LAND MARKET IMPACTS OF URBAN RAIL TRANSIT AND JOINT DEVELOPMENT: AN EMPIRICAL STUDY OF RAIL TRANSIT IN WASHINGTON, D.C. AND ATLANTA

Robert CERVERO
Associate Professor
University of California
Berkeley - USA

INTRODUCTION

Joint development is based on the premise that transit investments significantly improve regional accessibility which leads to higher land values around stations. Higher values, in turn, should give rise to higher commercial rents, densification, and a fairly rapid absorption of building space. Through programmes like air rights leasing, benefit assessment financing, and fees for connecting adjacent commercial buildings to stations, transit agencies should be able to share in these benefits.

In the U.S., past studies have been conducted on the land use impacts of San Francisco's BART (Gannon and Dear, 1975; Webber, 1976), San Diego's trolley (San Diego Association of Governments, 1984), Washington's Metrorail (Lerman et al., 1978) and a combination of systems (Knight and Trygg, 1978; Cervero, 1984). In general, the conclusions of these studies have been similar: urban rail transit will produce significant land use and site rent benefits only if a region's economy is growing and a number of complementary programmes are in place, such as permissive zoning to allow higher densities and the provision of supporting infrastructure like pedestrian plazas and street improvements.

This paper aims to extend our knowledge on the impacts of urban transit investments as well as joint development programmes on site rents and other land use characteristics using data from two new-generation heavy rail transit systems in the U.S.: Washington's Metrorail and Atlanta's MARTA, both of which commenced rail services in the mid-to-late 1970s. Since both systems have been in operation for well over a decade, they provide a reasonable time lapse for measuring land use impacts. This analysis concentrates on office and commercial land uses around suburban stations, in part because almost all joint development programmes to date have involved these uses and also because commercial tracts around suburban stations often increase the most in relative worth. Since both metropolitan areas experienced healthy regional growth during the 1980s, this analysis admittedly presents a "best case" context for examining what is possible when conditions are ripe for transit-induced land use changes. To the extent that rail transit is shown to have a positive impact on commercial rents, absorption rates, and other measures of real estate performance, joint development, when used under favorable economic conditions, one might argue, gains creditability as a tool for recapturing some of the value benefits created by transit investments.

1. RAIL TRANSIT JOINT DEVELOPMENT IN THE UNITED STATES

Joint development can be defined as "any formal, legally binding arrangement between a public entity and a private individual or organization that involves either private-sector payments to the public entity or private-sector sharing of capital or operating costs in mutual recognition of the enhanced real estate development potential or higher land values created by the siting of a public transit facility". Based on this rather strict definition, around 115 transit joint development projects had been constructed in more than two dozen U.S. cities up to 1990; 85% of these were completed between 1980 and 1989 (Cervero, et al., 1991). A combination of factors have been behind joint development's recent popularity: construction and completion of ten new U.S. urban rail systems during the 1980s; the suburban office boom and the resurgence of downtown real estate markets in several large cities with rail systems; deep cuts in federal transit assistance, pressuring local authorities to seek more creative ways of financing transit; and the emergence of public-private partnerships for redeveloping cities and building infrastructure.

Of the 115 joint development projects completed by 1990, around two-fifths involved cost sharing -- e.g, public-private sharing of excavation costs, joint staging sites, labor and heavy equipment, heating/ventilating/air-conditioning systems, and parking lots. Rail operators in New York City (MTA) and Philadelphia (SEPTA) have, by far, entered into the most cost-sharing agreements to date -- New York uses zoning incentives like density bonuses to encourage developers to renovate subway stations and relocate passageways while Philadelphia leases commercial space within suburban rail stations at favorable rates in return for developers upgrading and maintaining public ares like concourses and passageways. Approximately one out of four joint development projects in the U.S. have involved revenue-sharing -- like air-rights and property leasing, connection fees (for physically linking a retail store to a station), and benefit assessment financing. Washington's Metrorail is the national leader in striking revenue-sharing deals, having entered into nine separate station leases and eleven station connection agreements to date. Atlanta ranks second behind Washington, D.C. -- to date, MARTA has received revenues from three air-rights leases (IBM Tower, Southern Bell Tower, and Georgia State Office Building) and three station connection projects (Atlantic Plaza, Resurgens Plaza, and Rich's Department Store). The remaining joint-development projects in the U.S. have been of multiple forms -- the most common involving joint station space leasing and cost-sharing of station rehabilitation.

