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Most people believe that publicly funded transportation infrastructure can produce huge financial benefits for the few private property owners lucky enough to own choice sites near the new facilities. According to classical location theory, accessibility is the primary determinant of urban land value (see, e.g., Alonso, 1964). Casual observation seems to confirm this conclusion: high-rise development around suburban subway stations and large shopping malls at highway interchanges suggest that public investments in transportation facilities do indeed play a key role in shaping site rents.

The fairness of these property value windfalls has been debated for decades (see, e.g., *Windfalls for Wipeouts*, 1978); however, in recent years there has been heightened interest in ways to exploit the phenomenon to advance public goals. As federal funds for transportation improvements have disappeared, localities have turned to value-capture techniques— which tax away the property value increment attributable to public infrastructure— to raise funds for facility construction and/or operations (Zamora, 1988). In addition, they have tried to use infrastructure investment to encourage and focus development that supports public land use plans.[1]

This paper assembles literature on the effects of public transit and highway facilities on nearby property values. It has two basic goals: (1) to summarize the current state of empirical research, and (2) to identify what, if any, insights those studies have for policymakers.[2] Part I briefly explains the capitalization theory of value as applied to real property. Part II summarizes the results of selected empirical studies on the property value capitalization effects of transit and highways. In Part III, the literature review is expanded to include other types of durable, fixed-location infrastructure. Finally, Part IV discusses selected policy applications for property value capitalization studies.

I. AN INTRODUCTION TO PROPERTY VALUE CAPITALIZATION STUDIES

The Capitalization of Amenities in Property Values

Under the capitalization theory of value, the market price of an asset is equal to the net present value of the flow of the benefits and costs of owning it. Real property can be viewed as a bundle of services, obligations, and rights. A housing unit, for example, is a composite good defined in terms of the unit's structural characteristics; the location of the unit with respect to work, entertainment, education, and shopping opportunities; the public services provided by the jurisdiction in which the unit is located; the use rights associated with the property; and the tax burden of living within the jurisdiction.

In theory, the benefits and costs in any given time period from each of these characteristics can be quantified in dollars. All else being equal, consumers and firms will try to outbid one another for properties that provide more benefits. Therefore, in equilibrium, the dollar value of the amenity benefit stream, properly discounted, should equal the price premium associated with the property:

$$PREM = S_1/(1+i_1) + S_2/((1+i_1)(1+i_2)) + S_3/((1+i_1)(1+i_2)(1+i_3)) + \ldots + S_n/((1+i_1)(1+i_2)(1+i_3)\ldots(1+i_n))$$

(where benefits are experienced during n time periods; S_t equals the amenity-related benefits/savings in time period t; and i_t equals the discount rate associated with time period t).

Public programs can change the value of real property if they produce new private benefits or impose new private costs on landowners. Construction of a highway interchange, for example, can increase nearby land values by lowering the transportation costs associated with particular uses. If the availability of public utility connections decreases construction or operating costs or makes profitable, higher-density development possible, those effects will be reflected in higher property values. Park dedications can increase the value of abutting parcels by providing views and decreasing the cost of recreation. A landfill or electric power plant can generate increased traffic congestion or air pollution, driving down the price of nearby parcels.

Property value capitalization studies try to measure the magnitude and extent of such price effects. They provide an empirical test for basic theories of urban form; studies that show real property premiums associated with transportation improvements, for example, support economic theories that identify transportation cost as a major determinant of urban land value. Capitalization effects can be used to measure the efficiency of urban land markets and to identify the specific amenities or amenity combinations that have the largest effect on land values and urban form.

Potential Problems in Property Value Capitalization Studies

Although the theory of property value capitalization is simple, the measurement of capitalization effects can be complicated. Two major techniques have been used to study the property value effects of fixed-location, public infrastructure: (1) hedonic price modeling based on cross-sectional data, and (2) analyses of longitudinal data on property value changes over time.

Hedonic price models are relatively easy to interpret. Multiple regression analysis provides a precise estimate of the market price effect of changes in the level of any specific amenity. The statistical tests for evaluating regression results are widely accepted, and techniques have been developed to analyze data that do not satisfy the assumptions of ordinary least squares analysis.

