with an even mix of land uses will average 73 percent more egress trips by walking than one with a single land use. Adding 10 more jobs per acre can be expected to induce 3.33 percent more egress trips by foot, holding other factors constant. Working against walk egress trips are parking supplies, transit service levels, and interestingly, the presence of freeway medians. Table 14 suggests that BART stations in freeway medians average around 7 percent fewer egress trips by foot, controlling for densities and other factors. This finding suggests that the quality of walking environment could have some bearing on walking egress (and, by extension, walking access, though this variable was not very significant in the access model shown in Table

Table 14. Regression Model for Predicting Percentage of Egress Trips from BART Stations by Walking

Dependent Variable: Percent of Egress Trips by Walking

Variable:	Coefficient	Standard Error	Probability
Employees/acre within one-half mile of station	0.333	0.057	.000
Households/acre within one-half mile of station	1.556	0.313	.000
Percent of land area within one-half mile of station in residential use	0.637	0.310	.050
Entropy index of land-use mixture within one-half mile of station[1]	73.577	37.090	.058
Park-and-ride spaces at station	-0.012	0.003	.000
Transit service levels, in route miles per 1,000 households within one-half mile of station[2]	-3.629	1.054	.002
Station located in freeway median (0 = no, 1 = yes)	-6.892	4.323	.131
Constant	-35.37	42.293	.411

Summary Statistics:

R^2 = .886
F = 28.91, prob. = .000
No. of cases = 34

Notes:
[1]Relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i, and k = number of land-use categories. Ranges between 0 and 1, where 0 signifies land devoted to a single use and 1 signifies land area evenly spread among all uses.
[2]Route miles of all surface transportation, including bus transit, streetcar trams, light rail transit, and cable car services, within one-half mile of rail station, excluding BART services.

13). Freeway medians represent barriers to movement in many ways — physically, visually, psychologically, and symbolically. The vibrations created by heavy freeway traffic and shadows cast by elevated freeway structures can also discourage foot travel.

To summarize the results of this section, Table 15 presents the regression results as midpoint elasticities — revealing the relative sensitivity of access and egress modal splits to changes in land-use and other variables.[16] The table shows that, in general, access and egress trips are inelastically related to the land-use environment, though the influences of land-use variables are generally as strong as other factors. Access and egress modal splits were most sensitive to land-use mixtures — highly mixed uses around rail stations encourage foot travel and discourage automobile usage. Having considerable amounts of compact residential development within one-half mile of stations also significantly induces walk access and reduces automobile access. In general, access and egress modal splits were more sensitive to residential than employment densities. Parking supplies exerted stronger influences on access and egress modal splits than did land-use densities, though less of an influence than land-use mixtures. Parking supplies had their strongest effect on reducing walk trips from homes to stations. Transit access and egress was strongly influenced by feeder service levels; land uses played a relatively modest role in affecting transit travel to and from stations. Lastly, besides parking lots, the physical characteristics of stations, such as lying in the median of a freeway, had a fairly weak influence on access and egress modal splits.

Table 15. Midpoint Elasticities of Access and Egress Modal Shares as Functions of Land-Use and Other Variables

Independent Variable:	Automobile Access/Egress	Transit Access/Egress	Walk Access	Walk Egress
Employees/acre within one-half mile of station	-.116	-.177	.220	.196
Households/acre within one-half mile of station	-.209	-.270	.269	.328
Percent of land area within one-half mile of station in commercial use	-.339	—	—	—
Percent of land area within one-half mile of station in residential use	-1.167	—	.733	.775
Entropy index of land-use mixture within one-half mile of station[1]	-1.281	—	.989	1.153
Park-and-ride spaces at station	.300	—	-.484	-.257
Transit service levels, in route miles per 1,000 households within one-half mile of station[2]	—	.888	-.328	-.337
Terminal or near-terminal station (0=no, 1=yes)[3]	—	—	.093	—
Station located in freeway median (0=no, 1=yes)	—	—	—	-.029

Notes:

[1] Relative entropy = $\{\Sigma_i[p_i * \ln(p_i)]\}/\ln(k)$ where p_i = proportion of land area in land-use category i, and k = number of land-use categories. Ranges between 0 and 1, where 0 signifies land devoted to a single use and 1 signifies land area evenly spread among all uses.

[2] Route miles of all surface transportation, including bus transit, streetcar trams, light rail transit, and cable car services, within one-half mile of rail station, excluding BART services.

[3] Near terminal represents stations toward the end of the line that function like terminals because they are closer to freeways than the actual terminals and thus serve a larger catchment area. BART's near terminal stations, El Cerrito del Norte and Pleasant Hill, have larger supplies of parking than terminal stations since they are easier to reach by freeway.

The results presented in Tables 11 to 15 are also noteworthy for the variables which did not enter the models as significant predictors. Average household incomes in the vicinity of stations, for instance, had no significant effect on modes of access and egress. Nor did factors like station function (e.g., transfer stations) or proximity of freeways. Far more important were the land-use environment — mixtures of use and densities — as well as two supply-side variables — parking spaces and transit service levels.

8. ACCESS MODES AS A FUNCTION OF DISTANCE TO STATIONS

In this section, the influences of distance on modes of access to and egress from the six classes of BART stations are examined, for both home-end and work-end trips. This analysis allows the interactive effects of the land-use setting and distance on access and egress modal splits to be explored.

Table 16 shows the means and standard deviations of access and egress trips to and from each station class. For each station class, access trips tend to be much longer than egress trips, particularly in the case of the downtown San Francisco and Oakland stations, wherein egress trips are around 10 to 12 times as long. While home-end access trips to the downtown San Francisco and Oakland stations tended to be the longest among station classes, egress trips from these stations to workplaces tended to be the shortest. (It should be noted that downtown stations average far more work-end egress trips than home-end access trips — typically by a ratio of 10:1 — so, overall, trip connections to and from these stations tend to be short.) For the non-downtown stations, home-end access trips (which by far predominate over work-end egress trips) are most often in the 2- to 3-mile range.

Table 16. Summary Statistics for Access and Egress Trips by Station Class

Station Class	Home-End Mean	Access Trips Std. Deviation	Work-end Mean	Egress Trips Std. Deviation	Ratio of Mean Access Trip Length to Mean Egress Trip Length
San Francisco Office Center	3.62	2.19	0.31	0.14	11.7 : 1
San FranciscoCommercial/ Civic Center	4.68	2.71	0.38	0.18	18.3 : 1
Downtown Oakland	3.86	2.54	0.36	0.21	10.7 : 1
Urban Districts	2.35	2.24	0.38	0.17	6.1 : 1
Suburban Centers	3.00	2.11	0.51	0.30	5.9 : 1
Low-Density Areas	2.87	2.08	0.72	0.43	4.0 : 1

In the figures that follow, access and egress modal splits are plotted for distances of up to 2 to 3 miles. While longer access and egress trips are made, there tends to be relatively few sample cases over these longer distances. Including longer access and egress trips would have generated less interpretable plots due to sampling bias (and seemingly random appearance) of modal splits for distances of 4 miles and longer. Over such longer distances, the influences of sampling errors would have overly dominated the graphs.[17] Beyond 4 or so miles, moreover, modal splits tend to vary much less (e.g., automobile travel dominates for home-end access trips to stations in low-density areas), so extending plots out any farther usually reveals little new information.

San Francisco Office Center

Figure 4 shows that walk trips are the predominant egress mode from San Francisco Office Center stations (Embarcadero and Montgomery) to workplaces up to around 9/16 of a mile (3,000 feet). Beyond this distance, surface transit (bus, tram, light rail, and cable cars) serve the majority of trips. Beyond one mile, virtually all egress trips to workplaces are by some form of feeder transit.

Figure 5 indicates access trips from home to San Francisco Office Center stations follow a similar pattern, with transit becoming the dominant access mode at a distance of around 5/8 of a mile (3,300 feet). Where stations are are around two miles from a BART commuter's home, around 20 percent of access trips to San Francisco Office Center stations are by automobile. Compared to work-end egress trips, a wider variety of access modes are used for home-end trips.

Figure 6 combines all home-end and work-end access and egress trips. Overall, the Bay Area's densest, most urban rail station areas are associated with two distinct access features: (1) high levels of transit riding for longer access trips — over 80 percent for distances beyond a mile; and (2) relatively long walk trips, with walking being dominant access mode for trips as far as 4,000 feet to and from stations.

San Francisco Commercial/Civic Center

Figures 7, 8, and 9 reveal similar relationships between distance and access/egress modal splits for the San Francisco Commercial/Civic Center stations (Powell Street and Civic Center). In these fairly dense, very mixed-use settings, walking is the dominant access and egress mode up to around 3,200 feet. Compared to the Office Center stations, walking predominates over slightly longer distances for access trips and shorter distances for egress trips. The hillier terrain separating nearby residential areas and the Powell Street and Civic Center stations, as well as the high levels of feeder transit services into these two stations, likely account for transit's popularity as access/egress modes to these stations. Figure 8 shows transit's market share exceeds 95 percent for all access and egress trips to and from the commercial/civic center stations that are in the 2- to 3-mile range; at 3 miles, however, over 10 percent of BART patrons access or leave these stations as automobile passengers or by bicycle.

Downtown Oakland

Up to 3,500 feet, the majority of egress trips from downtown Oakland's 12th Street and 19th Street stations are by foot (Figure 10). Public transit captures virtually all egress journeys beyond three-quarters of a mile. These relatively long walking-egress distances in downtown Oakland could reflect the influences of two factors: (1) Oakland's downtown is less compact and its feeder transit services are

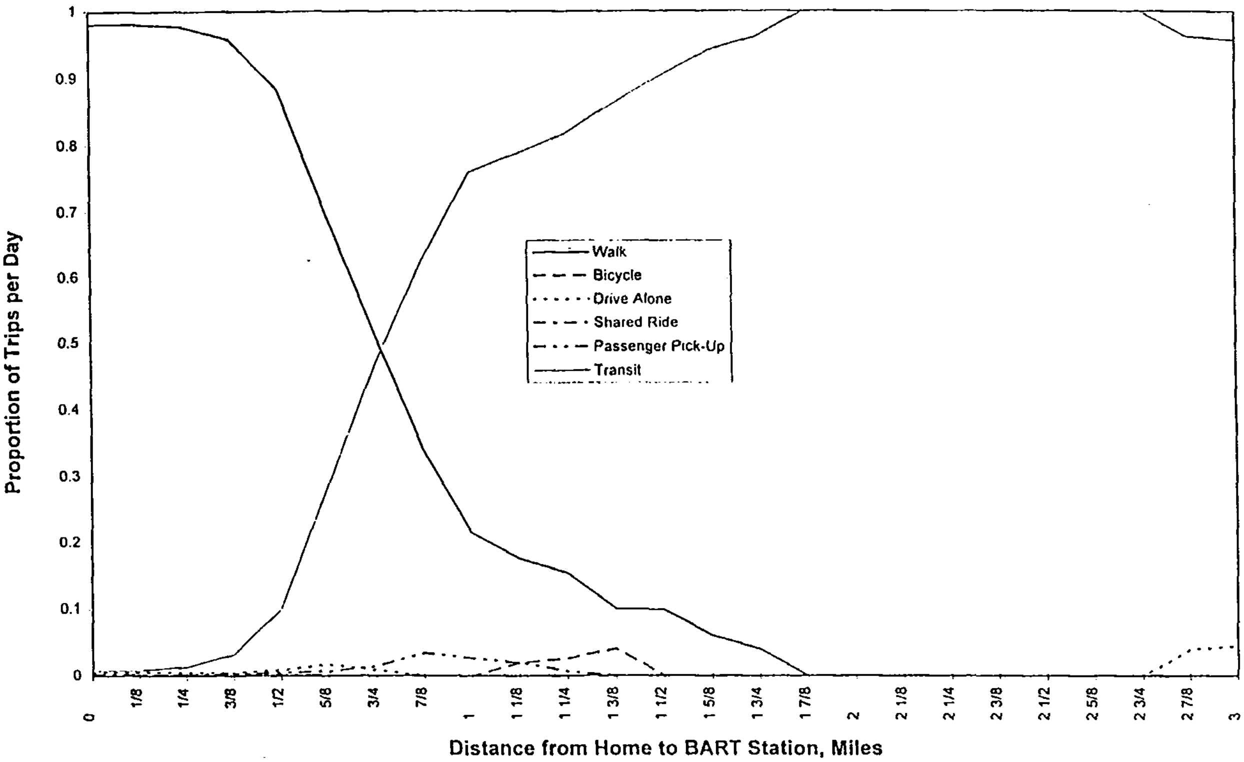


Figure 4. Mode of Egress for Commute Trips from San Francisco Office Center BART Stations to Work

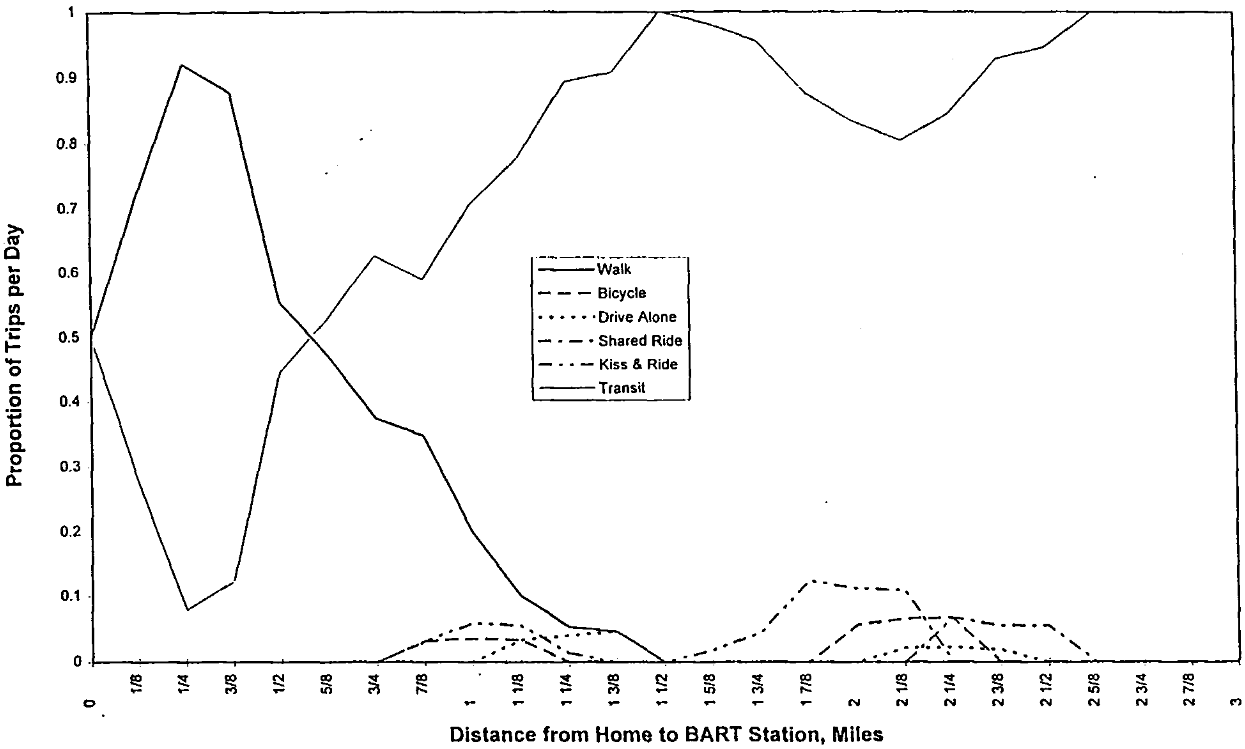


Figure 5. Mode of Access for Commute Trips from Home to San Francisco Office Center BART Stations

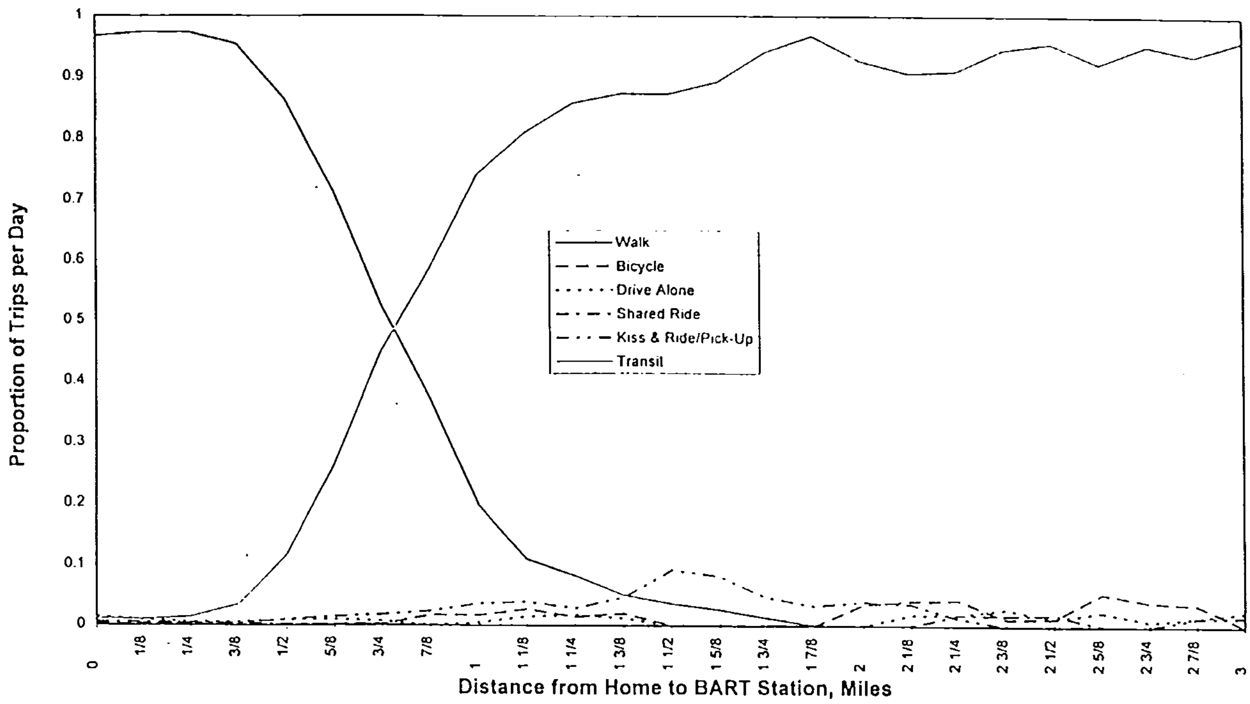


Figure 6. Mode of Access/Egress
for All San Francisco Office Center BART Commute Trips

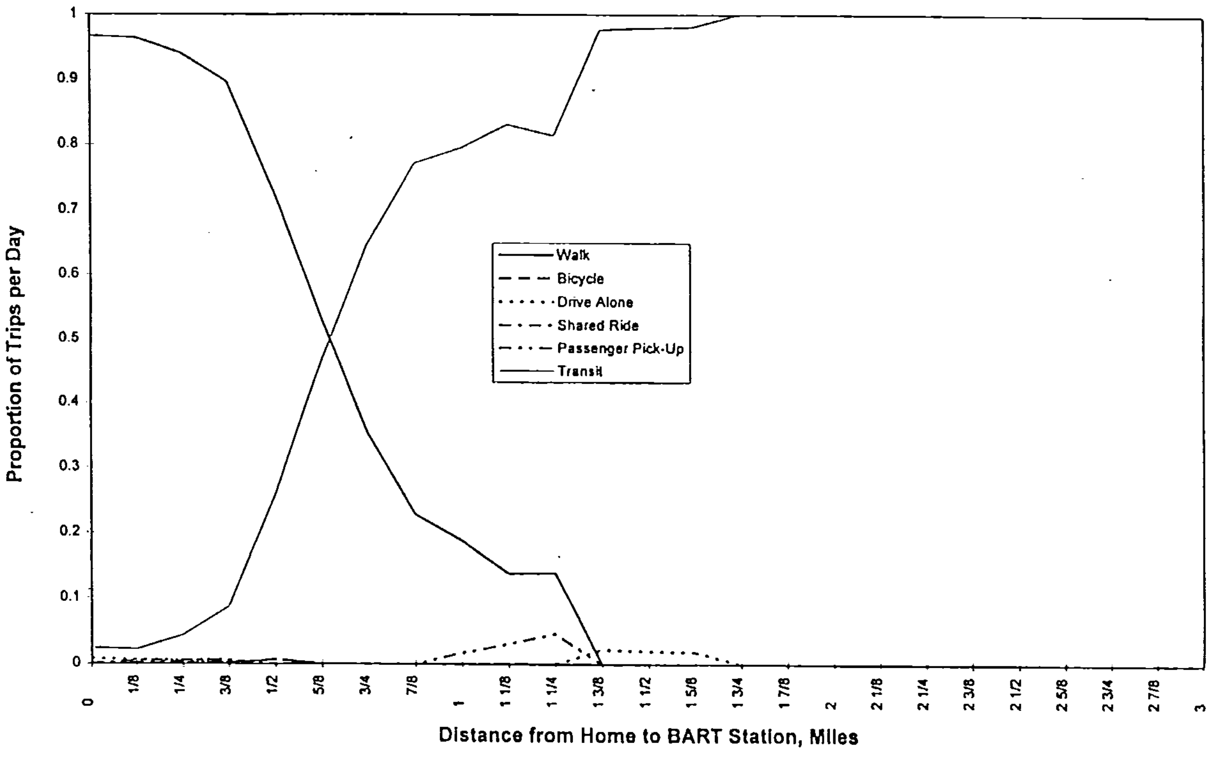


Figure 7. Mode of Egress for Commute Trips
from San Francisco Commercial/Civic Center BART Stations to Work

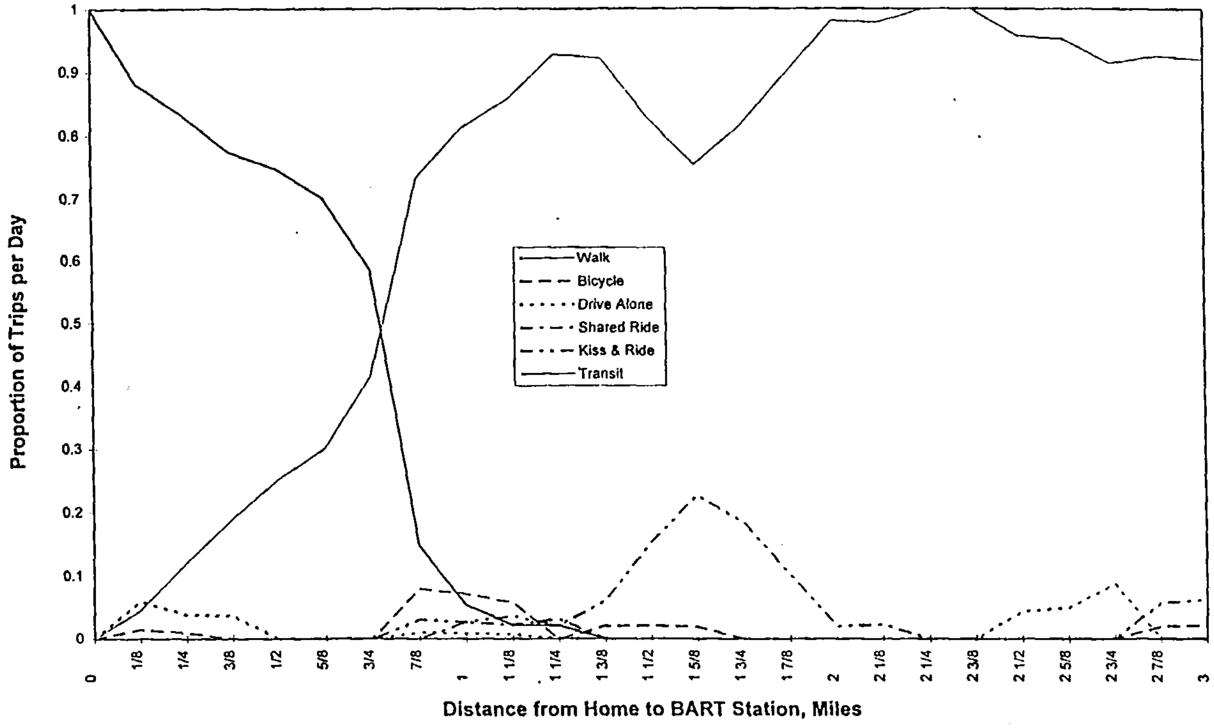


Figure 8. Mode of Access for Commute Trips
from Home to San Francisco Commercial/Civic Center BART Stations

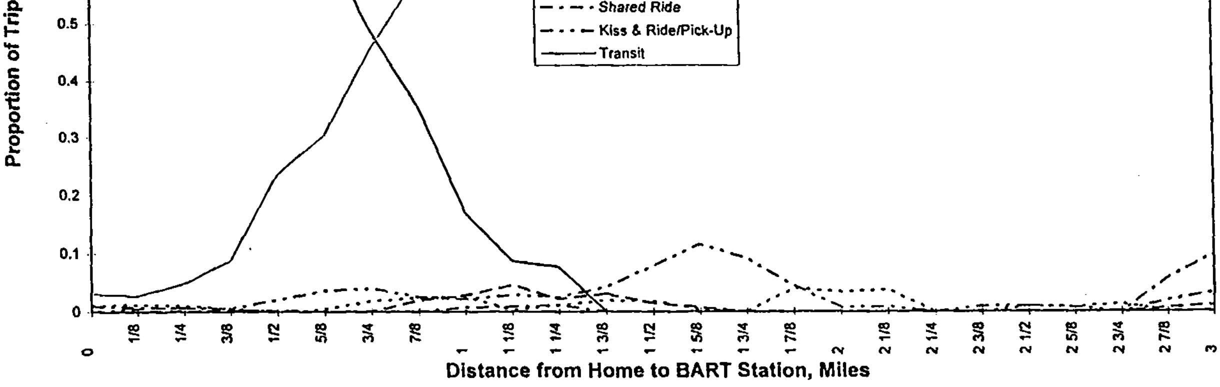


Figure 9. Mode of Access/Egress
for All San Francisco Commercial/Civic Center BART Commute Trips

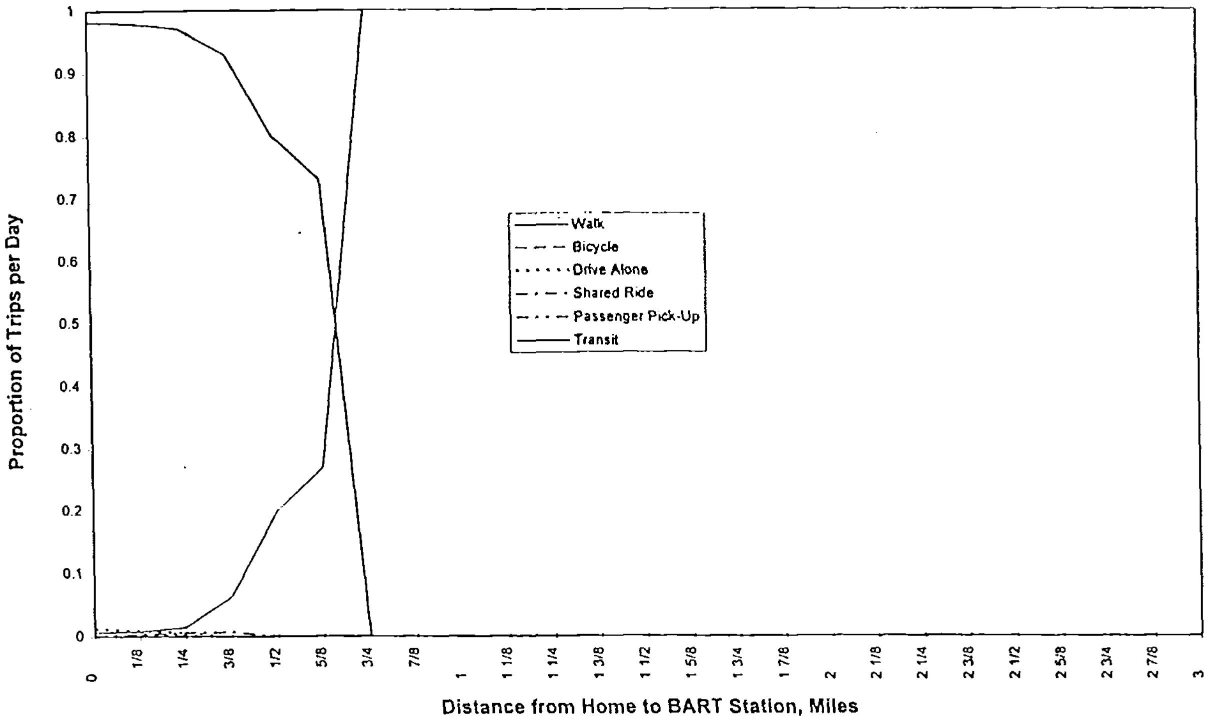


Figure 10. Mode of Egress for Commute Trips from Downtown Oakland BART Stations to Work

less frequent, resulting in people walking more to reach destinations that tend to be farther from stations (e.g., Jack London Square, Kaiser Center complex); and (2) Oakland's downtown has the widest variety of mixed uses among station classes (see Table 3), which could encourage some people leaving downtown stations to walk to their jobs and other destinations.

For access trips to downtown Oakland stations, Figure 11 shows transit eclipsing all other modes for distances beyond 5/8 of a mile. Beyond 11/16 of a mile, Figure 11 shows a greater variety of access modes than was the case for the downtown San Francisco stations. The modal split patterns are not tidy, however. Kiss-and-ride modal splits exceed those for walking beyond one mile. For access trips over 1/2 mile, some degree of park-and-ride and kiss-and-ride activities can be found at the downtown Oakland stations. The availability of surface parking at daily rates of $2-$3 in downtown Oakland likely has attracted some park-and-ride activities.

The composite plot of access and egress trips to downtown Oakland is shown in Figure 12. Overall, transit becomes the dominant mode at 5/8 mile and kiss-and-ride modal splits exceed those of walking at 7/8 mile.

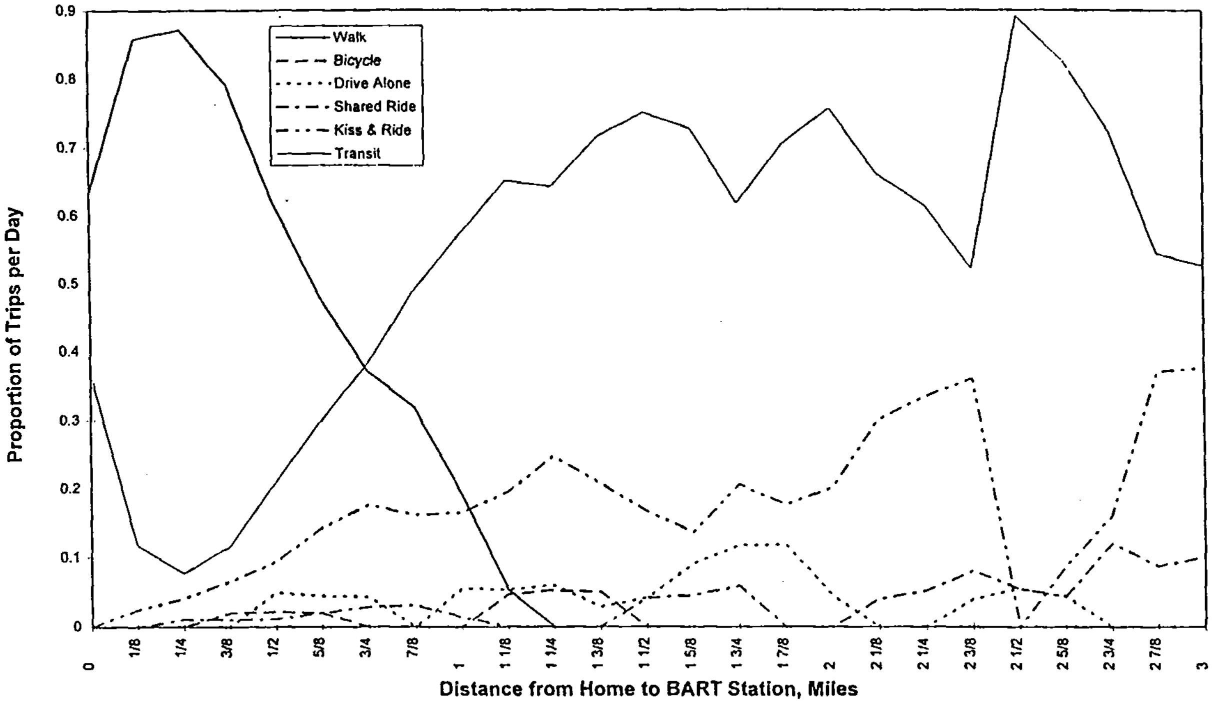


Figure 11. Mode of Access for Commute Trips from Home to Downtown Oakland BART Stations

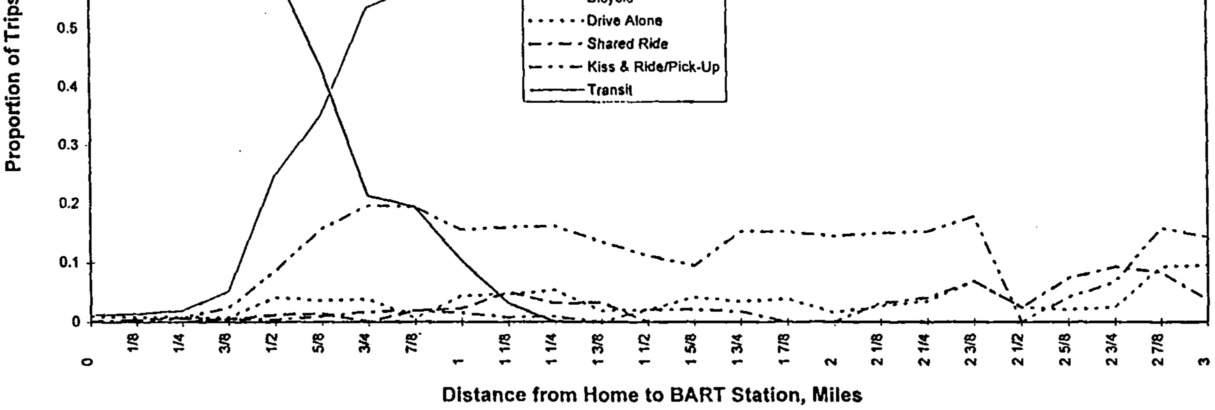


Figure 12. Mode of Access/Egress for all Downtown Oakland BART Commute Trips

Urban District Stations

For egress trips from urban district stations (Berkeley, Lake Merritt, Mission-16th Street, Mission-24th Street), Figure 13 shows that modal split patterns were similar to those of downtown BART stations for distances up to around one mile. Beyond 1-1/2 miles, there were so few sample cases of egress trips from urban district stations as to make the plotted information fairly meaningless.

Far more access trips from home to urban district stations occurred beyond one mile, producing the more interpretable patterns shown in Figure 14. Walking is again shown to be the predominant access mode to urban district for distances up to 5/8 mile. Transit access generally dominates over the 5/8-mile to 1-3/4-mile distance, beyond which most access trips are by private automobile (drive-alone and kiss-and-ride). Bicycle access plays a minor role for access trips up to around 1-1/2 miles, found mainly at the Berkeley station.

The composite graph of access and egress trips to and from urban district stations is shown in Figure 15. The dominance of home-to-station access trips on modal splits is revealed by this figure.

Suburban Center Stations

A starkly different pattern of modal splits for home-end access trips was found for suburban center stations (Figure 16). While walking predominates for all access trips up to one-half mile, beyond that distance park-and-ride access dominates. Even at a 1/8-mile access distance (660 feet), over one-quarter of home-end access trips are by drive-alone motorists or kiss-and-riders. At distances beyond one mile, well over half of access trips are by park-and-ride. Kiss-and-ride trips occur most frequently over the 1/2- to 1-mile distance. Beyond two miles, transit is the second most common access mode. Over the 1- to 3-mile range, riding as a passenger in a car accounts for around 10 to 15 percent of access trips.

Among egress trips from suburban center stations to workplace, Figure 17 shows that most trips under 3,000 feet were by foot. Beyond this distance, transit predominates, though some level of passenger pick-up occurs over the 1/2- to 3-mile distance. There are so few egress trips to workplaces more than 1-1/4 miles from suburban center stations that the right side of the graph is no doubt distorted by sampling errors.

The composite graph for access and egress trips to and from suburban center stations is shown in Figure 18. Here, the patterns seem clearest. Up to distances of around 3,000 feet, walking access and egress predominate. Beyond one mile, fewer than one out of ten access and egress trips are by foot. Beyond 5/8 mile, park-and-ride access predominates. Passenger pick-up and drop-off (kiss-and-ride) are most common over the 1/2- to 2-mile range. Beyond around 3/4 mile, transit access and egress captures a 15-20 percent market share.

