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Transit-based housing in California: evidence on ridership impacts

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Clustering of housing development around rail stations holds promise not only for increasing transit ridership, but also yielding important environmental and social benefits. This paper examines evidence on the degree to which existing housing complexes near rail stations in California have encouraged transit usage. For Bay Area cities served by BART, residents living near rail stations were around five times as likely to commute by rail transit as the average resident-worker in the same city. The strongest predictors of whether station-area residents commuted by rail was whether their destination was near a rail station and whether they could park for free at their destination. Neighbourhood density and proximity of housing to stations were also related to rail travel. The paper concludes that if transit-based housing is to reap significant mobility and environmental benefits, it must be accompanied by transit-based employment growth and programmes that pass on true costs to motorists and parkers.

Keywords: land use, modal split, housing

Over US$8 billion has been invested in urban rail transit in California over the past 20 years and billions more are committed to projects in various stages of planning and construction. While transit trips rose in absolute numbers in California between 1980 and 1990 (one of the few states where this was the case), transit's share of commute trips fell in all metropolitan areas: greater Los Angeles — 5.4 per cent to 4.8 per cent; San Francisco Bay Area — 11.9 per cent to 10 per cent; San Diego — 3.7 per cent to 3.6 per cent; and Sacramento — 3.7 per cent to 2.5 per cent. Such trends have not deterred Los Angeles from pushing ahead in building a planned $163 billion, 400 mile metrorail system over the next 30 years or the Bay Area Rapid Transit district from extending BART 23 miles beyond the hills of Oakland, at a cost of over one billion dollars.

Despite the protestations of many that such rail investments are too costly and amount to political pork barrels (Pickrell, 1992), the reality is that California has already invested in over 200 miles of urban rail systems and is poised to build hundreds of miles more. Yet most urban development of large metropolises has turned its back on rail and focused on freeway-served suburban corridors instead (Cervero, 1989; Pivo, 1990). One way to reverse transit's downward spiral and exploit the state's multi-billion dollar investments in rail might be to concentrate more development around rail stations. Whether clustered development around transit stops means substantially more Californians will patronize mass transit remains unclear.

The paper explores this question by examining the ridership impacts of existing large-scale housing projects near stations of five rail systems in the state — Bay Area Rapid Transit (BART), Santa Clara County Light Rail Transit, Peninsula CalTrain, Sacramento Regional Transit, and San Diego Trolley. Among California's urban rail systems, these have been in operation the longest and thus provide a context for studying the ridership impacts of transit-based housing around more mature station environments. Moreover, they span a range of rail transit technologies — heavy rail (BART), commuter rail (CalTrain), and light rail (Santa Clara, Sacramento, and San Diego). In addition to measuring ridership impacts, this paper identifies key factors that influence modal choices of station-area residents. The effects of the built environment — such as density and land-use mixtures — on rail modal splits are also examined. California is an intriguing context for studying these relationships because, despite its reputation as a land of automobility, it has the most urban rail systems — two heavy rail, five light rail, and three commuter rail services — and the highest population densities in the US (Larson, 1993).

The paper closes with a discussion on the broader

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urban planning and environmental policy implications of the research findings. The importance of clustered development at both the residential and employment ends of commute trips as an inducement to transit riding is stressed. In addition, the potential transit ridership implications of a more multi-nodal settlement pattern, such as in Stockholm, Sweden, are contrasted with transit ridership experiences in California.

Transit-focused development in California

Interest in clustering housing and commercial development around rail transit stations is growing in California. In conjunction with local redevelopment authorities, BART has recently negotiated several joint development deals with private builders to construct mid-rise housing complexes on existing parking lots at the Pleasant Hill and El Cerrito stations. Rising land values and pressures for affordable housing have prompted BART to seriously consider converting parts of its vast inventory of park-and-ride lots to mid-rise housing (Bernick, 1993). Developers have been attracted to these sites since, by building on existing parking lots, they do not bear the risk of negotiating land purchases among multiple property owners, any one of whom can hold out, thereby dooming a project. BART hopes these projects will eventually lead to mini-communities mushrooming around dozens of BART stations, as was envisaged when BART was originally conceived over 40 years ago.

A recent survey found that 10 of the 36 northern California jurisdictions with rail transit stations have undertaken major planning activities to attract housing and commercial development around stations, and several have made transit-based housing the centrepiece of local redevelopment efforts (Bernick, *et al.*, 1993). Sacramento's updated General Plan proposes using an array of development incentives at 13 LRT stations, including higher allowable densities, lower minimum parking requirements, tax-increment financing, and industrial development bonds. The Plan expressly aims to 'promote strong linkages between transit and land use by facilitating the development of higher residential densities and commercial intensities at transit stops and along transit corridors'. One master-planned new town, Laguna West, is being designed so that over 80 per cent of residents will be within a quarter mile walking distance of a transit stop.

In Santa Clara County, several large housing projects, called 'trandominiums' by local boosters, have recently been built that rely on rail proximity as a marketing tool. As part of the County's Housing Initiative Program, plans are underway to build over 13 700 units of moderate-density housing (at 12 to 40 dwelling units per acre) near light rail stations. San Diego has seen a flurry of apartment construction along the new El Cajon trolley extension, including more than 600 upscale apartment units recently built at the Amaya station. Otay Ranch, a master-planned community under construction adjacent to the cities of San Diego and Chula Vista, will feature five village clusters, at blended densities of 18 dwelling units to the acre, that will be served directly by an extension of the trolley line. The largest village cluster will be a major regional mixed-use node, with residential densities reaching 36 dwellings to the acre close to the trolley line.

