Walk-and-Ride: Factors Influencing Pedestrian Access to Transit

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Abstract

The predominant means of reaching suburban rail stations in the United States is by private car. Transit villages strive, among other things, to convert larger shares of rail access trips to walk-and-ride, bike-and-ride, and bus-and-ride. Empirical evidence on how built environments influence walk-access to rail transit remains sketchy. In this article, analyses are carried out at two resolutions to address this question. Aggregate data from the San Francisco Bay Area reveal compact, mixed-use settings with minimal obstructions are conducive to walk-and-ride rail patronage. A disaggregate-level analysis of access trips to Washington Metrorail services by residents of Montgomery County, Maryland, shows that urban design, and particularly sidewalk provisions and street dimensions, significantly influence whether someone reaches a rail stop by foot or not. Elasticities are presented that summarize findings. The article concludes that conversion of park-and-ride lots to transit-oriented developments holds considerable promise for promoting walk-and-ride transit usage in years to come.

Accessing Rail Transit

In much of America, and particularly in the suburbs, the automobile has become the mobility standard for accessing rail transit systems. Consequently, transit stations encircled by a sea of parking have become a common feature of

America's suburban landscape. Indeed, parking lots are the dominant "land uses" within a half-mile of most suburban rail stations in the United States.

In parts of the United States, efforts are underway to change this, converting parking lots and transforming station areas into "transit villages" (Cervero 1996a; Bernick and Cervero 1997). The transit village concept embraces many objectives, including neighborhood revitalization, improved transportation conditions, and enhancement of built and natural environments. While the chief environmental benefit of transit-oriented development comes from coaxing motorists over to mass transit, a secondary benefit is the inducement of more walk and bicycle access trips to and from transit.

Getting more rail transit users to walk-and-ride, bike-and-ride, or bus-and-ride rather than park-and-ride could yield a number of benefits. By reducing the need for parking lots, rail transit agencies could redirect investments and resources to improved mainline services. Less surface parking would also reduce the separation of land uses, effectively "de-scaling" suburban landscapes, and free up land for infill development. And encouraging nonmotorized forms of station access would yield transportation and environmental benefits by reducing vehicle-miles-traveled (and thus greenhouse gas emissions and energy consumption) as well as the traffic snarls and noise levels that often afflict neighborhoods located near rail stations. Research has shown that the "dis-amenity" of living near a park-and-ride lot can lower residential property values, all else being equal. In the case of the Santa Clara Light Rail Transit system, Landis et al. (1994, p. 28) found single-family homes within 800 feet of a light-rail station with a parking lot were worth about \$31,000 less than equivalent properties beyond the immediate impact zone of a station, controlling for other factors.

Perhaps the biggest environmental benefit from converting larger shares of rail access trips from park-and-ride to walk-and-ride and other means would be less air pollution. From an air quality standpoint, transit riding does little good if most people use their cars to reach stations. For a 3-mile automobile trip, the typical distance driven to access a suburban park-and-ride lot in the United States (Cervero 1995), 84 percent of hydrocarbon (HC) emissions and 54 per-

cent of nitrogen oxide (NO_x) 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 tailpipe emissions of the two main precursors to the formation of photochemical smog occur from turning the automobile engine on and driving a mile and turning it off. Drive-alone access trips to rail stations, regardless of how short they are, emit levels of pollutants that are not too much below those of the typical 10-mile solo commute. Thus, relying on a car to access a metropolitan rail service pretty much negates the air quality benefits of patronizing transit.

The three core dimensions, or “3 D’s,” of built environments—density, diversity, and design—as defined by Cervero and Kockelman (1997) are thought to influence access trips to rail stops, along with parking provisions, though to what degree remains unclear since relatively little systematic work has been conducted to date on this question. In general, we know that, as densities fall and distances to downtowns increase, Americans increasingly rely on mechanized means to reach stations. In downtowns, most people reach transit stops by foot. Surveys of residents accessing downtown San Francisco stations to take BART (Bay Area Rapid Transit) to work reveal that two-thirds arrive by foot (Cervero 1995). As one leaves downtown stations and heads outwards, the share of walk-on trips falls precipitously, replaced by mechanized access trips—park-and-ride, kiss-and-ride (i.e., passenger drop-off), and bus-and-ride. At suburban BART stations, like Walnut Creek and Fremont, over 85 percent of access trips 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 San Francisco Bay Area show that beyond 1 mile of a suburban rail station, 60 to 80 percent of access trips are by automobile, with the share rising steadily as access distance increases (Stringham 1982; JHK and Associates 1987, 1989; Cervero 1994).