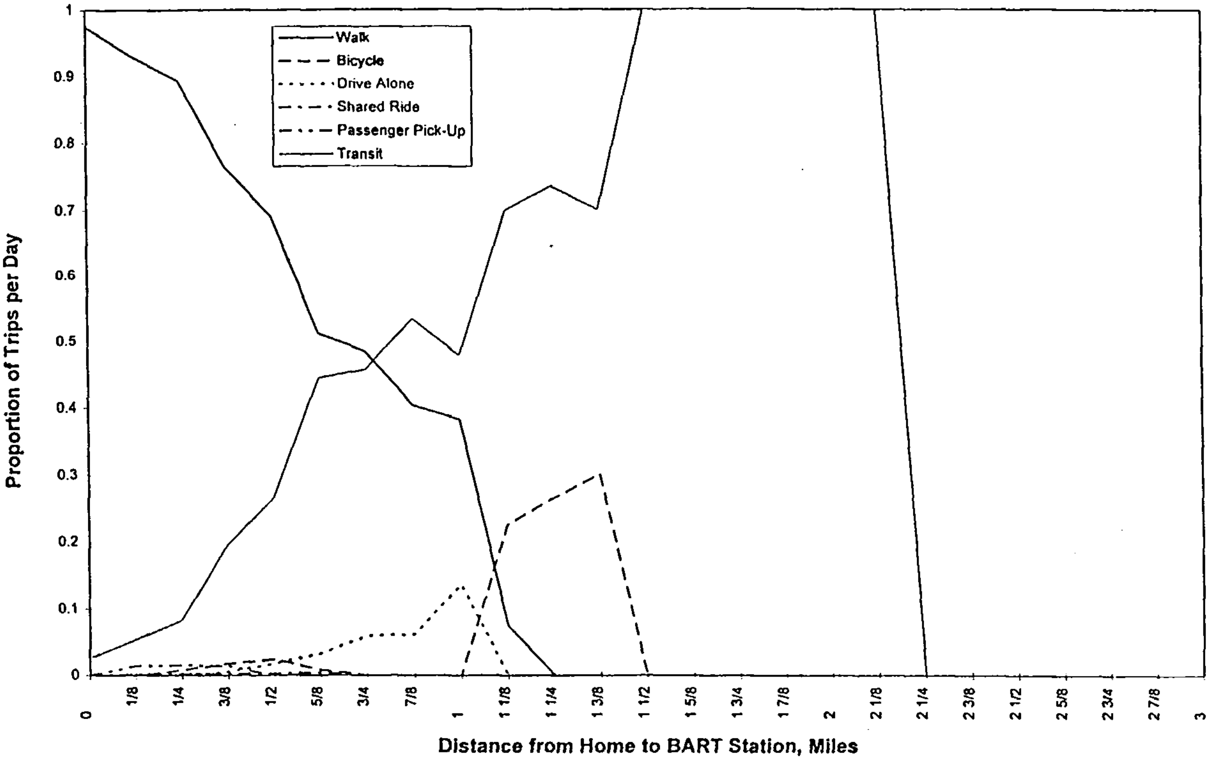


Figure 13. Mode of Egress for Commute Trips from Urban District BART Stations to Work

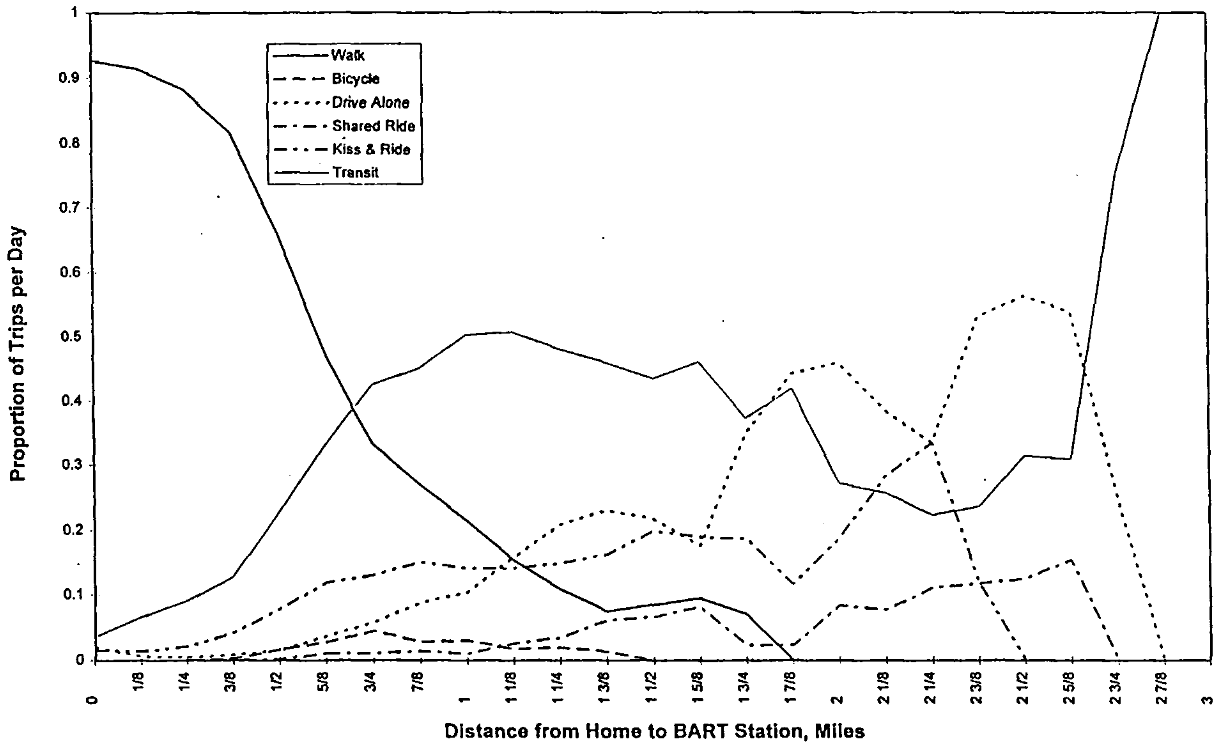


Figure 14. Mode of Access for Commute Trips from Home to Urban District BART Stations

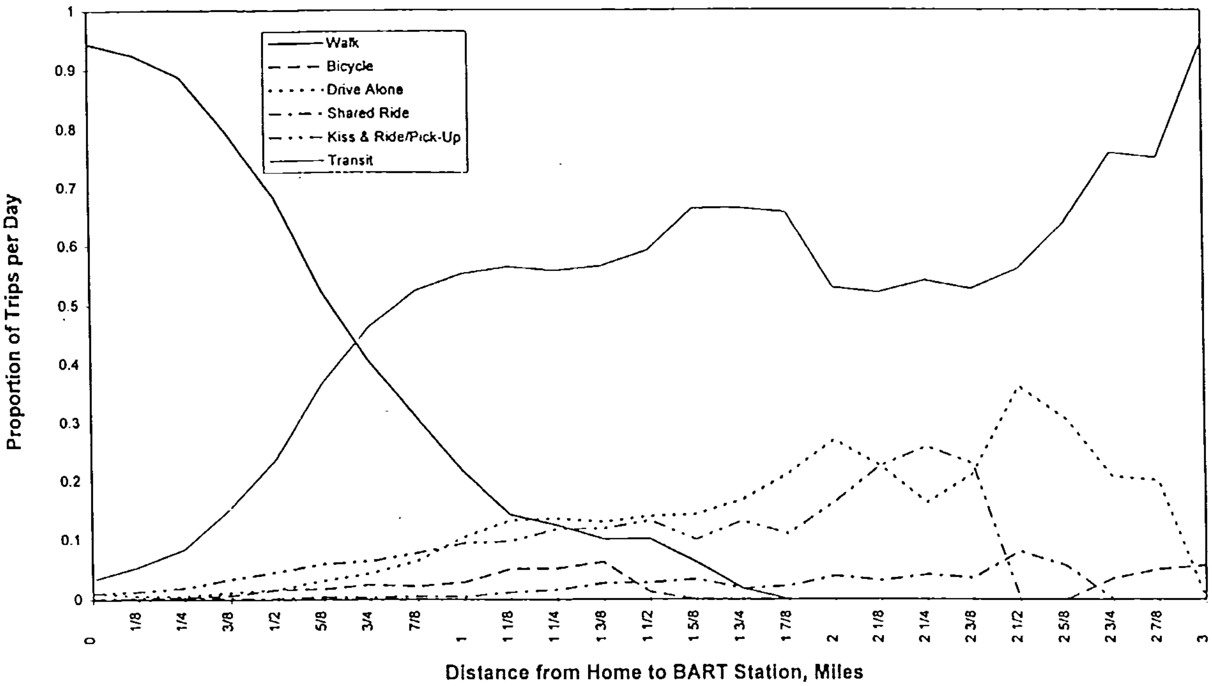


Figure 15. Mode of Access/Egress
For all Urban District BART Commute Trips

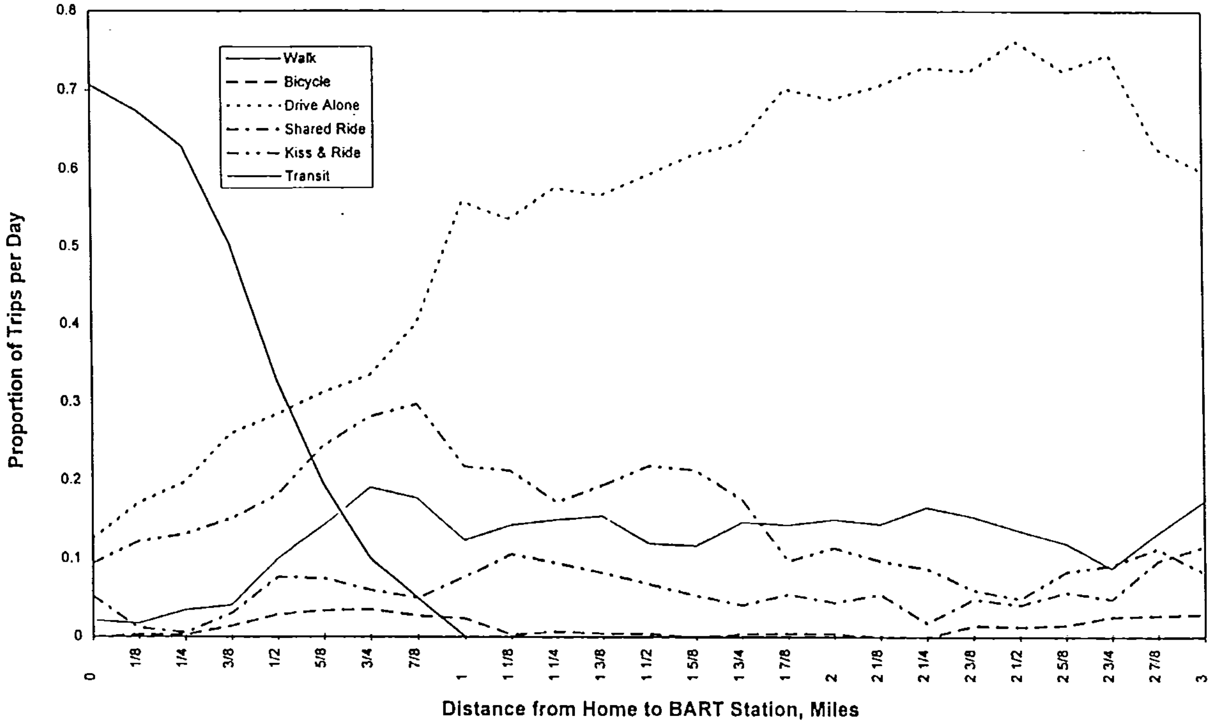


Figure 16. Mode of Access for Commute Trips
from Home to Suburban Center BART Stations

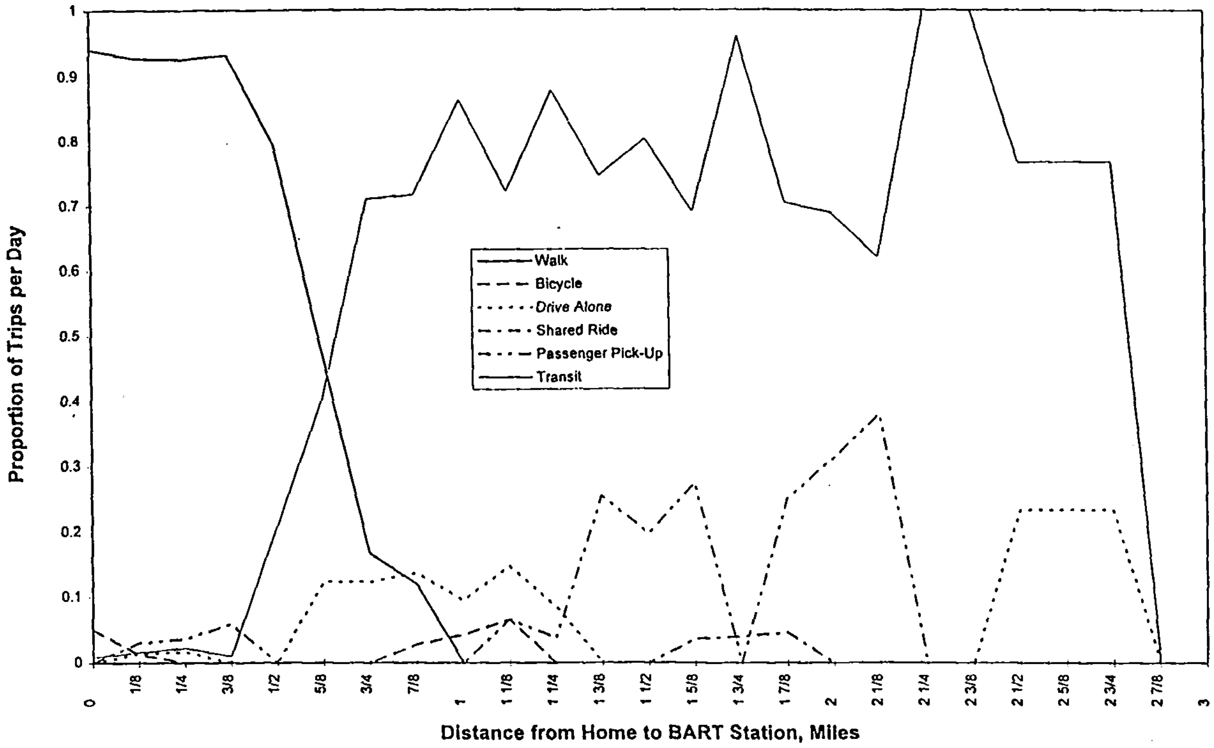


Figure 17. Mode of Egress for Commute Trips from Suburban Center BART Stations to Work

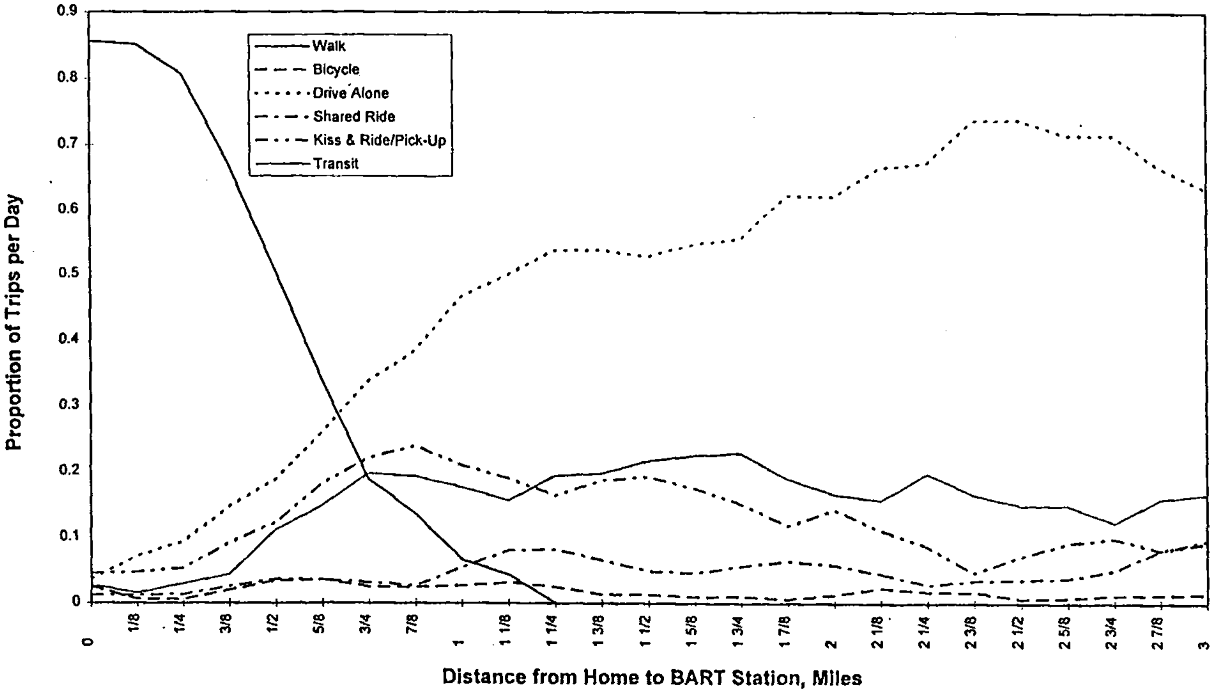


Figure 18. Mode of Access/Egress for All Suburban Center BART Commute Trips

Low-Density Areas

The modal split profiles for access and egress trips for low-density area stations are shown in Figures 19, 20, and 21. For access trips from home, Figure 19 shows walking predominates up to a distance of around 2,500 feet, beyond which park-and-ride becomes the main mode of access. Beyond 1/2 mile, transit is the second most common access mode. At 3 miles, comparable shares of access trips are by transit and kiss-and-ride.

For egress trips, Figure 20 reveals a modal split pattern similar to other station classes. As a market share, transit egress eclipses walking at slightly shorter distances at low-density station areas — around 2,800 feet.

The composite graph, shown in Figure 21, reinforces the findings. The private automobile is predominantly used to reach low-density stations for distances beyond one mile. Over intermediate distances, transit is the second most common access and egress mode, followed by kiss-and-ride/passenger pick-up.

Other Station Groupings

Access and egress trips were also studied for other station groupings to gain a better understanding of how modal splits varied over longer distances. The station grouping which produced the most discernable patterns for access and egress trips up to 10 miles in length was Terminal/Near-Terminal BART stations (Fremont, Daly City, Richmond, El Cerrito del Norte, Concord, and Pleasant Hill).[18] Figure 22 shows that park-and-ride was the predominant access mode over most distances except the very shortest (under 3/8 mile) and the intermediate distance of 6 to 6-3/4 miles. Walking predominated over the very short distances, and transit was the main feeder for the 6- to 6-3/4-mile distance. Overall, the patterns were not as smooth as one might expect. This could reflect the undersampling of access trips beyond 1-2 miles in length as well as the influences of localized factors (e.g., terrain, freeway locations).[19]

All Stations Combined

A final set of graphs were produced on access and egress modes for all 34 BART stations combined. Figure 23 reveals that the dominant modes of home-end access were: walking — 5/8 mile or less; transit — 5/8 to one mile; and park-and-ride — beyond one mile. Kiss-and-ride captured nearly 20 percent of home-end access trips over the 4,000- to 5,000-foot distance range. For work-end egress trips, Figure 24 shows transit eclipsed walking at a distance of around 3,600 feet; over the 1- to 3-mile range, no other mode captures more than 7 percent of all egress trips. Combining access and egress trips for all stations, Figure 25 indicates that transit is the most popular connecting mode over the 5/8-mile to 1-3/4-mile distance range; over longer distances, drive-alone travel predominates. Lastly, Figure 26 presents the summary modal splits for combined access and egress modes plotted over a much larger distance — 10 miles. This figure reveals that while general patterns hold over longer distances, the modal split plots are certainly not smooth or

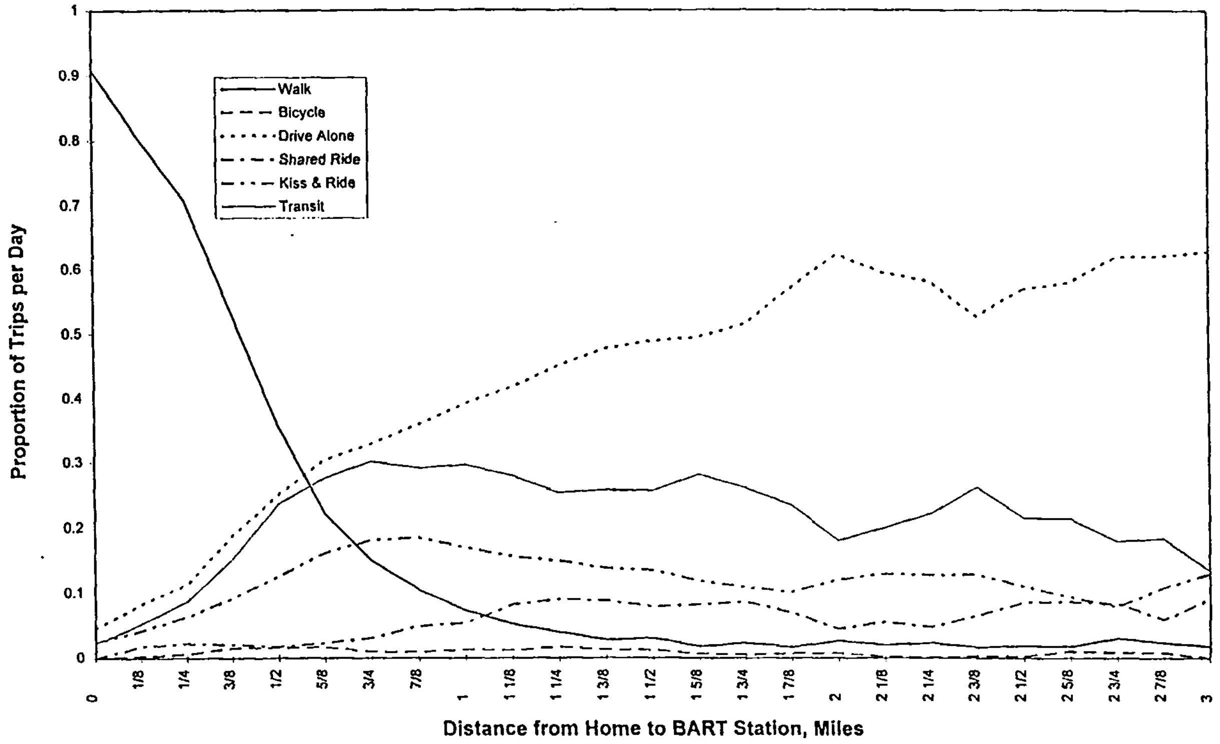


Figure 19. Mode of Access for Commute Trips from Home to Low-Density-Area BART Stations

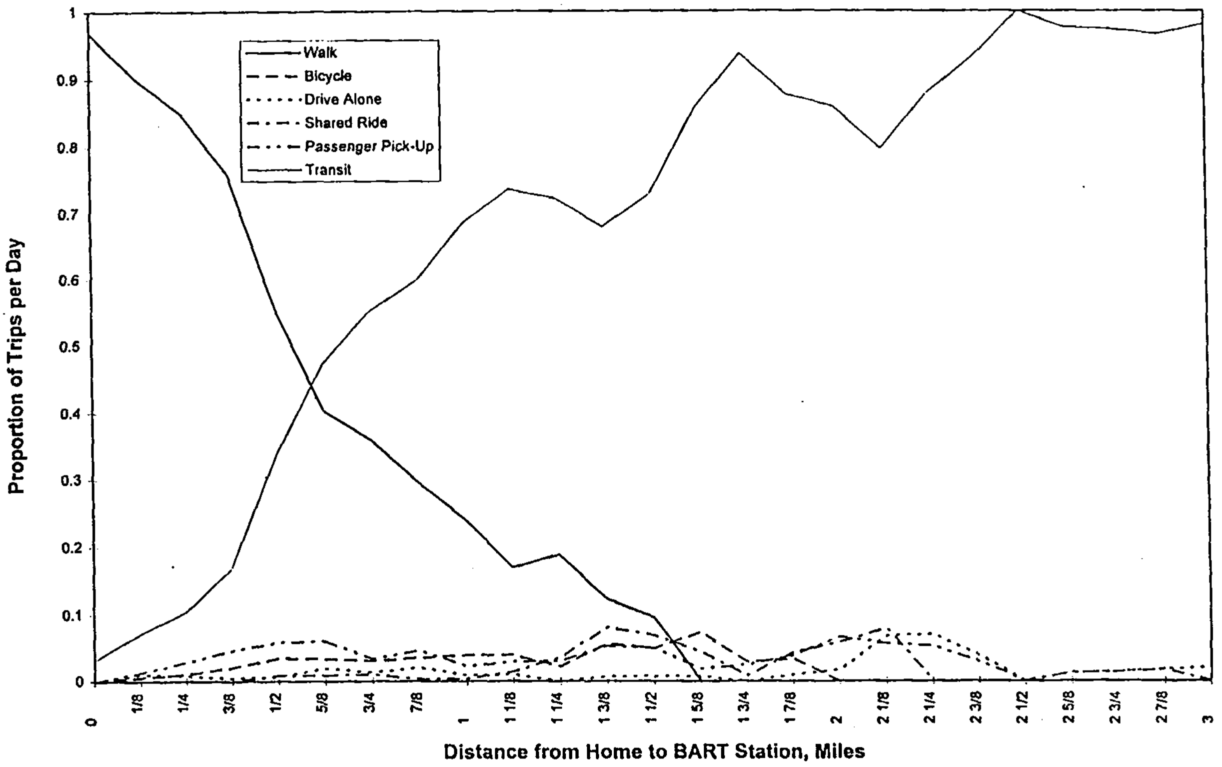


Figure 20. Mode of Egress for Commute Trips from Low-Density-Area BART Stations to Work

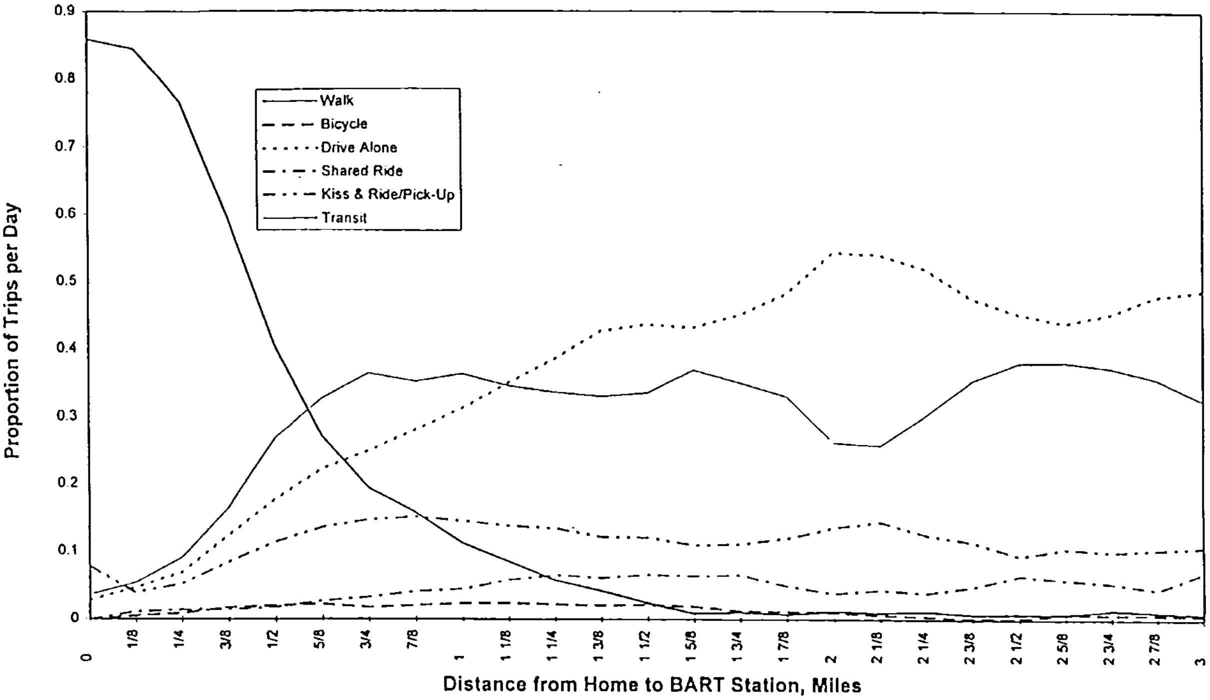


Figure 21. Mode of Access/Egress
For All Low-Density-Area BART Commute Trips

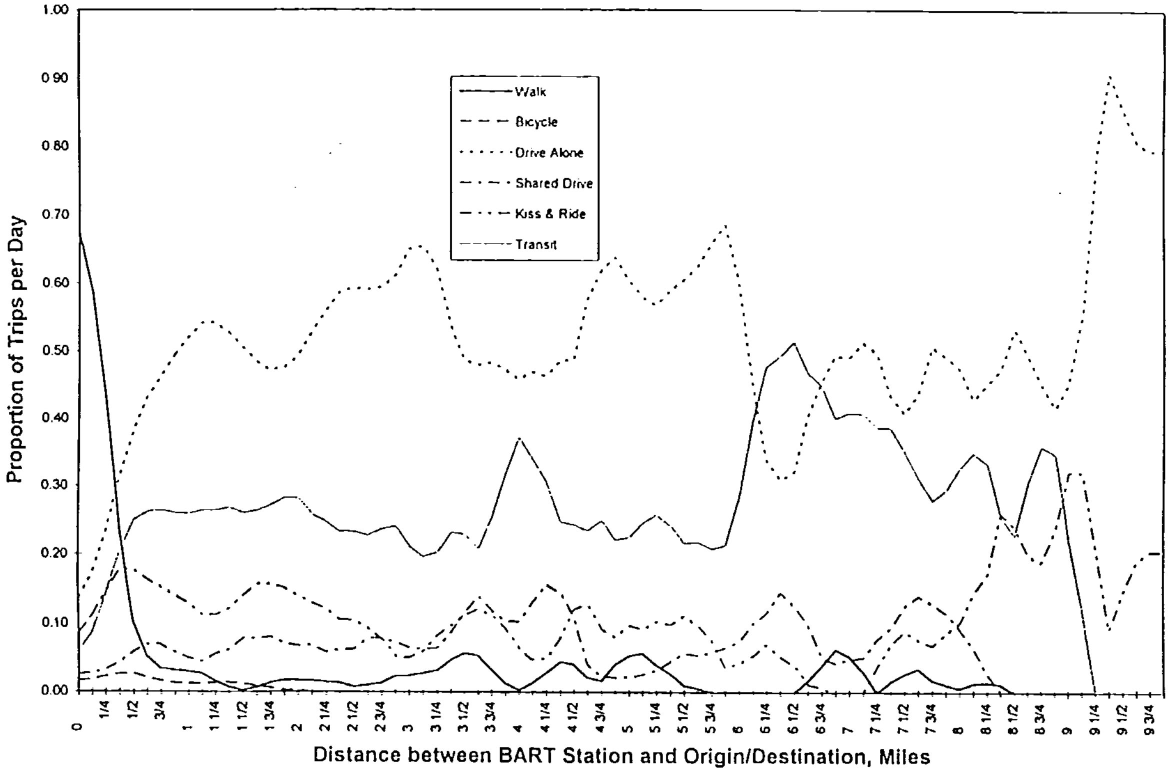


Figure 22. Mode of Access/Egress
For Terminal/Near-Terminal BART Commute Trips

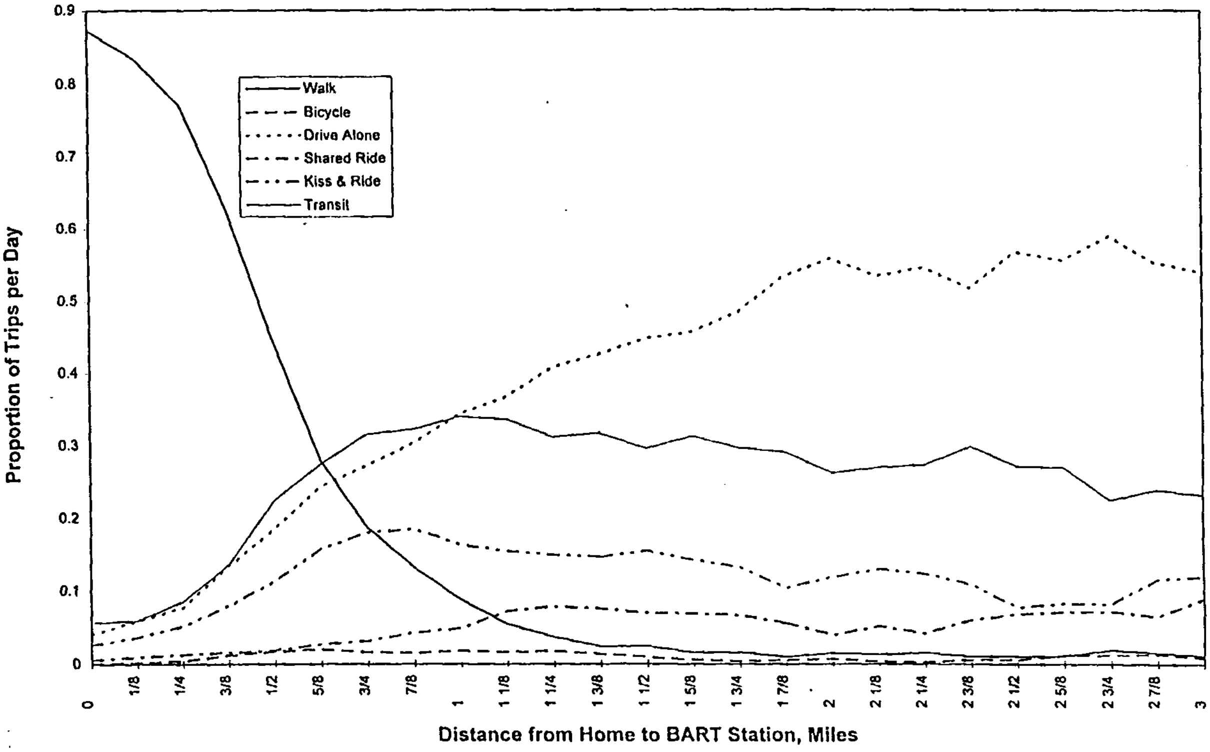


Figure 23. Mode of Access for Commute Trips from Home to All BART Stations

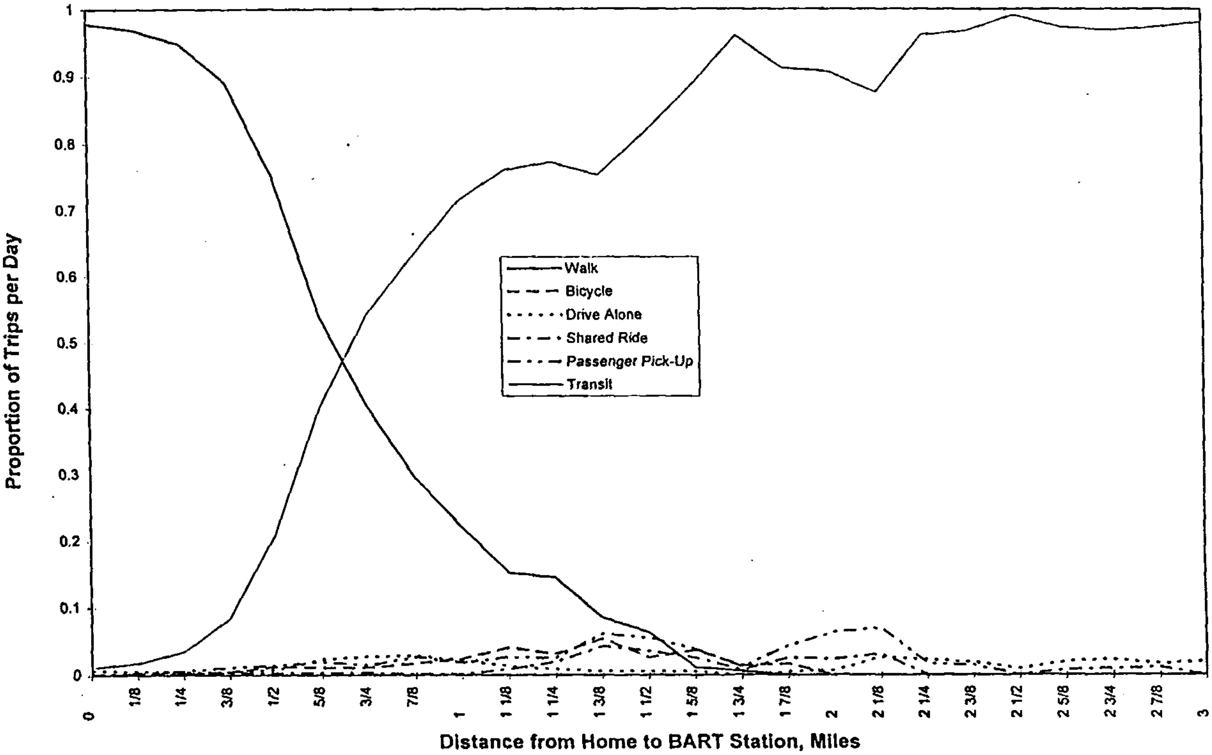


Figure 24. Mode of Egress for Commute Trips from All BART Stations to Work

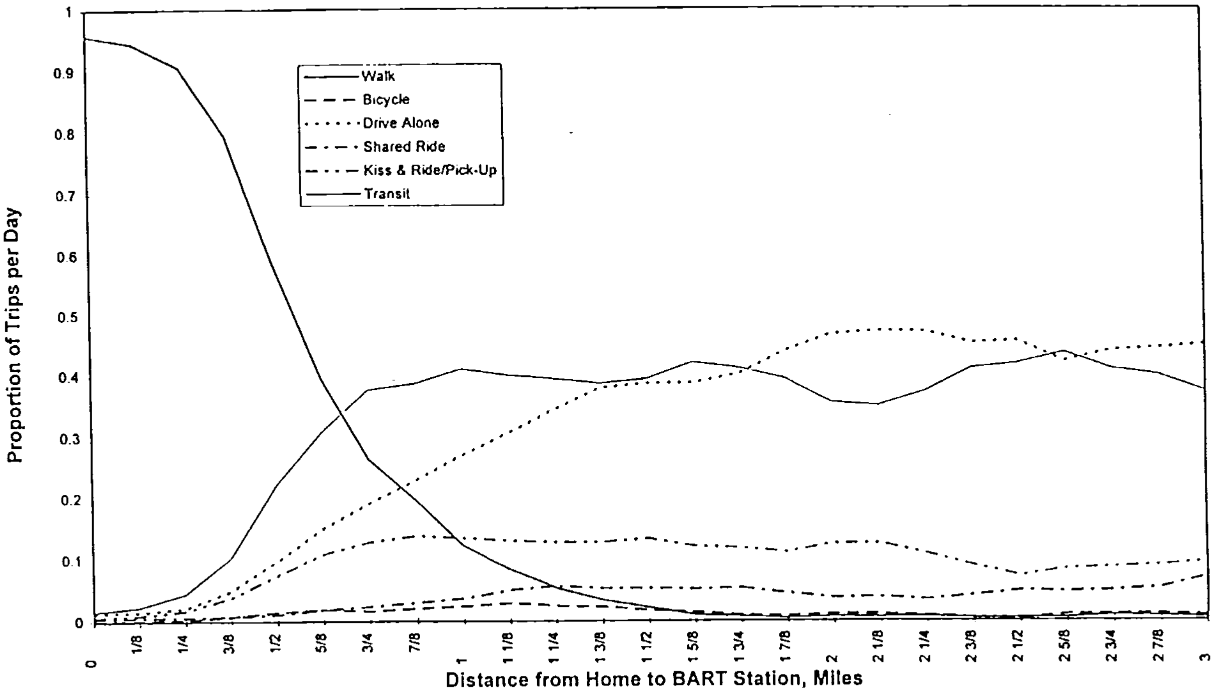


Figure 25. Mode of Access/Egress for All BART Commute Trips

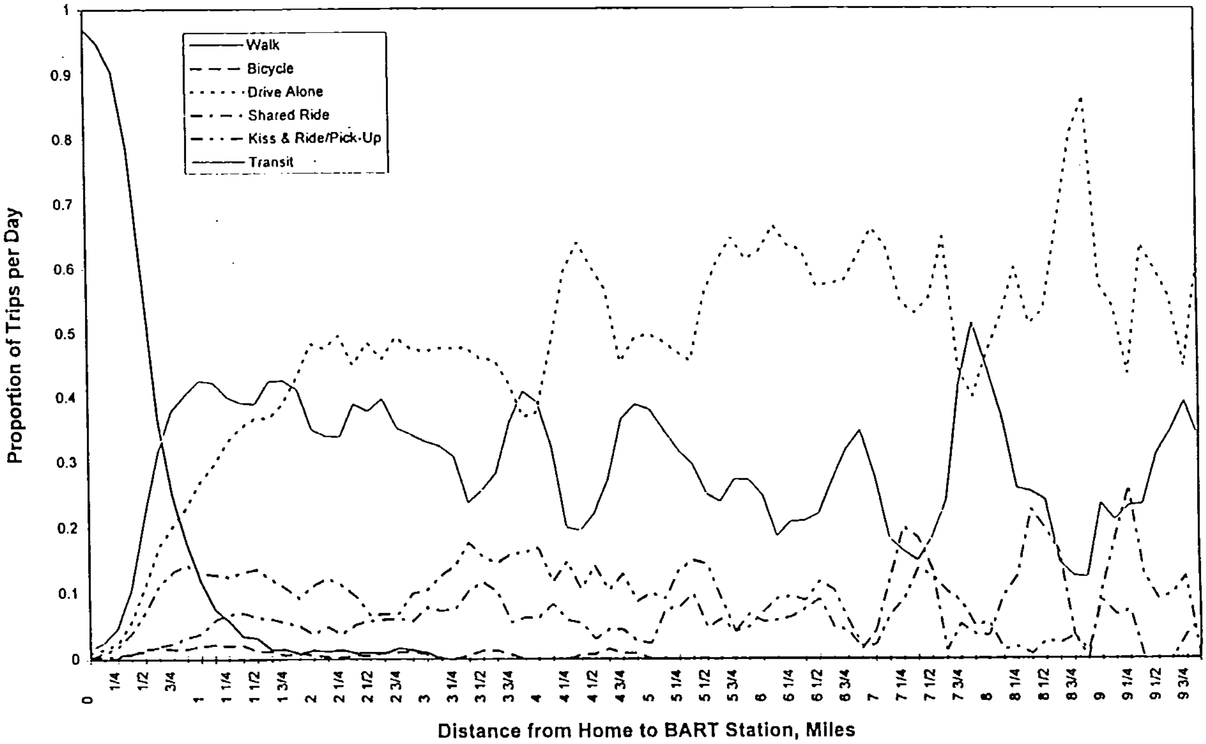


Figure 26. Mode of Access/Egress for All Home-to-Work BART Commute Trips, Longer Distance Plot

tidy, likely reflecting the combined effects of smaller sample sizes for longer distance access trips and localized factors (e.g., the presence of water bodies reducing transit travel over certain distance ranges).