Potential benefits of transit-based housing

The primary benefit of clustering housing around rail stations is that transit usage is likely to increase as a result. A number of secondary benefits might also accrue, but only if significant numbers of new transit users are former auto drivers. One possible secondary benefit is improved air quality, especially to the extent that park-and-ride trips are converted to walk-and-ride or bike-and-ride, thus reducing cold starts. Currently, over 80 per cent of suburban Bay Area residents who ride BART access stations by private automobile (BART Planning Office, 1993). For a five-mile journey, the typical distance of a BART park-and-ride trip, around 85 per cent of hydrocarbon emissions are due to cold starts and hot evaporative soaks (Cameron, 1991). The potential of transit-oriented development to reduce tailpipe emissions is particularly important in California in that the state's largest cities currently exceed federal and state clean air standards for ozone and carbon monoxide.

Transit-oriented development could also increase the stock of affordable housing. Greater Los Angeles and the Bay Area suffer from a shortage of affordable housing, forcing many younger families and first-time homebuyers to reside on the exurban fringes and Central Valley. Transit-based housing would also provide more live-travel options for retirees, empty-nesters, disabled persons, and other transit-needy groups. Other potential secondary benefits include: reduced traffic congestion along roads paralleling rail lines; increased revenues to transit agencies (not just from the farebox but also from possible joint development programmes like air-rights leasing); opportunities for inner-city redevelopment; and preservation of open space as a result of infill development. All of these secondary benefits will be limited, of course, by the degree to which station-area residents actually patronize transit, the question to which I now turn.

Research methodology

Since no pre-existing data sources were available on the travel characteristics of California's station-area residents, primary data needed to be collected, mainly in the form of responses to travel diary surveys sent to targeted populations. Following

extensive pretesting, surveys were sent to all households at 27 housing complexes located near suburban stations of the five rail systems studied. Five of the 27 complexes were condominiums, two were mixed condo-apartments, and the remaining 20 were exclusively rental apartments. All sites were within walking distance of a station (ranging from 360 to 3100 feet, with the majority lying within a quarter mile), and contained between 76 and 892 units. Thus, the universe of this study consisted of fairly large housing complexes within reasonable walking distance of suburban rail stations in California. See Cervero (1993a) for further details on the research methodology.

All surveys were administered during October–November 1992 and February–March 1993. In all, usable questionnaires were returned from 885 households, providing an 18.4 per cent response rate and records for 2560 trips. The mean household size was 1.89, considerably smaller than the combined 1990 weighted-average of 2.71 for the Bay Area, Sacramento, and San Diego regions. Surveyed residences averaged 1.53 vehicles, also less than the weighted-average of 1.73 vehicles per household for the three metropolitan areas. For most housing complexes, whites made up 80–90 per cent of respondents; only in the case of complexes near BART did non-whites represent more than one-third of the survey respondents. Nearly one-half of the employed respondents worked as managers or professionals and 32 per cent worked in clerical or sales positions. Median household incomes were around $34 000, closely approximating the weighted average for the three metropolitan areas. In general, station-area residents surveyed were from small, predominantly white, and middle-income households with moderately high levels of automobility.

There is some evidence that survey respondents and non-respondents were fairly similar. Based on paired comparisons between the sociodemographic characteristics of respondents (from surveys) and of all residents in the census tracts where respondents resided (from the 1990 census), median incomes, racial composition, age distributions, and vehicle ownership levels were found to be remarkably similar. On average, pairwise differences in median incomes and mean number of vehicles per household (between surveyed housing projects and their corresponding census tracts) were 3.2 per cent and 1.5 per cent, respectively. Percent of white households and median ages were nearly identical between survey respondents and residents of surrounding census tracts. The similar sociodemographic profiles of respondents and other nearby residents bodes favourably for the generalizability of the research findings.

Rail modal splits

The overwhelming majority of station-area residents travelled by automobile to get around (Figure 1). Of

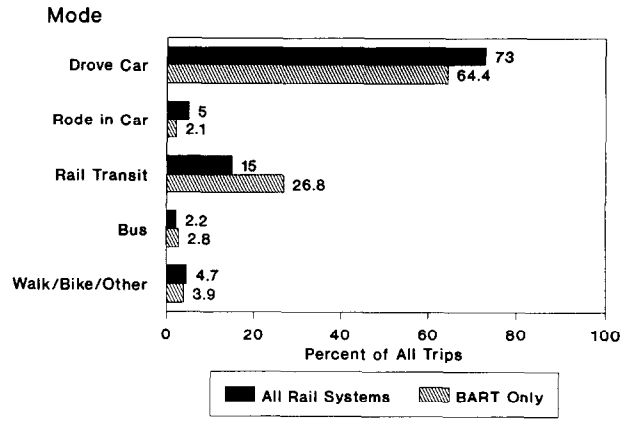

Figure 1 Modal splits for all trips by station-area residents.
Source: Survey of 2560 trips

the over 2500 'main trips' for which survey data were obtained, 15 per cent were by rail transit. Modal splits varied widely by system, however. In the case of BART, over one-quarter of main trips taken by station-area residents were by rail, whereas for Santa Clara County Transit, rail's market share was less than 7 per cent. Among the 27 surveyed projects, rail shares as high as 79 per cent and as low as 2 per cent were found. Overall, those residing near California rail stations are fairly auto-dependent — over 75 per cent relied on a car, either as a driver or a passenger, for their primary trips.