Nevertheless, the apparent precision of hedonic price models belies a variety of measurement problems. If a property market is not in equilibrium, the implicit prices revealed by an hedonic model may be inaccurate (Allen, Stevens, and More, 1985: 470). Real estate markets are constantly in flux. Consumer preferences and production functions change. Since real property is a complex composite good, the markets for at least some of its components are likely to be in disequilibrium at any given moment. As Witte and Long note, this is only a problem if "the deviations from equilibrium are non random" (Witte and Long, 1980: 151). Property value capitalization studies that focus on the effects of public infrastructure, however, often involve rapidly growing areas — exactly the context in which non-random deviations would be anticipated (id.).

Some studies try to avoid the problem by frankly focusing on the short-term effects of facility announcement, recognizing that the long-term value effects may be different from the initial speculative price response (Damm et al., 1980; Ferguson et al., 1988; Falcke, 1978; Gatzlaff and Smith, 1993). Most analysts, however, seem to assume that the markets they study are in equilibrium (but see Cribbins et al. [1962], who suggest [at 43] that their study areas might not have reached equilibrium after highway construction). Where the effects of new infrastructure are being measured, they may delay their analysis to give the property market time to settle down (see, e.g., Palmquist, 1982: 24). Although little is known about whether or how fast real property markets move toward equilibrium,[3] this strategy should at least reduce the chance that model results will reflect only transient market conditions.

Hedonic price models also may lack the sensitivity needed to measure capitalization effects accurately. Theory suggests that the property value effect of certain public facilities decreases with distance from the facility. If so, the magnitude of the effect on distant parcels will be small, and even if a large number of properties is affected, it could be masked by the random "noise" of other neighborhood characteristics. Under these circumstances, an hedonic price model could substantially underestimate the extent of capitalization effects (Allen, Stevens, and More, 1985: 470-72).

In addition, the implicit prices revealed by hedonic models may be inaccurate if the various components of the composite real property good are not independent. If there is a high degree of multicollinearity, or if the markets for various amenities are horizontally linked, it may be difficult to isolate the implicit price for any particular characteristic. The estimates generated by regression analysis would be highly unstable.

Finally, causality is especially difficult to establish with cross-sectional data. A regression analysis, for example, might reveal a strong correlation between residential property values and the level of certain public services. Since public service and investment decisions are produced by local political processes, however, the direction of causality is unclear: are high property values generated by high public service levels; or are high public service levels the product of decisionmaking processes dominated by high-income households with expensive homes? This distinction is critical, because only in the former case can it be argued that higher public service levels create value.

Longitudinal studies examine changes in property value over time. The period analyzed often brackets the announcement and construction of the relevant facility. In the studies reviewed, the samples were divided into proximity zones or into experimental and control categories. In some cases, an hedonic price model, comparisons of matched property pairs, or repeat-sales indices were used to account for the effects of key property attributes other than proximity to the infrastructure being studied.

Sophisticated time-series analyses generally have heavy data requirements. Langley's 1981 study of the property value effects of the Washington Capital Beltway, for example, used 17 years of residential sales data. Collection of this information can be time-consuming and expensive, and results are available only many years after the infrastructure investment is made.

As Dowall notes, times-series analyses also cannot incorporate "exogenous factors, such as demand shifts, that are not specified in the equation" (Dowall, 1980: 170). Supply and demand functions may change during the long study periods needed for rigorous time-series analysis. Moreover, the study area may undergo major, unanticipated physical changes. The traffic on the Capital Beltway, for example, increased dramatically during Langley's study period (Langley, 1981: 17); during the last several years included in his analysis, the number of lanes was doubled and noise barriers were constructed (id.).

Finally, the estimate of the land market effects of a particular facility will depend on the boundaries selected for the study area. If the impact of a particular project extends beyond the study area, for example, a time-series analysis may seriously underestimate the extent of the land value effect (Dowall, 1980: 170).