Summary

The salient findings on the influence of distance on modes of access and egress are summarized in Table 17. One major distinction between station classes is the distance at which walking is eclipsed by other modes as the predominate means of access and egress. In general, people seem willing to walk farther to and from stations in denser, mixed-use settings. The largest walkshed was for downtown Oakland stations, which also have the greatest mixture of land uses. Downtown San Francisco and urban district stations had the second-largest walksheds, with the exception of home-end access trips to San Francisco Office Center stations. In general, net residential densities are so high near these stations that most resident accessing them are fairly close, many under 1,000 feet. For the two lowest-density station classes, transit and park-and-ride eclipsed walking as the predominant modes at shorter distances. People seem most averse to walking to suburban center stations, the station class with the largest size parking lots, the least land use mixes, and the lowest surrounding residential densities.

Table 17. Summary on Influence of Distance on Modes of Access and Egress Among Classes of BART Stations

	Distance up to which Walking Predominates		Mode of Access Beyond Walking Distance		Mode of Egress Beyond Walking Distance	
Station Class	Home-End Access	Work-End Egress	Dominant	Secondary	Dominant	Secondary
San Francisco Office Center	3,000 ft.	4,000 ft.	Transit	—	Transit	—
San Francisco Commercial/ Civic Center	4,000 ft.	3,300 ft.	Transit	Kiss-n-ride	Transit	—
Downtown Oakland	3,800 ft.	3,600 ft.	Transit	Kiss-n-ride	Transit	—
Urban Drive-alone/ Districts	3,300 ft.	3,600 ft.	Transit	Kiss-n-ride	Transit	Bicycle
Suburban Centers	2,700 ft.	3,300 ft.	Park Kiss-n-ride/ n-Ride	Passenger Transit	Transit	Pick-up
Low-Density Areas	2,900 ft.	2,900 ft.	Park- Transit/ n-Ride	Passenger Kiss-n-ride	Transit	Pick-up

In general, more dense, mixed-use settings seem to stretch walking access distances by 200-300 feet and walking egress distances by 200-600 feet. Overall, the land-use environments immediately around stations appear to have a modest yet measurable influence on walking access/egress distances. Quality of walking environment (e.g., amount of landscaping, sidewalk and street furniture provisions, extensiveness and attractiveness of ground-floor retail) could very well have an even bigger effect on the size of walksheds; there is likely not enough variation in walking quality among the 34 BART stations (once variables like land-use mixture are accounted for) to statistically gauge whether this is the case. One other finding is that walking tends to predominate over a longer distance for egress trips to workplaces than for access trips from home. This suggests that people might be less inclined to wait for a bus at exit stations when they can walk to their workplaces in 5 to 10 minutes. And in the case of suburban center and low-density area stations, the existence of park-and-ride lots encourages some nearby residents to drive when access distances are less than 1,000 feet.

Table 17 also reveals that for access trips beyond walking distance, modes vary markedly between higher-density urban stations and lower-density suburban ones. For downtown and urban district stations, where average employment densities exceed 20 workers per acre and average residential densities exceed 17 dwelling units per acre, transit is the dominant access mode for trips beyond one-half mile. Kiss-and-ride is the second most common access mode beyond this distance. For suburban-center and low-density area stations, park-and-ride is the dominant mode of access beyond 3,000 feet distance. Given the abundance of parking spaces at these stations, this is no great surprise. Both kiss-and-ride and transit function as secondary modes for longer-distance access trips to these suburban-like stations. In general, kiss-n-ride is more common as a secondary mode at suburban center stations, likely because of their good freeway accessibility. Transit, on the other hand, is the more common secondary mode for low-density area stations.

The smallest differences were recorded for egress trips made beyond walking distance. Regardless of station class, transit was the predominant mode for egress trips beyond one-half mile. For downtown stations, there is little option to walking or riding transit from the exit BART station to one's workplace. In lower density settings, a secondary egress mode was passenger pick-up.

Overall, the hypotheses posed by this research are supported. The land-use environment exerts a significant influence on modes of access and egress, especially with regard to the distance people will walk to or from a BART station. Beyond normal walking distances, factors like the supply of parking have a far stronger influence on access modal splits.

9. RIDERSHIP CATCHMENT AREAS

This section presents findings on the physical shapes, ranges, and other characteristics of the catchment areas for access and egress trips to and from BART stations. In examining the areas around which transit ridership is drawn, catchment areas were defined as contiguous census tracts which encompass the origins of 90 percent of all access trips to BART stations (or destinations of 90 percent of all egress trips from stations). The use of the 90 percent rank to demarcate catchment areas was chosen to represent the distances at which the vast majority of access trips are drawn. It was selected largely based on visual inspections of the cumulative distances of access trips to all BART stations. Beyond 90 percent, most access trips fall toward the extreme tail of the distance distribution. That is, some people make fairly long access trips of 20 or more miles from the exurban and rural fringes to reach suburban BART stations; however, these access trips represent statistical outliers. Invoking the criterion that a zone had to be contiguous to at least one other zone in a cluster to become a member of that cluster ensured that a reasonably well-defined territorial representation was obtained. The catchment areas for walk-on trips to BART stations were defined as the census tracts encompassing the origins of 90 percent of all access trips made by foot. This second catchment represents, we believe, an area that reflects the degree of urbanization around stations. As already shown, people seem willing to walk farther in denser, more mixed-use environs. Mapping of these walk-on catchment areas should further corroborate this finding. Still, walking catchments of lower-density areas can be expected to be larger simply by virtue of the greater distances that must be overcome by foot.[20]

In this section, the catchment areas for each station are portrayed using Geographic Information System (GIS) tools. The maps produced by GIS provide some understanding of how catchment areas vary in shape and size. Additionally, the average radii of catchment areas were estimated and compared across each class of station.

It should be added that using census tracts to define catchment boundaries is not ideal. In more urbanized settings, census tracts tend to be small enough that composites of census tracts tend to be reasonable representations of catchments. In lower-density areas, however, census tracts generally increase in size, meaning that catchments will tend to be larger in these settings. In some suburban and exurban parts of the Bay Area, for instance, large amounts of open space are within several census tracts, producing large territorial units. Even if one access trip origin is in one of these zones, using our criteria, the zone will be added to the catchment, thus skewing the estimate of land coverage. From visual inspections of our results, this turned out not to be a serious problem. Virtually all census tracts that met the catchment criteria had far more land that was developed than undeveloped. Still, ideally, smaller geographic units, like block groups or even blocks, would be used in defining catchments.

9.1. Catchment Areas for All Modes of Access and Egress

This section presents the catchment areas that capture 90 percent of access and egress trips for all modes combined, with census boundaries used to delineate areas. The GIS maps are presented in the appendix organized around the six station classes. Maps are first presented for home access trips by all modes, grouped by station classes. This is then followed by series of GIS maps for home access trips by walking only, also grouped by station classes.

Visual inspection of these maps reveals some patterns. Perhaps one is first struck by the finding that catchments do not follow simple, tidy concentric patterns. This is not surprising. Because of natural features, historical patterns of development, zoning restrictions, and other factors, residential development itself tends to be spread out and spatially uneven. As expected, the catchments for all modes are many orders of magnitude larger than those for walking access. Walking catchments, however, tend to be more compact and concentric-like in shape. Lastly, as hypothesized, catchments tend to enlarge in suburban station settings, particularly those with large park-and-ride lots and especially those that are terminals or near-terminals (i.e., function like terminals). The Daly City, Pleasant Hill, and El Cerrito del Norte stations, in particular, have huge catchments. Some of the intermediate stations closer in, like Lafayette, Balboa Park, and Hayward, as well as major transfer stations, like MacArthur, also have spacious catchments. The very large catchments, however, are mainly limited to the two lowest-density classes of stations: "suburban centers" and "low-density areas." And we see that being an end-of-the-line station does not alway gaurantee a large catchment area. The Richmond station, for instance, has a fairly small catchment for all access trips, encompassing just 23 square kilometers, compared to the next-in station, El Cerrito del Norte, whose catchment is 146 square kilometers in size. This difference is partly explained by differences in freeway accessibility — El Cerrito del Norte station sits right off of Interstate 80 whereas the Richmond station is several miles away from the freeway. It is also explained by differences in parking supplies (which are likely also influenced by level of freeway accessibility) — the Richmond station has 796 parking spaces, compared to 2,516 at El Cerrito del Norte.

For all access trips, the largest catchment areas were along the Concord line: Lafayette (628 sq. kms), Concord (420 sq. kms), Pleasant Hill (335 sq. kms), and Orinda (313 sq. kms). This partly reflects the vast amounts of suburban residential development that lies east of these stations as well as the existence of some large census tracts in the suburban East Bay. Lake Merritt (5.8 sq. kms), Mission 16th Street (9.86 kms), and Embarcadero (14.6 sq. kms) have the smallest catchments for all trips, reflecting their high-density surroundings and absence of free parking (though Lake Merritt does have 205 paid parking spaces at 25 cents per day).

9.2. Catchment Areas for Walking Access Modes

As noted, 90 percent catchments for walk-on trips tended to be smaller and more concentric-like than those for all modes. Differentials in the catchment areas for all modes versus walk modes varied significantly by stations — from the all-mode catchment being just 2.8 times larger in the case of the downtown Berkeley station to over 55 times as large for the El Cerrito del Norte station. In general, the differentials were smallest for urban district stations (Berkeley, the Mission stations, and Lake Merritt) and were largest for terminal and suburban center stations. Some of the densest stations, however, also had large differentials — the all-mode catchment was 17 times larger for the Montgomery Street station and 13 times larger for Oakland's 12th Street station.

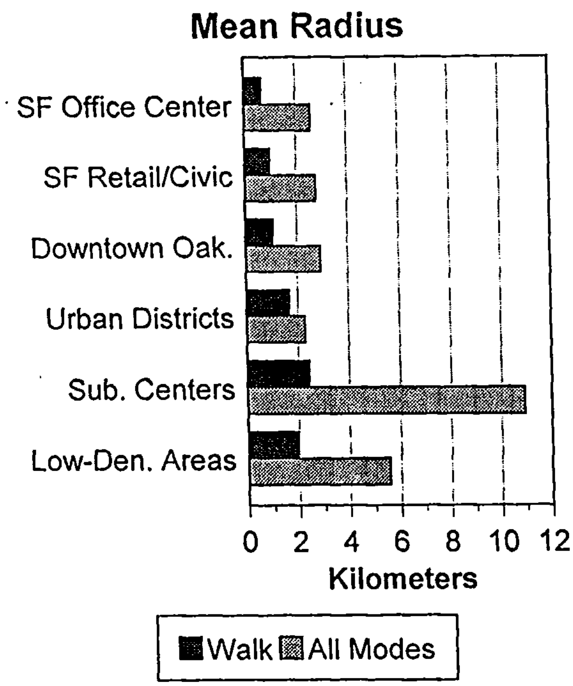
9.3. Comparison of Catchments Across Station Classes, for all Modes

Significant variation was found in the size, radius, service population, and density of catchments across the six classes of stations. For all modes of access, Table 18 and Figure 27 show that the Suburban Center stations tended to have catchments with the largest land coverage and average radii. Relative to

Table 18. Comparison of Catchment Radii, Land Areas, Populations, and Densities for Six Station Classes, for all Home-Access Modes

	Radius[1]	Land Area[2]	Population[3]	Density[4]
San Francisco Office Center	2.60 (0.62)	21.78 (10.09)	164,836 (57,416)	7,793 (972)
San Francisco Retail/Civic Center	2.77 (0.41)	24.29 (7.06)	200,089 (69,914)	8,165 (506)
Downtown Oakland	2.94 (1.05)	28.90 (19.35)	102,623 (45,513)	3,898 (1,036)
Urban Districts	2.29 (0.91)	18.40 (13.75)	98,448 (53,693)	6,138 (2.565)
Suburban Centers	10.94 (2.06)	386.99 (150.01)	220,570 (77,295)	598 (200)
Low Density	5.59 (2.26)	113.55 (84.64)	172,938 (71,488)	1,523 (1.247)
F-Statistic (F probability)	11.58 (.000)	11.47 (.000)	1.84 (.137)	20.49 (.000)

Notes:
[1] Mean radius of catchment = $\{\Sigma_i \sqrt{(\text{Land Area})/\Pi}\ \} / n_i$, where Σ_i = sum over all cases in catchment i and n_i = number of cases in catchment i (std. dev. in parentheses),
[2] Mean land area (square kilometers) of catchment (std. dev. in parentheses),
[3] Mean population of catchment (std. dev. in parentheses).
[4] Mean population density of catchment (people/square kilometer) (std. dev. in parentheses).



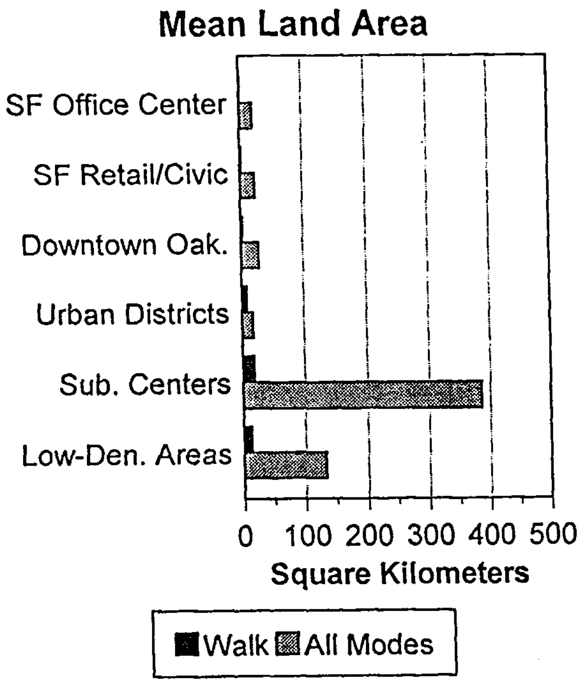


Figure 27. Comparison of Mean Catchment Radii and Land Areas Among Station Classes

the station class with the smallest average catchment area and radius, the San Francisco Office Centers (Embarcadero and Montgomery Streets), the Suburban Center stations are, on average, 1,677 percent larger in area and 321 percent larger in radius (Figure 28). Next in average catchment size was the Low-Density station class, which were around 421 percent larger than the San Francisco Office Centers stations. Surprisingly, the average catchment areas and radii of the six remaining stations were fairly similar — average land areas in the range of 18.4 to 28.9 square kilometers, and average radii from 2.29 to 2.94 lineal kilometers. This likely reflects the fact that nearly all stations in these four station classes contain no parking, as was shown previously in Table 3. It is parking supplies, we suspect, that is the principal explainer of differences in catchment area, much more so than land-use variables like density or mixtures of use. The simple correlation between catchment area (for all modes of access) and parking supply for the 34 BART stations was 0.63; the correlation between employment density and catchment area was -.46. Of course, density and parking supply are highly correlated among themselves, so these relationships are interconnected.

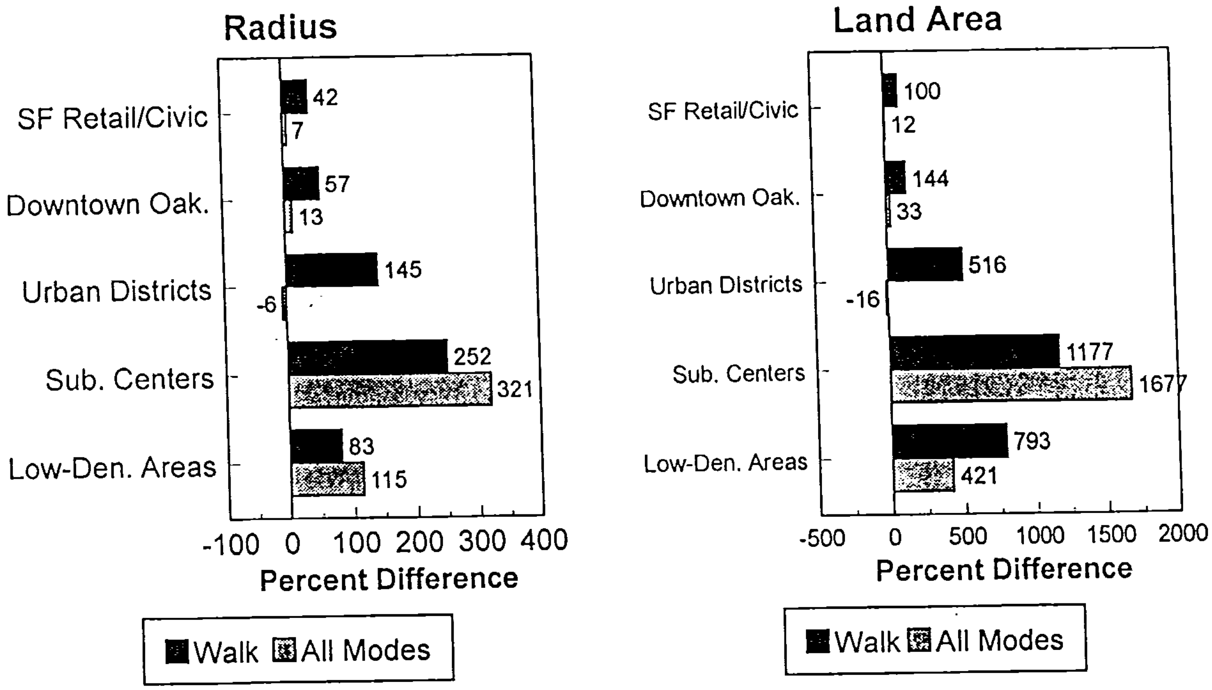


Figure 28. Mean Radii and Land Areas as Percent of the "San Francisco Office Center" Catchment

To further explore these associations, regression models were produced that predict catchment size and radius (Table 19). As expected, catchment areas were generally smaller for stations in dense settings (e.g., downtown San Francisco), and were generally larger in those with high parking supplies (e.g.,

Table 19. Regression Model for Predicting Size and Radius of Catchment Areas for BART Stations, Walking Modes

	Dependent Variable: Catchment Size (sq. km) Coefficient	Dependent Variable: Catchment Radius (km) Coefficient
Employees/acre within one-half mile of station	-0.803*	-.019**
	(.417)	(.008)
Households/acre within one-half mile of station	-3.679*	-.095*
	(2.402)	(.046)
Median household income ($1,000s)	7.185***	0.161***
	(1.951)	(.037)
Park-and-ride spaces at station	0.052**	0.0014***
	(.025)	(.0005)
Constant	-52.23	1.465
	(56.13)	(1.89)
R-squared	.607	.720
F Statistic	11.19	18.61
F probability	.000	.000

Notes:
Values in parentheses are standard errors.
Number of cases = 34
*** = significant at .01 probabilty level
** = significant at .05 probability level
* = significant at .10 probability level

Pleasant Hill) and fairly high incomes (e.g., Lafayette, Orinda). Incomes and parking were most highly associated with catchment size.

Table 18 indicates there were statistically significant differences in land area and radius among the six station classes (ANOVA F statistics). Even more significant were differences in the catchment densities. The catchment densities for urban districts, for example, were ten times as dense as those of suburban centers. Catchment population sizes, however, varied less among the six classes.

9.4. Comparison of Catchments Across Station Classes, for Walking Trips

As noted, there was less variation in catchment sizes for walk trips. Table 20 and Figure 27 reveal walking catchments were in downtown San Francisco were 1.5 to 3 square kilometers in size with radii of 0.7 to 1 kilometers. As one moved down the urban hierarchy, walking catchments generally enlarged and catchment densities fell. The largest walking catchments were for suburban centers, reflecting their low surrounding residential densities as well as vast inventories of parking (which spatially separates walkers from rail stations). Figure 28 shows the typical walking catchments around suburban center stations were more than 11 times larger and had 2.5 times longer radii than those in downtown San Francisco.

Table 20. Comparison of Catchment Radii, Land Areas, Populations, and Densities for Six Station Classes, for Home-Access Walk Trips

	Radius[1]	Land Area[2]	Population[3]	Density[4]
San Francisco Office Center	0.69 (0.04)	1.52 (0.18)	18,715 (35372)	12,047 (4,,637)
San Francisco Retail/Civic Center	0.98 (0.02)	3.04 (0.11)	45,890 (7,828)	15,080 (2,013)
Downtown Oakland	1.08 (0.09)	3.70 (0.58)	23,028 (9,782)	6,086 (1,684)
Urban Districts	1.69 (0.39)	9.37 (4.05)	62,200 (28,541)	6,662 (1,799)
Suburban Centers	2.43 (0.61)	19.41 (9.69)	23,600 (12,741)	1,412 (1,006)
Low Density	1.95 (0.75)	13.58 (13.85	35,372 (16,907)	3,527 (1,803)
F-Statistic (F probability)	3.33 (.017)	1.25 (.311)	3.07 (.025)	23.43 (.000)

Notes:
[1] Mean radius of catchment = $\{\Sigma_i \sqrt{(\text{Land Area})/\Pi}\} / n_i$, where Σ_i = sum over all cases in catchment i and n_i = number of cases in catchment i (std. dev. in parentheses),
[2] Mean land area (square kilometers) of catchment (std. dev. in parentheses),
[3] Mean population of catchment (std. dev. in parentheses).
[4] Mean population density of catchment (people/square kilometer) (std. dev. in parentheses).

The regression model produced for estimating the size and radii of walking catchments did not have as good a fit (Table 21). Parking supplies increase catchment sizes, while, controlling for parking, terminal and near-terminal stations averaged smaller walking catchments. Walking catchment radii tended to decline with denser station environs.

9.5. Catchments Among Station Types with Different Parking Supplies

Since parking supply was found to have a significant bearing on sizes of catchment areas, these relationships were also studied for three other types of stations: (1) Urban/No Parking; (2) Suburban/ Parking (but not a terminal or near terminal); and (3) Terminal/Near-Terminal. Table 22 and Figure 29 show that catchment areas varied even more strongly as a function of these classificatons. The urban stations with no parking averaged catchments which were around 2.6 kms in radius and 22 square kilometers in land area. Terminal/Near-Terminal stations averaged catchments that were nearly ten times as large (Figure 30).

Relationships were similar for walk trips (Table 23). However, suburban stations with parking generally had the largest pedestrian catchments. This is consistent with the findings of the previous section that, controlling for parking supplies, terminal/near-terminal stations generally had smaller walking catchments than other suburban station areas.

Table 21. Regression Model for Predicting Size and Radius of Catchment Areas for BART Stations, Walking Modes

	Dependent Variable: Catchment Size (sq. km) Coefficient	Dependent Variable: Catchment Radius (km) Coefficient
Park-and-ride spaces at station	0.0091*** (.0029)	4.885** (.002)
Terminal or near-terminal (0 = no, 1 = yes)	-17.672** (6.658)	-1.087*** (.3793)
Employees/acre within one-half mile of station	-(.0024)	-.0057**
Constant	6.875 (2.747)	1.695 (0.198)
R-squared	.423	.497
F Statistic	7.63	5.08
F Probability	.001	.012

Notes:
Values in parentheses are standard errors.
Number of cases = 34
*** = significant at .01 probabilty level
** = significant at .05 probability level
* = significant at .10 probability level

Table 22. Comparison of Catchment Radii, Land Areas, Populations, and Densities for Three Station Types, for All Home-Access Modes

	Radius[1]	Land Area[2]	Population[3]	Density[4]
Urban/ No Parking	2.58 (0.73)	22.35 (11.78)	160,832 (68,196)	6,498 (2,225)
Suburban/ Parking	6.08 (3.20)	146.47 (154.87)	160,832 (68,197)	2,119 (1,407)
Terminal/ Near Terminal	8.59 (2.02)	242.66 (114.53)	248,947 (46,621)	1,153 (363)
F-Statistic (F probability)	11.60 (.000)	6.42 (.005)	6.44 (.005)	30.43 (.000)

Notes:
[1]Mean radius of catchment = $\{\Sigma_i \sqrt{(\text{Land Area})/\Pi}\} / n_i$, where Σ_i = sum over all cases in catchment i and n_i = number of cases in catchment i (std. dev. in parentheses),
[2]Mean land area (square kilometers) of catchment (std. dev. in parentheses),
[3]Mean population of catchment (std. dev. in parentheses).
[4]Mean population density of catchment (people/square kilometer) (std. dev. in parentheses).

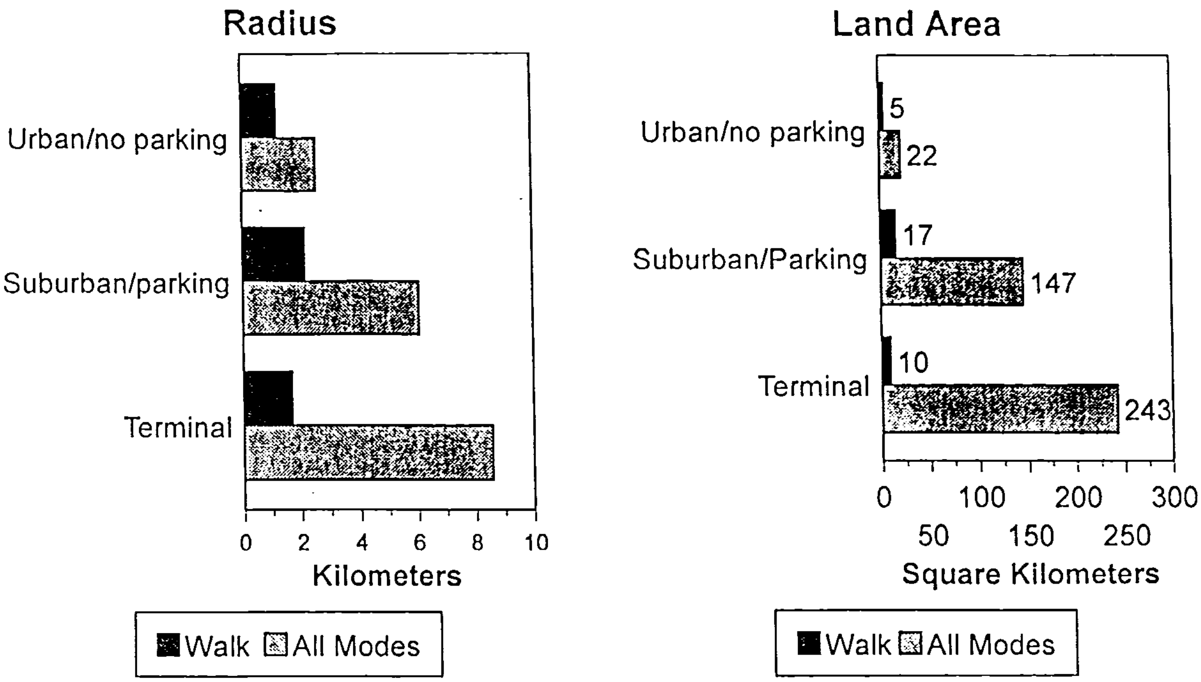


Figure 29. Comparison of Mean Catchment Radii and Land Areas Among Three Station Types

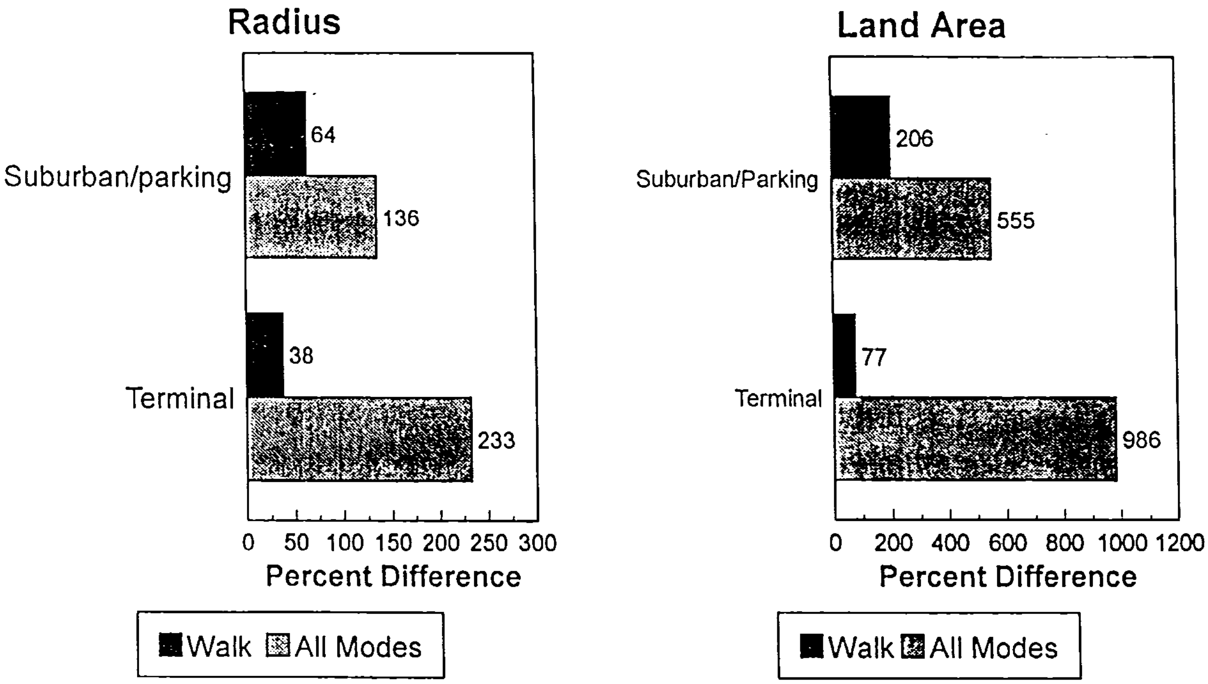


Figure 30. Mean Radii and Land Areas as Percent of the "Urban/No Parking" Catchment

Table 23. Comparison of Catchment Radii, Land Areas, Populations, and Densities for Three Station Types, for Home-Access Walk Trips

	Radius[1]	Land Area[2]	Population[3]	Density[4]
Urban/	1.23	5.40	42,407	9,307
No Parking	(0.48)	(4.21)	(26,142)	(4,327)
Suburban/	2.16	16.54	32,177	2,860
Parking	(0.80)	(14.70)	(15,097)	(1,857)
Terminal/	1.70	9.55	35,147	3,766
Near Terminal	(0.41)	(3.74)	(22,043)	(1,893)
F-Statistic	6.38	3.35	0.84	17.51
(F probability)	(.01)	(.048)	(.441)	(.000)

Notes:
[1]Mean radius of catchment = $\{\Sigma_i \sqrt{(\text{Land Area})/\Pi}\} / n_i$, where Σ_i = sum over all cases in catchment i and n_i = number of cases in catchment i (std. dev. in parentheses),
[2]Mean land area (square kilometers) of catchment (std. dev. in parentheses),
[3]Mean population of catchment (std. dev. in parentheses).
[4]Mean population density of catchment (people/square kilometer) (std. dev. in parentheses).

10. CONCLUSION

The hypotheses posited at the outset of this report were largely substantiated by empirical evidence from the San Francisco Bay Area. In short, densities and, to a lesser extent, land-use mixtures do matter in determining how people access rail stations and what the general size of catchment areas are for access trips.

The key findings of the research are summarized below:

- Dense, mixed-use urban areas average high shares of walk access trips. Most suburbanites access stations by private automobile.
- Land use mixture was most strongly associated with access and egress modal splits. This suggests that creating communities around rail stations that provide services to walk-on users and that are more pedestrian-friendly in design could encourage higher shares on non-motorized access trips.
- The built environment appears to have the weakest influence on whether access and egress trips to and from rail stations are by bus transit. Quality of transit services is a far more important factor.
- Parking supplies had their strongest influence on reducing walk trips from homes to stations. When facing the prospects of wading through seas of surface parking, some would-be walkers opted to park-and-ride instead.
- People are willing to walk farther to and from stations in denser, mixed-use settings. People are most averse to walking to suburban center stations, the station class which, in the Bay Area, has the largest-size parking lots, the least land use mixes, and the lowest surrounding residential densities.
- More dense, mixed-use station settings seem to stretch acceptable walking access distances by 200-300 feet and walking egress distances by 200-600 feet.

- Walking tends to predominate over a longer distance for egress trips to workplaces than for access trips from home.
- For downtown and dense, urban stations, transit is the dominant access mode for trips beyond one-half mile. For suburban stations, park-and-ride is the dominant access mode beyond a half a mile from a station. For egress trips beyond one-half mile, transit is the dominant mode.
- Home-access catchment areas varied sharply by land-use environment. The lowest-density station areas and suburban centers generally had catchment areas that were 6 to 10 times larger in size than those of downtown and urban station areas.
- Parking supplies, densities, and neighborhood incomes were the strongest predictors of catchment area. Catchments were smaller for stations in denser settings and larger for those with large parking lots and in affluent communities.
- There was less variation in catchment sizes for pedestrian access trips. Suburban walk-on catchments tended to be 8 to 10 times larger than those of downtown station areas and 3 to 4 times larger than those of urbanized areas.