Modal shares also varied sharply by trip purpose (Figure 2). Rail captured 19 per cent of work trips by station-area residents, and in the case of BART, 32 per cent. This is much higher than the three BART-served counties' rail modal split of 5 per cent of work trips in 1990 (Metropolitan Transportation Commission, 1993). It is also considerably higher than the 1990 average of 17.8 per cent for all Bay Area residents living within a half mile of a BART station. On a city-by-city basis, the ridership benefits of

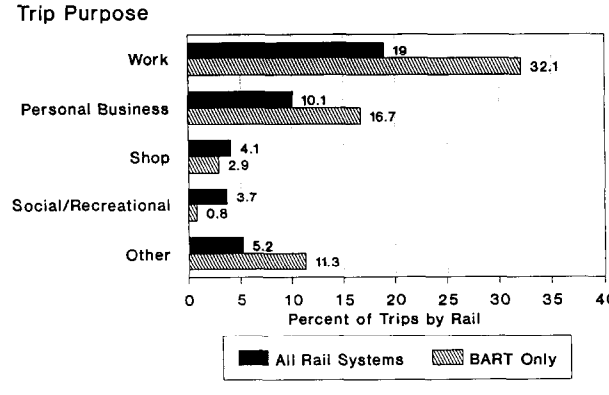

Figure 2 Percent trips by rail for different purposes, station-area residents.
Source: Survey of 2560 trips

Table 1 Comparison of work-trip transit modal splits between Bay Area station-area and citywide residents

City	Work-trip transit modal splits (%) for Station-area residents[c]	Citywide[d]
BART[a]		
Pleasant Hill	46.7	16.0
Fremont	12.9	2.7
Union City	27.5	3.8
Hayward	25.7	4.4
San Leandro	27.7	6.1
Oakland	10.0	6.1
CalTrain[a]:		
San Mateo	26.2	2.8
SCCTA[b]:		
San Jose	7.0	3.6

[a]Statistics presented for urban rail transit trips only
[b]Statistics presented for all transit modes combined, including both rail and bus transit
[c]Based on survey results from 1992–93, aggregated according to city jurisdiction
[d]1990 statistics
Sources: Metropolitan Transportation Commission (1993) and 1990 journey-to-work census statistics, STF-3A. All statistics exclude workers who work at home

transit-based housing are even more evident. Table 1 compares work-trip modal splits for station-area residents to citywide averages from the 1990 journey-to-work census. Workers residing near rail stations in the Bay Area clearly patronize rail transit far more than their counterparts residing farther away from stations but within the same city. On average, residents living near stations were five times as likely to commute by rail transit as the average worker living in the same city, and in some cases as much as seven times as likely.

Station-area residents were also asked to provide information on how they commuted at their prior residence, if that residence was in the same metropolitan area. Changes in mode of travel were examined only for those whose workplace location did not change between their former and present residence. Table 2 shows that many residents changed modes of travel once they moved close to rail — around 29 per cent who usually drove alone to work at their previous residence now commute by rail. The conversion of these trips to rail represents a real economic benefit, measured in terms of reduced vehicle miles travelled and tailpipe emissions. A larger share (42.5 per cent) of current rail commuters, however, previously rode rail and around 14 per cent previously commuted by bus. Thus, a majority of current rail users previously patronized some form of mass transit when they resided farther away from a rail station. Part of the high incidence of rail usage among station-area residents, then, could be due to the fact they have a proclivity to patronize rail transit, whether due to habit, personal taste, or happenstance. Additionally, the decision to rent or buy a home near a rail station might have been influenced by a desire to regularly commute by rail.

Table 2 Comparison of current mode for work trip and usual mode at prior residence

Usual mode for prior residence	Current usual mode to work: Drive car	Ride car	Rail	Bus	Walk	Other
Drove car	82.0%	65.5%	28.8%	23.5%	40.0%	20.0%
Rode car	2.0	10.3	3.9	5.9	0.0	0.0
Rail	9.3	6.9	42.5	23.5	13.3	0.0
Bus	2.6	10.3	13.7	41.2	20.0	30.0
Walk	3.2	6.9	4.6	5.9	20.0	15.4
Other	0.9	0.0	6.5	0.0	6.7	34.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Factors associated with rail commuting

The number of vehicles available to station-area residents strongly influenced travel choices — 42.3 per cent of trips by no-vehicle households were made by rail versus only 3.5 per cent of trips for households with three or more vehicles. Relatively high rail shares were also found for station-area residents who were African-American, were from small households, were middle-aged, and worked in clerical or sales positions. For example, 24.4 per cent of all trips made by station-area residents who were African-Americans were by rail, compared to just 14.5 per cent in the case of whites. Around one out of five trips by surveyed residents who were 31–40 years of age were by rail, compared to just one out of eight trips by those in the 21–30 years age bracket. No strong pattern emerged between rail usage and household income.