This article probes the influences of various factors, particularly those related to physical land-use patterns and built environments, which explain walk-and-ride forms of rail-transit usage. It is postulated that the three core dimensions of the built environment—density, diversity, and design—promote

walk-and-ride access. Density does this mainly by bringing larger shares of residents within walking distances of rail stops. Diversity, reflecting the degree of land-use mixture, promotes walking by allowing pedestrians to efficiently consolidate trip ends—such as between a station, retail shop, and a residence, and without the need of a car—by bringing mixed activities closer together (Cervero 1988). And design matters, in that having a continuous and complete sidewalk network in place in addition to a visually stimulating environment enhances the walking experience. Research by Untermann (1984) shows the typical “maximum” acceptable suburban walking distance of one-quarter to a half-mile can be stretched considerably (perhaps as much as doubled) by creating pleasant and interesting urban spaces and corridors.

To test these propositions, two sets of analyses are carried out. The first analysis is conducted at an aggregate scale, using multiple regression to explain walk access market shares for 34 BART stations in the San Francisco Bay Area. The second analysis is disaggregate in scale, using binomial logit models to predict the probability that a resident of Montgomery County, Maryland, reached a Washington Metrorail station by foot versus private car. (Efforts to model bicycle-and-ride access as well were unsuccessful because sample sizes were too small in both case studies.) By shedding light on the link between built environments and walk-and-ride access, it is hoped this research can inform ongoing efforts to promote and design transit-oriented developments as well as provide insights into planning and design for station-area circulation.

Aggregate Analysis: Walk-and-Ride Access to and Egress from Bart Stations

This section presents regression models that predict the influences of land-use variables as well as other factors (e.g., parking supplies) on percentages of access and egress trips by walking. The distinction between the two is that access represents travel from one's residence to a rail stop whereas egress signifies movement from a rail stop to one's nonresidential destination, such as a workplace. BART's 34 stations and their surrounding one-half-mile areas served as cases for studying variation in walk access and walk egress modal splits.

Data Sources and Model Structure

For purposes of estimating market shares of access trips by walking for each of BART's original 34 stations, data from on-board surveys of over 35,000 BART passengers compiled in late-1992 were used (Bay Area Rapid Transit District 1993). The effects of distance on access modes were plotted from these data (using GIS to measure the straight-line distance from the residence of each surveyed passenger to the nearest BART station portal). For distance intervals within a 3-mile access-shed, Figure 1 shows the dominant means of home-end access for commute trips were: walking, 5/8 mile or less; transit, 5/8 to 1 mile; and park-and-ride, beyond 1 mile. Clearly, concentrating housing near rail stops induces walk-and-ride trips. BART's 5/8-mile threshold for walk trips considerably exceeds the one-quarter mile threshold customarily used to define walking access to transit but is less than the 4,000-foot "walking impact zone" (wherein the majority of rail trips were by walk-ons) that Stringham (1982) found for rail stations in Toronto.

Figure 1. Distribution of means of access as a function of distance to BART station for journeys-to-work: 0- to 3-mile distance, derived for all BART stations

The principal land-use data used in the analyses that follow were a digital inventory of dominant land uses within hectare grid cells (100 x 100 meters), compiled by the Association of Bay Area Government (ABAG) for the entire San Francisco Bay Area. Using GIS, buffers were drawn to estimate the composition of land uses within a one-half-mile radius of each of the 34 stations. Residential and employment densities were estimated for block groups and census tracts surrounding each station, based on 1990 census data. Transit data, such as parking supplies at BART stations and feeder bus service levels in and around stations, were compiled from local transit agencies in the Bay Area including BART, AC Transit, and San Francisco Muni.