To date, the financial benefits of joint development schemes to U.S. transit agencies has been modest. Over $62 million in capital contributions were received by New York's MTA between 1979 and 1989 (in 1989 dollars), though when these funds are amortized over the typical 30-year bond period for transit projects at an interest rate of 12.5%, they amount to only around 4% of New York MTA's capital expenditures over this period. Examined this way, capital contributions from joint development projects accounted for only 0.7% and 0.2% of rail capital expenditures

in Washington, D.C. and Atlanta, respectively, over the same period. Leasing and fee revenues have generally been smaller as a proportion of each rail system's annual operating budget. Over the 1979-89 period, Washington's WMATA received over $20 million in joint development revenues, though these payments have never amounted to more than 0.7% of annual income in any one year. One possible explanation for these meager results is that, perhaps with the exception of WMATA, most U.S. transit agenices have limited experience in appraising the market value potential of joint development sites and in structuring favorable real estate deals. They also likely reflect the reluctance of most transit boards to engage in real estate transactions and other entrepreneurial pursuits as well as the presence of legal restrictions which preclude transit authorities from land banking and recapturing land value gains induced by public investments.

2. STUDY CASES

In studying the land use impacts of rail transit and joint development, data were pooled across five station areas which experienced significant commercial development over the 1978-1989 period. Based on data availability and reliability, three stations areas were chosen and examined on the Washington Metrorail system -- Ballston, Bethesda, and Silver Spring, and two stations on the Atlanta MARTA system -- Arts Center and Lenox Square. All station areas had at least one form of joint development project that commenced some time between the 1978 to 1989 study period.

2.1. Ballston

When Metrorail services began to Ballston in 1979, Ballston was a small commercial district in Arlington, Virginia, surrounded by single-family homes and garden apartments. Since then, Ballston has blossomed into one of the city's "new downtowns", surrounded by high-rise commercial towers and a massive shopping mall. Ballston's major joint development project is the Metro Centre, located above the Metrorail station on what was earlier a major bus transfer lot. In addition to office space, this 28 story tower contains 200 hotel rooms, 284 condominium units, retail shops, and a health club. Washington's transit authority, WMATA, receives approximately $200,000 in annual revenues in the form of base rent plus a percentage of rent for a portion of WMATA-owned land leased to the developer.

2.2. Bethesda and Silver Spring

Both Bethesda and Silver Springs lie just north of Washington, D.C. on Metrorail's Red line, and together form two of the largest commercial centers in Montgomery County, Maryland. Bethesda has been a long-time suburban center in its own right, but has densified considerably since 1980. Bethesda Metro Center,

located above the Bethesda Metrorail station, is a massive mixed-use (office, hotel, retail) joint development project that yields $1.6 million in annual leasing revenues, the highest sum for any single project in the U.S. Silver Spring, a much smaller suburban center, has not experienced quite the boom seen at Bethesda. To date local residents have resisted efforts to development the area. Presently, the only form of joint development in Silver Spring is some small concession fees paid by retail vendors and nearby shops.

2.3. Arts Center and Lenox Square

Located midway between central Atlanta and the booming Buckhead retail area along MARTA's north line, the Arts Center area was, until recently, a major cultural center, not a major office center. In 1985, the 50 story IBM Tower was built adjacent to the MARTA station, sparking the construction of several other smaller office complexes. To date, the IBM Tower has generated over $1.5 million in lease revenues to MARTA. Lenox Square lies several miles vorth of the Arts Center station, in an area that was historically known for its super-regional shopping mall. Since MARTA's 1984 opening, the Lenox Square area has received over 3 million square feet of office space, today making up nearly 10% of greater Atlanta's total office inventory. Owners of Resurgens Plaza, a luxurious office building adjacent to MARTA's Lenox station, pay MARTA over $100,000 in lease revenues annually.

3. STUDY APPROACH

Multiple regression analysis was used for isolating the effects of rail transit from other factors that also influence property values and local real estate market conditions, such as the opening of a new freeway nearby or overall regional growth. Stepwise procedures were used to obtain the best-fitting, most parsimonious models. In all, 60 data points were obtained by pooling data for five station areas across 12 years of time (1978-89). For most models, first-order auto-regressive estimation was used to correct for serial correlation of error terms.