Notes

[1]The San Francisco Bay Area is somewhat unique in that there are a range of common-carrier access modes beyond bus transit available in San Francisco. These include light-rail transit, bus trolleys, jitneys, and cable cars.

[2]Summing information on the dominant land use for each hectare over the number of hectares within a half-mile radius of rail stations provided counts of the total square meters of land area devoted to each land use within a circle of one-mile diameter around each BART station.

[3]Data on residential densities were obtained from STF 3-A for 1990 census tracts and block groups that most closely corresponded to a half-mile radius surrounding each station. Data on employment densities were obtained from the 1990 CTPP, provided by the Metropolitan Transportation Commission, for 1990 ncensus tracts that most closely corresponded to a half-mile radius of each station.

[4]The use of census tracts for defining catchment areas posed problems for studying walk-on trips in suburban areas where cencus tracts can be large, often with dimensions well beyond the one-quarter- to one-half-mile distance normally considered to be the maximum distance Americans will walk. In more urbanized areas, especially downtown San Francisco, census tracts (sometimes as small as four or five city blocks) are more suitable for studying the catchments for pedestrian access trips.

[5]The average radius for the catchment of each station was estimated by assuming the calculated land area represents a circle. The radius of a circle of equivalent area was then calculated.

[6]The measure used for joining clusters was the average linkage between groups, often called UPGMA (unweighted pair-group method using weighted average [see Everitt, 1980]). Here, the distance measured between two clusters is the average of distances between all pairs of cases in which one member of the pair is from each of the clusters.

[7]Under this approach, all cases are initially considered as separate clusters, i.e., there are as many clusters as cases. As the second step, the two cases with the most comparable squared Euclidean distances (i.e., the ones whose sum of squared factor scores are the msot alike) are combined into a single cluster. At the third step, either a third case is added to the cluster already containing two cases, or two additional cases are merged into a new cluster. The process continues until all cases are grouped together. See Everitt (1980) for further discussions of this approach.

[8]This is because the squared Euclidean distances between station cases for the parking variable was so huge that the distance metrics for other variables were comparatively small and thus played a small role in fusing together cases in the clustering algorithm.

[9]The Pleasant Hill station was assigned to a different group than that shown in Figure 1, because of its unique development characteristics. Specifically, Pleasant Hill was assigned to the cluster of Suburban Centers, with Walnut Creek, Concord, Lafayette, and Orinda. This is because Pleasant Hill emerged as a suburban center mainly after 1990. From 1990 to 1992, around one million square feet of office floorspace and over 1,000 dwelling units were added to the one-half-mile ring around the Pleasant Hill station. Thus, Pleasant Hill's development post-dated the 1990 land-use data compiled from the census and ABAG inventory. By 1992, the year for which the BART passenger survey was conducted, Pleasant Hill clearly had the character of a suburban center, similar to Walnut Creek and Concord.

[10]These six cluster groups of BART stations are reasonably similar to those created by Johnston and Tracy (1982). Their classifications were far more impressionistic, however, based on "windshield surveys" of land uses near stations. They grouped all downtown San Francisco, Oakland, and Berkeley stations in a single group (failing to acknowledge large differences in employment densities across these stations. Their classifications of "urban high-density residential" stations matched our classification of "urban districts," with the exception that the MacArthur station was placed in this group in lieu of the Berkeley station. In addition to Walnut Creek and Lafayette, they grouped San Leandro, Hayward, and Richmond as suburban stations. Remaining stations were placed in three different levels of suburban densities: medium, low, and low-density/rural. Their general criteria for judgementally classifying stations were based on densities and land use activities. Other factors used in our analysis, such as related to levels of land-use mixture, parking supplies, and rail modal splits, were not explicitly used.

[11]Six hundred new spaces were added to the Concord station in the summer of 1994, bringing the total up to 2,575 spaces. In 1992, the year for which the BART passenger data were compiled, however, the parking supplies shown

in Table 3 existed. With the new parking supply at the Concord station, the average number of parking spaces at the Suburban Centers class of BART station is currently 2,048.

[12]As residential densities decline among the six station clases, so do auto access market shares. The relationship is not quite as tidy as a function of employment densities in that suburban centers, though they have higher employment densities than low-density areas, average higher auto acccess trips than low-density areas. Changes in home-end access trips seem most closely correlated with changes in parking supplies.

[13]Modal splits for home-end egress trips by transit were nearly identical to those of home-end access trips, and thus are not presented.

[14]While transit service levels (e.g., vehicle miles of transit service per day within catchment zone) were not directly used to classify stations in the cluster anazlysis, their influences are generally captured by the land-use variables. Transit agencies generally focus their services in the most urbanized areas, meaning dense, mixed-use settings often receive the most intensive services.

[15]For some variables, such as parking supplies and the dependent variables (modal splits), data are recorded directly for stations themselves. For land-use variables (e.g., density, percent land area), the areas encompassed by a one-half-mile radius around the stations served as cases.

[16]Mispoint elasticities are measured at the mean values of both the dependent and independent variables.

[17]Plots of distances up to 5 to 10 miles were initially generated; however, the results were not particularly decipherable for longer distances. As a result, the plots generated in this section are only for distances up to 2 to 3 miles.

[18]Near-terminal represents stations toward the end of a line that function like terminals because they are closer to freeways than the actual terminal stations and thus serve a larger catchment area. BART's near-terminal stations El Cerrito del Norte and Pleasant Hill have larger supplies of parking than terminal stations since they are easier to reach by freeways.

[19]Mis-sampling of longer-distance access and egress trips could reflect the tendency of those traveling longer distance to have less time available to complete a questionnaire form. This might particularly be the case for those pressed to reach job sites that are relatively far form their exit BART stations.

[20]The way membership was determined was that zones that were closest to the station were grouped into a catchment. Working outward from the station, if a zone contained trip ends that were within the 90 percentile rank of access distances to a station and shared a boundary or a point with a zone already assigned to the catchment, then the zone was added. Sharing a point means that the two zones only had to connect at one point, and not necessarily share a boundary, to be considered contiguous.

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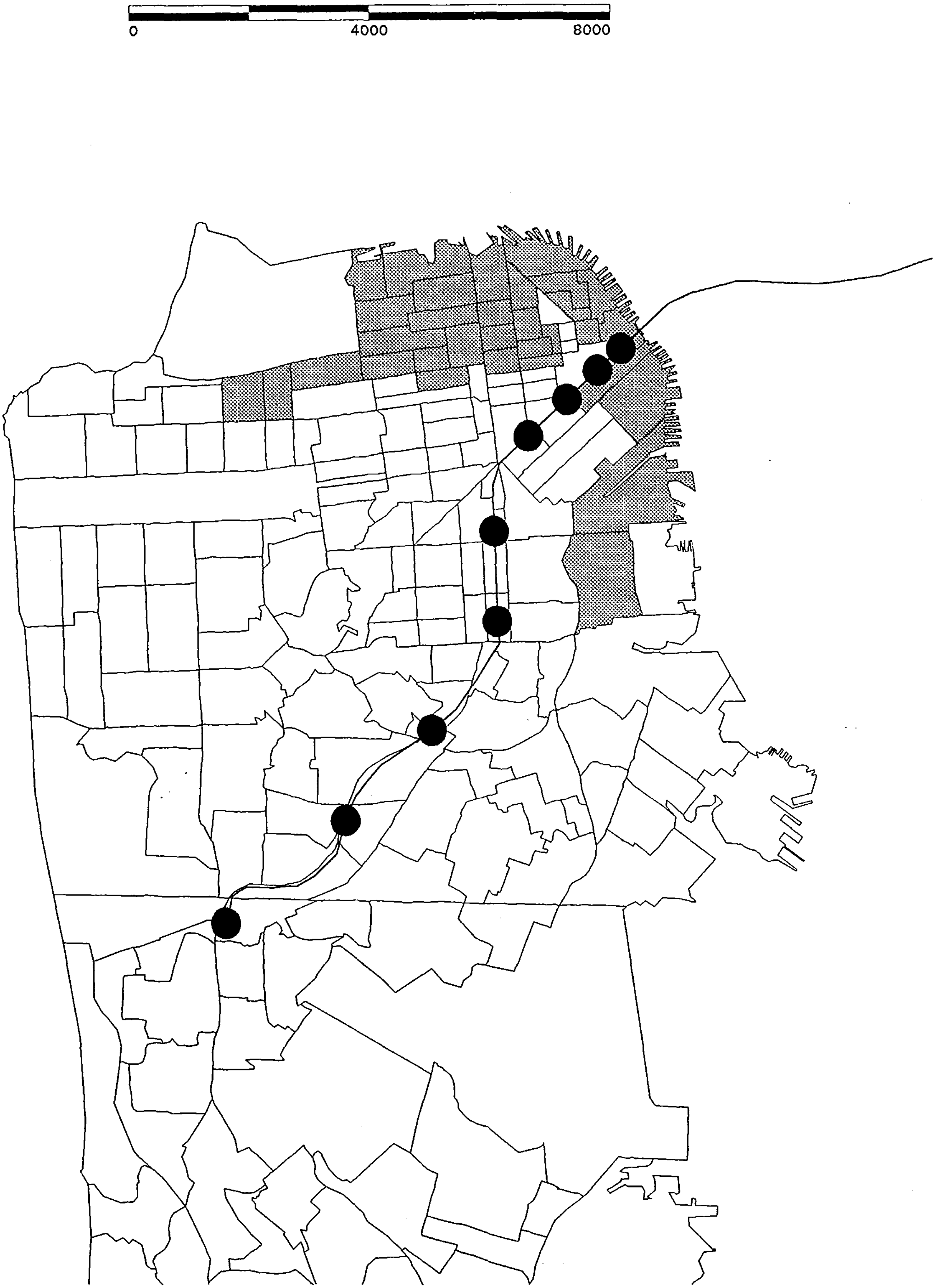
90% Catchment Area for

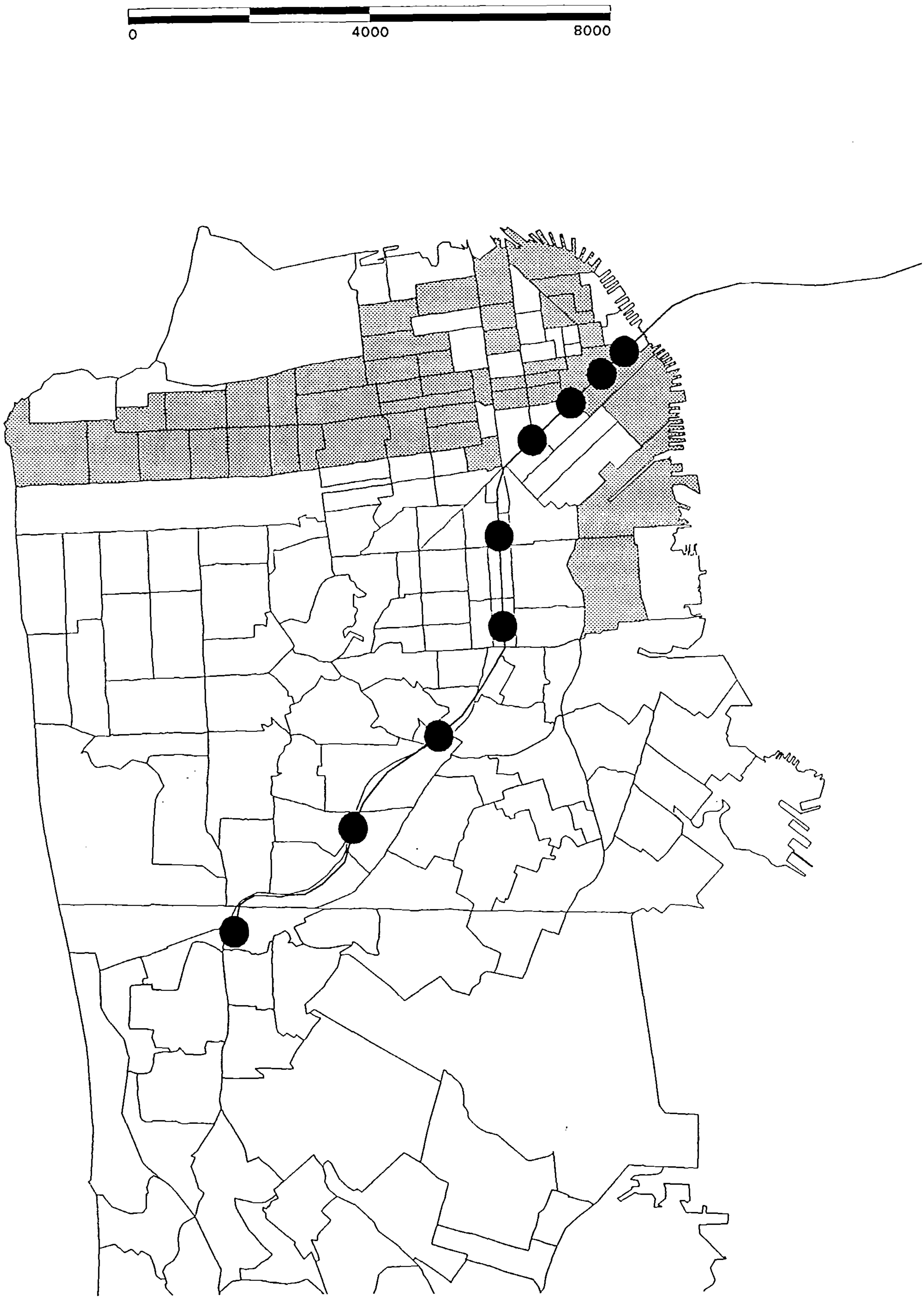
SAN FRANCISCO OFFICE CENTER

All Modes

Embarcadero Station - 90% Catchment Area - Home Access by All Modes



Montgomery Station - 90% Catchment Area - Home Access by All Modes

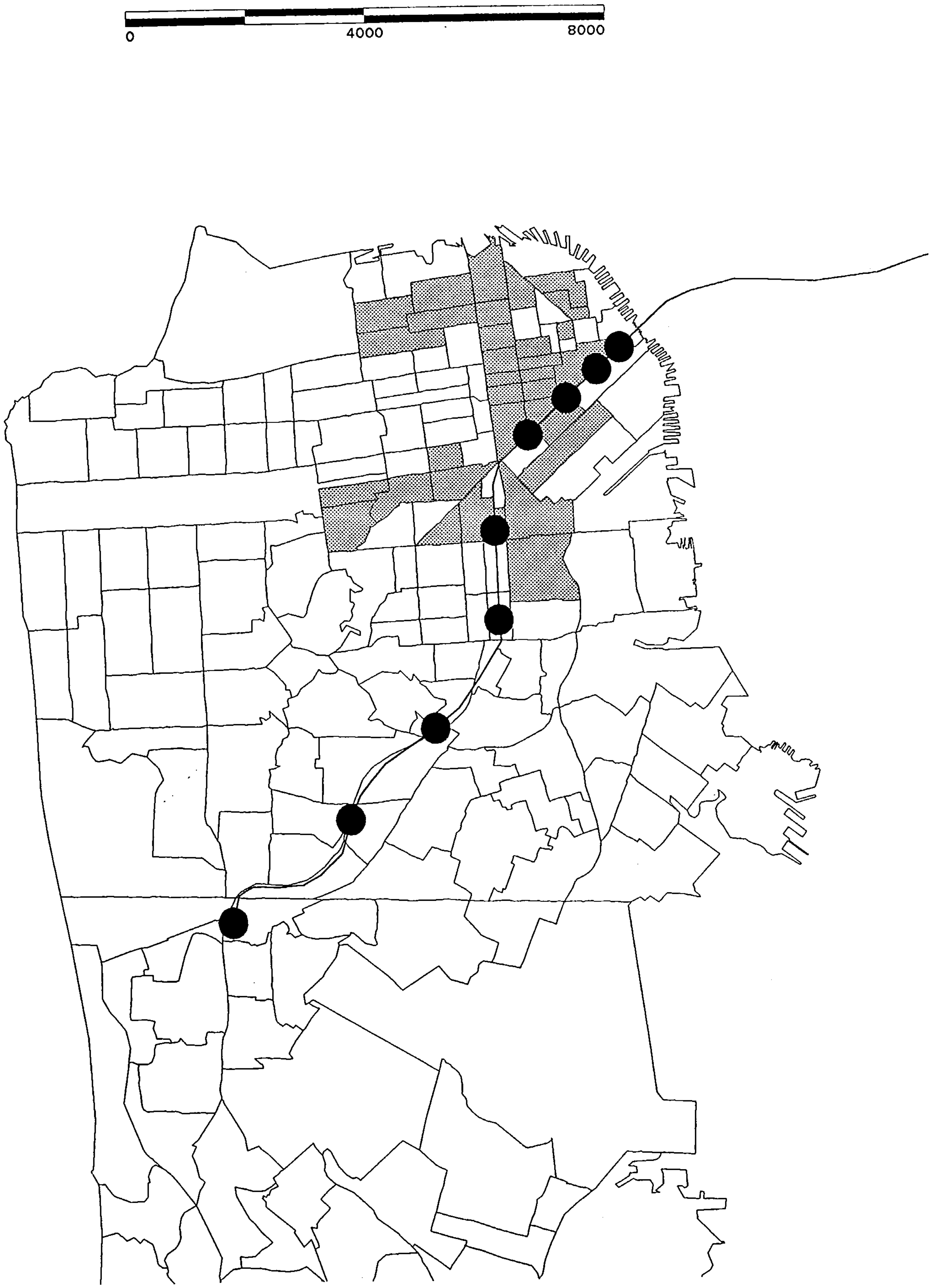


90% Catchment Area for

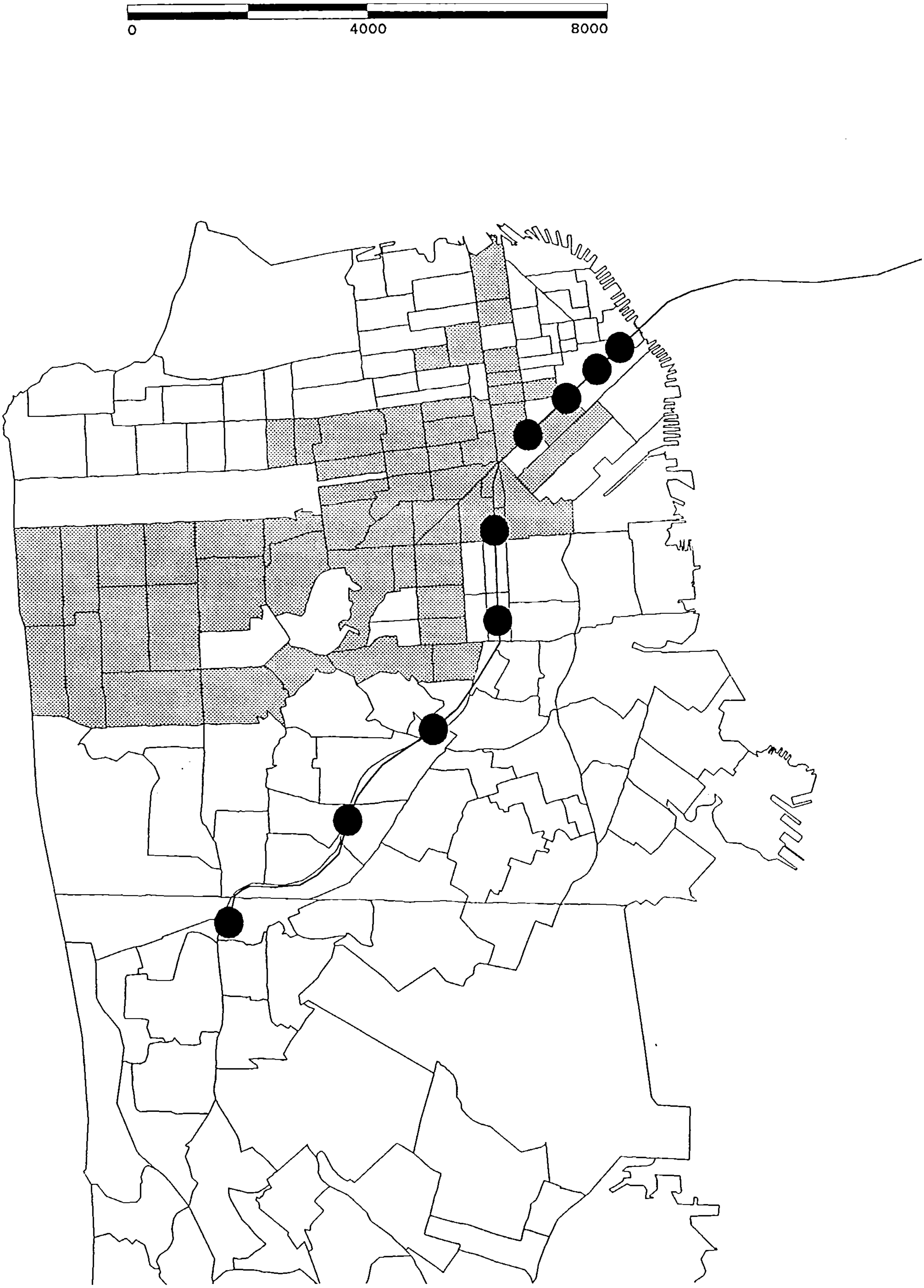
SAN FRANCISCO COMMERCIAL/CIVIC CENTER

All Modes

Powell Station - 90% Catchment Area - Home Access by All Modes



Civic Center Station - 90% Catchment Area - Home Access by All Modes

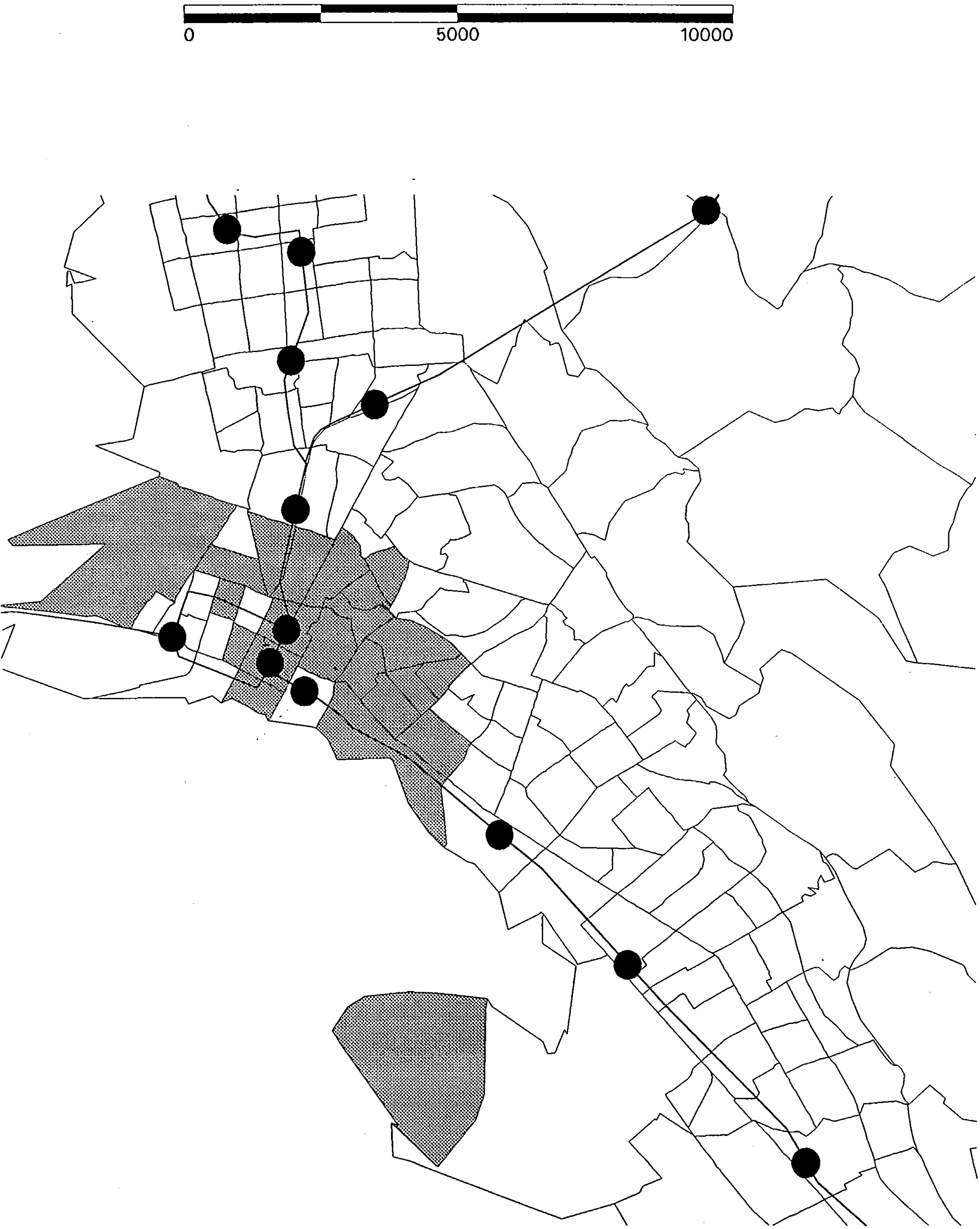


90% Catchment Area for

DOWNTOWN OAKLAND

All Modes

12th St. Oakland Station - 90% Catchment Area - Home Access by All Modes



19th St. Oakland Station - 90% Catchment Area - Home Access by All Modes

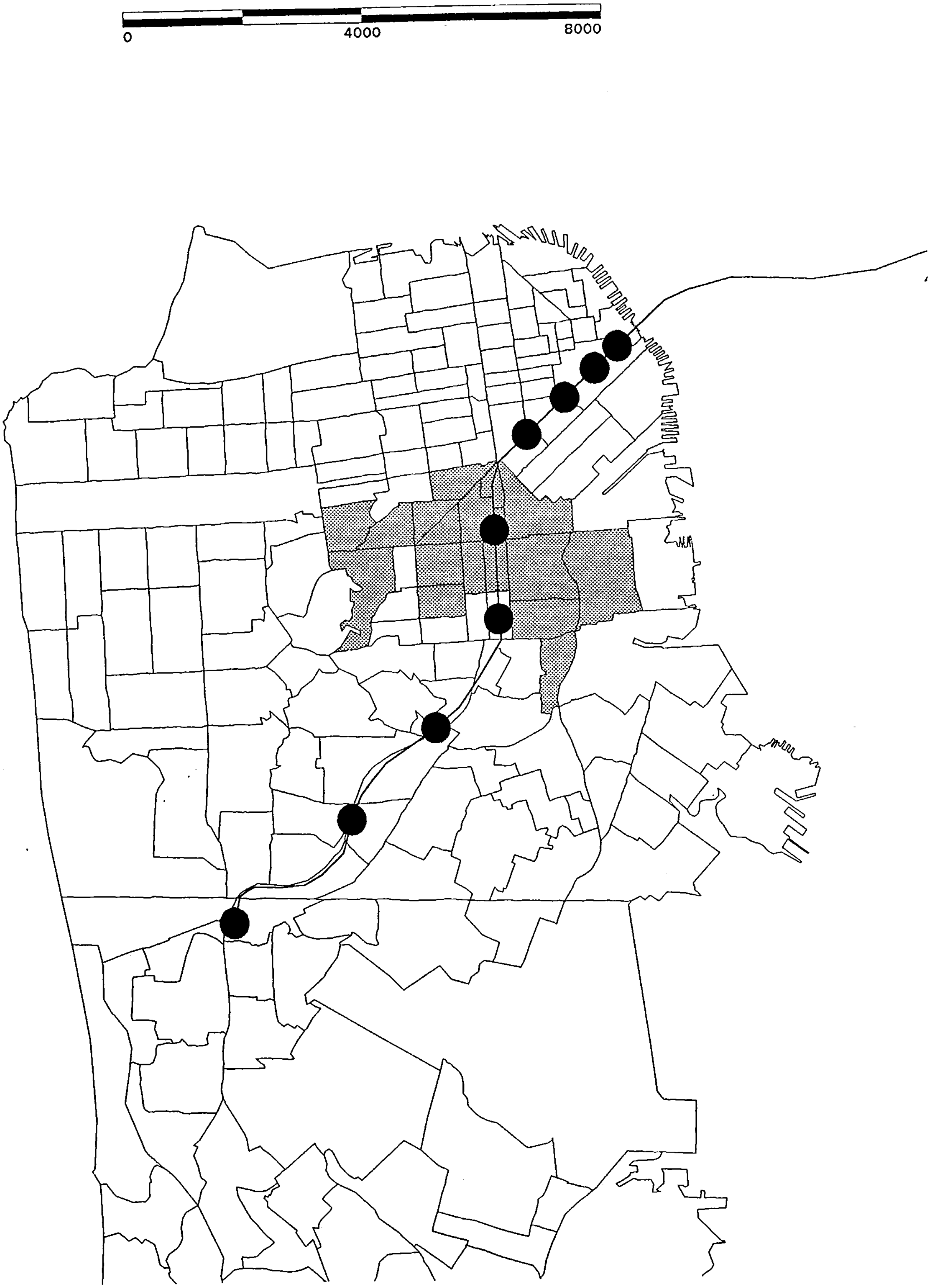
0 5000 10000

90% Catchment Area for

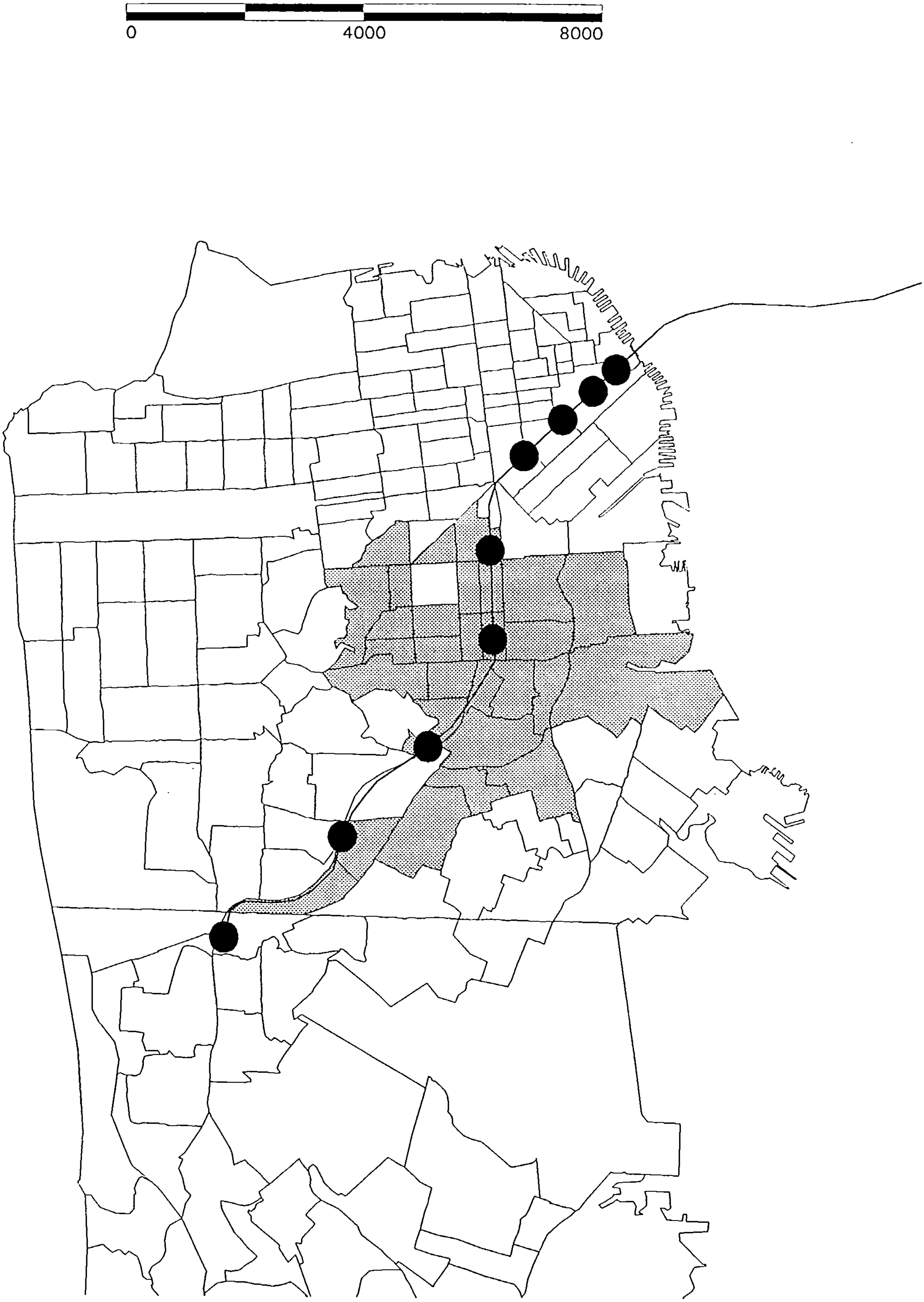
URBAN DISTRICTS

All Modes

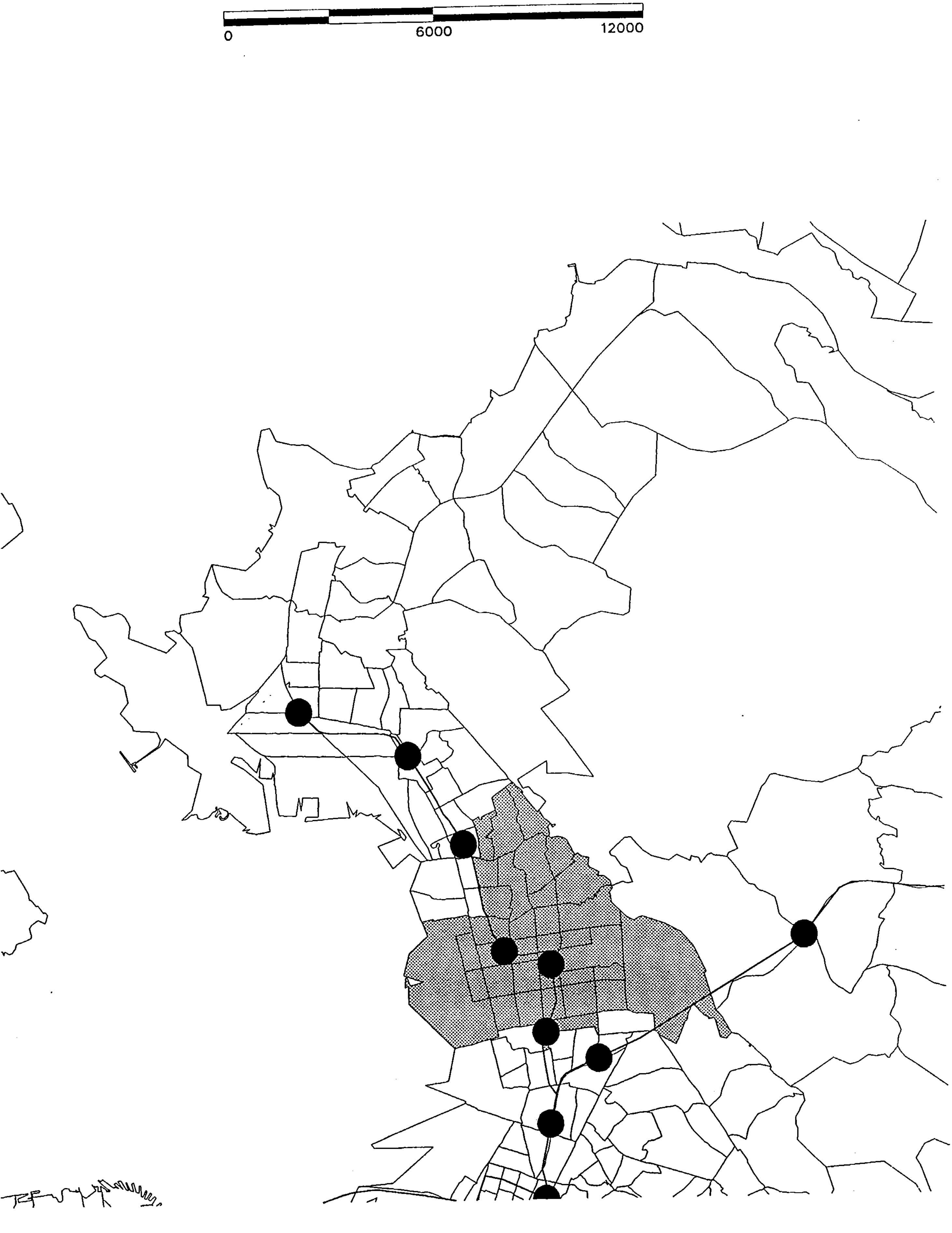
Mission-16th Street Station - 90% Catchment Area - Home Access by All Modes