Several transportation policies at the workplace also had a strong influence on the commuting choices of station-area residents. Most notable was the effect of parking prices — 42 per cent of station-area residents who paid for parking commuted by rail, compared to only 4.5 per cent who received free parking. Also, around one-third of station-area residents who received employer-paid transit passes commuted by rail, compared to 12.5 per cent of those who received no direct assistance.

Trip destination was also an important determinant of rail usage. If they were headed downtown — where parking is usually expensive, connecting highways are often congested, and rail services are the best — station-area residents were apt to choose transit. For trips to regional subcentres, rail usage dropped off markedly. And for most other destinations, fewer than one of 20 trips were by rail.

Table 3 underscores the importance of destination in the case of BART. Among those living near BART stations and heading to San Francisco, nearly nine out of ten work trips were by BART. For trips to secondary centres like Oakland and Berkeley,

Table 3 Modal splits for work trips by BART station-area residents, by destination city

Mode	Destination							Share of all trips
	San Francisco	Oakland	Berkeley/ Albany	Walnut Creek/ Pleasant Hill	San Leandro/ Hayward	Fremont/ Union City	All other	
Auto	10.6%	53.8%	35.7%	52.3%	70.3%	80.4%	89.7%	62.1%
Rail	88.1	40.4	57.1	38.7	18.6	16.1	6.0	31.7
Other	1.3	5.8	7.2	9.0	11.1	3.5	4.3	6.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Share of work trips	13.8%	8.6%	2.3%	18.3%	19.4%	18.4%	19.2%	100.0

Note: The body of this table shows the percent of all trips to each destination made by each mode. The bottom row shows the percent of all trips by station-area residents destined to jurisdictions. The last column shows the percent of all trips by station-area residents by each mode.

around 40–60 per cent of trips were by BART. For all destinations other than those listed in Table 3, only around 6 per cent of commute trips by station-area residents were by rail.

Predictive model of mode choice

Building upon these findings, a binomial logit model was estimated that predicts the probability of commuting by rail transit among station-area residents in the San Francisco Bay Area. The resulting model, shown in Table 4, confirms the importance of such factors as free parking, vehicle availability, and trip destination in influencing mode choice. The strongest predictor of rail usage was whether station-area residents had free parking at their workplace. The next strongest predictor was destination — specifically, whether residents worked in San Francisco or the large East Bay employment centres in Oakland, Berkeley, Walnut Creek, or Pleasant Hill. Other variables in the model were also consistent with expectations. Each additional vehicle in the household of station-area residents lowered the likelihood of patronizing rail transit by around 10 per cent, all other factors held constant. Two workplace policy variables that emerged as statistically significant predictors were the availability of a transit allowance and access to a company car (such as for midday trip-making), both of which increased the odds of rail commuting.

Using these model results, the sensitivity of rail transit usage to changes in the three strongest predictor variables — parking policy, destination, and vehicle availability — was plotted (Figure 3). In this figure, the values of the other predictor variables are set to zero — e.g., non-East Bay destination, no transit allowance, and no access to a company car. The plot shows that if someone living near a Bay Area rail station owns no car, works in San Francisco, and has to pay for parking, there is an 88 per cent likelihood she will commute via rail transit. If they receive a transit voucher and have midday access to a company car, the odds jump to 98 per cent. At the other extreme, if they have three cars available, can park free, and are destined anywhere other than San Francisco, there is only about a 1 per cent probability they will opt for rail travel.

The fact that probabilities drop the sharpest between paid versus free parking underscores the importance of parking policies in influencing mode choice, even among those living within easy walking distance of a station and heading to a dense workplace, as in downtown San Francisco, that is well-served by transit. The differentials in probabilities between lines in the graph suggests that, all else being equal, paid parking increases the likelihood of rail commuting by around 40–50 percentage points. Probabilities also change markedly between destina-

Table 4 Binomial logit model for predicting likelihood of station-area residents commuting by rail transit, San Francisco Bay Area

	Coefficient	Standard error	Significance
Free parking[a]	−2.467	0.232	0.000
San Francisco Dummy[b]	2.089	0.364	0.000
East Bay Primary Center Dummy[c]	0.610	0.312	0.050
Vehicles available[d]	−0.725	0.186	0.000
Transit allowance[e]	0.815	0.260	0.002
Company car access[f]	0.567	0.331	0.047
Constant	−0.066	0.311	0.831

Summary statistics
Number of cases = 1913
Chi-square = −2 (log likelihood ratio) = 262.78, p = 0.0000
Pseudo-R-Squared = 1 − (likelihood ratio) = 0.618
Percent of all cases correctly predicted by model = 89.9
Percent of rail trip cases correctly predicted by model = 68.4

[a] 1 = Free parking at workplace; 0 = paid parking at workplace
[b] 1 = San Francisco destination; 0 = other destination
[c] 1 = Destination is primary East Bay employment centre — Oakland, Berkeley, Walnut Creek, or Pleasant Hill; 0 = other destination
[d] Number of vehicles available for use by household members
[e] 1 = Employer helps pay transit expenses; 0 = employer provides no assistance
[f] 1 = Employer makes available company car; 0 = no company car available