The regression models that follow explain walk-and-ride market shares mainly in terms of the land-use features (e.g., residential densities) and transportation provisions (e.g., supply of parking spaces) in and around BART stations. Only variables that were reasonably statistically significant and had interpretable results were included in the models. An ordinal variable that rated stations in terms of sidewalk provisions was a candidate for model entry but was statistically insignificant. Efforts were also made to introduce various control variables; however, none of these variables was significant enough to enter the model either. Median household incomes in the vicinity of stations, for instance, had no appreciable effect on whether BART users walked to stations once variables like density were controlled. Nor did factors like station function (e.g., whether a transfer station) or proximity of a station to freeways. Far more important were attributes of built environments—namely, densities and mixtures of land uses—as well as supply-side variables related to parking provisions, transit service levels, and station setting.

Walk-and-Ride Access

Table 1 presents a best-fitting regression model that explained 89 percent of the variation in walk-access modal splits for BART's 34 stations. Consistent with the hypotheses, the table shows that the share of BART access trips by foot increased sharply with densities (especially residential densities) and mixed-land uses around stations and fell as substitutes to walking (i.e., lots of parking and good transit connections) were more plentiful. According to the

model, an increase in residential densities of 10 households per gross acre was associated with an 11.3 percentage point increase in the share of access trips by walking, controlling for parking supplies and other explanatory variables. Also, devoting large shares of station-area land to residential uses is a strong inducement to walk-and-ride. This finding supports the contention of transit

Table 1
Regression Model for Predicting Percentage of Access Trips
to BART Stations by Walking, All Trip Purposes, 1992

<i>Variables</i>	<i>Estimates:</i>		
	<i>Coefficient</i>	<i>Standard Error</i>	<i>Probability</i>
Density			
Employment density: Workers per gross acre within one-half mile of station	.330	.057	.000
Residential density: Households per gross acre within one-half-mile of station	1.130	.314	.001
Land-Use Type and Diversity			
Residential orientation: Percent of land area within one-half mile of station in residential use	.532	.312	.100
Land-use diversity: Normalized entropy index of land-use mixture within one-half mile of station ^a	55.746	35.308	.127
Transit Provisions			
Number of park-and-ride spaces at station	-0.020	.004	.000
Transit service levels: Route miles per 1,000 households within one-half mile of station ^b	-3.121	1.099	.009
Terminal or near-terminal station: 0 = no, 1 = yes ^c	19.569	6.886	.009
Constant	-18.664	42.474	.664
Summary Statistics			
Number of cases			34
F Statistic (probability)			29.30 (.000)
R ²			.887

^aNormalized entropy = $\{ - \sum_k [(p_i) (\ln p_i)] \} / (\ln k)$, where: p_i = proportion of total land area devoted to dominant use for land-use category i (where the i categories are residential, commercial, industrial/office, public, and other); and $k = 5$ (number of land-use categories). A 0 value signifies land devoted to a single use and 1 denotes land area evenly spread among the five land-use categories.

^b Route miles of all surface transit modes, including bus transit, streetcar trams, light-rail transit, and cable car services, within one-half mile of rail station, excluding BART services.

^c 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 tend to serve larger ridership catchments. 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.

village design that calls for a significant residential presence for purposes of invigorating station areas and providing “eyes on the community 24 hours a day” (Bernick and Cervero 1997, p. 10). This finding also likely reflects the dynamics of “residential sorting”—the tendency of those who have a proclivity to commute via transit and are drawn to the idea of not having to drive to work to conscientiously locate near a station when renting or buying a place to live (Voith 1991; Cervero 1994).

As expected, provisions for competitive means of station access worked against walking-and-riding. Plentiful parking spaces evidently prompted significant shares of BART users to drive instead of walk to stations, even when controlling for factors like residential densities and land-use mixes. Similarly, intensive transit services around stations encouraged bus-and-ride at the expense of pedestrian access. Interestingly, the table shows that, once parking supplies and other factors were 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 two near-terminal stations, Pleasant Hill and El Cerrito del Norte, yielding high shares of walk-access trips to these two stations.