Mission-24th Street Station - 90% Catchment Area - Home Access by All Modes



Berkeley Station - 90% Catchment Area - Home Access by All Modes



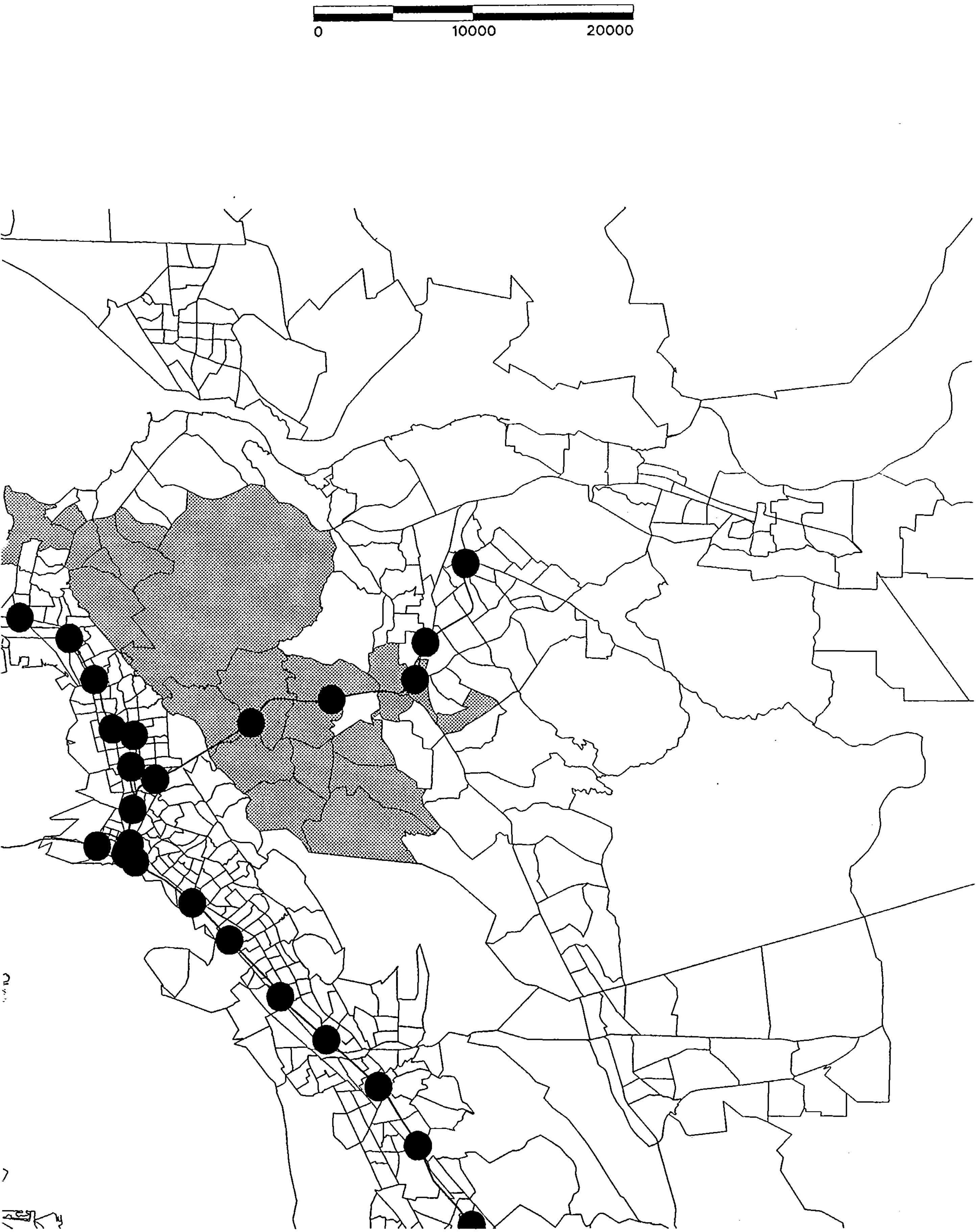
Lake Merritt Station - 90% Catchment Area - Home Access by All Modes

90% Catchment Area for

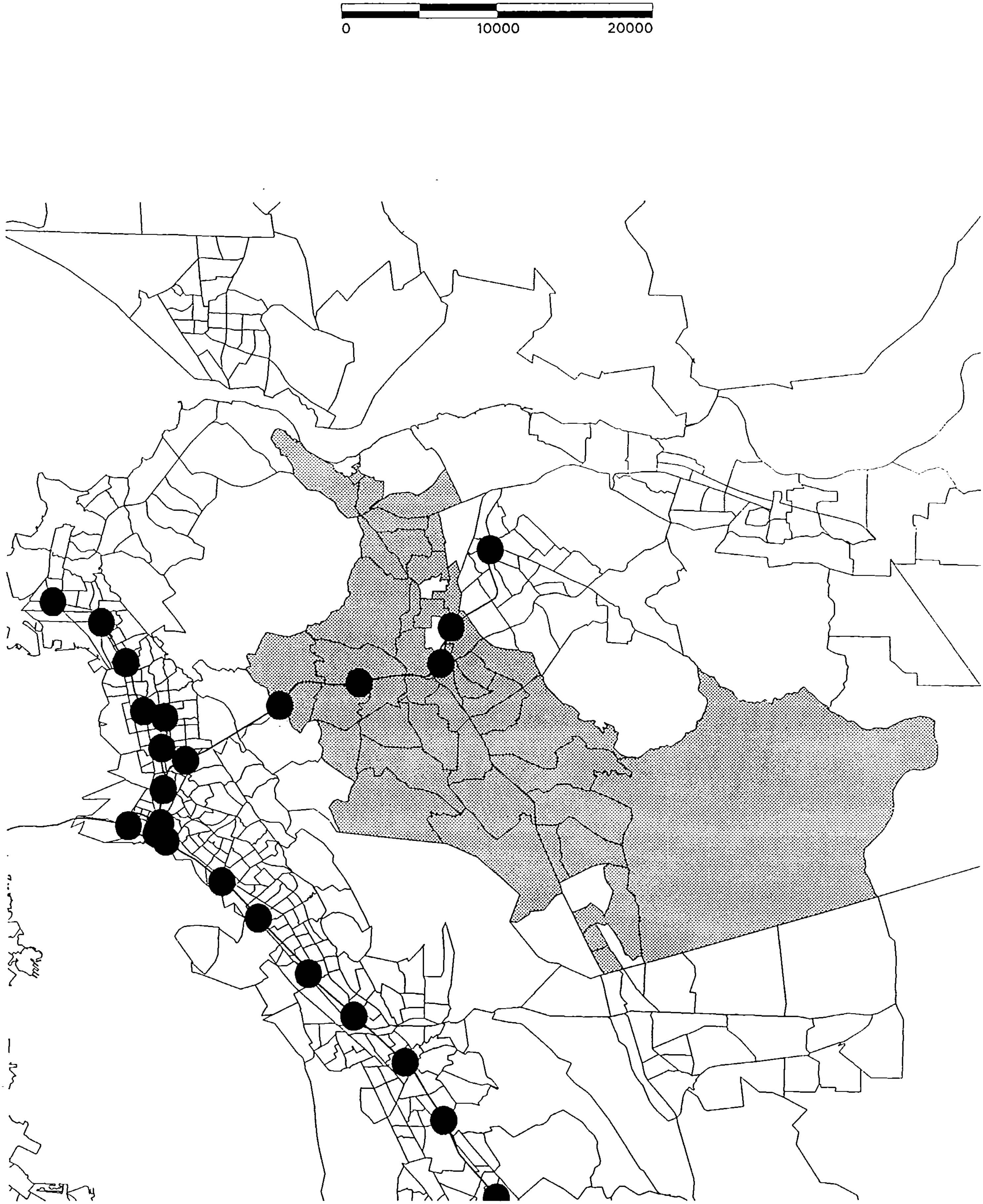
SUBURBAN CENTERS

All Modes

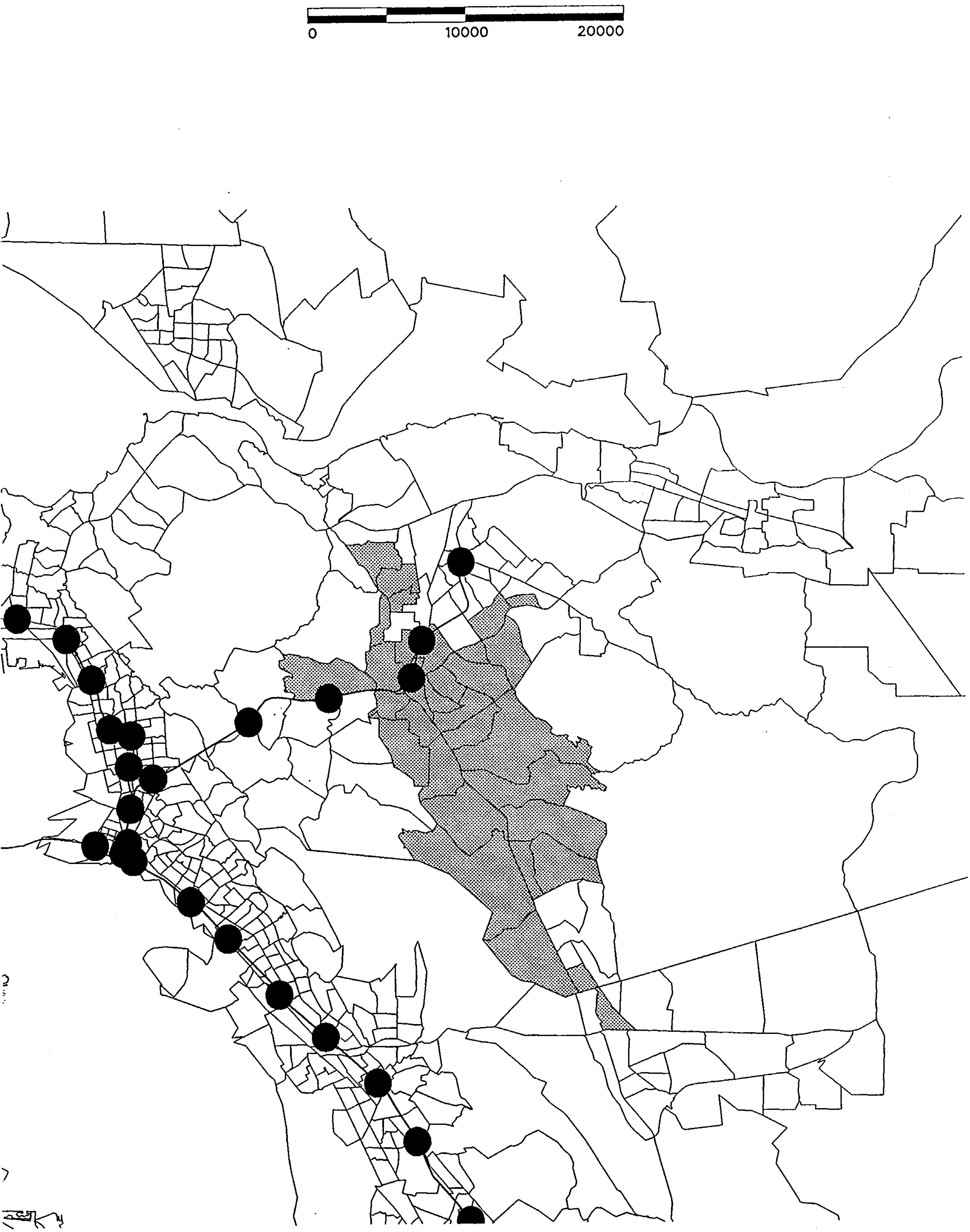
Orinda Station - 90% Catchment Area - Home Access by All Modes



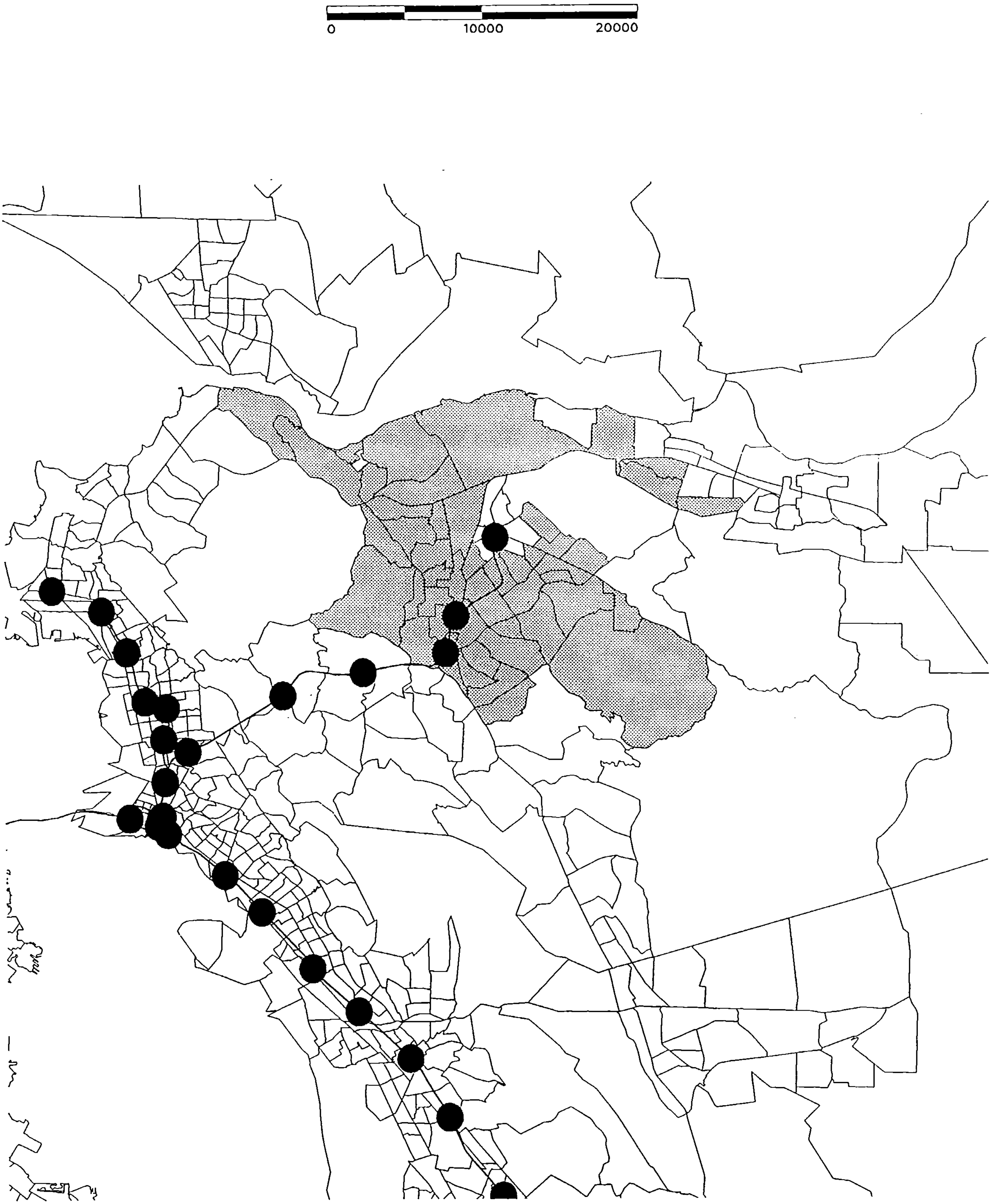
Lafayette Station - 90% Catchment Area - Home Access by All Modes



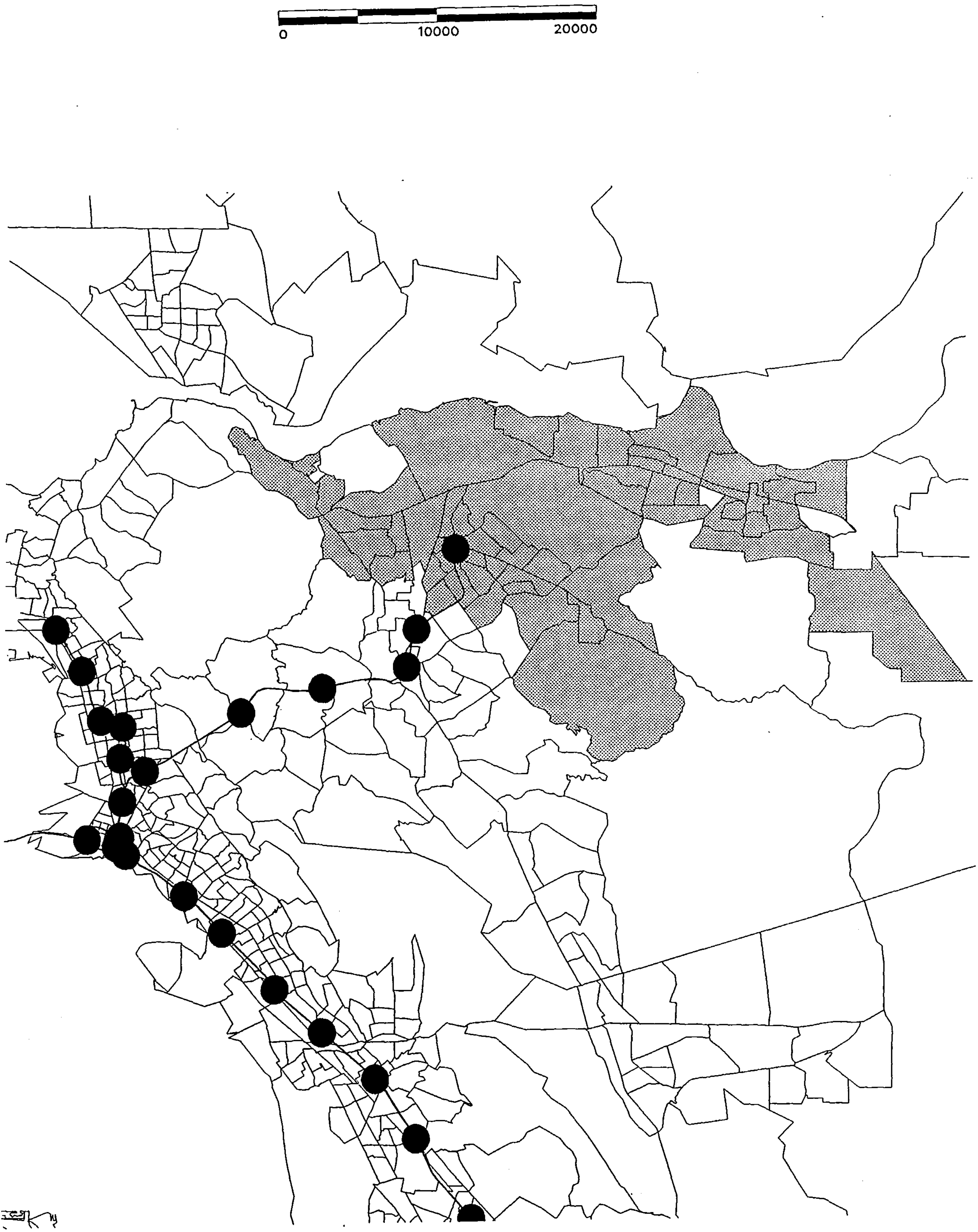
Walnut Creek Station - 90% Catchment Area - Home Access by All Modes



Pleasant Hill Station - 90% Catchment Area - Home Access by All Modes



oncord Station - 90% Catchment Area - Home Access by All Modes

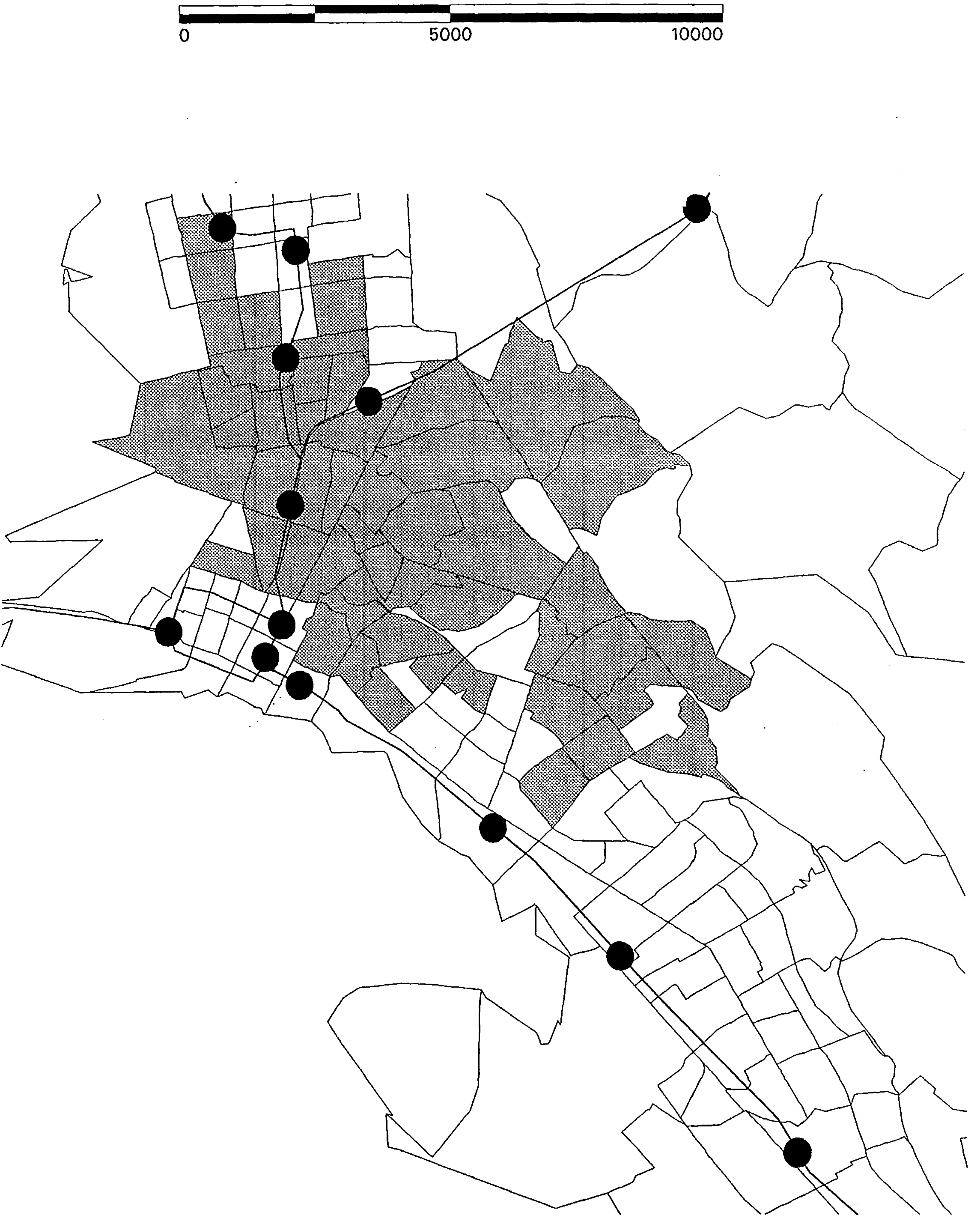


90% Catchment Area for

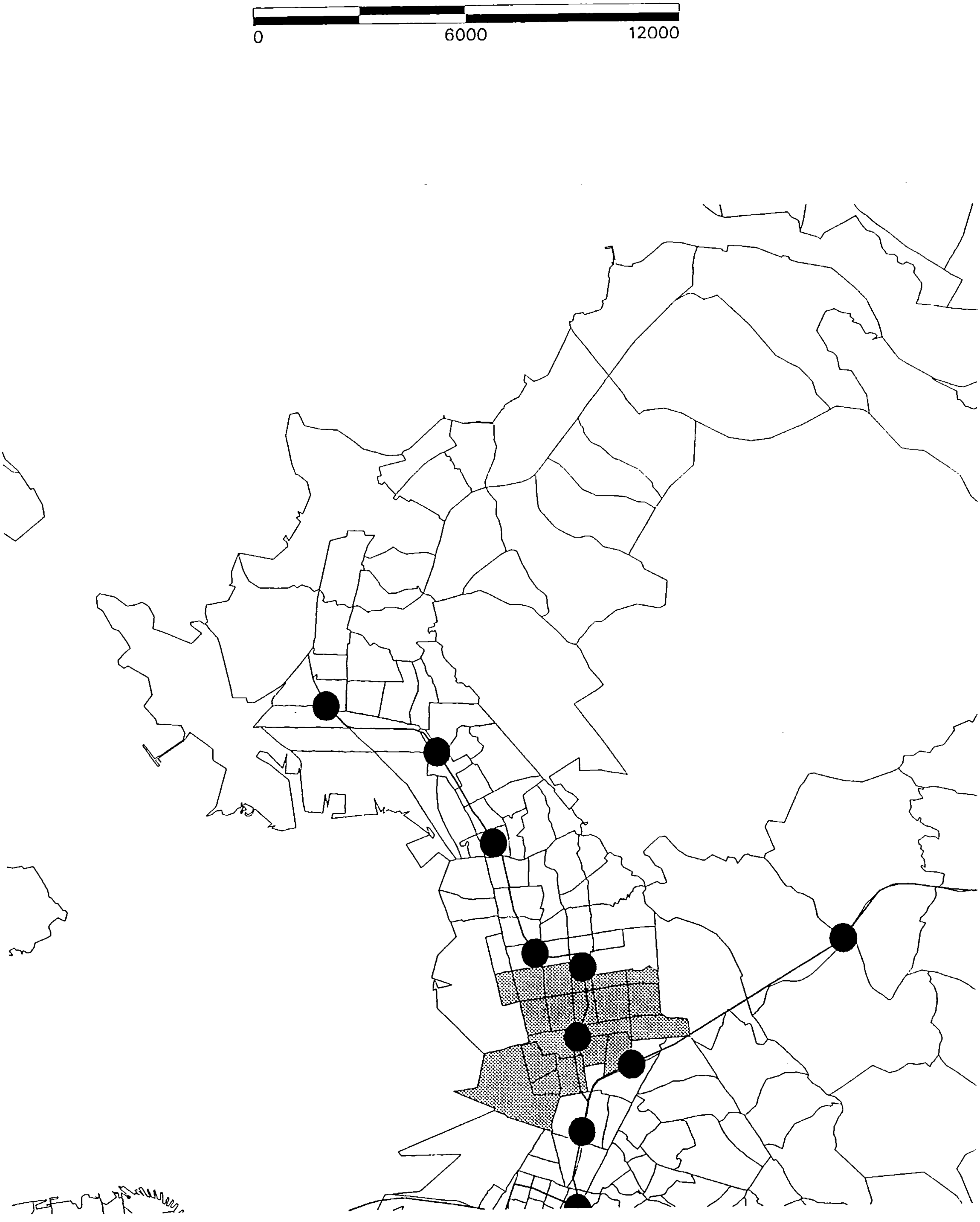
LOW-DENSITY AREAS

All Modes

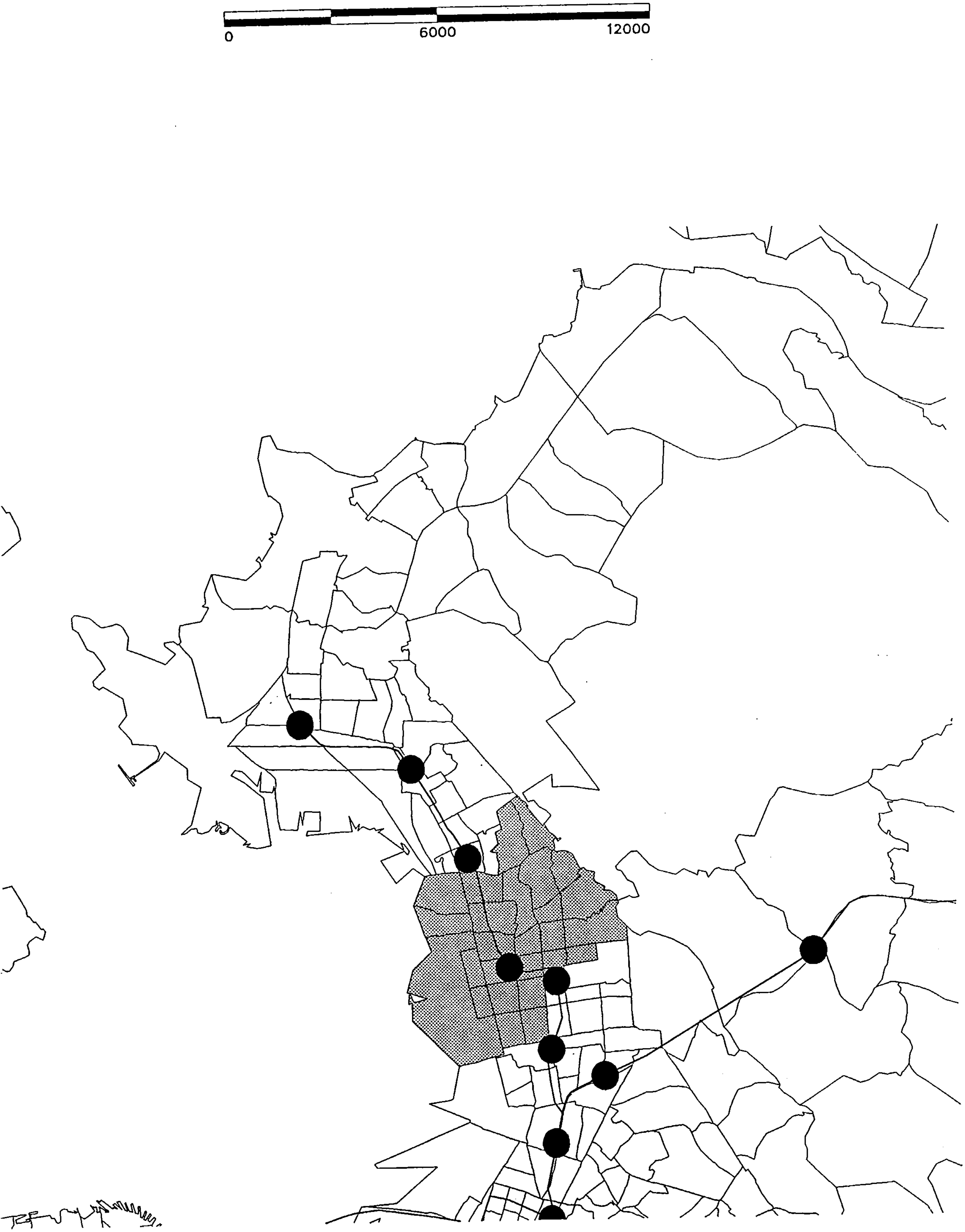
MacArthur Station - 90% Catchment Area - Access by All Mode



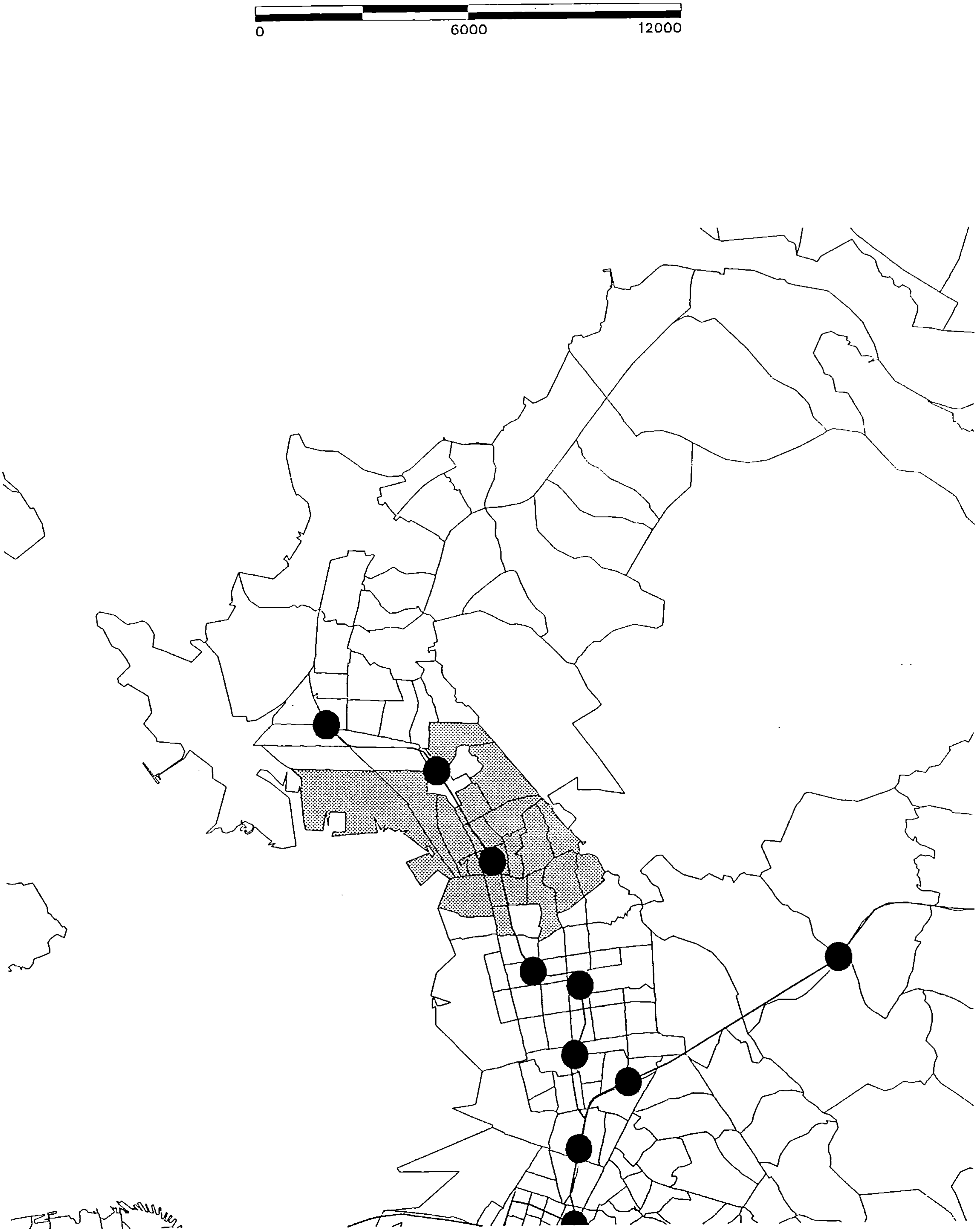
Ashby Station - 90% Catchment Area - Home Access by All Modes



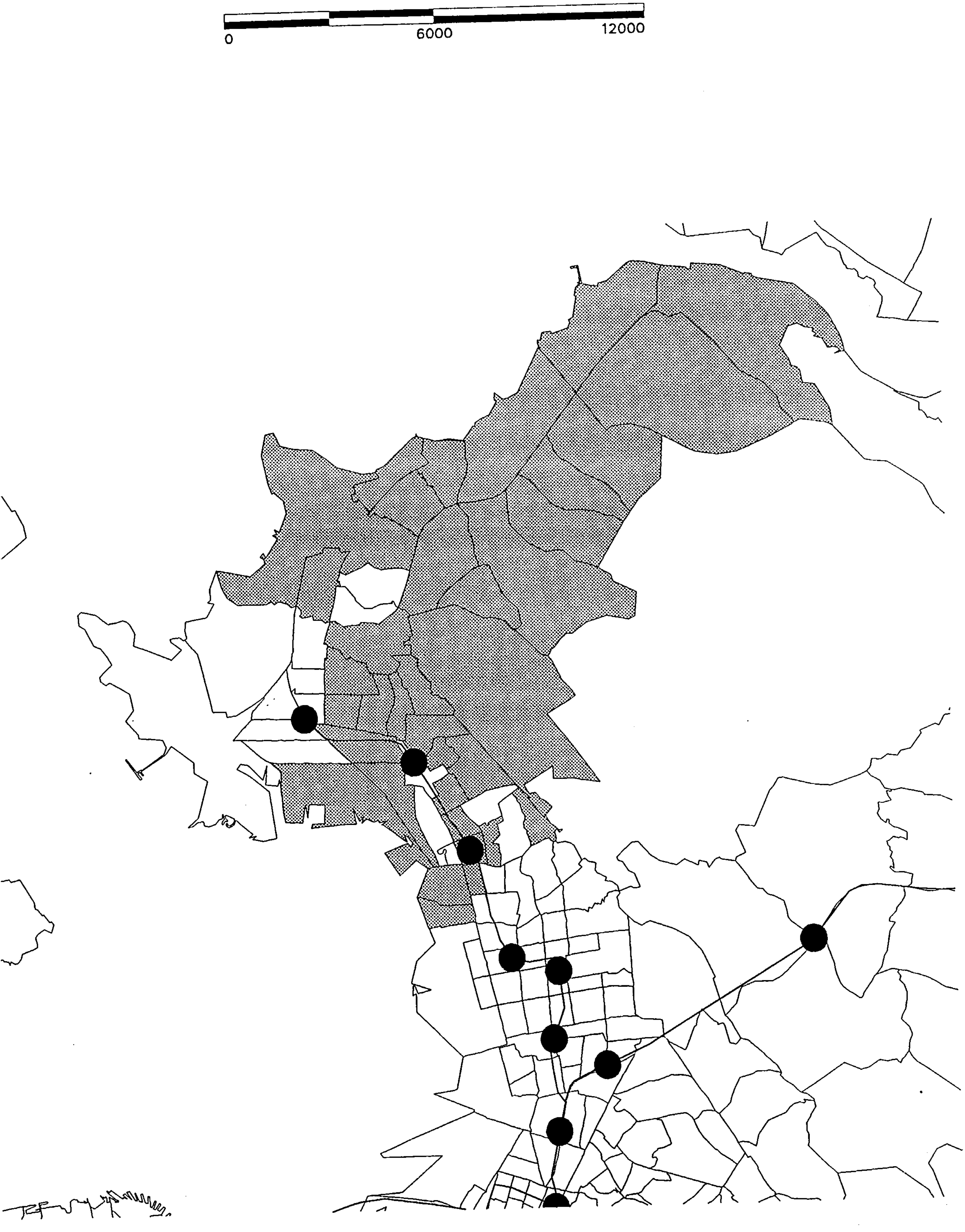
North Berkeley Station - 90% Catchment Area - Home Access by All Modes