In compiling data, land use impacts were measured for specific areas with defined boundaries around each of the five station areas. All impact areas were within one-quarter mile radius of transit sations. For each time point, station area averages were taken for all land use and transportation variables. Variables broke down into four different sets: (1) Station-area real estate market performance variables: office rents, vacancy rates, absorption rates, and total square footage of commercial floorspace; these are the policy, or dependent, variables. (2) Transit service variables: ridership, frequency of train services, average fares, and other characteristics of rail services; these are the chief explanatory variables of interest. (3) Regional economic and growth factors: metropolitan employment totals as well as regional averages for commercial rents, absorption rates, new office construction, and vacancy rates; these are control variables. (4) Station-area transportation,

infrastructure, and development characteristics: lane miles of nearby freeway facilities, average daily traffic volumes on nearby roads, maximum allowable floor area ratios, zoning requirements, and the existence of joint development initiatives; these are also control variables. Land use data were obtained from local real estate leasing guides while transportation and other data were obtained from local transportation and planning agencies.

The following sections present the research results. Separate regression models are presented for explaining: station-area office rents, vacancy rates, average office building size (a proxy for density), and the share of total and new regional office space located in the case study station areas.

4. OFFICE RENTS

Average annual office rents at the five case study station areas drifted steadily upwards during the 1980s, as shown in Figure 1. In the cases of Bethesda and Lennox, office rents appeared to increase most sharply in anticipation of, rather than after, rail services -- i.e., during the year prior to station opening.

Table 1 presents the model that best predicted average office rents for the five Washington Metrorail and MARTA stations between 1978 and 1989. Controlling for other factors, office rents near stations tended to increase as systemwide transit ridership increased -- rising by nearly $4 per square foot for every 100,000 additional daily passengers. The fact that "systemwide ridership" instead of "station ridership" entered the equation is important. This suggests that transit's influence on office rents was not so much related to ridership activity at specific stations as it was to overall system demand. The next most significant variable in Table 1 is a dummy variable signifying whether or not a station is a terminus, which represented Silver Spring and Ballston (until 1986). Offices near terminal stations rented for around $3.35 less per square foot than offices near non-terminal stations, ceteris paribus. These lower average rents likely reflect not only the fact that terminal stations tend to lie farthest from the city center but also because terminal stations function as

Table 1: Trends in Office Rents

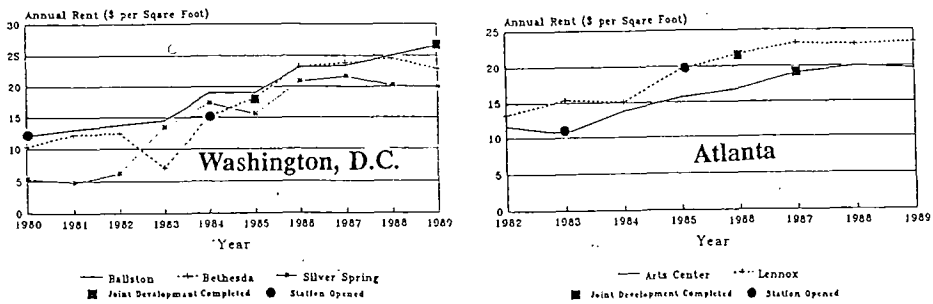

Table 1: Office Rent Model

Dependent Variable: Average Annual Office Rent per Square Foot, in current dollars

	Coefficient	t-statistic	Significance
SYSTEM RIDERSHIP	0.0396	3.72	.001
TERMINAL STATION	-3.3543	-2.53	.016
JOINT DEVELOPMENT	3.1718	2.46	.019
UNEMPLOYMENT RATE	-1.3755	-2.16	.038
Constant	15.2250	3.31	.002

Summary Statistics:

R^2 = .823
F = 31.61
Prob(F) = .000
Durban Watson Statistic = 2.223

Variable Definitions:

SYSTEM RIDERSHIP = Daily systemwide rail ridership, paid passengers, in 1,000s.

TERMINAL STATION = Dummy variable designating a terminal station at the end of a line. Equals 1 if a terminal station and 0 otherwise.

JOINT DEVELOPMENT = Dummy variable designating the existence of a joint development program, involving some form of either revenue-sharing or cost-sharing. Equals 1 if a joint development program exists and 0 otherwise.

UNEMPLOYMENT RATE = Regional unemployment rate, expressed as a percentage.

major bus transfer points, and the presence of bus activity near stations may have a somewhat depressing effect on rents.

Table 1 also reveals that the presence of joint development projects at stations has a positive influence on rents. All else being equal, it appears that office rents are about $3 per square foot higher at station areas with joint development projects. Of course, the relationship between joint development and rents is both indirect and simultaneous. Joint development projects induce greater building activity, promote higher densities and agglomeration economies, and improve station environments (as through the direct linkage of a station concourse with an adjoining building and the coordination of building designs); in tandem, these factors likely produce a rent premium.