Walk-and-Ride Egress

To explore whether the influences of land-use variables on walking market shares were symmetrical at both ends of a transit trip, models were also estimated for egress trips (i.e., from a rail stop to the final trip destination). Table 2 shows that the relationships for explaining walk egress trips were very similar as those found for walk access trips, though land-use variables exerted even stronger influences in this model. Controlling for densities, parking supplies, and other factors, for instance, Table 2 indicates a station area that had a balanced mix of land uses averaged 73 percent more egress trips by walking than one surrounded by a single land use. Every 10 additional jobs per acre, the model suggests, were associated with a 3.33 percentage point increase in egress trips by foot, holding other factors constant. Working against walk egress trips were parking supplies, bus service levels, and interestingly, the

presence of a freeway median. The results suggest that BART stations situated in freeway medians averaged around 7 percent fewer egress trips by foot, controlling for densities and other factors. This finding buttresses the argument that quality of walking environment matters. Freeway medians often form bar-

Table 2
Regression Model for Predicting Percentage of Egress Trips
from BART Stations by Walking, All Trip Purposes, 1992

<i>Variables</i>	<i>Estimates:</i>		
	<i>Coefficient</i>	<i>Standard Error</i>	<i>Probability</i>
Density			
Employment density: Workers per gross acre within one-half mile of station	.338	.050	.000
Residential density: Households per gross acre within one-half-mile of station	1.556	.310	.000
Land-Use Type and Diversity			
Residential orientation: Percent of land area within one-half mile of station in residential use	.637	.310	.050
Land-use diversity: Normalized entropy index of land-use mixture within one-half mile of station ^a	73.577	37.090	.058
Transit Provisions			
Number of park-and-ride spaces at station	-0.012	.003	.000
Transit service levels: Route miles per 1,000 households within one-half mile of station ^b	-3.629	1.054	.002
Station located in freeway median: 0=no, 1=yes	19.569	6.886	.009
Constant	-35.370	42.293	.441
Summary Statistics			
Number of cases			34
F Statistic (probability)			28.91 (.000)
R ²			.886

^aNormalized entropy = $-\sum_i [(p_i) (\ln p_i)] / (\ln k)$, where: p_i = proportion of total land area devoted to dominant use for land-use category i (where the i categories are residential, commercial, industrial/office, public, and other); and $k = 5$ (number of land-use categories). A 0 value signifies land devoted to a single use and 1 denotes land area evenly spread among the five land use categories.

^bRoute miles of all surface transit modes, including bus transit, streetcar trams, light-rail transit, and cable car services, within one-half mile of rail station, excluding BART services.

^cNear-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 tend to serve larger ridership catchments. 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.

riers to movement in many ways—physically, visually, psychologically, and symbolically. The vibrations caused by heavy freeway traffic, and shadows cast by elevated structures can also discourage foot travel.

Synopsis: Elasticities

While the regression results reveal the statistical significance of factors shaping walk-and-ride access, it is difficult to judge the relative importance of particular explanatory variables from model outputs. To shed light on the relative sensitivity of walk-access to land-use variables and other factors, results are best summarized in elasticity form. Table 3 presents midpoint elasticities imputed from the regression results, revealing the percentage of change in walk-and-ride market shares for every 1 percent increase in the mean value of each land-use variable.¹ The table shows that, in general, the relationship between built environments and walking-and-riding is fairly inelastic, though the influences of land-use variables are generally as strong as other predictors. Walk-access and walk-egress market shares were most influenced by concentrated development around stations. This lends credibility to the transit village concept for the results clearly reveal that compact residential development within a half-mile of a rail stop significantly induces travel to and from stations. Also, access and egress modal splits were more sensitive to residential densities than to employment densities. Land-use diversity also mattered: high mixed-use settings around rail stops encouraged walk-and-ride, ostensibly because residents can take care of personal needs, like picking up a few groceries after work, when retail shops and other services lie between stations and their homes. Loutzenheiser (1997) also showed the presence of retail near stations encouraged walk-access trips to BART. In a study of transit usage nationwide using the American Housing Survey, Cervero (1996b) similarly found mixed-land uses to be an inducement to transit riding for those living within several miles of a rail station.

In addition to land-use variables, Table 3 shows factors related to transit provisions also appreciably influenced walk-and-ride behavior. Notably, park-and-ride supplies were a significant deterrent to walk-access and walk-egress.

Table 3
Mid-point Elasticities of Access and Egress Walk Trips
as Functions of Land-Use and Other Explanatory Variables

<i>Explanatory Variables</i>	<i>Mid-point elasticities for:</i>	
	<i>Walk Access</i>	<i>Walk Egress</i>
Employment density	.220	.196
Residential density	.269	.328
Residential orientation	.733	.775
Land-use diversity	.119	.152
Park-and-ride spaces at station	-.484	-.257
Transit service levels	-.474	-.107
Terminal or near-terminal station	.093	—
Station in freeway median	—	-.029

The physical characteristics of stations, such as being situated in the median of a freeway or at (or near) the end of a line, exerted relatively weak influences on whether BART patrons walked-and-rode, once factors like density and parking supplies were controlled for.