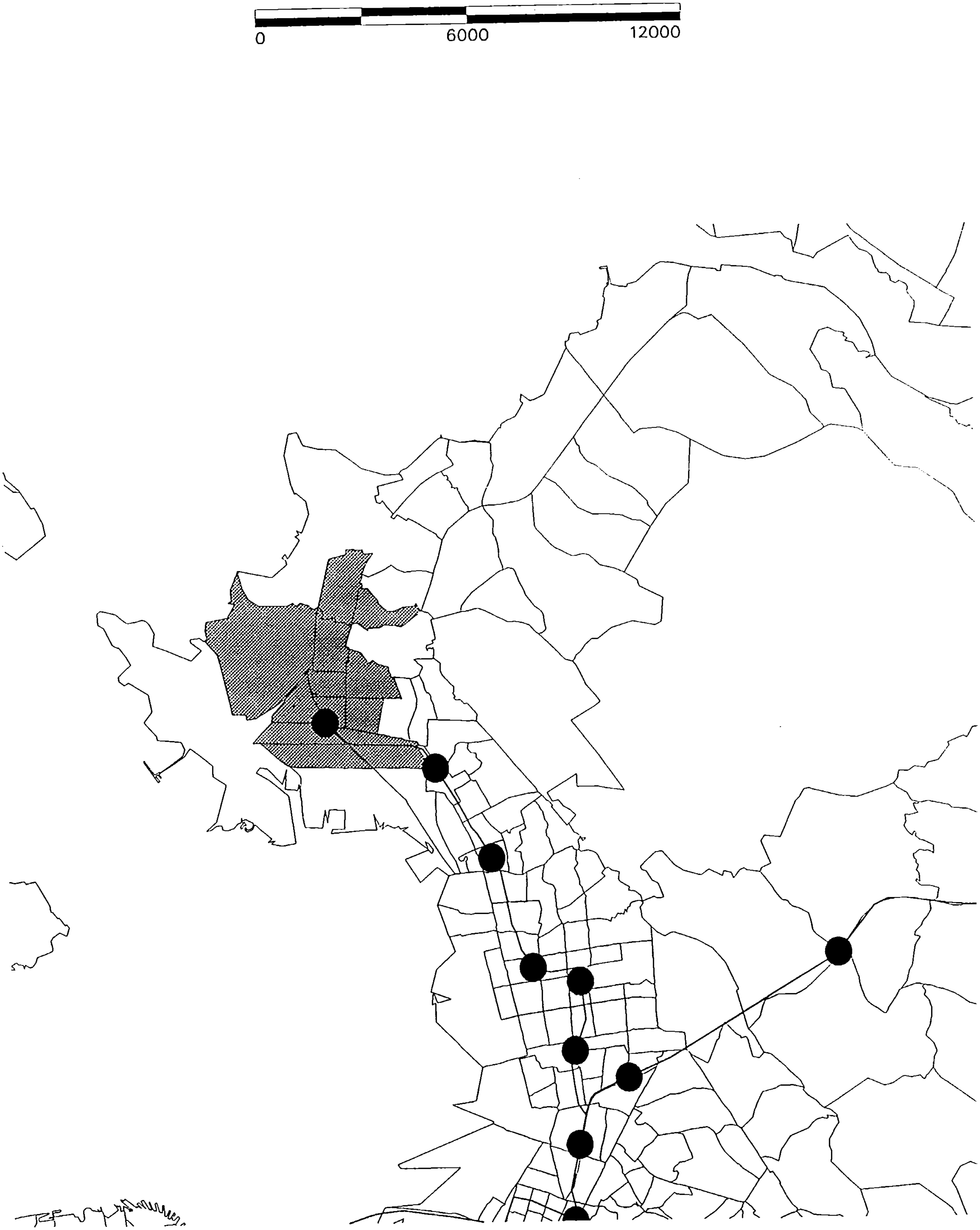
El Cerrito Station - 90% Catchment Area - Home Access by All Modes



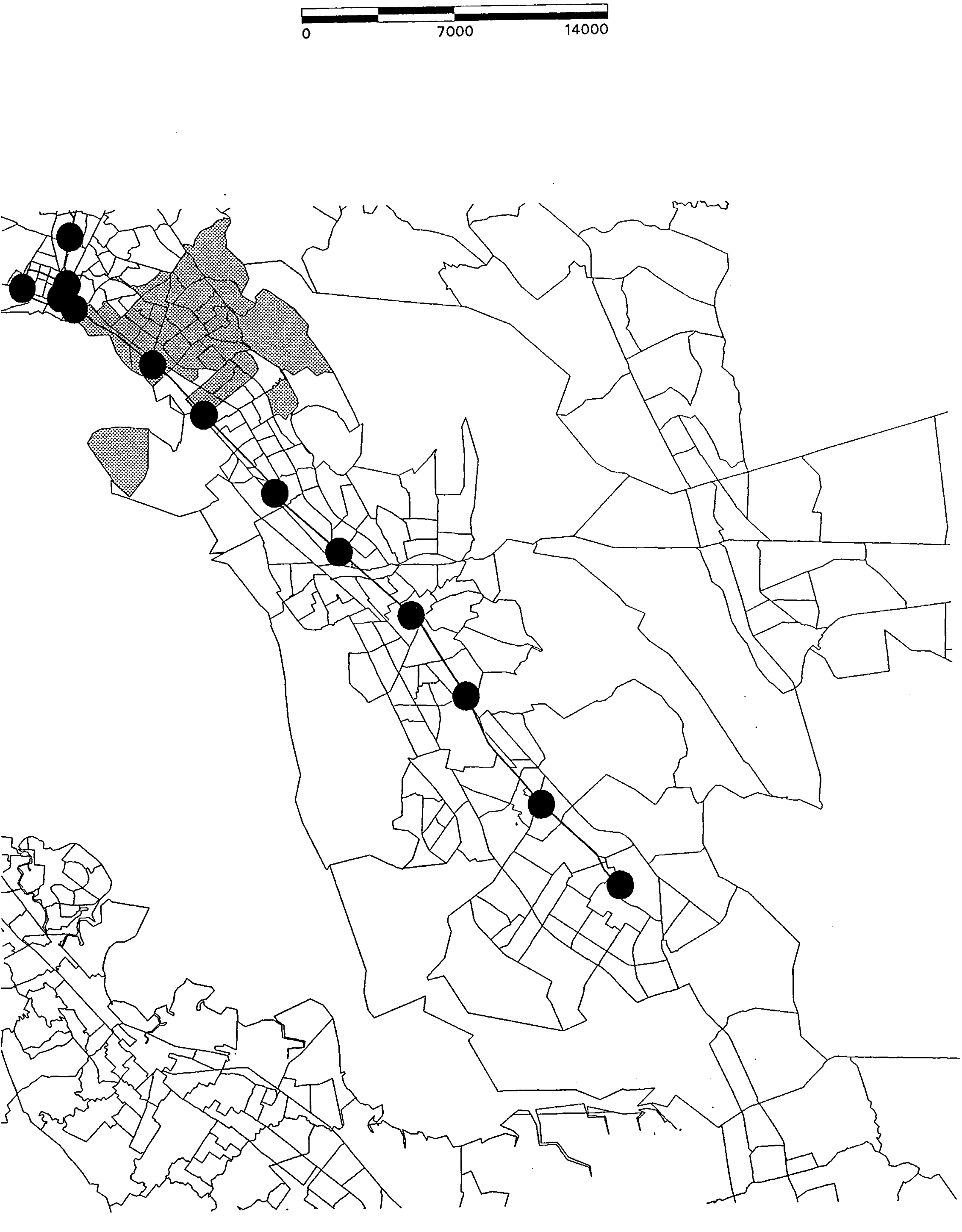
El Cerrito del Norte Station - 90% Catchment Area - Home Access by All Modes



Richmond Station - 90% Catchment Area - Home Access by All Modes



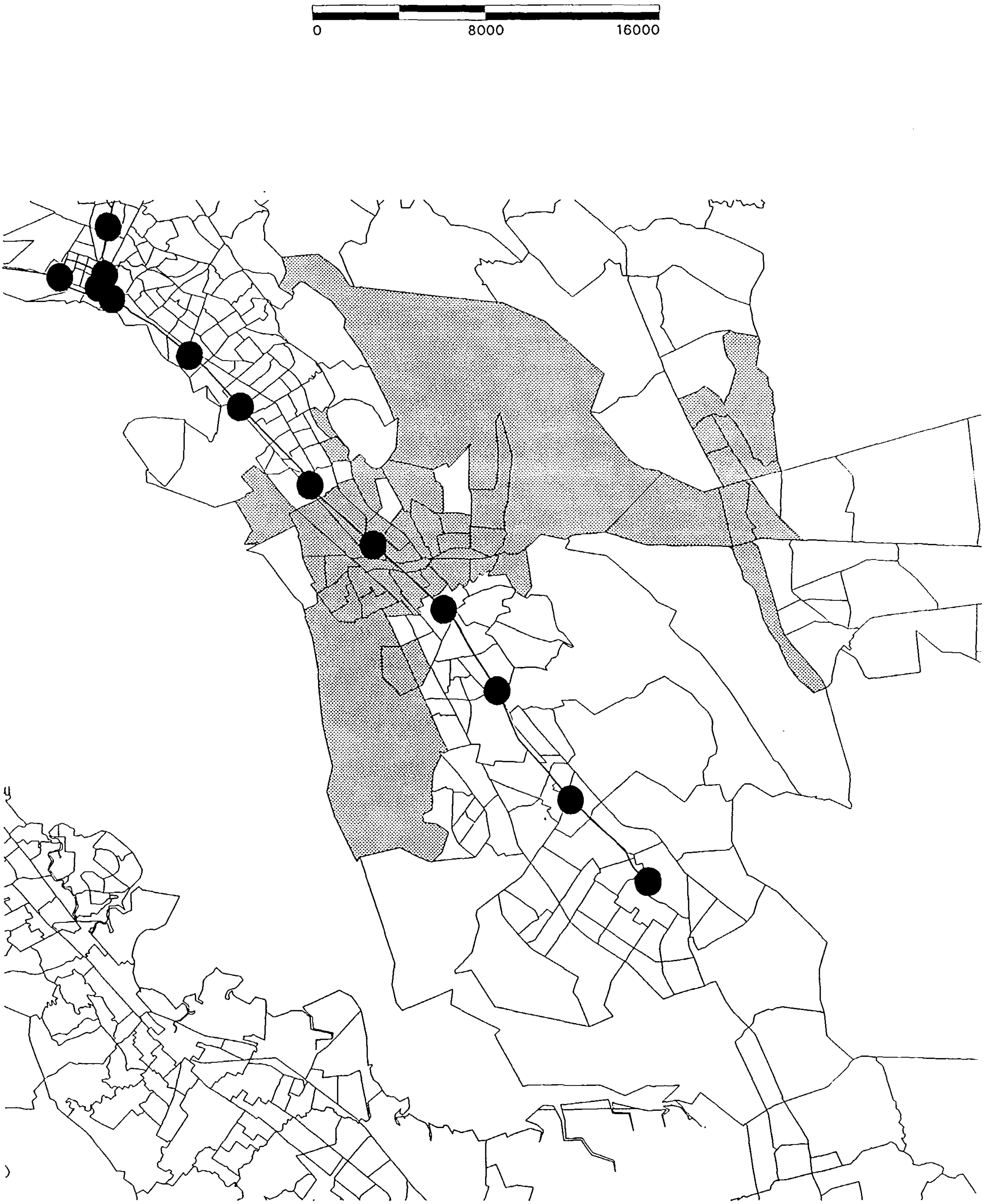
Fruitvale Station - 90% Catchment Area - Home Access by All Modes



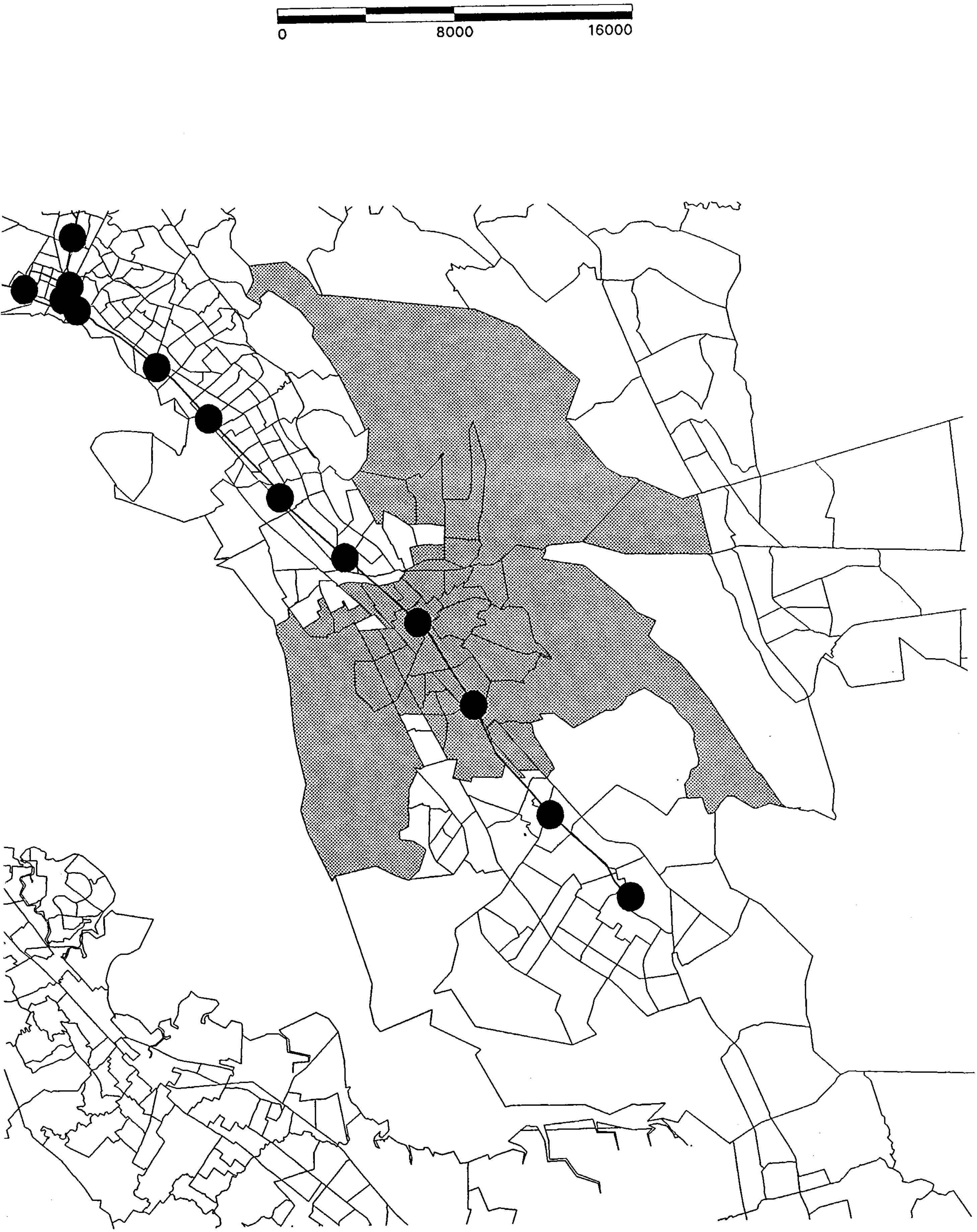
Coliseum Station - 90% Catchment Area - Home Access by All Modes

San Leandro Station - 90% Catchment Area - Home Access by All Modes

Bayfair Station - 90% Catchment Area - Home Access by All Modes

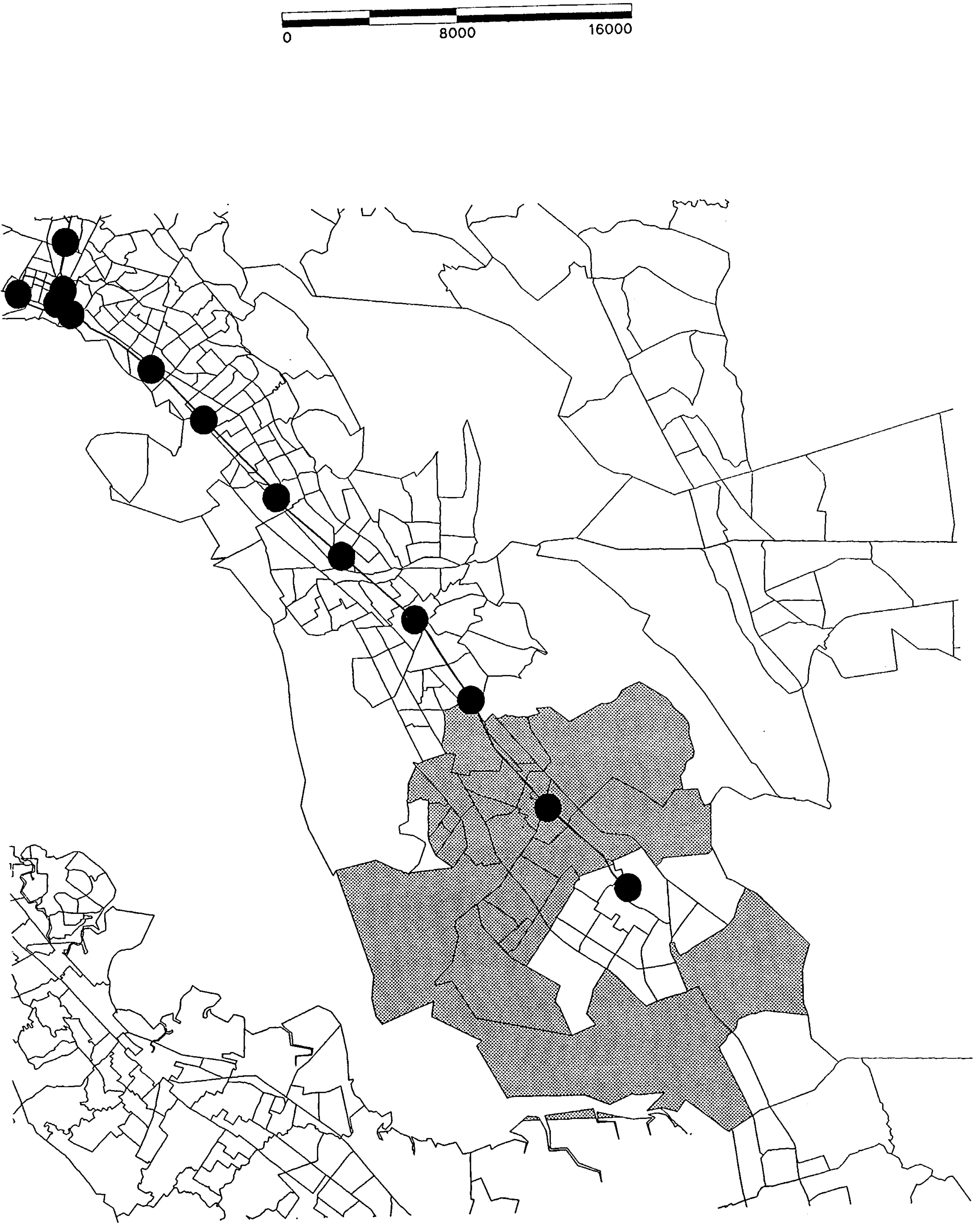


Hayward Station - 90% Catchment Area - Home Access by All Modes

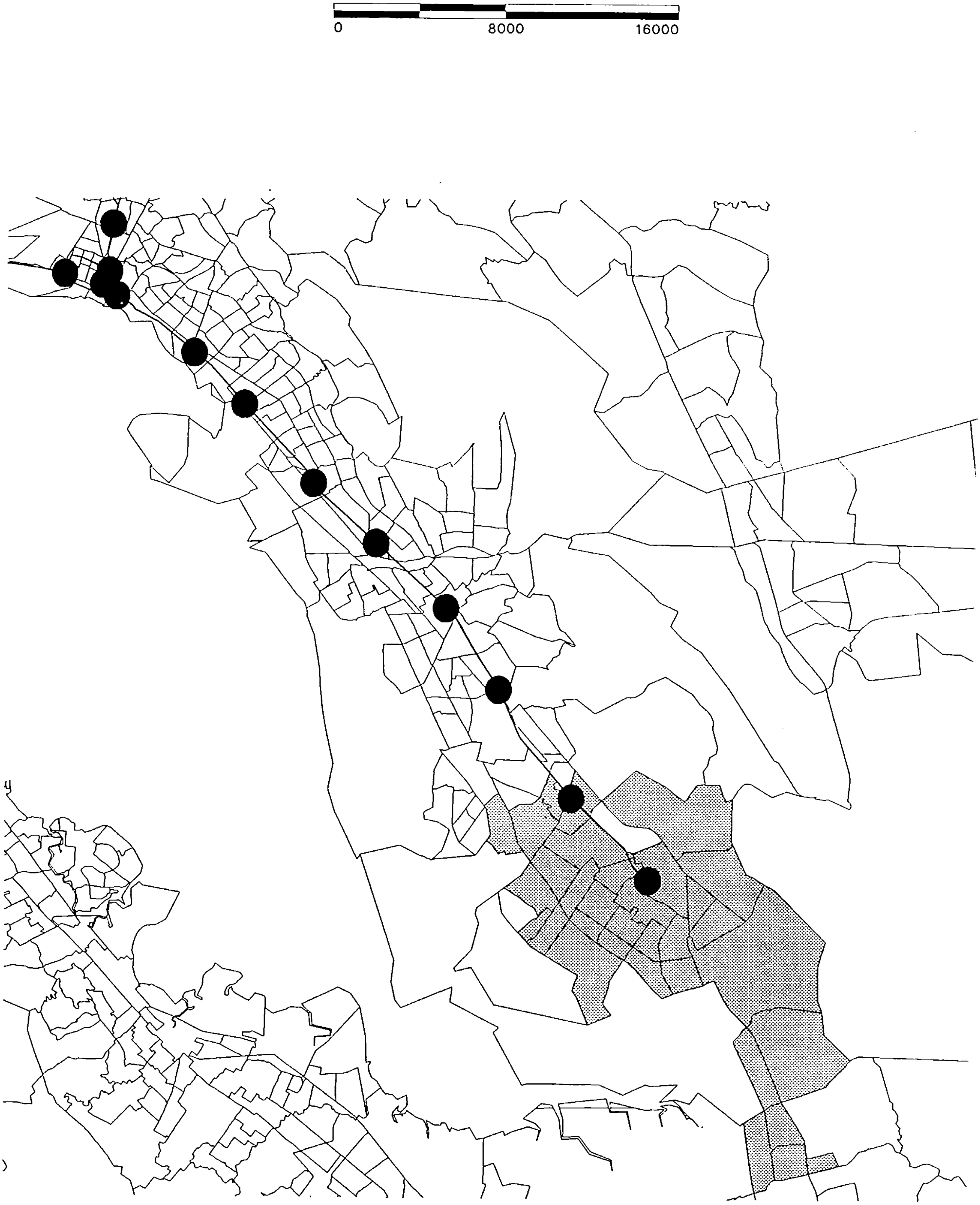


South Hayward Station - 90% Catchment Area - Home Access by All Modes

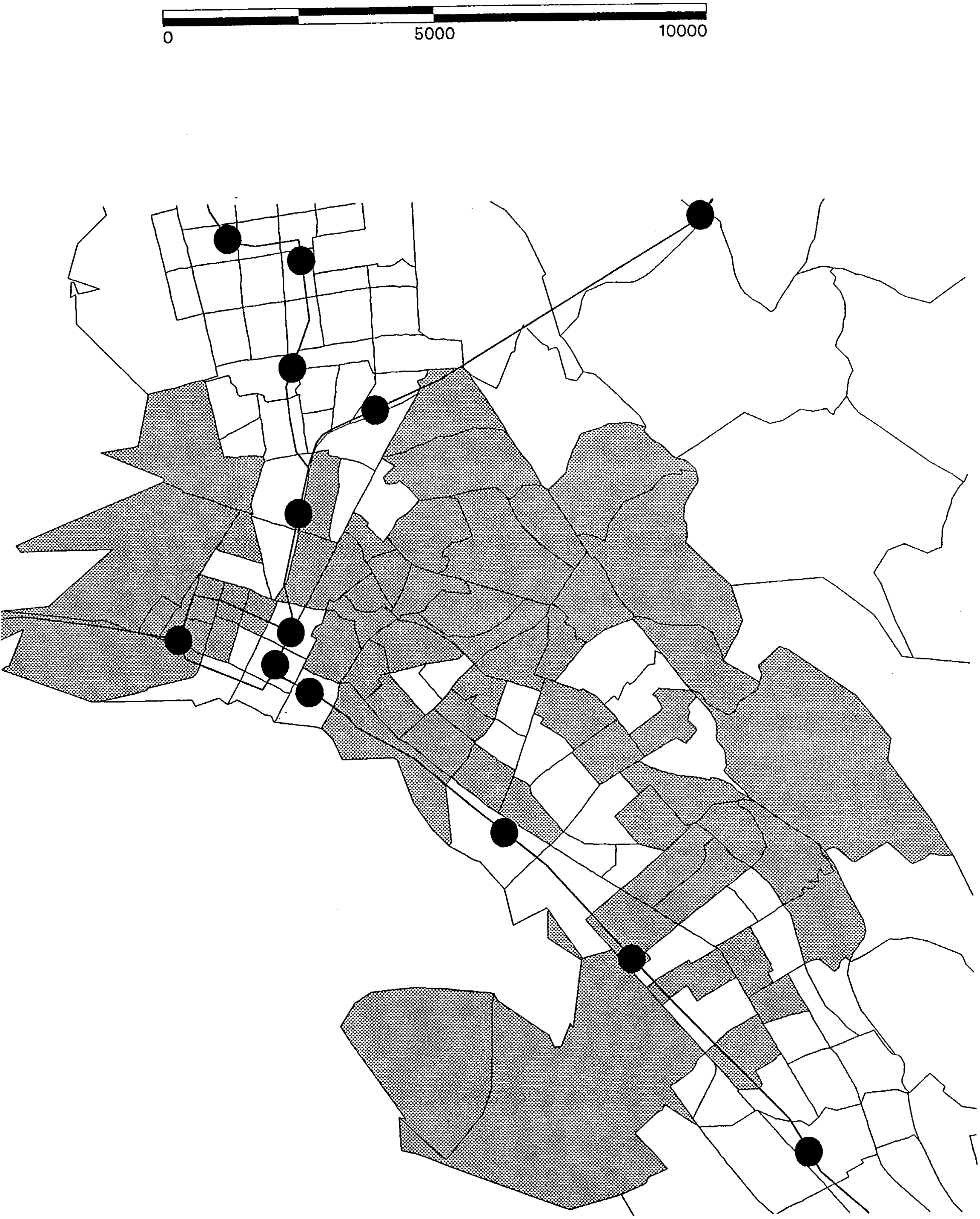
Union City - 90% Catchment Area - Home Access by All Modes



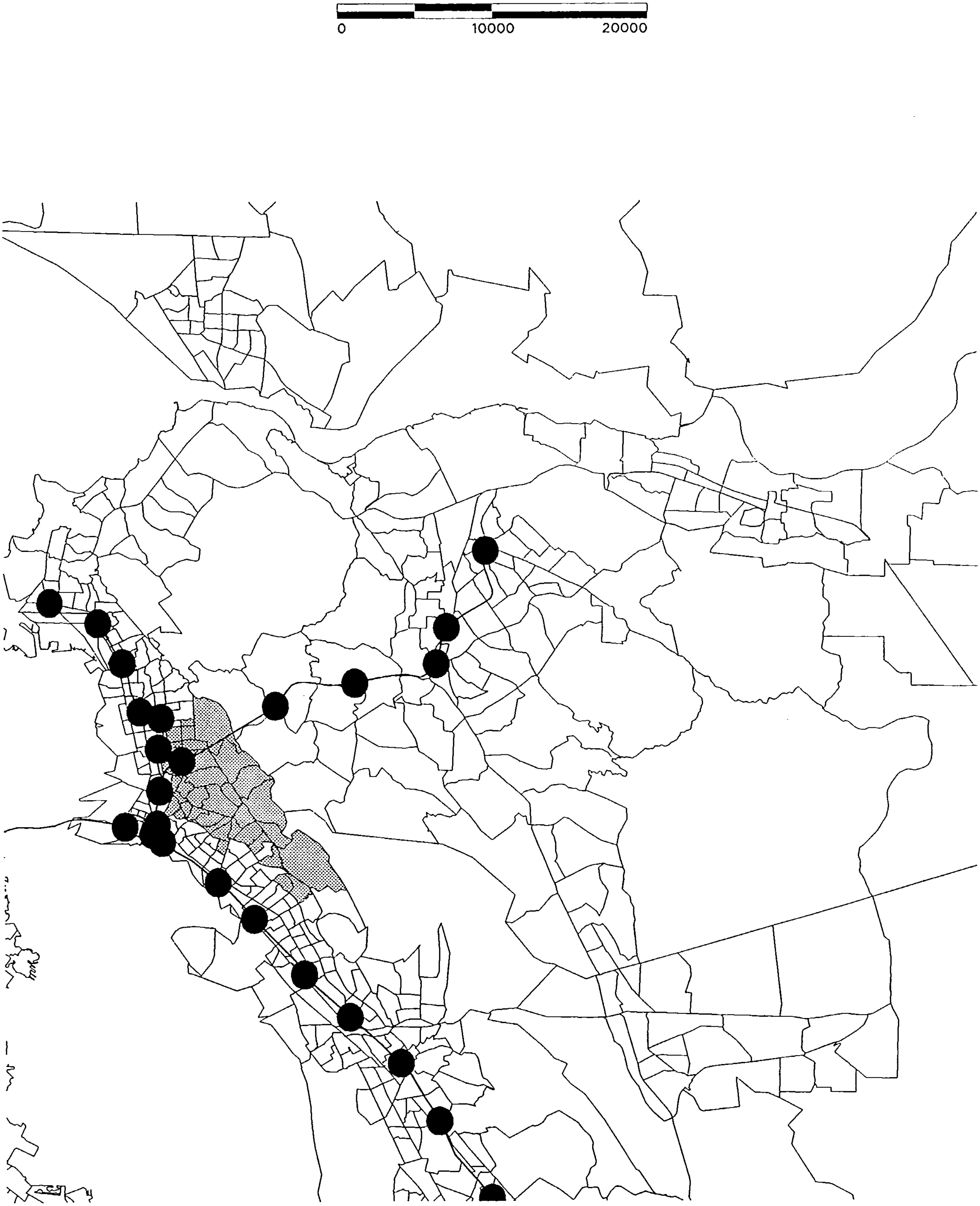
Fremont Station - 90% Catchment Area - Home Access by All Modes



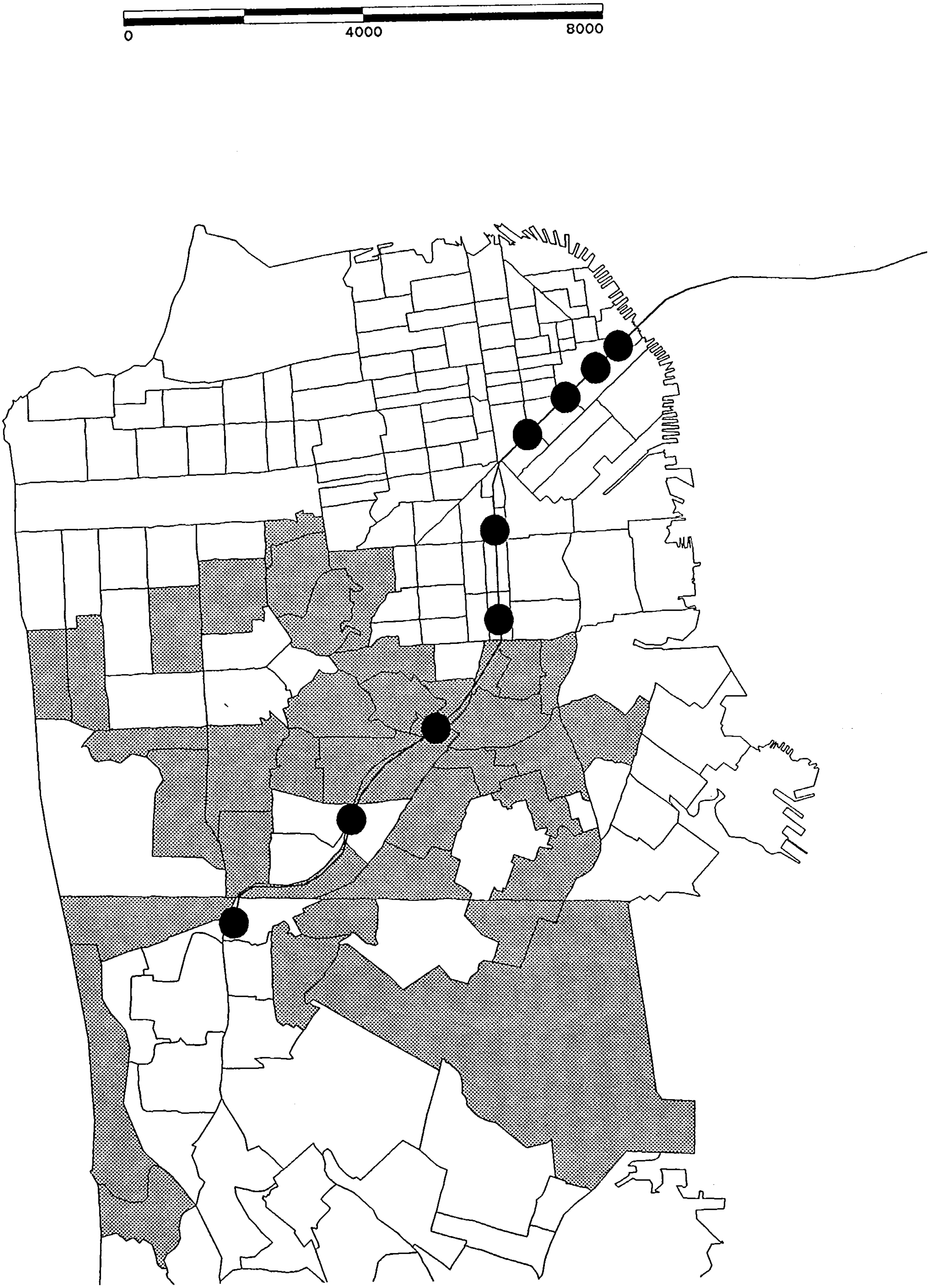
West Oakland Station - 90% Catchment Area - Home Access by All Modes



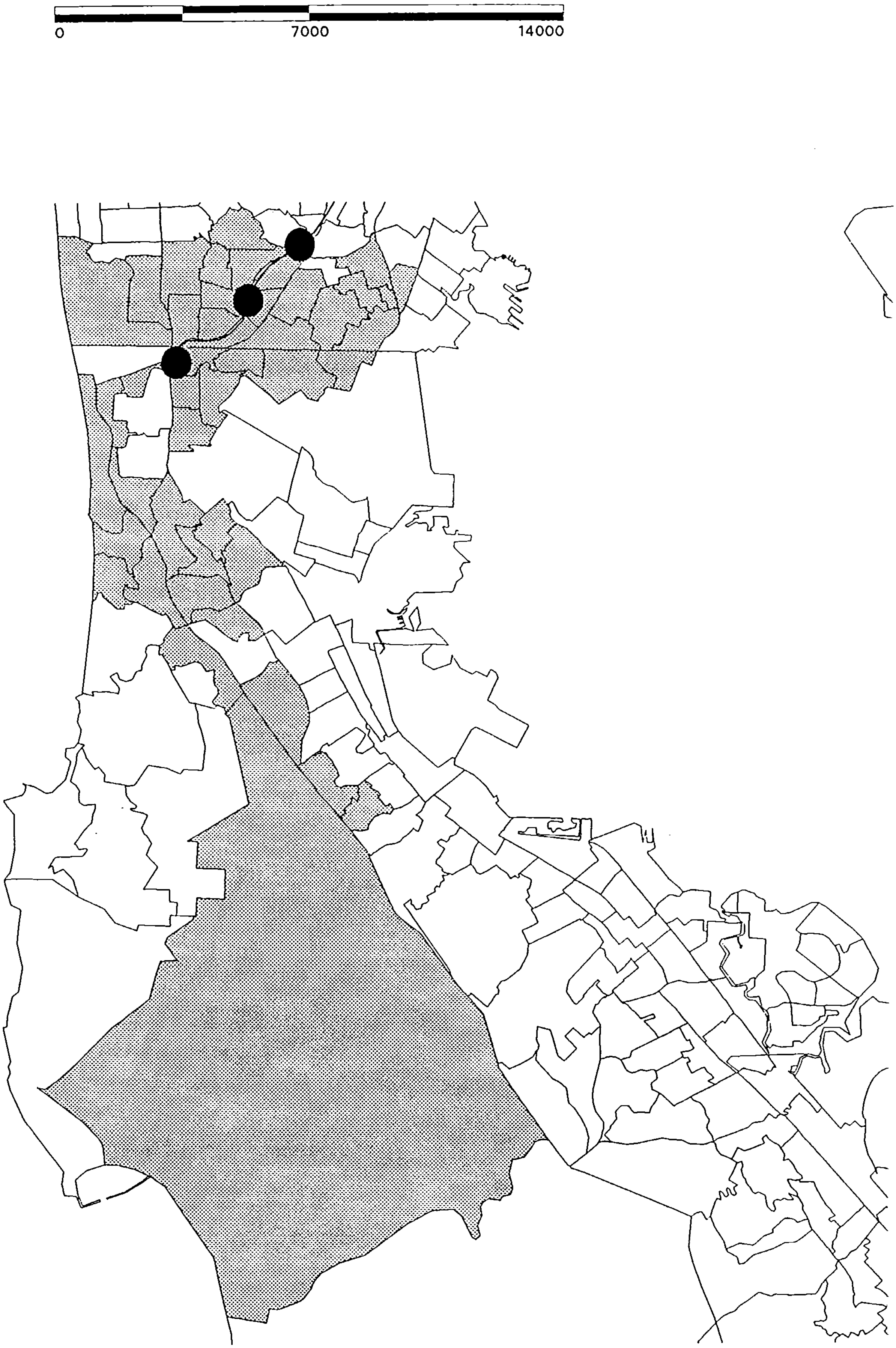
Rockridge Station - 90% Catchment Area - Home Access by All Modes