II. EMPIRICAL STUDIES ESTIMATING THE PROPERTY VALUE EFFECTS OF TRANSPORTATION INVESTMENT

Studies of the property value effects of transportation infrastructure should be relatively straightforward. Anecdotal evidence suggests that value changes will be large and easy to detect— virtually everyone has heard of or seen farmland converted to shopping centers near major highway interchanges. Moreover, substantial capitalization effects are predicted by theory: highways and fixed-rail systems directly affect the transportation costs associated with nearby sites, and classical location theory identifies such costs as the primary determinant of urban land value.

Most important, in contrast to many other public services, the positive property value effects of transportation infrastructure typically have not been offset by an associated increase in local taxes to fund the improvements. Because facility alignment is determined by regional system requirements— not just the willingness of a particular neighborhood to fund construction— the benefits of transportation infrastructure often have a very different spatial distribution from the costs. In the United States, this decoupling is compounded by large federal subsidies for the construction and operation of transportation facilities.

Given this context, it should come as no surprise that virtually all of the reviewed studies concluded that major transportation facilities affect the value of nearby land. Estimates of the magnitude and extent of the effect, however, varied widely from study to study. Moreover, while the methodology of each study can be evaluated on its own merits, the results of any one study cannot be used to test the accuracy of the others: there are plausible theoretical explanations for substantial variation in the implicit prices reported.

First, each of the studies analyzes a different transportation facility. The cost and performance characteristics of the transportation system, as well as the range and number of other locations served, will affect how much nearby sites benefit. Second, the relevant demand functions may be different. Each study examines a different period, and consumer preferences may change over time. Aggregate consumer preferences may also be different in different parts of the country; on an even smaller scale, given residential segregation patterns, substantial intra-metropolitan variation also seems likely.

Third, differences in implicit price can be explained by variations in supply. If highly accessible sites within the relevant market are already plentiful, then new transportation facilities may have little or no effect on nearby land values. A whole range of factors may produce different land supply functions in different locations. Real cities are not built on flat, featureless plains. Topography and other natural features can have a dramatic effect on the supply function for accessible sites. Existing development may constrain new construction. Infrastructure differences can affect land supply.[4]

Changes in urban form can also affect the accessibility advantage of specific sites within the metropolitan area. If, for example, potential destinations are dispersed, the accessibility advantage of residential building sites near transit stations could fall. Finally, land use regulations and other institutional arrangements may constrain the supply of accessible parcels. The overall land value effect of such regulations is particularly difficult to predict. Development limits near transit stations or major highway interchanges, for example, could depress site premiums by restricting the intensity of new development, while simultaneously increasing the premium for those units actually built by maintaining scarcity.

The Property Value Effects of Transit Stations

The capitalization studies reviewed in Table 1 produced wildly different estimates of the value of station proximity. Two studies published in 1993 illustrate the range. At one extreme, Gatzlaff and Smith used both repeat-sales indices and hedonic regression methods to evaluate property values before and after the announcement of the Miami Metrorail system. They concluded (at 64) that residential values were, at most, only weakly affected by the announcement of the new rail system. Gatzlaff and Smith noted (at 54, 56-57) several distinctive features of the Metrorail system that may explain their failure to find a substantial property value effect, including: (1) the system is new; (2) Miami is a Sunbelt city with no large downtown employment center and decentralized growth patterns oriented around the automobile; (3) system alignment indicates an effort to revitalize certain areas, rather than to locate the rail line in the path of growth; and (4) Metrorail ridership has been dramatically lower than predicted.

At the other extreme, Al-Mosaind, Dueker, and Strathman used data on single-family home sales to study the effects of "neighborhood-type" light-rail transit stations located in established low- and medium-density residential areas in Portland, Gresham, and Multnomah County, Oregon. They developed an hedonic price model for single-family home sales within 500 meters (straight-line distance) of the LRT line and no more than 1.6 km walking distance from a station. According to Al-Mosaind et al., houses

Table 1. Property Value Effects of Proximity to Public Transit (see Appendix A for notes on studies)