Disaggregate Analysis: Walk-and-Ride Access to and Egress from Washington Metrorail Stations

While the analysis of walk-and-ride behavior in the San Francisco Bay Area supported the core hypotheses of this research, the findings captured aggregate patterns of travel behavior. Because variables defining attributes of surveyed BART riders were sparse, disaggregate analyses could not be conducted. For this purpose, data were compiled on access trips among residents of Montgomery County, Maryland, who patronized the Washington Metrorail system.

Montgomery County, Maryland, a fairly affluent county of 850,000 inhabitants adjacent to the District of Columbia, provides a good setting to explore the research hypotheses in greater depth because the county planning department maintains fairly rich data on land-use characteristics of its 318 traffic analysis zones (TAZs). In particular, far more variables were available from Montgomery County to explore the effects of urban design factors on walk access.

Data Sources and Model Structure

Trip records for 177 Montgomery County residents who made a trip aboard Washington Metrorail were drawn from the 1994 Household Travel Survey compiled for the Metropolitan Washington Council of Government (MWCOC) region. Added to these records were various land-use, activity-location, urban design, and accessibility measures associated with the TAZ of the origin of each trip record, typically representing a person's place of residence. A number of additional variables (e.g., land-use diversity, gross densities) were created using input variables of each TAZ.

A binomial logit model, of the following form, was used to estimate the probability a Montgomery County resident patronizing Metrorail accessed the station by foot:

$$P_{nio} = \exp(V_{nio}) / \sum_{j \in C_{no}} \exp(V_{njo}), \quad \forall V_{nio} = f(T_{io}, SE_n, BE_o, BE_d)$$

where:

P_{nio} = probability of person n choosing means i for accessing the nearest Metrorail station from the person's residence at origin o ;

C_{nod} = choice set of modes available to person n traveling from origin o to the nearest Metrorail station;

V_{nio} = utility function (systematic component) for person n traveling by mode i from origin o to the nearest Metrorail station;

T_{io} = trip characteristics for travel (e.g., time) by mode i from origin o to the nearest Metrorail station;

SE_n = socioeconomic characteristics of trip-maker n (e.g., income and vehicle availability); and

BE_o = built environment vector for TAZ origin o , representing measures of land-use intensity, land-use mixture, and walking quality.

As with the analysis of access to BART, the aim was to estimate the best-fitting model that yielded significant and interpretable explanatory variables. A number of variables reflecting densities and land-use mixtures at trip origins were examined in terms of their ability to increase utility for walk-and-ride access; however, only a handful were found to be reasonably significant.

Among the candidate variables considered for gauging walking quality, the ones that proved to be the best predictors included the ratio of sidewalk miles to road miles (as an index of sidewalk provisions) and intersection density (number of intersections per square mile, an indicator of degree of traffic-stream conflict points and street connectivity).

The logit model was estimated only from records of Montgomery County residents who patronized Metrorail at stations where park-and-ride facilities were available. This meant park-and-ride as well as bus-and-ride and kiss-and-ride were bonafide alternatives for access a Metrorail station. Because the availability of park-and-ride was a control introduced in the analysis, the supply of parking spaces did not enter as a variable for predicting the probability of walk access.

Walk-and-Ride Access

The best-fitting binomial logit model, shown in Table 4, yielded a pseudo-R-squared (ρ) statistic of 0.57, indicating the model does a 57 percent better job than a simple flip of a coin at predicting whether a Montgomery County Metrorail patron accessed a station by walking or not. Land-use factors related to the “3 D” core dimensions—proximity (a correlate of density), diversity, and design—significantly influenced the odds of a Montgomery County resident reaching a station by foot versus a motorized mode. Travel time to a station impeded walking whereas having large shares of housing near a station spurred it. As with BART, living near Metrorail was a strong inducement to walk-on access. This finding is consistent with research by JHK and Associates (1987, 1989) that revealed remarkably high rates of transit commuting among apartment and condominium dwellers who resided close to Washington Metrorail stations, with transit capturing over a 50 percent market share in the case of several apartment projects.