The inclusion of a variable measuring regional unemployment rate adds an important macro-economic dimension to the model. Over time, every 1% increase in the regional unemployment rate, ceteris paribus, is associated with a $1.37 drop in office rents per square foot. Clearly, under recessionary and high unemployment conditions, as during the early 1980s, the demand for office space slackens and rents decline.

Several other analyses were conducted in probing the influences of rail transit and joint development on office rents. Another regression model, not shown here, expressed station area office rents relative to regional averages, finding that joint development projects provided about a 15% office rent premium above the regional

average, controlling for factors like ridership and quality of nearby infrastructure. Having good freeway access was also a signficant and positive predictor of relative rents, suggesting that good rail transit and freeway services can complement rather than work against one another in shaping suburban office growth.

Office rents were also compared between the five case-study station areas and nearby competitive office markets that were served only by freeways and not rail (e.g., matched-pairs testing). From 1978 to 1989, for instance, Ballston averaged an annual office rent premium of over $3 per square foot (in nominal terms) over Tysons Corner, a massive "suburban downtown" that lies six miles to the southwest. Bethesda, Arts Center, and Lenox Square likewise enjoyed more than a $2 per square foot office rent premium over their nearest freeway-oriented suburban competitors.

5. OFFICE VACANCY AND ABSORPTION RATES

Besides higher rents, rail-linked development should increase the demand for occupying available office space, leading to lower vacancy rates. Table 2, which presents the best-fitting model for predicting office vacancy rates, confirms what every office leasing agent knows: vacancy rates tend to be higher for larger buildings with high rents. The table also reveals that controlling for rents and building size, vacancy rates tend to be lower in station areas or at time points with joint develoment projects

Table 2: Vacancy Rate Model

Dependent Variable: Average Annual Office Vacancy Rate in Station Area minus Average Annual Office Vacancy Rate for the Region, expressed as a percentage

	Coefficient	t statistic	Significance
AVERAGE OFFICE SIZE	0.0187	8.18	.000
JOINT DEVELOPMENT	-5.5726	-2.36	.024
OFFICE GROWTH SHARE	-300.0708	-5.69	.000
Constant	5.5374	2.68	.011

Summary Statistics:

R^2 = .720
F = 30.81
Prob(F) = .000
Durban Watson Statistic = 1.734

Variable Definitions:

AVERAGE OFFICE SIZE	= Average square feet of office space per plot, in 1,000s.
JOINT DEVELOPMENT	= Dummy variable designating the existence of a joint development program, involving some form of either revenue-sharing or cost-sharing. Equals 1 if a joint development program exists and 0 otherwise.
OFFICE GROWTH SHARE	= New square feet of office space in the station area divided by new square feet of office space in the region, expressed as a proportion. This measures the relative share of new office space in the station area.

-- on average, 11 percentage points less than vacancy rates at comparable stations without joint development projects, controlling for other factors. When compared to the regional averages of the two metropolitan areas over the 1978-89 period, office vacancy rates for comparable properties were found to be 5.5 percentage points below the regional average. A separate analysis (not shown) revealed that stations with joint development projects also tended to lease up new office inventories faster. Every 10% of new regional office space that was located in the five station areas was statistically associated with an absoprtion rate that was 6.5 percentage points above metropolitan averages.

Matched-pairs comparisons further confirmed the attractiveness of joint development sites, especially in Atlanta. During 1980 to 1989, the inventory of leased office space at the Arts Center station increased at a rate of 10% per year. By contrast, office growth along the Northwest Interstate-75 Freeway corridor submarket, a collection of campus-sytle business parks some two miles to the west, was fairly sluggish over this same period, increasing by only about 1% per year.

In general, these findings reflect two market dynamics. First, joint development projects have tended to be built at precisely those station areas with low vacancy rates -- that is, in office submarkets that are expanding and profitable. The second and more important dynamic is that joint development projects, by virtue of their proximity to transit stations, are easier to lease. Put another way, large speculative office buildings near transit have higher-than-average vacancy rates while large office buildings developed as coordinated joint development projects tend to have lower-than-average vacancy rates.