Author (Date)	City/Transit System	Property Type	Accessibility Measure	Magnitude of Effect	Extent of Effect
Davis (1970)	San Francisco, BART	Residential	Within 6 blocks of station	BART had a positive effect on property values close to Glen Park Station	0 to 6 blocks from station
Dewees (1976)	Toronto, Bloor St. Subway Line	Low-density residential (up to 4 units)	Time cost to Bloor St. in equivalent travel-time units (transit time=1; waiting=1.5; and walking =3).	$2370 per hour (~$2370 per mile of walking distance)	0 to 1/3 mile from station
Falcke (1978)	San Francisco Bay Area, BART	Residential sales	Straight-line distance from station	Small, positive effect on property values near some stations	
		Residential rents		No distance-sensitive effect found, but BART may have had a positive effect on entire Walnut Creek station area (14,000 ft radius from station)	
	San Francisco CBD	Office rents		Small positive effect	0 to 100 ft from sta.
	Oakland CBD	Office rents		Small positive effect	0 to 1000 ft from sta.
	Walnut Creek CBD	Office rents		Positive effect	0 to 1000 ft from sta.
		Commerical		Large positive effect	0 to 1000 ft from sta.
Damm, et al. (1980)	Washington, D.C., Metro	SF homes	Straight-line distance from station	Price elasticity with respect to distance from station equals -0.06 to -0.13	
		MF residential	Straight-line distance from station	Price elasticity with respect to distance from station equals -0.19	
		Retail	Straight-line distance from station	Price elasticity with respect to distance from station equals -0.69	
Bajic (1983)	Toronto, Spadina Subway Line	SF homes	Weighted commute time using public transit, from house to 5 selected destinations (travel time=1; walking and waiting time=1.78)	Subway increased value of average nearby house by $2,237, based on effect of subway on commute times	

Table 1 (continued)

Author (Date)	City/Transit System	Property Type	Accessibility Measure	Magnitude of Effect	Extent of Effect
Pickett & Perrett (1984)	Tyne & Wear County, England; Metro	Residential	Proximity to station category	During 4 month period straddling Metro station opening, dwelling units close to stations appreciated by £360 more than more distant units. This increase maintained for up to a year after the station opened	0 to 200 m from a Metro station
Allen, et al. (1986)	Philadelphia-Lindenwold High Speed Line	SF homes	Commute-cost savings to Philadelphia CBD	$443/dollar of commute cost savings (average of $4581 per dwelling unit; 7.8% of mean sales price (at V-2))	"transit Census tracts" in which <=4% of work trips are by Line
Ferguson, et al. (1988)	Vancouver, ALRT	SF homes	Straight-line distance from station location	-C$4.90/ft (1983 only)	At least 0 to 1800 ft from station, but no farther than 2400 ft
Alterkawi (1991)	Washington, D.C. Metro; Atlanta MARTA	Land	Straight-line distance from stations	Assessed value of land parcels showed negative price gradient with respect to distance from station.	
Voith (1991)	Philadelphia, PATCO	SF homes	Census tracts served by PATCO	Premium for transit-served census tracts equal to 10% of median home value	Census tracts served
	Philadelphia, SEPTA	SF homes	Census tracts served by SEPTA	Premium for transit-served census tracts equal to 3.8% of median home value	Census tracts served
Nelson (1992)	Atlanta MARTA East Line	SF homes	Straight-line distance from station; and straight-line distance squared.	Detects a strong, positive effect on value in low-income neighborhoods, while proximity to station is a nuisance that decreases value in high-income areas	
Al-Mosaind, et al. (1993)	Portland, OR, MAX Light Rail Transit System	SF homes	2 categories: (1) within 500 m walking distance from station; (2) within 500 m of LRT line, up to 1.6 km walking distance from station, and not in category (1)	Proximity to LRT station associated with premium of $4324/house (10.6% of mean house value)	0 to 500 m walking distance from station
Gatzlaff & Smith (1993)	Miami Metrorail	SF homes	In same 1 mi. square section as station	Repeat sales indices did not reveal any significant effect.	
		SF homes	Distance from Station	Regression analysis did not reveal significant value changes after system announcement.	