Similar to the findings of the aggregate analysis, more mixed-use environments also seemed to promote walking access, ostensibly because transit riders can chain trip ends by foot in more diverse settings (e.g., walk from a station to a nearby shop to one’s residence when returning home from work via Metrorail in the evening). Diversity within a much larger 45-minute travel shed was likewise positively associated with walking access, suggesting subregional balance worked in favor of foot travel as well.

Of particular note was the value of urban design factors in inducing pedestrian access. Montgomery residents were more likely to walk-and-ride than park-and-ride in settings with fairly complete sidewalk networks. Intersection density, a proxy for degree of road connectivity, also promoted walking access. A neighborhood with a fine grain mesh of intersections, it appears, provided more possibilities for conveniently connecting origins and destinations by foot.

Table 4
Binomial Logit Model
for Predicting Probability Montgomery County Resident Taking
Metrorail Accessed Station by Walking, All Trip Purposes, 1994

<i>Variables</i>	<i>Estimates</i>		
	<i>Coefficient</i>	<i>Standard Error</i>	<i>Probability</i>
Nearness and Proximity			
Time to nearest Metrorail station from residence, highway network (minutes)			
Proportion of households in TAZ of residence within one-half mile of Metrorail Station	2.758	1.656	.096
Diversity			
Land-use diversity, TAZ of residence: Employment and population relative to county ratio ^a	18.500	11.256	.100
Job accessibility, TAZ of residence: Number of jobs (in 1000s) within 45-minute highway network travel time	-.005	.002	.036
Design			
Ratio of sidewalk miles to road miles, TAZ of residence ^b	1.133	.647	.080
Intersection density, TAZ of residence: Number of intersections per square mile	.008	.007	.272
Constant	-1.059	.220	.040
Summary Statistics			
Number of cases			177
-2L(c): Log likelihood function value, constant-only model			99.768
-2L(B): Log likelihood function value, parameterized model			58.283
Model chi-square (probability): -2[L(c) - L(B)]			41.485 (.0000)
p ² (Nagelkerke)			.574

^aDiversity = $1 - \{ABS [(b * (population - employment)) / ((b * (population + employment)))]\}$, where b = countywide ratio of employment to population, set at 0.464 for 1994 (based on data from *County Business Patterns*, Montgomery County, Maryland, U.S. Department of Commerce, 1995).

^bRatio of sidewalk miles to road miles – Values assigned to each segment of all public streets in TAZ: 0 = no sidewalk; 1 = sidewalk on one side; 2 = sidewalk on two sides.

Surprisingly, none of the socioeconomic control variables—including the person's age, gender, vehicle availability, and household income—entered the model as significant predictors. Evidently, walk-and-ride access, at least in Montgomery County, does not discriminate with respect to user demographics.

Walk-and-Ride Egress

A binomial logit model, shown in Table 5, was also estimated to predict the probability a Montgomery County resident who patronized Metrorail walked from the disembarking station to his or her trip destination. While

Table 5 Binomial Logit Model for Predicting Probability Montgomery County Resident Taking Metrorail Walked from Station to Destination, All Trip Purposes, 1994 Metrorail Accessed Station by Walking, All Trip Purposes, 1994			
<i>Variables</i>	<i>Estimates</i>		
	<i>Coefficient</i>	<i>Standard Error</i>	<i>Probability</i>
Nearness and Proximity			
Distance from Metrorail station to destination, highway network (miles)	-3.518	1.28	.006
Location			
Washington, D.C. destination: 0 = No, 1 = Yes	.376	.354	.288
Design			
Ratio of sidewalk miles to road miles, TAZ of destination ^a	.977	.766	.183
Median street width, TAZ of destination (feet)	-.058	.032	.066
Constant	5.273	2.989	.077
Summary Statistics			
Number of cases			177
-2L(c): Log likelihood function value, constant-only model			95.265
-2L(B): Log likelihood function value, parameterized model			57.006
Model chi-square (probability):			
-2[L(c) - L(B)]			38.259 (.0000)
p ² (Nagelkerke)			.745
^a Ratio of sidewalk miles to road miles—Values assigned to each segment of all public streets in TAZ: 0 = no sidewalk; 1 = sidewalk on one side; 2 = sidewalk on two sides.			

fewer predictor variables entered this model than the others, the model nonetheless had a good overall fit with a rho statistic of almost 0.75.