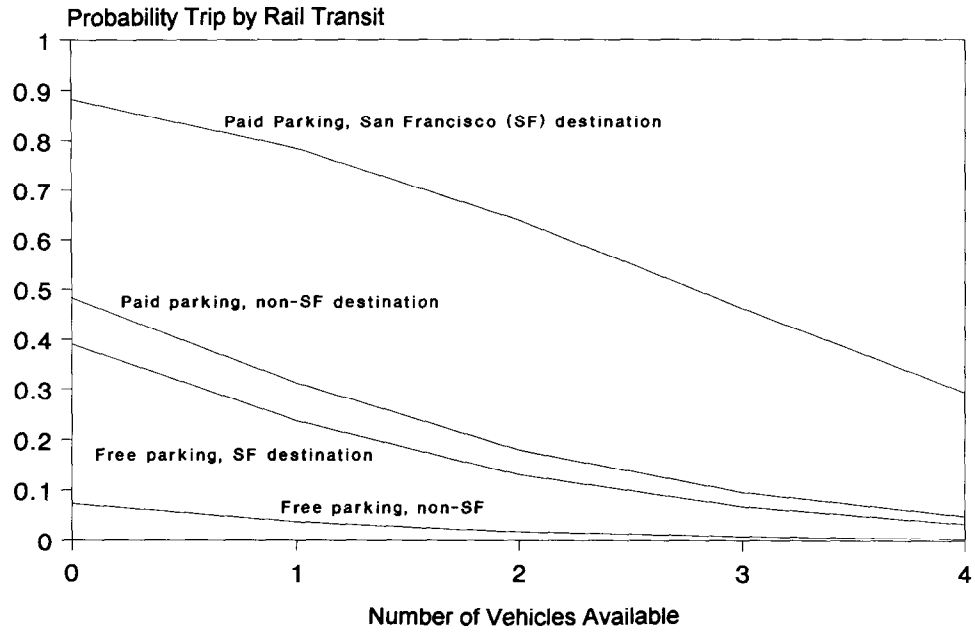

Figure 3 Sensitivity of rail commuting to parking prices, destination city, and vehicle availability.
Note: Other predictor variables equal 0

tions — a San Francisco destination increases the odds of rail commuting by 25–35 percentage points relative to a large East Bay destination and by 45–55 percentage points relative to any other Bay Area destination. Figure 3 also shows that the probability of rail usage falls the fastest (ie, steepest slopes) when going from a no-car to a one-car household.

In summary, if concentrating residential growth around stations is to yield substantial social benefits, it must be accompanied by programmes that pass on true costs to motorists, notably parking charges. Additionally, transit-based housing will not draw many people to transit if workplace destinations are scattered throughout a metropolitan area. In the Bay Area and elsewhere across the US, however, far more office and employment growth during the 1980s occurred in suburban areas with meagre transit services than in downtowns and major regional centres (Cervero, 1989; Pivo, 1990; Downs, 1992). Clearly, for transit-based housing to reap mobility and environmental dividends, there must be transit-based employment centres — both the origin and destination ends of commute trips need to be in reasonably close proximity to rail stations for there to be high levels of rail travel.

Mode of access to and from rail stations

For station-area residents who commuted by rail, Figure 4 shows that almost nine out of ten reached the station near their home by foot. This bodes well for transit-based housing from an air quality standpoint. Still, nearly 10 per cent of station-area residents actually drove their cars to the neighbourhood rail station. Since all of the surveyed housing complexes were near stations with ample park-and-ride facilities, some residents apparently find it more convenient and perhaps safer to drive their cars a quarter to a half mile rather than walk. Other factors, such as physical disabilities and fear of walking in the dark during the evening, might also explain why some choose to park-and-ride.

Once station-area residents reach their exit station, Figure 4 shows that around three-quarters walk to their destination. Bus travel is used as an access mode to a far higher degree at the destination

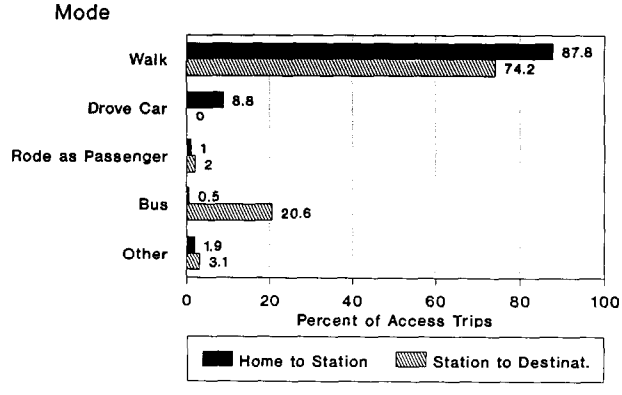

Figure 4 Mode of access by station-area residents, all rail systems.
Source: Survey of 2560 trips

end of the trip. For those working in San Francisco, trolleys, cable cars, and light rail transit are commonly used as feeder connections as well.