within 500 meters' walking distance of an LRT station sold for $4,324 more than other houses in the sample —a price differential of over 10 percent of the average sale price in the study area.[5] This large premium, however, should be understood in light of the land use policies associated with Portland's LRT system. Al-Mosaind et al., noted that "[h]igher densities, both residential and commercial, have been zoned within a half kilometer of LRT stations" (at 4). Moreover, transit supportive land use planning was done to promote ridership (id.). In this context, higher land values for single-family homes near transit stations may reflect previously existing price gradients, anticipated neighborhood development, and/or speculative premiums associated with possible land use conversion— not just the value of increased accessibility for the occupants of the single-family homes.[6]

Most of the remaining studies identified price effects somewhere between these two extremes. Almost all relied on actual sales data (*except* Pickett and Perrett, 1984; Alterkawi, 1991; and Voith, 1991) and hedonic price modeling techniques.[7] However, no single functional form for modeling the effect of distance on value has dominated the literature. Many of the studies used simple linear forms (see, e.g., Al-Mosaind et al., 1993; Alterkawi, 1991; Ferguson et al., 1988); others modeled multiplicative, exponential, or inverse relationships.[8] Moreover, each study used the independent variables that best predicted property value for its particular data set. Certain variables are common— floor area and/or lot size, for example, appear in virtually every model of single-family home value. The use of neighborhood characteristics, however, varied widely. Little information on land use controls was usually included.[9]

Most of the studies used straight-line or network distance from the nearest transit station (in measured units, or by distance category) as the critical independent variable for modeling the property value effects of transit infrastructure.[10] Studies of the Toronto Subway and the Philadelphia-Lindenwold High Speed Line, however, obtained good results using alternative independent variables. In 1976, for example, Dewees concluded that travel-time-based performance variables were superior to distance for predicting the rent gradient for the Bloor Street Subway in Toronto (Dewees, 1976: 368). His study showed that replacing a streetcar line with the subway "increased the site rent surface slope perpendicular to the facility, and this effect disappeared beyond the [weighted time] equivalent of a 1/3-mile walk from a station" [id.]. Stations, in effect, produced localized peaks in the city's rent gradient.

Bajic's 1983 study of the Toronto Subway's Spadina Line also used a weighted travel-time variable to model the property value effect of a new subway. Based on his regression model for housing price, Bajic concluded that decreased commuting times associated with the new subway increased the value of an average house in the Spadina area by $2,237 in 1978 (Bajic, 1983: 155). Bajic cross-checked his analysis by comparing (1) this real property premium to (2) the capitalized value of the time saved by the subway, based on reasonable discount rates and time horizons and the value-of-time estimates he developed in a earlier modal choice model. According to Bajic (at 156):[11]

> Comparing the present values of the savings from the subway (identified by the modal choice model) with the impact on an average private family house in the Spadina cor-

ridor (as identified by the hedonic price regressions model), we concluded that the direct savings from the improvement in transportation have been capitalized into the housing values, i.e. the savings in commuting costs which accrue to the commuters have been transferred to the home owners through the complex workings of the urban housing market.

Several studies of the property value effects of the Philadelphia-Lindenwold High Speed Line measured accessibility with a commute-cost term instead of distance. Three studies published in the 1970s used a derived travel cost savings variable (Boyce et al., 1972; Allen and Mudge, 1972; Mudge, 1974). Because the value of commute time was not systematically addressed, however, the savings variables in those studies cannot be interpreted as the actual daily commute-cost savings associated with using transit. Instead, they represented the *relative* savings between different locations.

In their 1986 study, Allen, Chang, Marchetti, and Pokalsky attempted to estimate the *actual* commute cost savings associated with the Lindenwold Line. For each of the census tracts in the Lindenwold corridor, they calculated the cost of driving to Philadelphia versus riding the Lindenwold Line by using: (1) road network and transit times to downtown Philadelphia; (2) cost of driving, toll, parking, and fare information; and (3) cost-of-time estimates based on 1980 census income/family/hour data and multipliers developed by other authors (Allen et al., 1986: iii-iv). The resulting commute-cost savings variable was used in a multiple regression analysis.