The walk-egress model magnified the importance of urban design factors in encouraging people to walk upon disembarking a station. Controlling for the fact that walk egress eroded rapidly with distance from a station and was highest for egress trips from a station in the District of Columbia, the model reveals scale of streets and sidewalk provisions weighed in on the decision to walk (versus, say, take a bus or taxi). Notably, streetscapes with relatively narrow curb-to-curb widths and flanked by continuous and complete sidewalk networks were the most conducive to walk-egress travel.

Synopsis: Elasticities

As in the case of regression results, it is difficult to judge the relative importance of particular explanatory variables from logit model outputs. To do this, it is best to again translate and summarize logit results in elasticity form. Disaggregate elasticities represent the sensitivity of an individual's choice probability to a change in the value of some attribute (Ben-Akiva and Lerman 1985). They were imputed by systematically increasing one built-environment variable at a time by 1 percent and applying each of the models to measure the corresponding percentage change in mode-choice probabilities, setting values for all other variables in the utility function at their statistical means (in the case of ratio-scale variables) or modes (in the case of categorical-scale variables).² Estimates represent mode-choice point elasticities for the "typical" Montgomery County traveler. Mathematically, the elasticity (E) of the probability of person n choosing mode i (P_{ni}) as a function of a change in the value of variable X_k for person n and mode i (X_{kni}), with all other variables set at their mean or modal values, equals:

$$E_{X_{kni}}^{P_{ni}} = (\partial P_{ni} / \partial X_{kni}) (X_{kni} / P_{ni}); \forall V_{ni} = f(\bar{x}_{1ni}, \bar{x}_{2ni}, \dots, \bar{x}_{k-1ni}, \bar{x}_{k+1ni}, \dots)$$

Table 6 presents imputed point elasticities. Overall, the disaggregate analysis reveals fairly inelastic, though still meaningful, relationships. Distance and time were the greatest impedances to Montgomery County residents walking-and-riding. Next in importance were urban design features, par-

Table 6
Point Elasticity Estimates Imputed from Logit Models:
Percentage Change in Probability of Walk-and-Ride Travel
with a 1-Percent Increase in Explanatory Variable

<i>Explanatory Variables</i>	<i>Walk Access</i>	<i>Walk Egress</i>
Time to Metrorail Station	-.362	—
Distance from Metrorail Station	—	-.506
Sidewalk Ratio	.231	.160
Intersection Density	.061	—
Street Width	—	-.382
Housing Proximity	.163	—
Land-Use Diversity	.147	—
Job Accessibility	.211	—

ticularly at the trip destination. Land-use diversity also worked in favor of walk access, though only marginally. In contrast to the aggregate analysis from the Bay Area, densities at either trip end exerted no discernible influences on the likelihood of walking-and-riding in the disaggregate analyses.

Toward Walking-Friendly Transit Environments

Walk-and-ride transit usage is one of the most sustainable forms of urban mobility. Giving up a car in favor of walking to a station can improve air quality by eliminating cold-start emissions associated with park-and-ride access. Converting parking lots to residential and commercial land uses can also help leverage transit village development and the environmental and transportation benefits associated with it (Calthorpe 1993; Bernick and Cervero 1997).

Based on a triangulated research design, drawing insights from two different metropolitan areas at two different grains of analyses, this research revealed that built environments exert significant influences on walk-and-ride access. Assuming they are within reasonable distance of a station, rail passengers are more likely to walk to and from a station in compact, mixed-use settings with ample sidewalk provisions and minimal physical obstructions. Concentrated development around stations likely stimulates walk-and-ride in

many instances among those who purposefully opt to live within walking distance of rail transit for the very purpose of economizing on commuting.

The fact that these relationships were uncovered in two settings at two different grains analysis suggests that they are robust. In general, the analyses at both grains were fairly consistent and reinforcing. Whatever differences existed between the aggregate and disaggregate analyses could be due to contextual differences as much as differences in research resolutions. In a study of access trips to BART stations, Loutzenheiser (1997) similarly obtained somewhat different, though overall reinforcing, results depending on the scale of analysis.