Ridership gradients

Several studies have sought to define the walking catchment of rail stations by measuring how rapidly ridership declines with distance to a station. For Washington's Metrorail system, JHK and Associates (1987; 1989) found that the share of trips by rail declined by approximately 0.65 per cent for every 100-foot increase in distance of a residential site from a Metrorail station portal. In the case of the suburban housing project closest to a Metrorail station (300 feet away), 63 per cent of residents commuted by rail; at the farthest complex studied, 3800 feet from the same station, 24 per cent rode Metrorail to work. In a study of housing near Toronto's subway and Edmonton's light rail system, Stringham (1982) found that within a 3000 foot radius of a station, rail modal splits ranged from 30 to 60 per cent of all work and school trips. He estimated the 'impact zone' where residents will walk to stations in significant numbers to extend as far as 4000 feet. At 3200 feet from a station, Stringham found that bus transit eclipsed walking as the predominant mode of access. These distances are significantly farther than the ten-minute, or 2300 foot, walk that Untermann (1984) found to be the maximum distance most Americans are willing to walk. Untermann and others have shown that walking distances can be stretched considerably (perhaps as much as doubled) by creating interesting urban spaces and building nicely landscaped pathways. A recent study of commuting in greater Toronto confirmed the importance of proximity to subway as the primary determinant of mode choice (Pivo, 1993).

Pooling data for the 27 California housing projects produced the following linear relationship between rail modal splits and walking distance:

$$\text{Percent rail} = 32.24 - 0.0085 \text{ (distance, in feet)} \quad R^2 = 0.381 \qquad (1)$$

Clearly, distance had a deterring effect on rail commuting, though the relationship was not particularly strong. On average, rail's modal share fell by about 0.85 per cent for every 100-foot increase in walking distance to California's rail stations.

Figure 5 compares the ridership gradient for the 27 rail-served California housing sites versus those found for Washington Metrorail stations and stations near the Canadian rail systems. In addition to modal splits being consistently lower in California, the relationship between ridership and distance was weaker in California, reflected by the flatter line. Some of this difference might be explained by the fact that most of the California rail systems studied function mainly as commuter systems, and thus have suburban stations with abundant park-and-ride facilities. The availability of ample parking at California suburban rail stations has drawn a large share of rail users beyond walking distances. Higher average residential densities, higher primacy (eg, dominant downtowns), better feeder bus connections, and perhaps even better quality walking

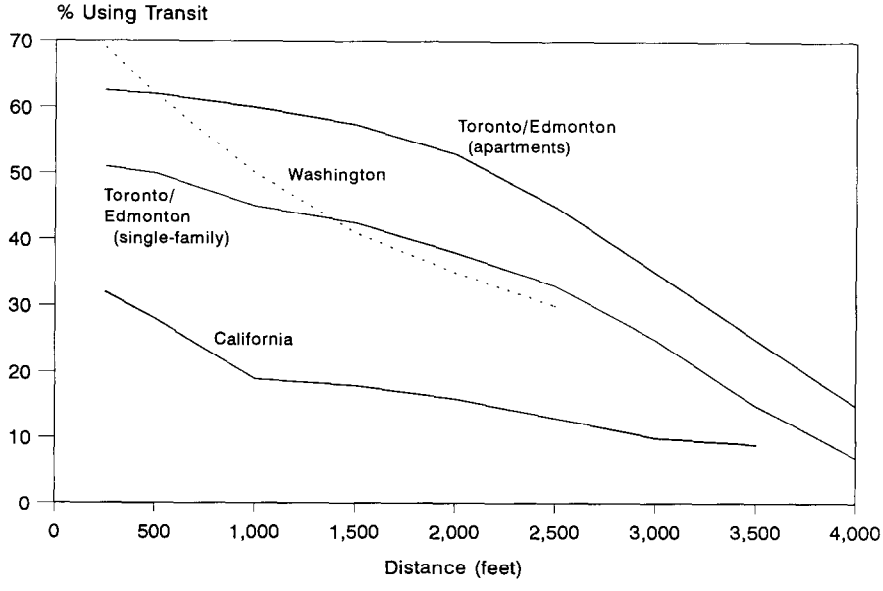

Figure 5 Rail modal share by distance to residential sites, comparison of California and other rail systems.
Note: Washington data includes all transit.
Sources: Stringham (1982); JHK and Associates (1989)

environments might also explain why these other cities capture higher shares of rail commuting among station-area residents than in California. The possible influence of such factors in California is explored next.

Impact of neighbourhood characteristics on rail modal splits

A body of research has shown that density and other features of the built environment strongly influence transit trip-making (Pushkarev and Zupan, 1977; Zehner, 1977; Smith, 1984; Holtzclaw, 1990). Do the same relationships hold for housing development clustered within a half mile of California's rail stations? Pooling data across the 27 surveyed housing sites, two neighbourhood characteristics were found to be the strongest predictors of rail modal split (for all trip purposes combined): proximity to the station and residential density. Table 5 shows that transit modal splits were, in general, highest for residential projects that were nearest a station and in relatively dense settings. The effect of density was convex-shaped, following a quadratic curve. This is because two sites were in relatively dense settings yet had comparatively low modal split.

Of equal interest are variables that were candidates for entering the regression model but did not because of statistical insignificance. None of eight different indicators of 'walking quality' (eg, existence of a continuous sidewalk, number of signalized crosswalks between the housing site and station) or land-use mixture helped explain modal splits.