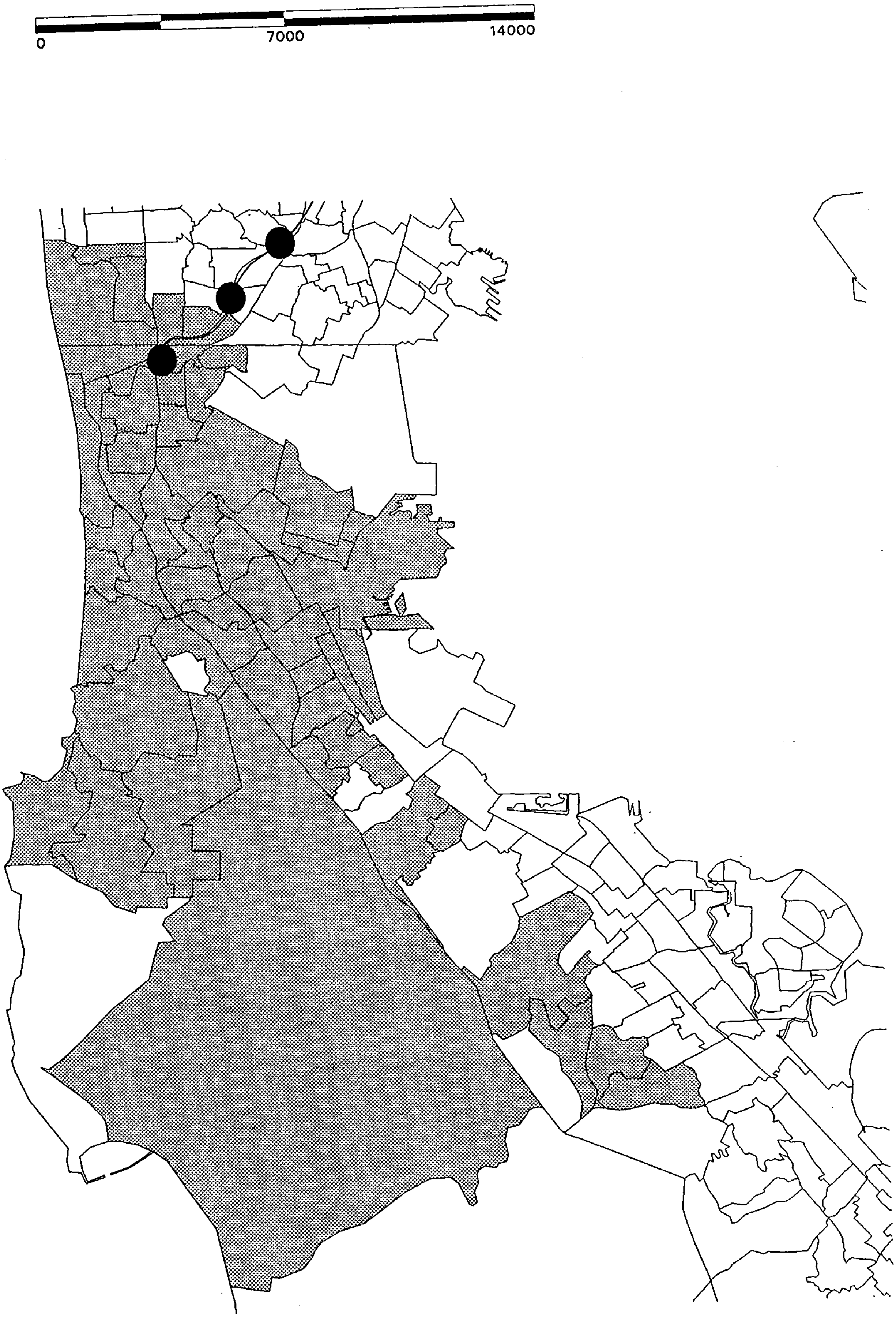
Glen Park Station - 90% Catchment Area - Home Access by All Modes



Balboa Station - 90% Catchment Area - Home Access by All Modes



Daly City Station - 90% Catchment Area - Home Access by All Modes

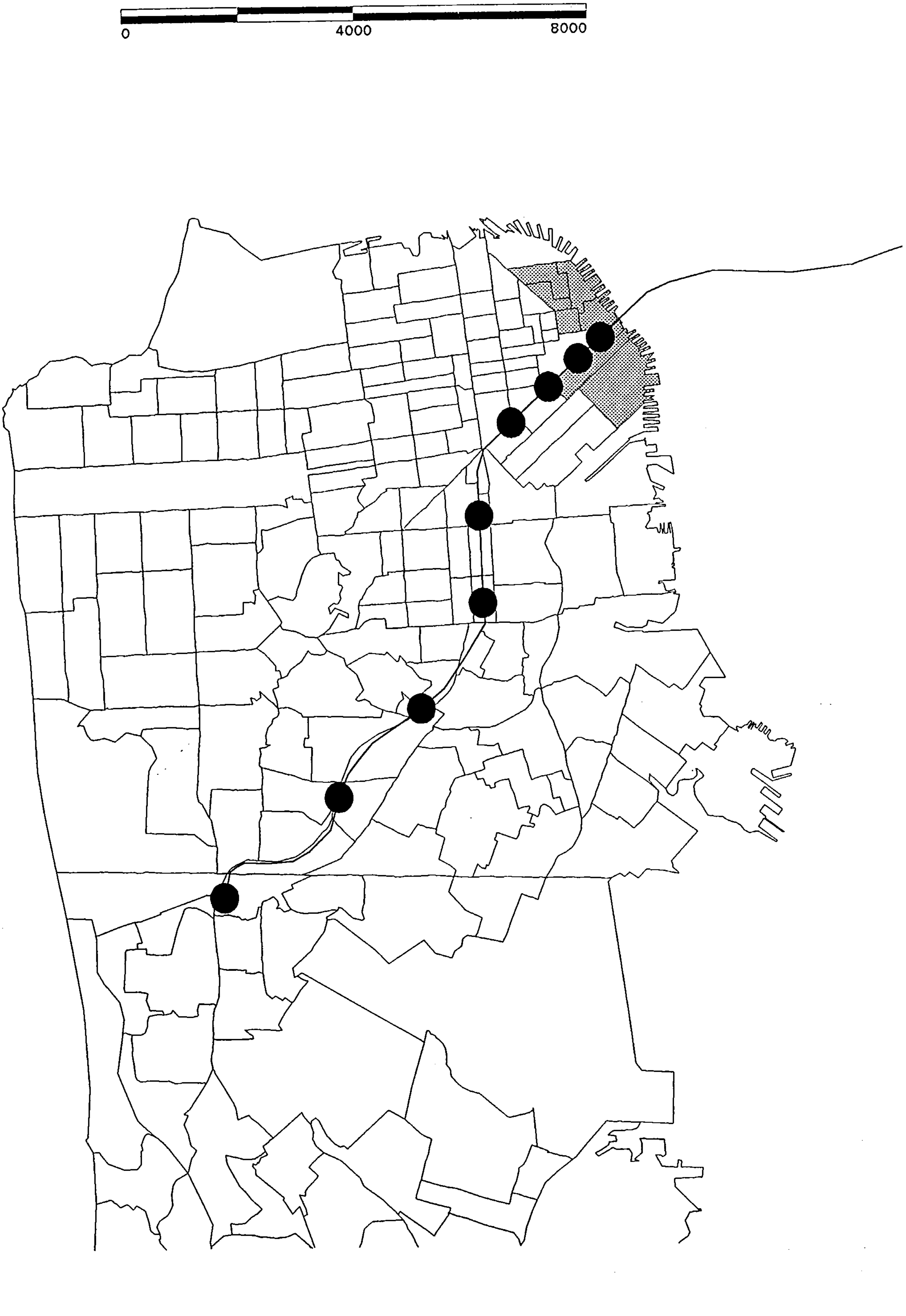


90% Catchment Area for

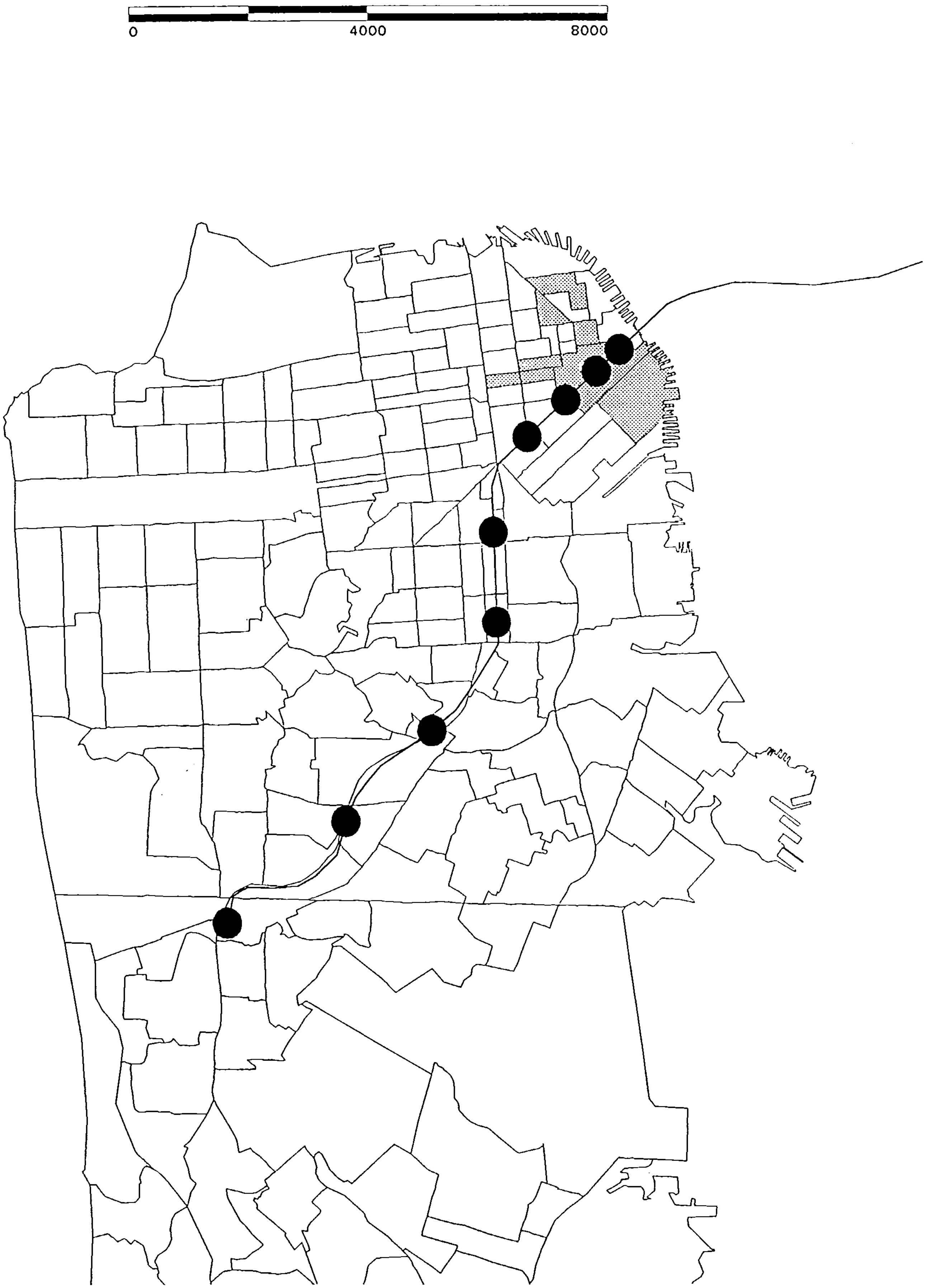
SAN FRANCISCO OFFICE CENTER

Walking Mode

Embarcadero Station - 90% Catchment Area - Home Access by Walking



Montgomery Station - 90% Catchment Area - Home Access by Walking

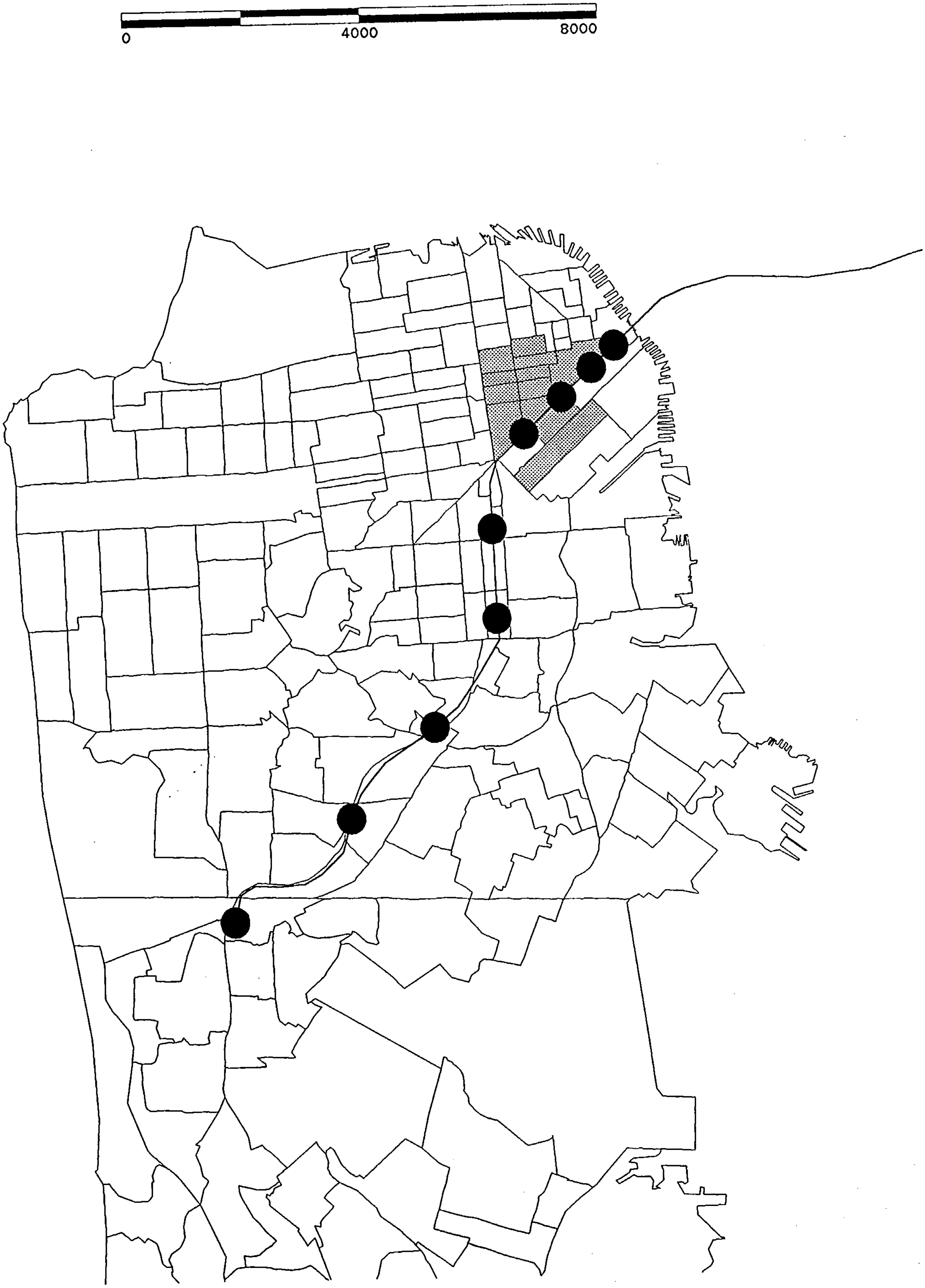


90% Catchment Area for

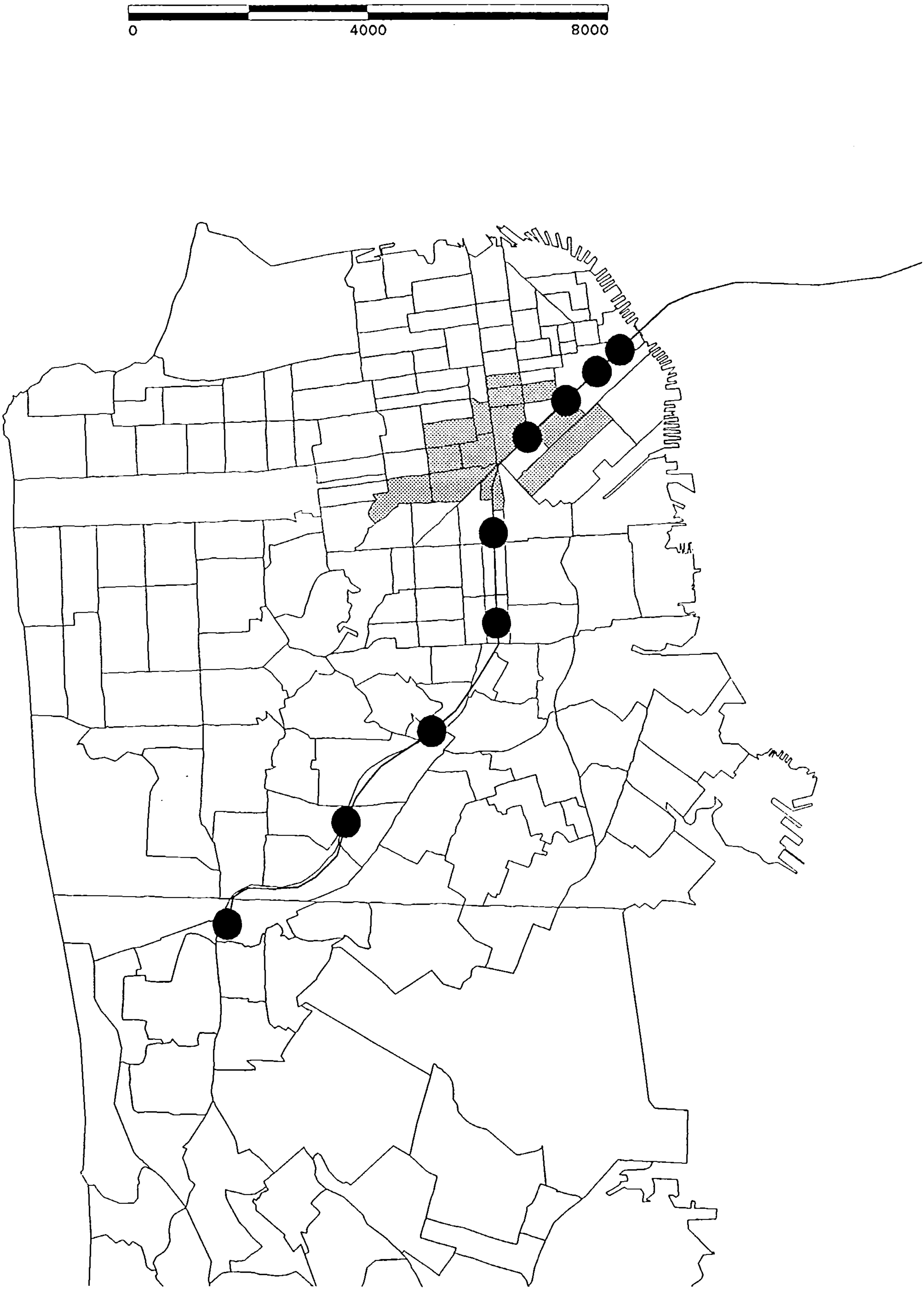
SAN FRANCISCO COMMERCIAL/CIVIC CENTER

Walking Mode

Powell Station - 90% Catchment Area - Home Access by Walking



Civic Center Station - 90% Catchment Area - Home Access by Walking



90% Catchment Area for

DOWNTOWN OAKLAND

Walking Mode

12th St. Oakland Station - 90% Catchment Area - Home Access by Walking

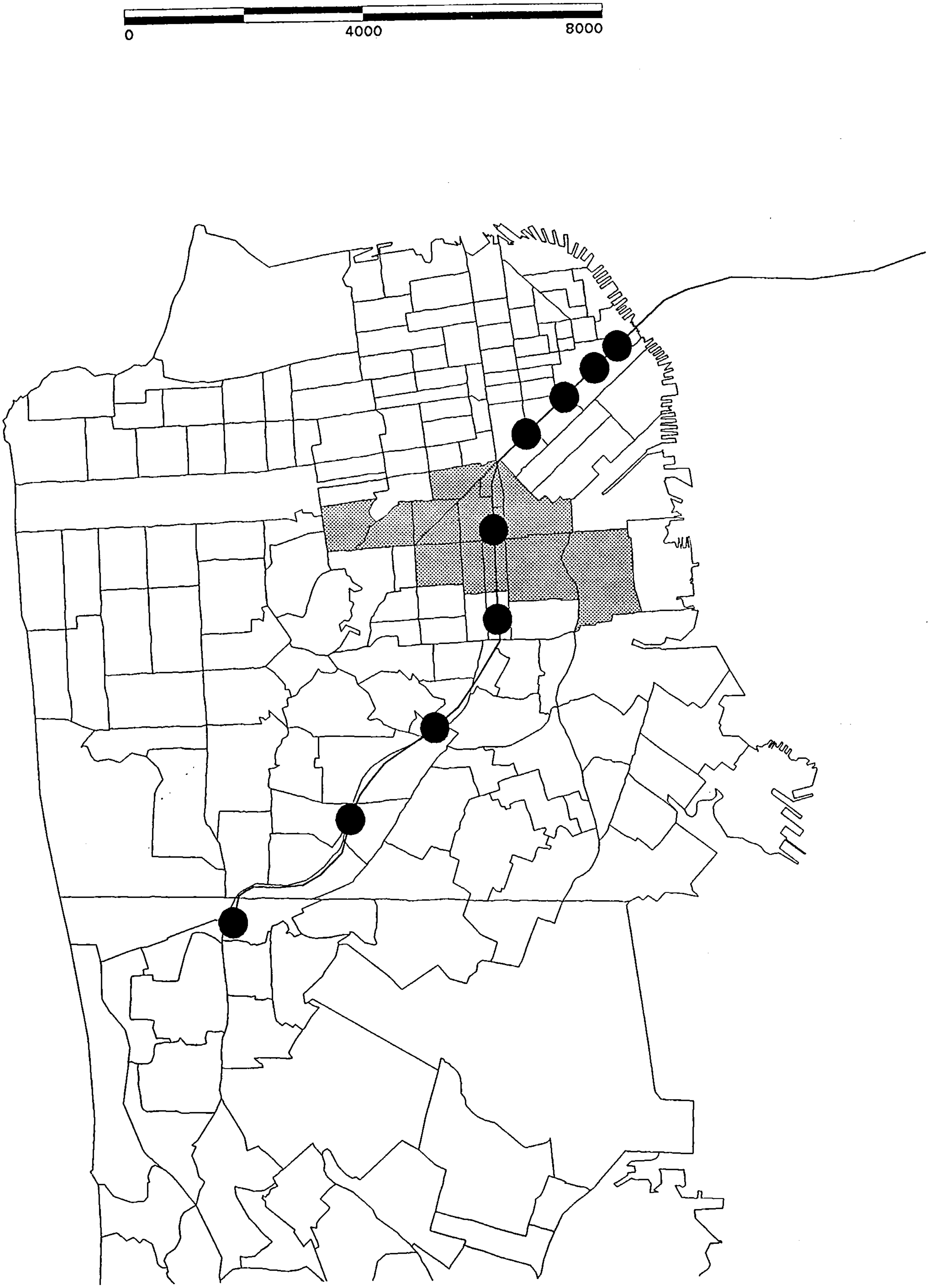
19th St. Oakland Station - 90% Catchment Area - Home Access by Walking

90% Catchment Area for

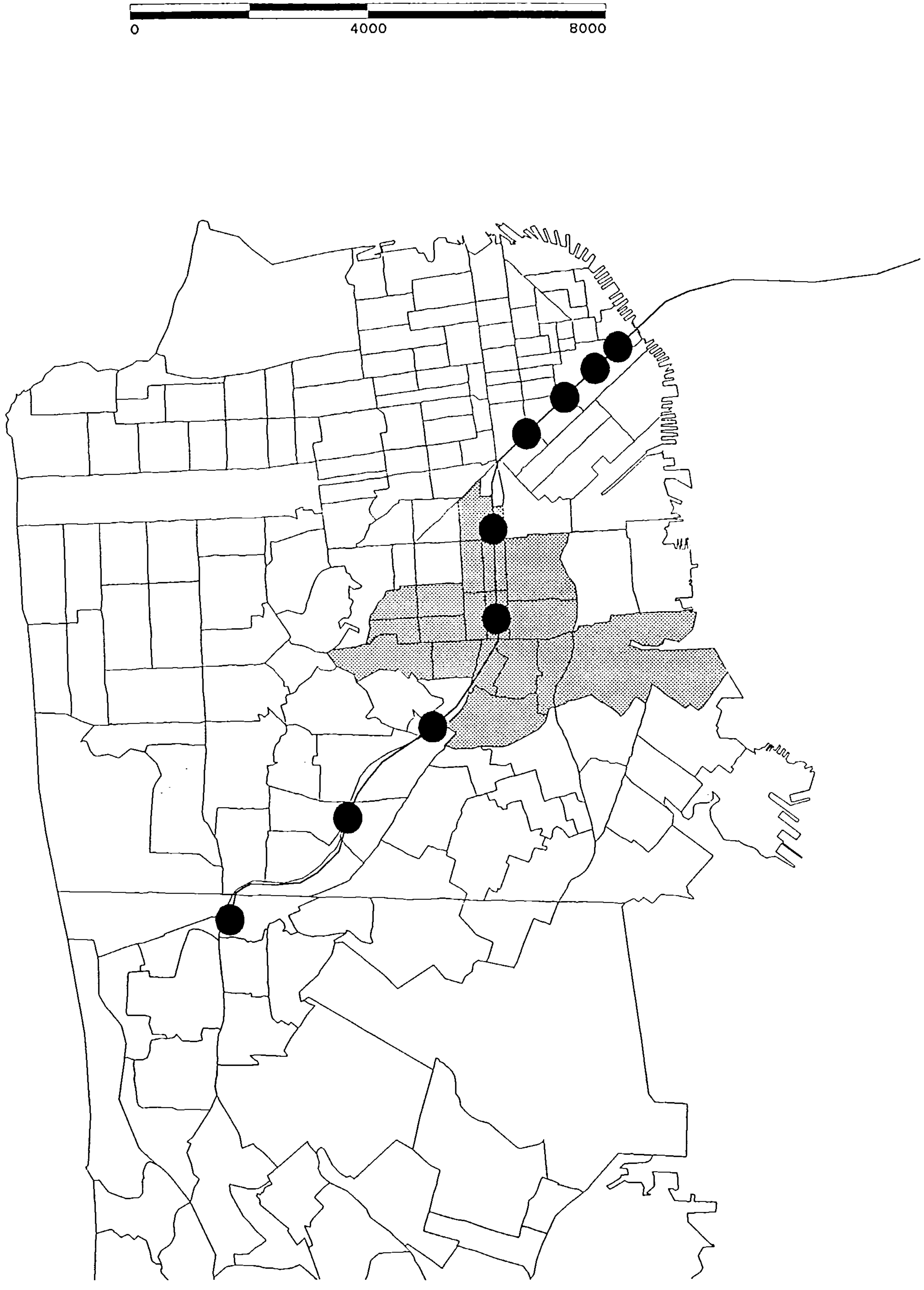
URBAN DISTRICTS

Walking Mode

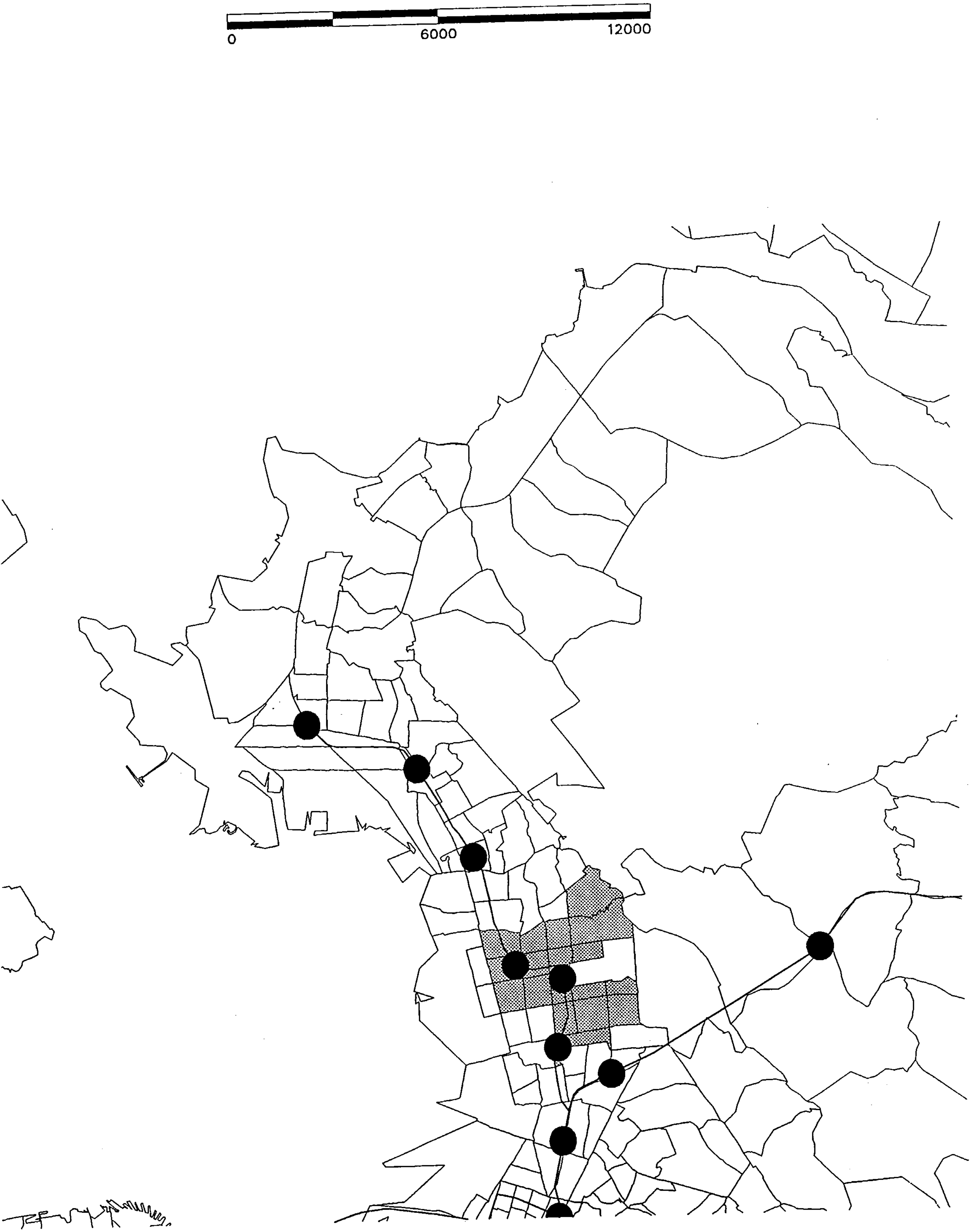
Mission-16th Street Station - 90% Catchment Area - Home Access by Walking



Mission-24th Street Station - 90% Catchment Area - Home Access by Walking



Berkeley Station - 90% Catchment Area - Home Access by Walking



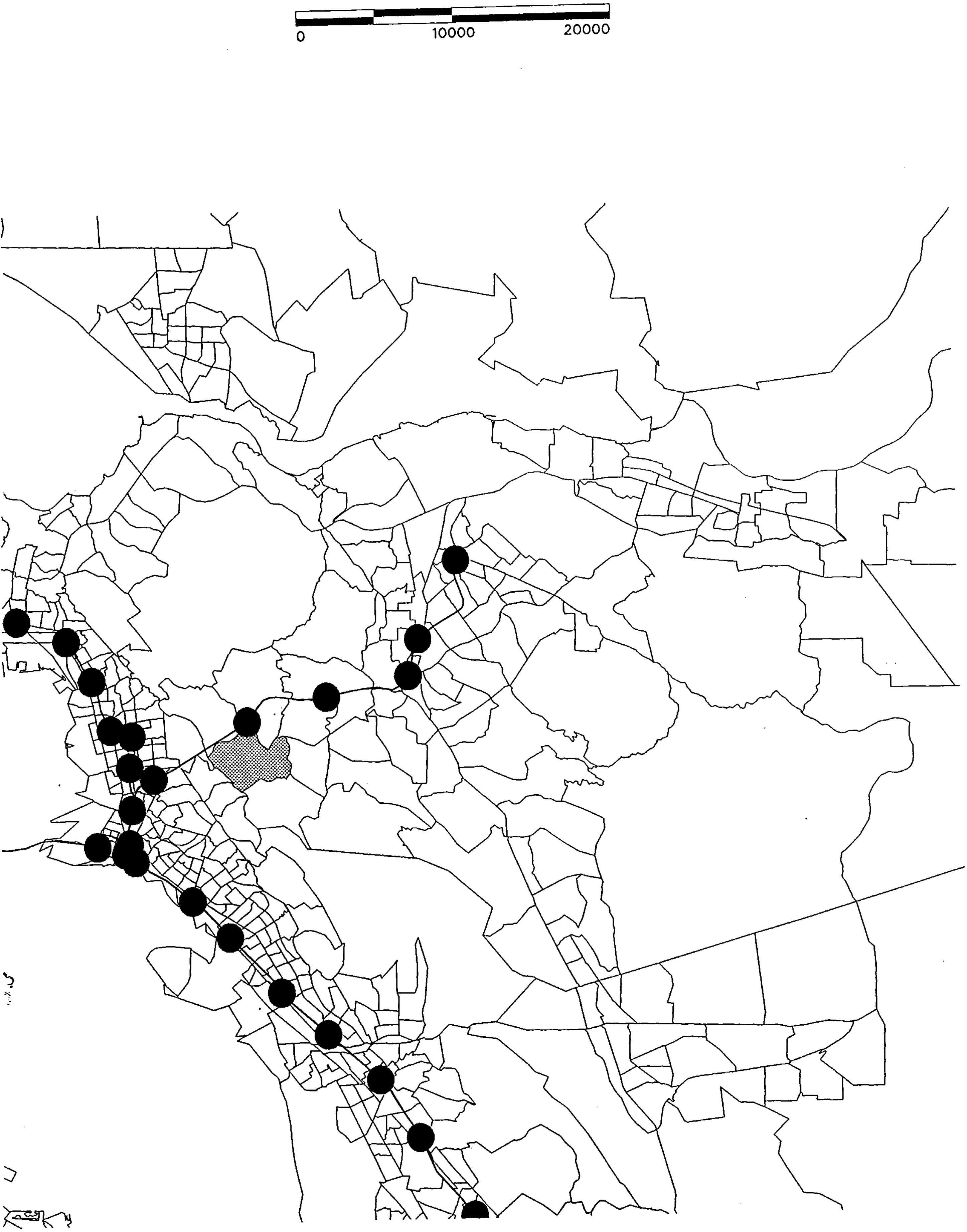
Lake Merritt Station - 90% Catchment Area - Home Access by Walking