All transit trips involve some degree of walking; however, this research makes clear that attending to the mobility and design needs of those who exclusively walk to and from stations is especially important. While many programs for enhancing station-area environments tend to focus on residential settings, facilitating pedestrian movements once passengers disembark at stations is equally important. Often, egress needs are neglected altogether. In the case of commuter rail services to Santa Clara County, California, quality of egress has deteriorated to the point where patrons are keeping a second car near their destination station to complete the final leg of their journeys to work. A recent article in the *San Jose Mercury News* (2000) reports:

Silicon Valley is spawning a new type of commuter: a hybrid who takes the train to escape the misery of the freeway but makes the final leg of the journey to work by car. In a trend that has taken planners by surprise, so many riders on the Altamont Commuter Express and Capital Corridor trains are keeping second cars in Santa Clara that the city is building a new lot for overnight parking.

The one trend that could go a long way toward promoting walk-and-ride transit usage is the conversion and adaptive reuse of park-and-ride lots. With time, surface parking lots that envelope rail stations across the United States are proving to be a blessing in disguise for they provide large swaths of pre-assembled land. Many were originally overbuilt, thanks to generous federal funding for rail transit development. As neighborhoods around rail stops have

matured and land values have increased, market pressures are prompting some U.S. transit agencies to sell off at least portions of them as a means both to create a ridership base and to reap windfalls in the form of value capture. Often the profits earned are more than enough to cover the cost of replacement structured parking, freeing up land for infill development. Surface parking conversion, then, is a back-door form of land-banking, a strategy long used in Scandinavia to create transit villages (Cervero 1998).

An important event that has made the retrofitting and adaptive reuse of parking lots possible has been the Federal Transit Administration's revised policy on joint development. In the past, transit agencies that sold off parking lots to private developers had to return most of the proceeds to the U.S. Treasury since federal grant monies originally paid for the parking facilities (Bernick and Freilich 1998). Under the new ruling, transit agencies can retain all income as long as the resulting real estate project is transit-supportive in its design and tied to a specific plan aimed at station-area redevelopment. While well intentioned, this is hardly philanthropy on the federal government's part. Encouraging infill, station-area development is in the direct financial interest of the U.S. Department of Transportation since the addition of new riders will help reduce operating deficits, thus lessening the demand for federal transit operating subsidies.

One of the first places to take advantage of the new federal ruling on joint development is San Jose, California. The City and the Santa Clara Valley Transportation Authority (SCVTA) have joined forces in designing a mid-rise, mixed-use project on the park-and-ride lot at the Ohlone-Chynoweth light rail station (Figure 2). Historically, Santa Clara County's light-rail system has struggled to build a ridership base in large part because much of its service territory consists of a landscape of sprawling office campuses (including the Silicon Valley) and car-oriented shopping plazas. However, as the demand for affordable housing with good access to the Silicon Valley has intensified, local policy-makers have come to the realization that parking-lot infilling was too good an opportunity to pass up. At the time of project development, only 30 percent of the 1,140 original parking spaces at the Ohlone-Chynoweth station

Figure 2. Adaptive reuse of a parking lot. Mixed housing—market and below-market rate units—on the former park-and-ride lot at the Ohlone-Chynoweth Station, San Jose, California

were used. Currently, 500 parking spaces are being converted to 195 units of two- and three-story town homes, a retail plaza, a child-care facility, and a community recreation center.

Whether the Ohlone-Chynoweth project is a bellwether for what is in store for station areas across the United States or just one more example of California as a “statistical outlier,” only time will tell. Regardless, for both environmental and economic reasons, transit agencies and city planners need to seriously focus on strategies that will promote alternatives to park-and-ride access to rail transit. While there will always be a need for park-and-ride provisions, this need not be at the expense of overlooking the needs of pedestrians, bicyclists, and bus riders. As revealed by this research, creating built environments that attend to the needs of pedestrians and commingle activities within reasonable distances of each other can encourage more and more Americans to leave their cars at home and access rail stations by some other means.

Endnotes

1. Midpoint elasticities are measured at the mean values of both the dependent and independent variable, using mean values for all other "control" variables in the equation as well.
2. The following mean values were used in calculating binomial probabilities: travel time = 9; travel distance = 1; land-use diversity (based on comparative population and employment ratios) = 0.34; sidewalk ratio at residential end = 0.835; sidewalk ratio at destination end = 0.958; intersection density = 157; median street width = 35; proportion of housing within a half-mile of a rail station = 0.076; and job access index = 1500. For the computation of walk egress elasticities, the dummy variable for a Washington, D.C. location was set at the modal (most frequently occurring) value of 0.

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