In summary, besides proximity and density, no other feature of the built environment, including various metrics of environmental quality, influenced travel choices among residents of the surveyed housing sites. This finding could mean either that other factors, unrelated to land use, were significant explainers or that the measures used to gauge attributes of the built environment were deficient. Based on the earlier findings, I believe the results reflect more of the former than the latter. That is, factors like the availability of free parking at destinations are likely far stronger predictors of modal splits than the number of signalized intersections passed en route to a station or the existence of varied land uses in the neighbourhood. It could be that within a quarter to a half mile radius of a station, features of the built environment (ignoring issues of safety and urban blight) matter little — as long as places are near a station, the physical characteristics of the immediate neighbourhood are inconsequential.

Table 5 Significant predictors of percent of trips by rail transit among surveyed residential sites, all trips

	Coefficient	Standard error	Significance
Station distance (feet)	−0.007	0.0035	0.0593
DU per acre	−0.124	0.0064	0.0670
(DU per acre)^2	1.303	0.6580	0.0620
Constant	4.863	15.1770	0.7604
Summary statistics			
Number of cases = 27			
R-Squared = 0.303			
F = 2.899			
Prob = 0.0604			

Policy considerations

The principal conclusion of this research is that if transit-based housing is to reap significant mobility and environmental benefits, then it must be accompanied by land-use measures which attract employment growth to rail stations as well as transportation demand management programmes, like mandatory parking charges. Housing clustered around stations does little good if, as has been the case in California's metropolises over the past decade, most job growth occurs outside of CBDs or far removed from rail stations. In short, for rail transit to compete with the automobile in California, the metropolitan structures of the Bay Area, greater Los Angeles, and other areas will need to more closely resemble those of places like greater Stockholm and Toronto — both of which have high shares of rail commuting and significant concentrations of housing and offices within walking distance of stations (Thomson, 1977; Hall, 1988; Pivo, 1993). Market-rate parking charges are also prevalent in these and other large metropolises with high levels of rail usage.

Whether more clustered development and a multicentre urban form is socially desirable is a bigger question that cannot be answered by this research. And if it is, whether market-based measures like road pricing or more centralized planning initiatives would be the best means of achieving a transit-supportive built environment is largely a political question. What can be said from this research is that for transit-based housing to yield significant benefits, there must also be large concentrations of employment near rail stations and programmes which pass on true costs to motorists and parkers.

Of course, a number of institutional barriers stand in the way of transit-oriented development. Many suburbanites dislike densification and fight it every step of the way, whether through ballot-box zoning or voting NIMBY-sensitive politicians into local office. Residents around BART's Rockridge, Orinda, and North Berkeley stations have over the years pressured their respective city councils to downzone their neighbourhoods. Many local governments also shunned apartment development because they believe apartments demand high levels of public service which are not covered by the property taxes they generate. Also, housing builders

seem more interested in single-family home-ownership markets these days. A fundamental rule in California's development community is that 'as density goes up, the general interest from the consumer goes down' (Bookout, 1992, p. 15). Tight credit, questionable market viability, and the potentially high development costs of clustered housing are also significant barriers to transit-based housing.

Even if such resistance could be overcome, some analysts are fairly sceptical about the prospects of transit-focused development ever doing much good. Downs (1992) argues that the permanence of the existing built environment will prevent dramatic gains in density, and that only huge increases in average suburban residential densities would substantially reduce average commute distances and solo-commuting. Even under the most generous assumptions, according to Downs, clustered high-density housing near suburban rail stations would unlikely reduce VMT by more than 2 per cent.

Simple mathematics suggest that Downs could very well be right. Table 6 shows that only 8.9 per cent of residents from the three BART-served counties lived within a half mile of a BART station in 1990 — ranging from 4.5 per cent in Contra Costa County to 12.3 per cent in San Francisco. Based on 1990 journey-to-work statistics, only 17.8 per cent of these station-area residents commuted by rail transit. This suggests that only 1.6 per cent of 1990 commute trips within the three BART-served counties were by station-area rail users. Doubling the number of station-area rail users would have a pretty small impact on current commuting and environmental conditions in the Bay Area. While Downs believes concentrated employment around rail stations has a higher potential to win over motorists to transit, his overall conclusion about land-use initiatives is that the efforts they require are 'wholly disproportionate to the severity of the problem, the pain it is causing, and the benefits of ending it' (p. 94).

While the benefits of singularly achieving transit-based housing or clustered office development are likely to be modest, the effects of such initiatives in combination can be far more substantial, especially when introduced in combination with parking restraints and other TDM measures. Experiences in Stockholm are instructive in this regard. Stockholm is an appropriate comparison, I would argue, in that Sweden is one of the world's most affluent countries and has a high automobile ownership rate (2.1 persons/vehicle) (Westin, 1993). Moreover, greater Stockholm is surrounded by vast open spaces and experienced rapid growth following World War II, meaning that it could easily have followed a highway-oriented development pattern. Instead, Stockholm's city council built a number of satellite new towns over the past three decades, most surrounded by greenbelts and connected to Stockholm city by rail. An overriding principle was to distribute industry and offices to satellites roughly in proportion to residential population in order to avoid a 'dormitory town environment' (Hall, 1988; City of Stockholm, 1989; Cervero, 1993b).