Based on this methodology, Allen et al. concluded that house price increased by $443 for each dollar of daily transit savings (id.: V-2). They noted that this level of capitalization implies a discount rate of 56.4 percent — a very high number — and they suggested a variety of possible explanations, including uncertainty that savings will persist and polycentric urban forms (id.: V-2 to V-3).[12] According to Allen et al., "[t]he average savings was $10.34 implying that $4,581 is available to be captured per single family dwelling unit" (id.: VI-1). This is equal to over 7 percent of the mean house sale price in the study area.

Despite their differences, a common theme runs through the transit capitalization studies: virtually all found that proximity to stations had a positive property value effect. Only one study (Nelson, 1992) found that transit stations had a net *negative* effect on land values, and the results of that analysis might have been affected by the particular pattern of racial segregation within the study area.[13]

Beyond this basic agreement, it is difficult to extract any other general conclusions from the studies as a group. As discussed above, each models a different land market. Moreover, even where price effects are clearly demonstrated, most studies do not systematically isolate: (a) the accessibility benefits actually realized by current residents; (b) disamenities from station proximity; and (c) the speculative premium associated with possible land use change. Only a few of the studies explicitly try to isolate the disamenity effects of station proximity. (Damm et al. [1980] include a separate dummy variable for sites very close to stations (at 323); Ferguson et al. [1988] and Falcke [1978] include separate variables for distance to tracks and distance to station sites; Nelson [1992] uses both simple distance and distance squared in his formulation; and

Pickett and Perrett [1984] deliberately exclude negatively affected parcels from their study sample.) None of the reviewed studies tried to isolate the speculative premium associated with possible land use change.[14]

The author is also unaware of any empirical study that systematically explains variations in the observed rent gradient around transit stations in different cities. A few recent studies have taken initial steps toward filling that gap. Gatzlaff and Smith's 1993 analysis of Miami Metrorail neighborhoods and Nelson's 1992 study of neighborhoods around MARTA stations, for example, both suggest that the magnitude and direction of property value effects may depend on neighborhood incomes. The two studies, however, reach opposite conclusions.[15]

Voith's (1991) analysis of the effect of rail transit on Philadelphia-area home values suggests that level of service affects capitalization. His study area, however, includes only two systems: the Southeastern Pennsylvania Transportation Authority's (SEPTA) rapid transit service, and the Port Authority of Pennsylvania and New Jersey's (PATCO) commuter rail service to Philadelphia's New Jersey suburbs. Moreover, while he found that the number of peak-hour trains had a significant, positive relationship with census-reported median house values in Pennsylvania census tracts (at 134), he did not find either (1) a significant relationship for all areas studied, or (2) a significant effect on the value of residences located in the New Jersey census tracts studied (id.).

The Property Value Effects of Highways

Table 2 summarizes the results of selected studies on the property value effects of highways. Many of the studies substantially pre-date the analogous literature on transit investment. Since hedonic price modeling did not become common until the late 1960s (Witte and Long, 1980: 134), the early highway impact studies rely heavily on descriptive statistics and analyses of longitudinal data.

Virtually all of the early studies identified large land value effects near highway interchanges (but see Cribbins et al., 1962). Buffington's and Meuth's 1964 report on Temple, Texas, for example, used 19 years of data. They developed a "price increase index" — a hybrid of the percentage and dollar value increase in land value —and concluded (at 11) that

> the probable highway bypass influence in the Temple area was 2562% or $2331. This represents a tremendous increase in land value in the study area as opposed to the control area. These figures are based on changes occurring between the before and whole after periods.