6. OFFICE DENSITY

As land around rail transit stations increases in value, building densities can likewise be expected to rise. Indeed, one of the strongest arguments in favor of building rail transit systems is that they may encourage a more compact urban form (Pushkarev and Zupan, 1977; Smith, 1984). Data on such common density measures as the number of employees per 1,000 square feet of building space or average floor area ratios (FARs) were not available for the five stations during the twelve year period studied; however average building size was easily estimated from available time series data on each station's total number and square footage of office buildings. While this figure does directly indicate land use intensity (since it is not indexed to land area), it does provide some indication of relative density.

Table 3 shows that average office building size tended to increase with systemwide ridership in the prior year and joint development activity. The model suggests that that the effect of ridership on building density is not instantaneous but rather lagged. It may take a while before the accessibility advantages of transit service are capitalized into increased land values which, in turn, encourages higher densities. Even when developers anticipate this, it still takes several years to design a structure, secure financing, get necessary government approvals, and construct the

Table 3: Average Building Size Model

Dependent Variable: Average Square Feet of Office Buildings on Individual Pluts in Station Area

	Coefficient	t statistic	Significance
SYSTEMWIDE RIDERSHIP (-1)	5.0352	5.52	.000
JOINT DEVELOPMENT	345,381.49	3.31	.002
Constant	-586,012.29	3.31	.004

Summary Statistics:

R^2 = .603
F = 25.82
Prob(F) = .000
Durban Watson Statistic = 2.083

Variable Definitions:

SYSTEMWIDE RIDERSHIP (-1) = Daily systemwide rail ridership, paid passengers, in 1,000s, lagged by one year.

JOINT DEVELOPMENT = Dummy variable designating the existence of a joint development program, involving some form of either revenue-sharing or cost-sharing. Equals 1 if a joint development program exists and 0 otherwise.

building. The model further indicates that the presence of a joint development project was associated with buildings that were around 350,000 square feet bigger than the typical office building. This is a huge difference and no doubt reflects that the fact there are several high-rise towers in the case study areas, including Atlantic Center at the Arts Center station, Resurgens Plaza at Lenox Station, and Metro Centre above the Ballston station.

In sum, these results support previous research findings that transit investments -- and the ridership and coordinated joint development that they induce -- encourage high-density development. While both developers and transit agencies usually benefit directly from more intensive growth, society at-large also benefits to the extent that more compact growth increases transit modal splits and, as a result, conserves energy, reduces pollution, and improves regional mobility. Recent evidence from Washington, D.C. suggests that rail has had a significant impact on mode split. Over 25% of those working in office buildings within one-half mile of the Silver Spring Metrorail station arrive to work each day by transit, far above the regional work trip average of 12% (JHK & Associates, 1989). Moreover, over 60% of those residing near a suburban rail station and working within a 5 minute walk of the Silver Spring station take the train to work.

7. REGIONAL OFFICE SPACE AND GROWTH SHARE

A final model explored whether the existence of a joint development project increased a station area's relative attractiveness as an office center. Table 4 suggests only slightly, adding about two percentage points to the share of regional office space

Table 4: Regional Office Space Share Model

Dependent Variable: Average Square Feet of Office and Commercial Buildings in Station Area divided by Total Regional Office and Commercial Square Footage

	Coefficient	t statistic	Significance
JOINT DEVELOPMENT	0.0195	3.11	.003
TERMINAL STATION	-0.0133	-2.21	.034
Constant	0.0338	6.86	.000

Summary Statistics:

R^2 = .539
F = 19.91
Prob(F) = .000
Durban Watson Statistic = 1.935

Variable Definitions:

JOINT DEVELOPMENT	= Dummy variable designating the existence of a joint development program, involving some form of either revenue-sharing or cost-sharing. Equals 1 if a joint development program exists and 0 otherwise.
TERMINAL STATION	= Dummy variable designating a terminal station at the end of a line. Equals 1 if a terminal station and 0 otherwise.

at a particular station area. Being at the end of a transit line, on the other hand, lowers the share of regional growth by 1.3 percentage points. In terms of new regional office inventories, it was also found that a joint development project added about a 5 percentage point increase in any station's share of annual metropolitan-wide office space growth. Thus, joint development activities were not only correlated with high rents, low vacancy rates, and tall nearby buildings; they also characterized station areas that were undergoing a building boom. Certainly, the causality between these variables works both ways. While joint development induces new construction activity, growth itself usually encourages greater interest in coordinated development from both the public and private sectors.