90% Catchment Area for

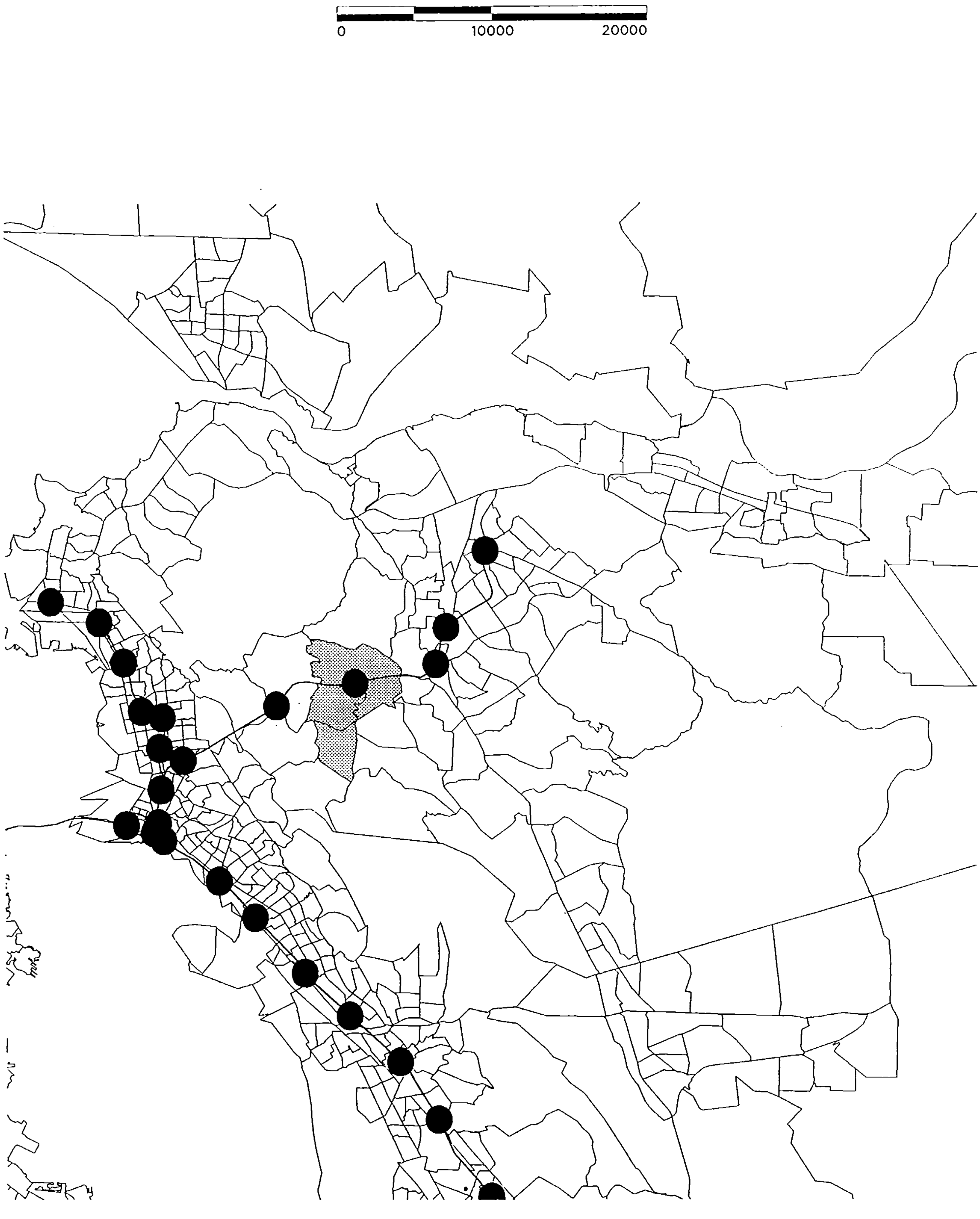
SUBURBAN CENTERS

Walking Mode

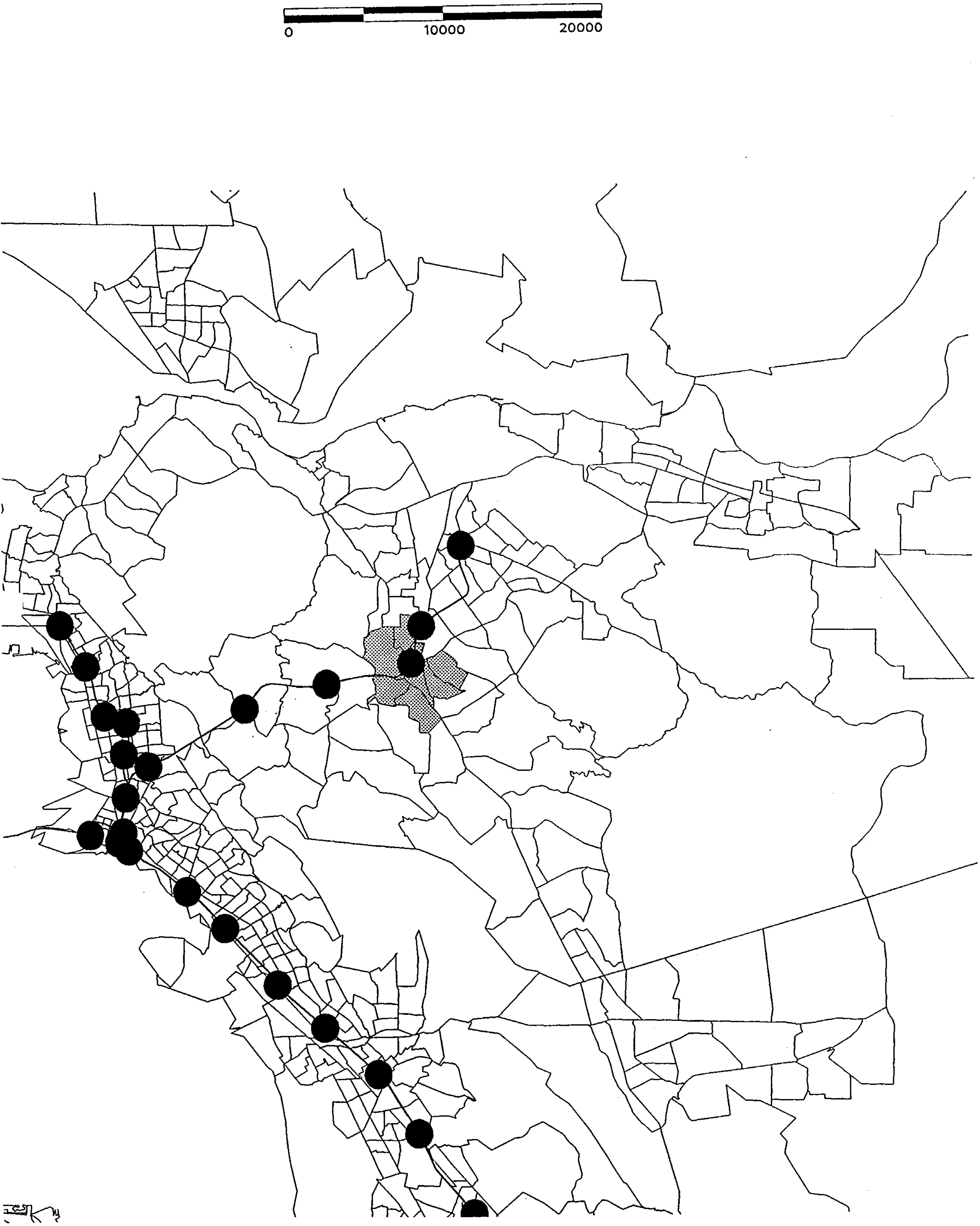
Orinda Station - 90% Catchment Area - Home Access by Walking



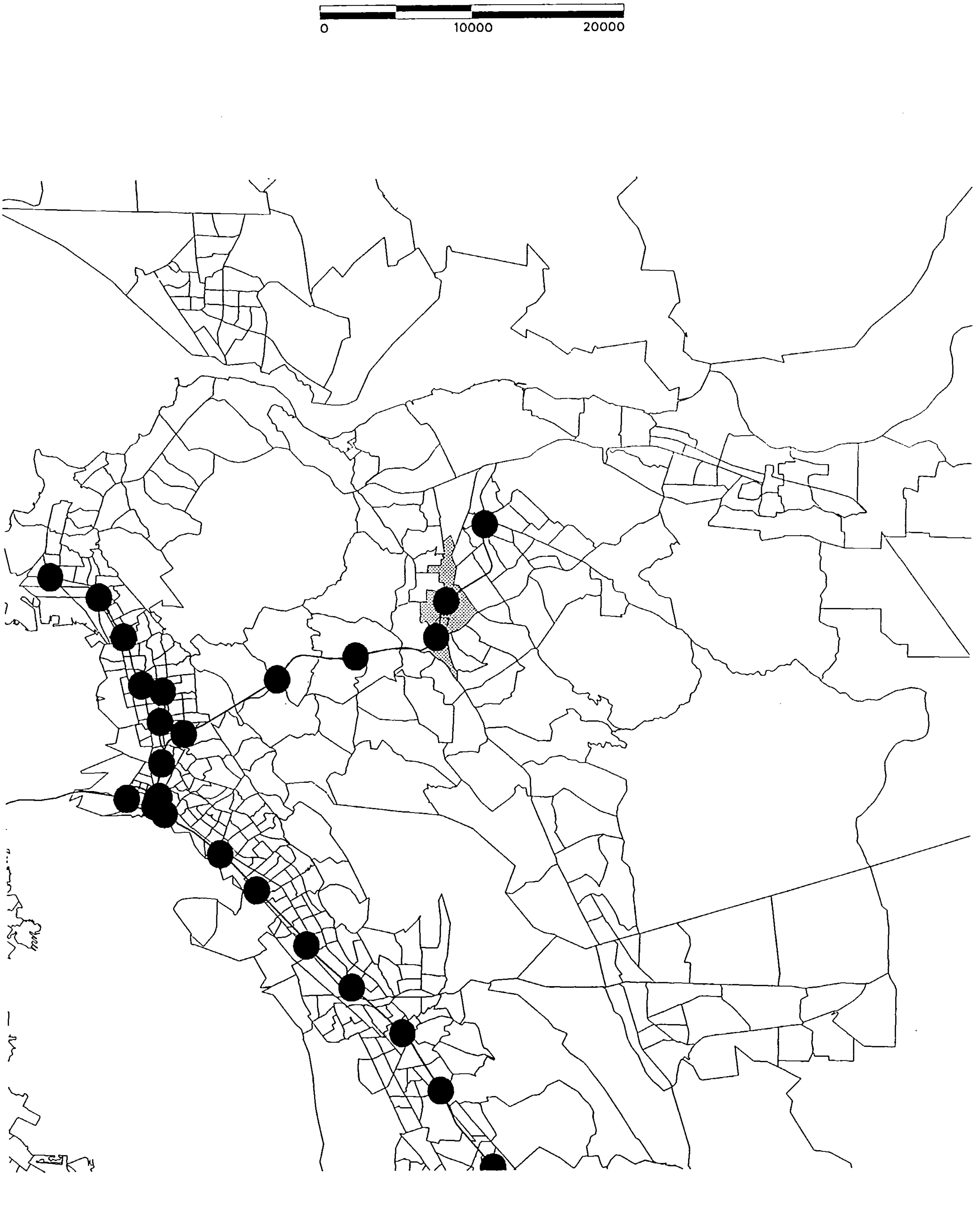
Lafayette Station - 90% Catchment Area - Home Access by Walking



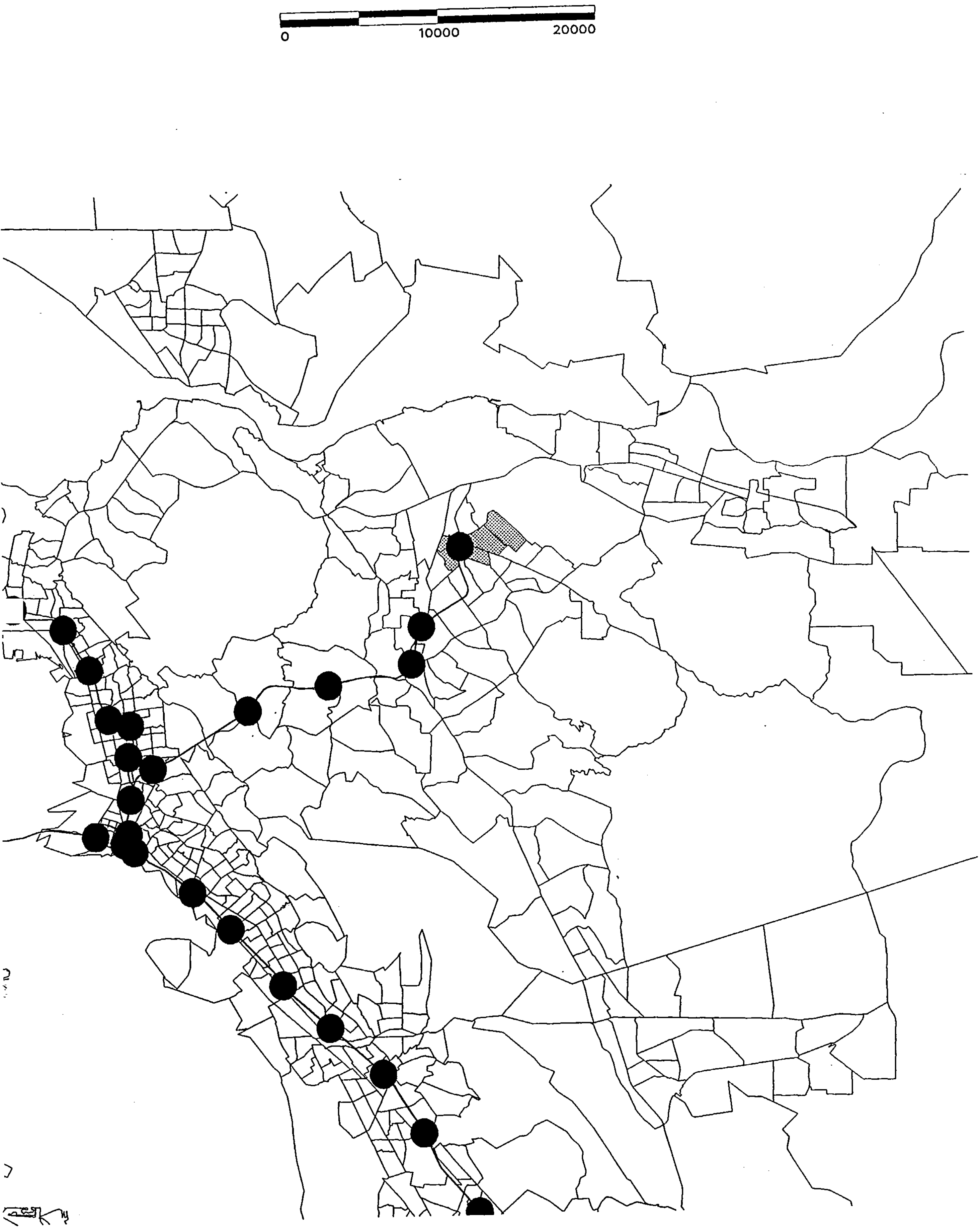
Walnut Creek Station - 90% Catchment Area - Home Access by Walking



Pleasant Hill Station - 90% Catchment Area - Home Access by Walking



Concord Station - 90% Catchment Area - Home Access by Walking



90% Catchment Area for

LOW-DENSITY AREAS

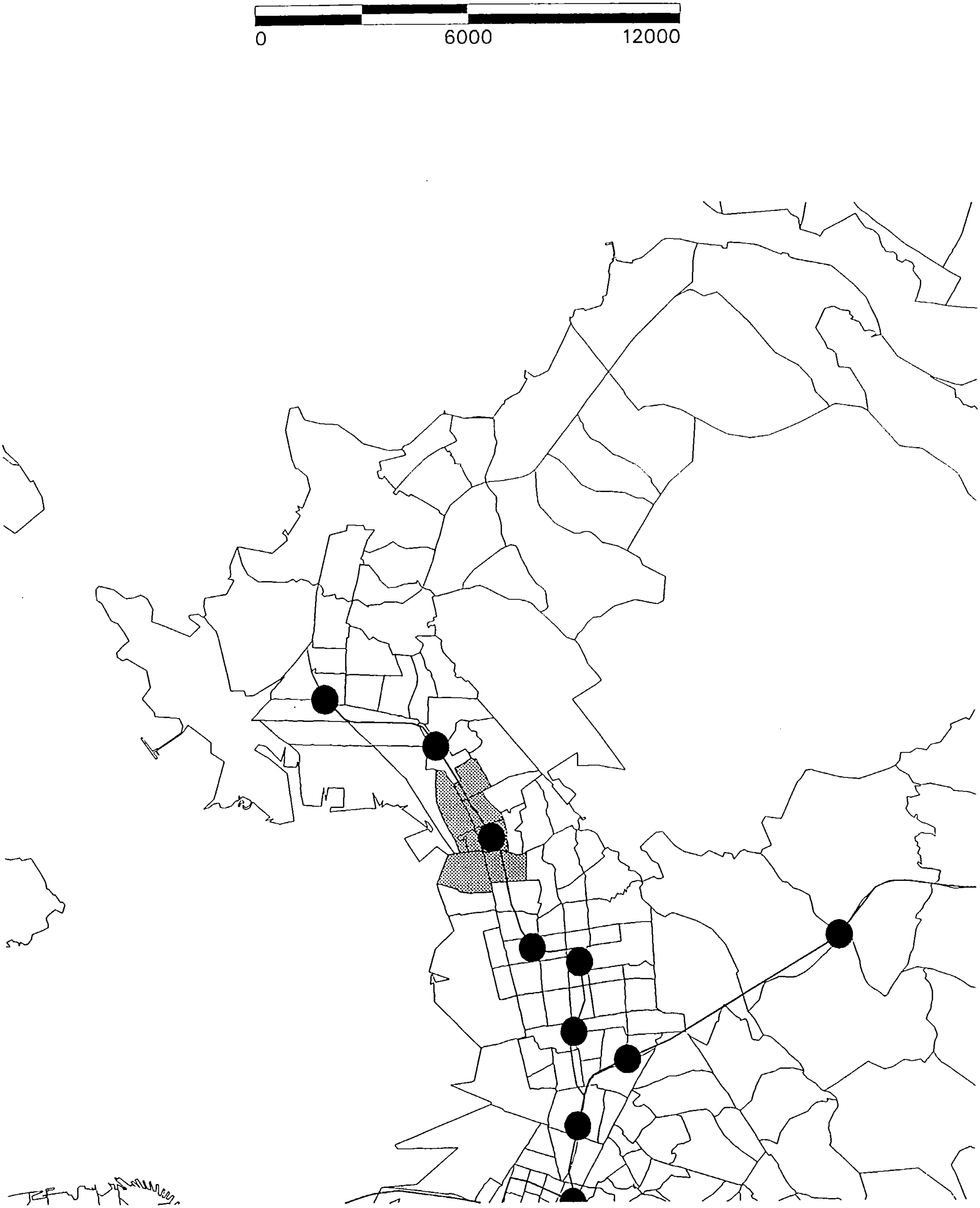
Walking Mode

MacArthur Station - 90% Catchment Area - Access by Walking

Ashby Station - 90% Catchment Area - Home Access by Walking

North Berkeley Station - 90% Catchment Area - Home Access by Walking

El Cerrito Station - 90% Catchment Area - Home Access by Walking



El Cerrito del Norte Station - 90% Catchment Area - Home Access by Walking

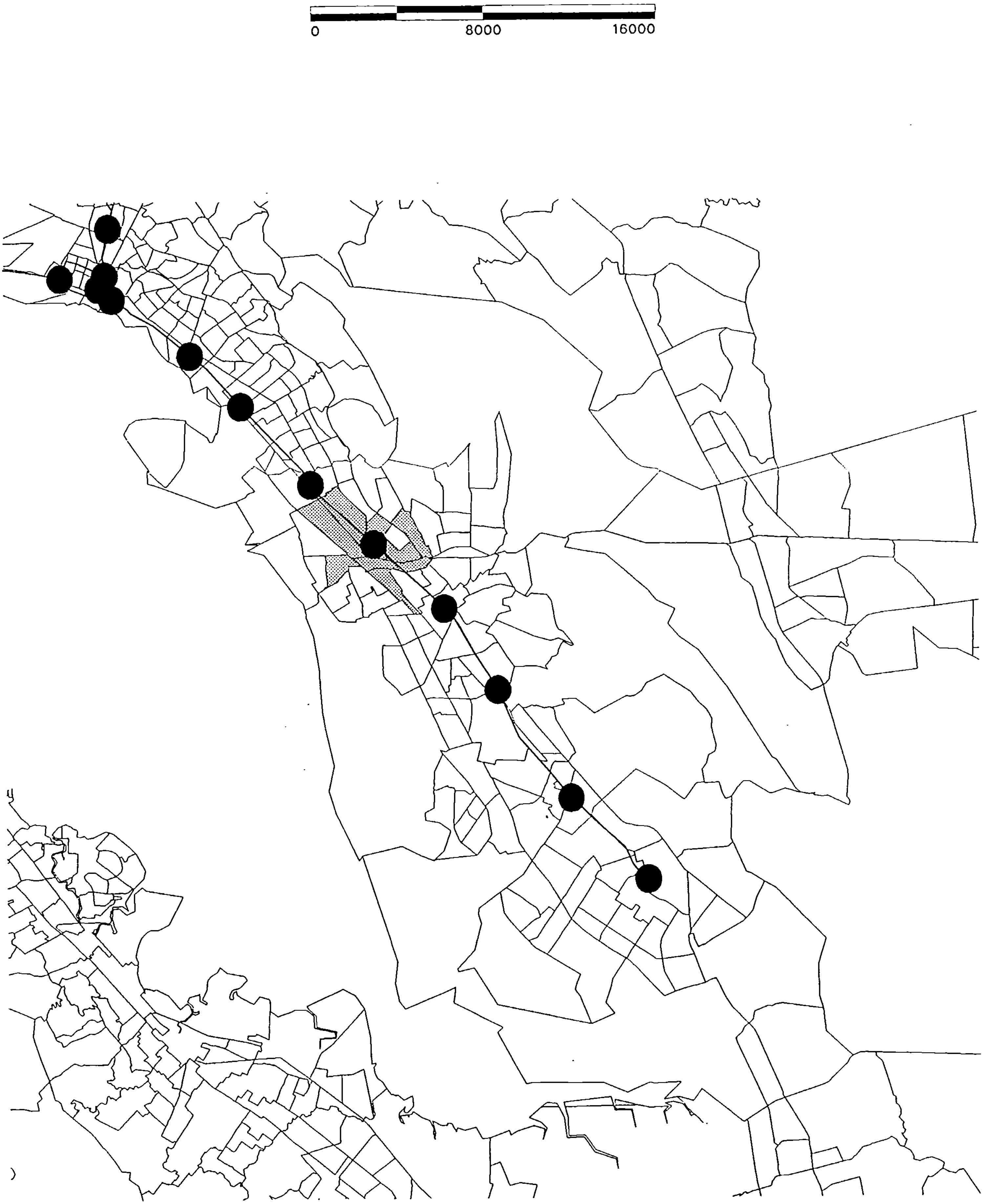
Richmond Station - 90% Catchment Area - Access by Walking

Fruitvale Station - 90% Catchment Area - Home Access by Walking

Coliseum Station - 90% Catchment Area - Home Access by Walking

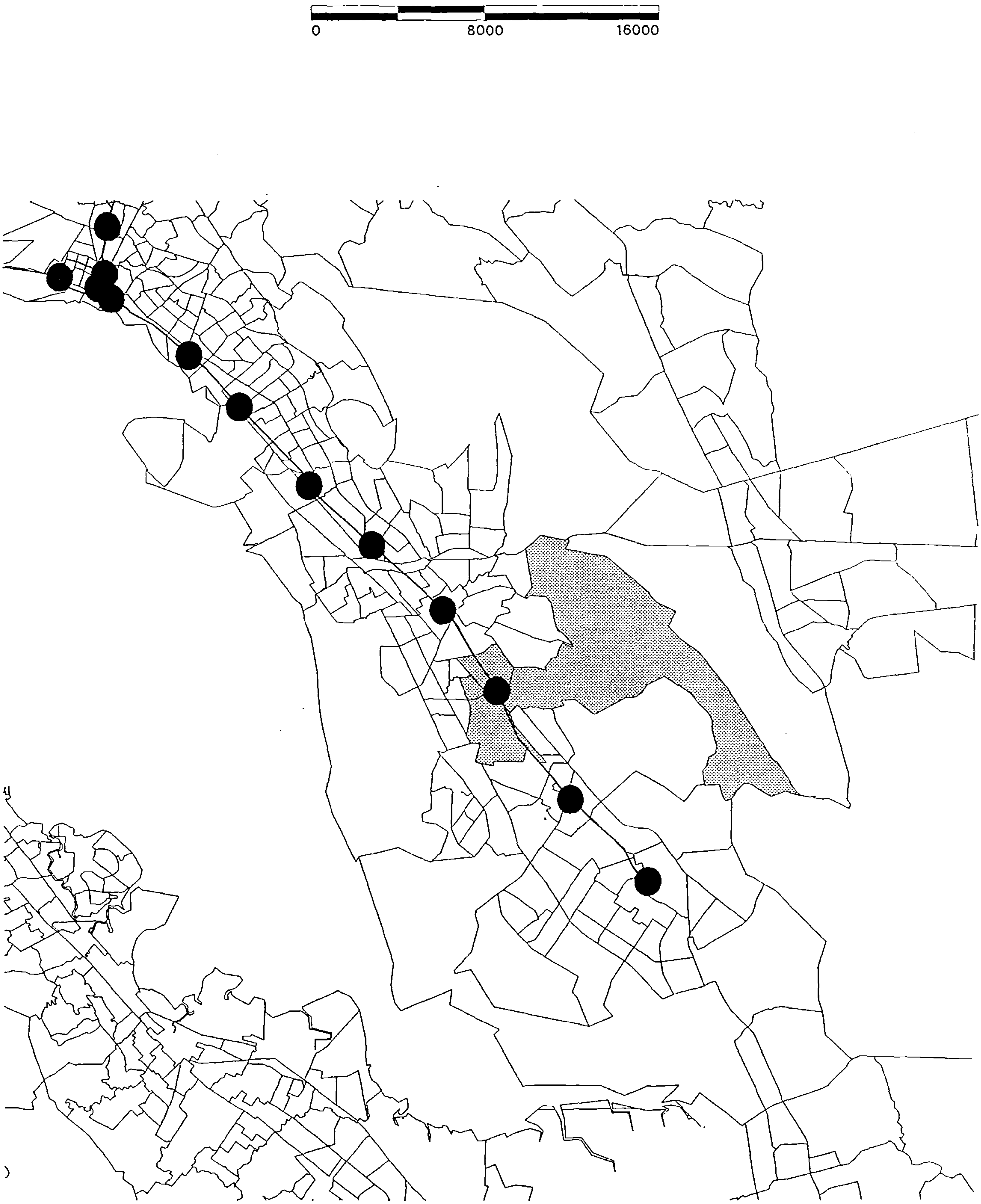
San Leandro Station - 90% Catchment Area - Home Access by Walking

Bayfair Station - 90% Catchment Area - Home Access by Walking



Hayward Station - 90% Catchment Area - Home Access by Walking

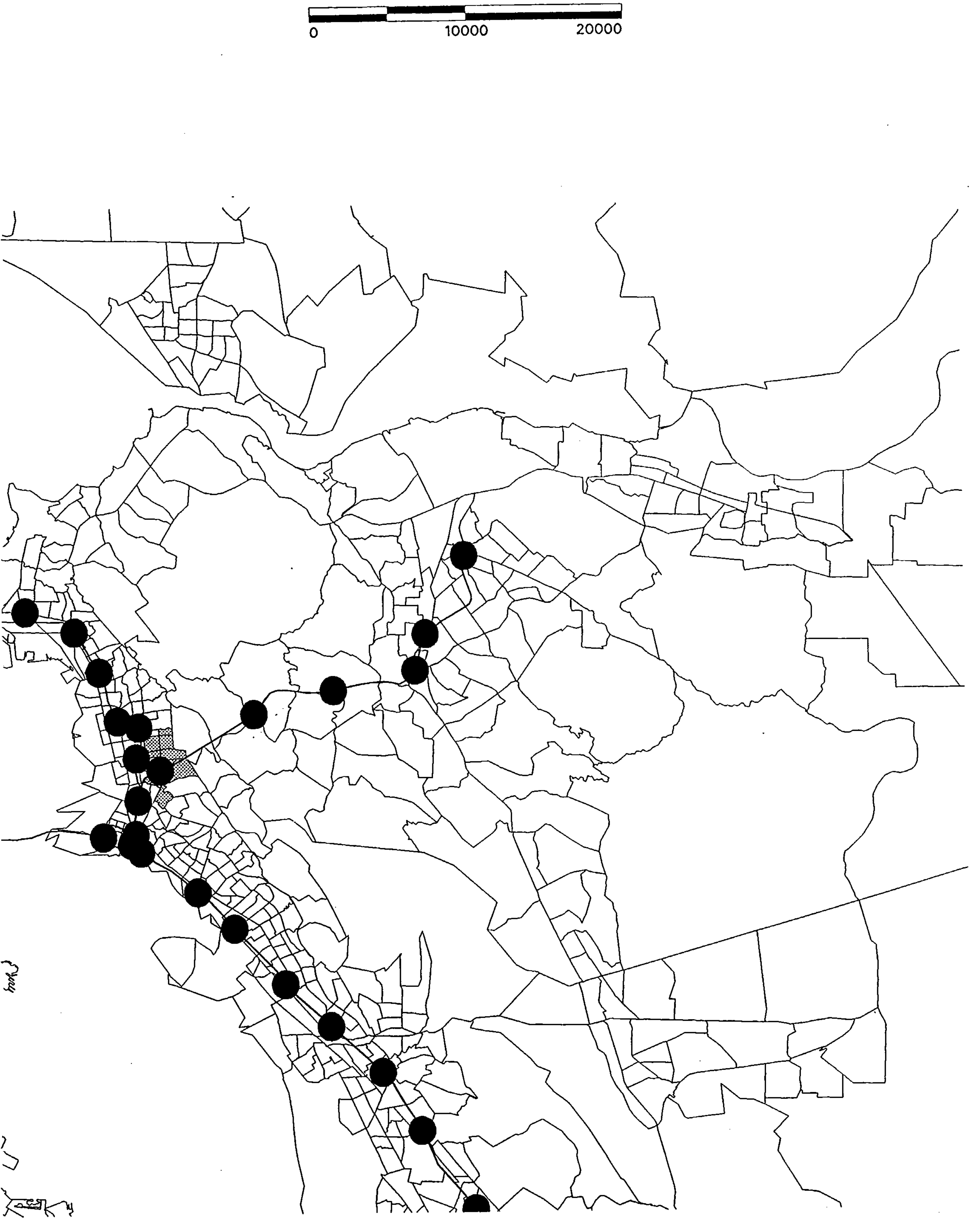
South Hayward Station - 90% Catchment Area - Home Access by Walking



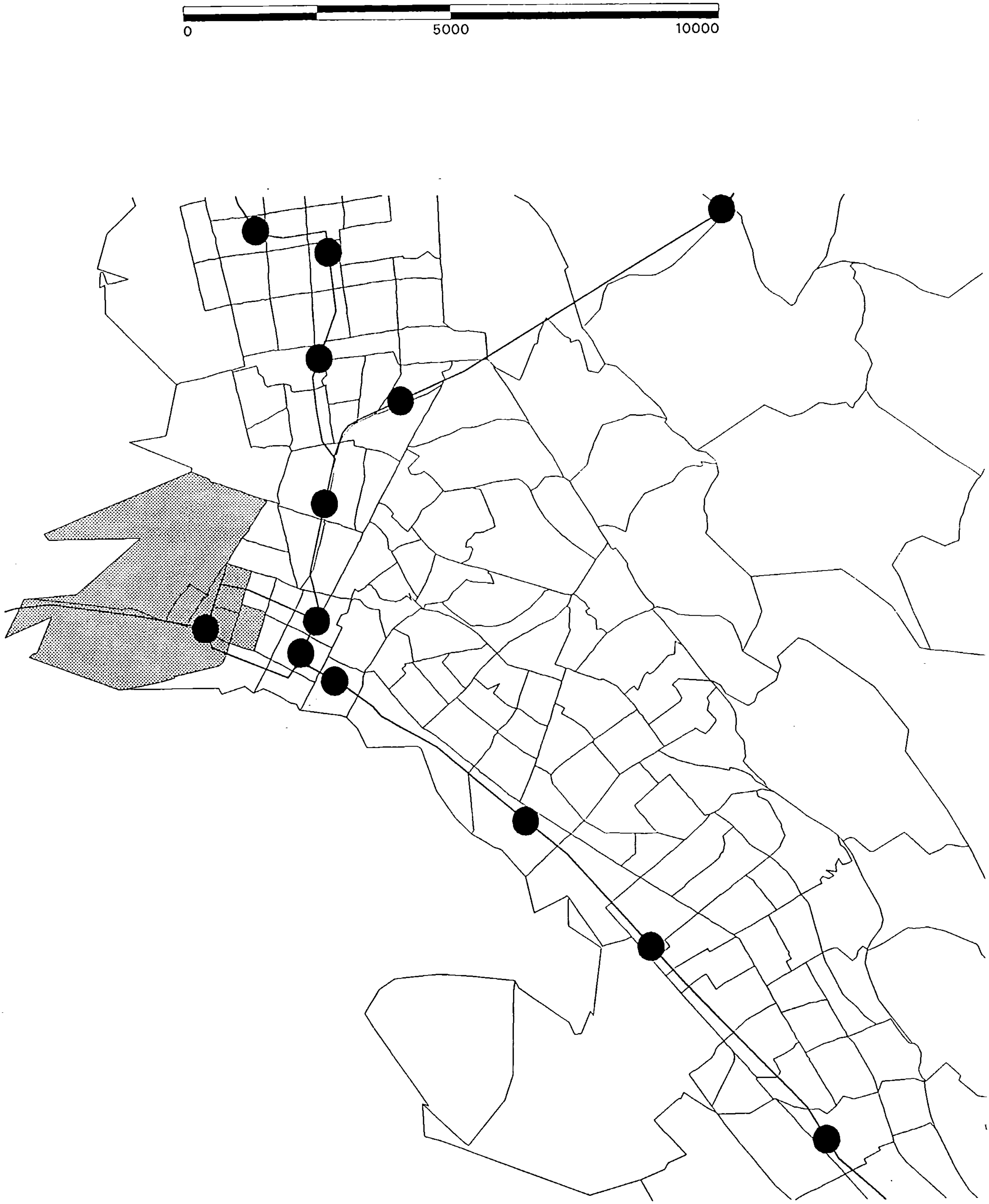
Union City Station - 90% Catchment Area - Home Access by Walking

Fremont Station - 90% Catchment Area - Home Access by Walking

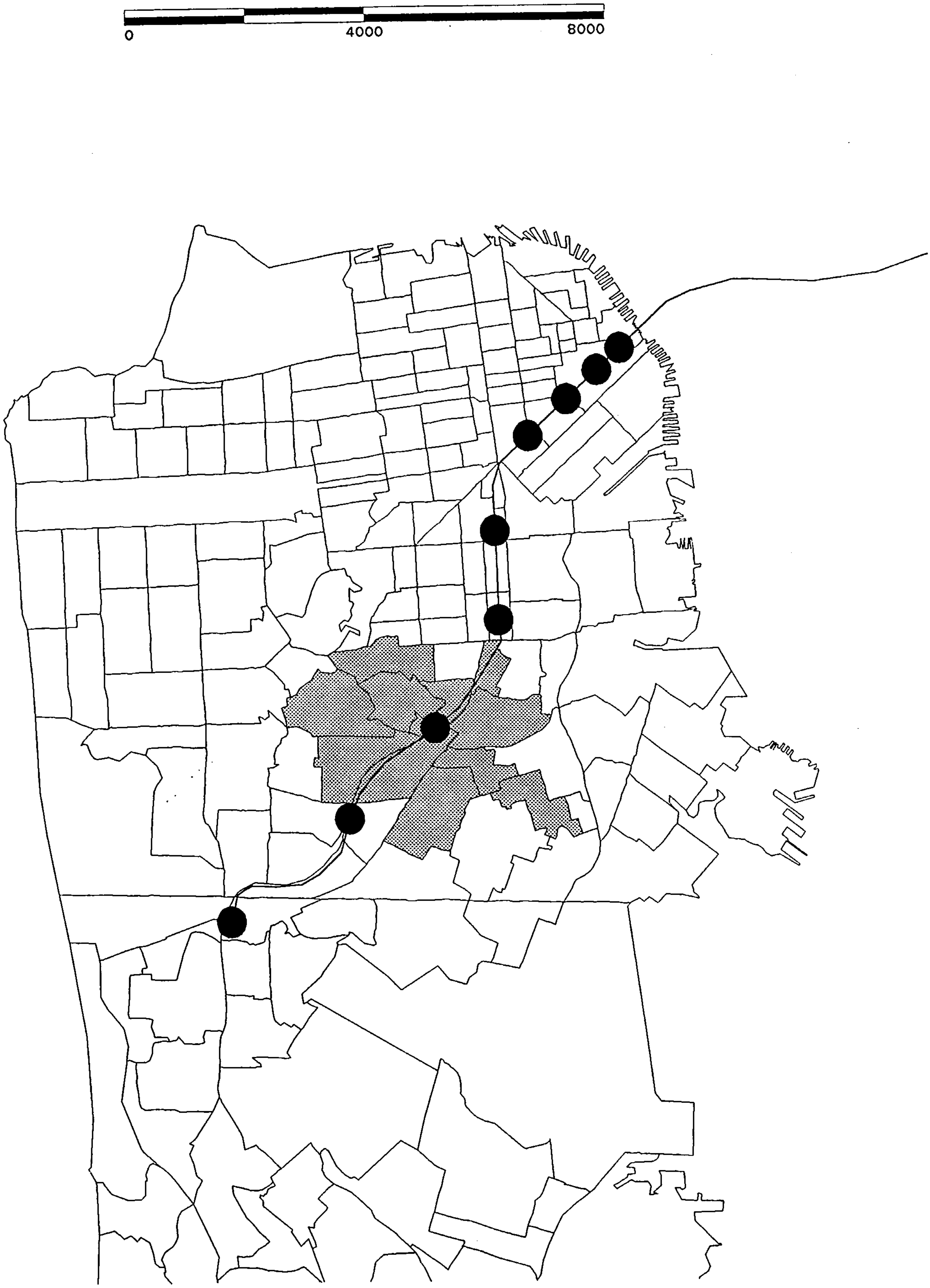
Rockridge Station - 90% Catchment Area - Home Access by Walking



West Oakland Station - 90% Catchment Area - Home Access by Walking



Glen Park Station - 90% Catchment Area - Home Access by Walking



Daly City Station - 90% Catchment Area - Home Access by Walking