The impacts of this built form on travel choices has been unmistakable. In 1990, 38 per cent of the residents and 53 per cent of the workers of Stockholm's rail-served new towns commuted by rail transit. For all of Stockholm County, rail accounted for 42 per cent of commute trips (Cervero, 1993b). Urban development patterns, alone, did not produce these results, however. Parking and motoring are expensive in all Swedish cities, and nearly all apartments are publicly subsidized. Cities like Stockholm are testaments to how integrated rail and land-use planning in combination with market-rate pricing of automobile travel and other TDM efforts can reduce auto-dependency.

Recently, market-based principles have been embraced by California's policy makers. The South Coast Air Quality Management District has opted for pricing, tradable permits, and various market incentives over 'command-and-control' planning in its efforts to reduce air pollution in the region. One variation of efficient pricing would be to grant credits of various forms — such as against impact fee obligations — to projects that are conducive to transit riding, ridesharing, and walking. If transit-focused development indeed yields public benefits, as in the case of Stockholm, then this 'positive impact' should be financially rewarded — a reverse exaction, so to speak. Better pricing along with better regional planning would go a long way toward producing built forms that begin to attract substantial numbers of Americans to transit and other alternatives to the drive-alone automobile.

Table 6 Estimated share of 1990 commute trips by station-area residents of the three BART-served counties

	% County population within ½ mile of BART station (1990)	% Work trips by BART among workers living within ½ mile of BART station (1990)	Estimated % total commutes by station-area rail commuters (1990)
Alameda County	9.8	17.3	1.7
Contra Costa County	4.5	11.3	0.5
San Francisco	12.3	25.5	3.1
Three County Total	8.9	17.8	1.6

Source: US Census, STF 3-A

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References

BART Planning Office (1993) '1992 Passenger Profile Survey: Summary Report', Oakland, California: San Francisco Bay Area Rapid Transit District, Office of Strategic Research

Bernick, M (1993) 'The Bay Area's emerging transit-based housing', *Urban Land*, 52(7), pp. 38–41

Bernick, M, Hall, P and Schaevitz, R (1993) 'Planning strategies for high-density housing near rail transit stations in northern California', *California Policy Seminar Brief*, 5(2), pp. 1–5

Bookout, L (1992) 'The future of higher-density housing', *Urban Land*, 51(9), pp. 14–18

Cameron, M (1991) *Transportation efficiency: tackling Southern California's air pollution and congestion*, Los Angeles: Environmental Defense Fund and the Regional Institute of Southern California

Cervero, R (1989) *America's suburban centers: the land use–transportation link*, Boston: Unwin-Hyman

Cervero, R (1993a) *Ridership impacts of transit-focused development in California*, Berkeley: Institute of Urban and Regional Development, Monograph 45

Cervero, R (1993b) *Transit-supportive development in the United States: experiences and prospects*, Washington, DC: Federal Transit Administration, US Department of Transportation

City of Stockholm (1989) *The development of Stockholm*, Stockholm: City of Stockholm

Downs, A (1992) *Stuck in traffic: coping with peak-hour traffic congestion*, Washington, DC: Brookings Institution

Hall, P (1988) *Cities of tomorrow: an intellectual history of urban planning and design in the twentieth century*, Oxford: Basil Blackwell

Holtzclaw, J (1990) 'Manhattanization versus sprawl: how density impacts auto use comparing five Bay Area communities', *Proceedings of the Eleventh International Pedestrian Conference*, Boulder, Colorado: City of Boulder, pp. 99–106

JHK and Associates (1987) *Development-related ridership survey I*, Washington, DC: Washington Metropolitan Area Transit Authority

JHK and Associates (1989) *Development-related ridership survey II*, Washington, DC: Washington Metropolitan Area Transit Authority

Larson, J (1993) 'Density is destiny', *American Demographics*, 15(2), pp. 38–42

Metropolitan Transportation Commission (1993) *Journey-to-work in the San Francisco Bay Area*, Oakland: Metropolitan Transportation Commission, Working Paper 5

Pickrell, D (1992) 'A desire named streetcar: fantasy and fact in rail transit planning', *Journal of the American Planning Association*, 58(2), pp. 158–176

Pivo, G (1990) 'The net of mixed beads: suburban office development in six metropolitan regions', *Journal of the American Planning Association*, 56(4), pp. 457–469

Pivo, G (1993) 'A taxonomy of suburban office clusters: the case of Toronto', *Urban Studies*, 30(1), pp. 31–49

Pushkarev, B and Zupan J (1977) *Public transportation and land use policy*, Bloomington: Indiana University Press

Smith, W (1984) 'Mass transit for high-rise, high-density living', *Journal of Transportation Engineering*, 110(6), pp. 521–535

Stringham, M (1982) 'Travel behavior associated with land uses adjacent to Rapid Transit stations', *ITE Journal*, 52(4), pp. 18–22

Thomson, M (1977) *Great cities and their traffic*, London: Penguin

Untermann, R (1984) *Accommodating the pedestrian: adapting towns and neighborhoods for walking and bicycling*, New York: Van Nostrand Reinhold

Westin, K (1993) 'Sweden: moving towards a safer environment' in Salomon *et al.* (eds) *Billions of trips a day*, Dordrecht: Kluwer, pp. 367–385

Zehner, R (1977) *Access, travel, and transportation in new communities*, Cambridge: Ballinger Publishing Company