8. SUMMARY AND CONCLUSIONS

For the most part, the basic proposition that transit investments in general, and joint development projects in particular, create measurable land value and associated benefits appears to be borne out by empirical evidence, at least in the case of the five Washington, D.C. and Atlanta station areas studied during the 1980s. All of these positive impacts would appear to build a compelling case for further expanding joint development, particularly where commercial real estate conditions are comparable to those found in the Washington, D.C. and Atlanta regions during the 1980s.

Table 5 summarizes the findings of this research by presenting the elasticities between various office market performance measures and the key explanatory variables that emerged from the stepwise analyses. All figures shown are midpoint

Table 5: Land Market-Transportation Elasticities

	Dependent Variables				
	Average Rents	Vacancy Rate	Absorption Rate	Average Building Size	Share of Regional Growth
Independent Variables:					
Transit Factors					
Ridership	0.496	–	–	0.210	–
Joint Development	0.063	-0.164	–	0.146	0.125
Terminal Station	-0.105	–	-0.382	–	-0.189
Other Factors					
Unemployment Rate	-0.389	–	–	–	–
Freeway Traffic or Miles	0.370	–	1.42	–	–

Dash lines indicates that the explanatory variables were not significant predictors of the dependent variables.

line elasticities. Among the dependent variables studied, the "average office rent" variable was more closely correlated with more transit factors than any of the dependent variables. The strongest relationship was between office rents and ridership. Of particular note, office rents were more strongly influenced by transit ridership than by nearby freeway traffic volumes. The existence of joint development appears to add a significant rent premium. At terminal stations, however, the presence of transit has a fairly weak influence on lease rates.

In station areas with joint development activities, vacancy rates tended to be low. Joint development was also positively linked with project size and a healthy local real estate market. Stations with joint development activity tended to capture a larger share of regional office and commercial growth than when stations had no such programmes. Additionally, joint development generally takes place in high density settings.

The outlook for joint development in the U.S. during the 1990s is mixed. Mitigating against more initiatives is the fact that while many new fixed-guideway transit systems are being discussed, few have obtained actual funding commitments. Thus joint development will like be limited to existing station areas or new rail extensions. A second limiting factor is that most commercial real estate markets in the U.S. are vastly over-built. Office and retail vacancy rates are high and will likely remain so, and credit is tight. Residential development remains the one real estate bright spot, and, depending on the city, there will be opportunities and pressures for high-density residential development within walking distance of transit stations. Joint residential development around transit stations is largely untested but has promise. In the San Francisco Bay Area, the regional rail transit authority, BART, has recently issued Requests for Proposals (RFPs) to lease existing parking lots to build 3-4 story

apartment buildings at four different rail stations. From rail cities like Toronto, Stockholm, and Singapore, it is clear that clustered residential growth is essential if transit is to capture significant shares of inter-suburban work trips and to achieve bi-directional ridership flows. Since transit systems like Washington's WMATA and Atlanta's Metrorail have moved "up the learning curve" from their years of office joint development, they should capitalize upon past experiences by negotiating the lease of land, such as from park-and-ride lots, to residential home builders for constructing garden apartments, condominiums, and mixed use projects.

BIBLIOGRAPHY

Cervero, R. Light Rail Transit and Urban Development. Journal of the American Planning Association 50, 2. 1984, pp. 133-47.

Cervero, R., Hall, P. and Landis, J. Transit Joint Development in the United States: A Review of Recent Experiences and an Assessment of Future Potential. Washington, D.C.: Urban Mass Transportation Administration, U.S. Department of Transportation. 1991.

Gannon, C. and Dear, M. Rapid Transit and Office Development. Traffic Quarterly 29, 2. 1975, pp. 223-42.

JHK and Associates. Development-related Ridership Survey. Washington, D.C.: Washington Metropolitan Area Transit Authority. 1989.

Knight, R. and Trygg, J. Urban Mass Transit and Land Use Impacts. Transportation 5, 1. 1978, pp. 12-24.

Lerman, S., Damm, D., Lam, E., and Young, J. The Effects of the Washington Metro on urban Property Values. Washington, D.C.: Urban Mass Transportation Administration. 1978.

Pushkarev, B. and Zupan, J. Public Transportation and Land Use Policy. Bloomington: Indiana Press University. 1977.

San Diego Association of Governments. San Diego Trolley: The First Three Years. San Diego: San Diego Association of Governments. 1984.

Smith, W. Mass Transit for High-Rise, High-Density Living. Journal of Transportation Engineering 100, 6. 1984, pp. 521-35.

Webber, M. The BART Experience -- What Have We Learned? The Public Interest 12, 3. 1976, pp. 79-108.