More recent studies generally report less dramatic effects. Although the increased accessibility associated with highway proximity adds value, the nuisance generated by highways may partially or completely offset that effect. Langley (1981), for example, used 17 years of home sale data from North Springfield, Virginia, to evaluate the effects of the Washington Capital Beltway (I-495). He analyzed 1,322 sale-resale pairs between 1962-78 and employed regression analysis to estimate yearly index numbers. According to Langley, those index numbers revealed that "properties nearer the highway exhibit a very

Table 2. Property Value Effects of Highways (see Appendix B for notes on studies)

Author (Date)	City/Region	Property Type	Accessibility Measure	Magnitude of Effect	Extent of Effect
Adkins (1957)	Dallas, TX	Land	Distance bands around RoW	Highway proximity tends to be associated with higher assessed values and sale prices	4 blocks beyond expressway frontage roads
Cribbins, et al. (1962)	Cumberland, Guilford, & Rowan Counties, NC	Land	Straight-line distance from interchange; straight-line distance to RoW	No discernable pattern which would have allowed documented value increases to be attributed to highway construction	
Buffington (1964a)	Austin, TX	Unimproved land	Highway corridor versus control area	Highway responsible for premium equal to 163% of original land value, based on hybrid price increase index. Very strong positive effect on abutting land.	Band around highway RoW, ~0.5 mi. on either side of RoW
		Subdivided land	Highway corridor versus control area	Highway responsible for discount equal to 13% of original value, based on hybrid price increase index. Effect on abutting land v. non-abutting land unclear.	Band around highway RoW, ~0.5 mi. on either side of RoW
Buffington & Meuth (1964b)	Temple, TX	Land	Highway corridor versus control area	Highway responsible for premium equal to 2562% of original land value, based on hybrid price increase index. Abutting land values increased more than non-abuttting land values.	Band around highway RoW
Brown & Michael (1973)	Indianapolis, IN	Land	Distance rings (based on straight-line distance from interchange)	Interchanges had a positive effect on value that decreased with distance	1 mile from interchange
Allen (1981)	Northern VA (Washington, DC area)	SF homes	Noise level exceeded 10% of the time	House value decreased by $94/decibel	
	Tidewater, VA	SF homes	various noise measures	No significant effect	
Langley (1981)	North Springfield, VA (Washington, DC area)	SF homes	Distance bands (based on straight-line distance to roadway)	Proximity to roadway associated with lower values: -$3000 to -$3500 per house	0 to 343 m from roadway
Palmquist (1982)	Washington State	SF homes	Study area versus control area	12%-15% higher appreciation in study area versus control area	Study area (up to 1 mi from roadway)
			Noise contours	Up to 7.2% lower appreciation than other study area houses	0 to 600 ft from roadway

Table 2 (continued)

Author (Date)	City/Region	Property Type	Accessibility Measure	Magnitude of Effect	Extent of Effect
Tomasik (1987)	Phoenix, AZ	SF homes	Study area versus local averages	No discernable negative property value effects. Homes within 0.5 mi. of highway appreciated more than distant houses. But within 0.5 mi. corridor, no correlation between unadjusted value and distance	0 to 0.5 mi. from highway

definite tendency to increase in value at a rate less than those more distant from the highway" (at 19). He concluded that properties in proximity to I-495 sold for approximately $3,000-$3,500 less than comparable but more distant properties.[16] Both Palmquist (1982) and Tomasik (1987) reported net positive property value effects from selected highways, but they acknowledged that highway noise may partially offset the accessibility premium.

This change may reflect, in part, the tendency for recent studies to focus on single-family residential property.[17] The benefits of highway access for single-family homes may be more limited than for other types of land uses. Moreover, contemporary homeowners may be more sensitive to the negative externalities of highways — noise and congestion — than other potential land users.

Economic theory, however, also suggests that the property value effects of highway infrastructure *should* decrease if the network continues to expand beyond a certain size. During the first wave of major limited-access highway construction, the accessibility advantages those roads provide are large and focused on a relatively small number of parcels. As the road mileage of the network grows, two opposing effects should occur simultaneously: (1) by increasing the number of places linked by high-speed roadways, the total accessibility of each site already connected grows (like telephone service, the benefits of being connected increase as more and more customers subscribe), placing upward pressure on land prices; and (2) the supply of sites with a highway-access advantage increases, tending to depress price. As the highway network grows beyond a certain tipping point, the second effect will begin to overshadow the first. Since the premium any given location can command depends on its *relative* advantage compared to other locations, we would expect the size of the positive property value effects of highways to decrease once highway access is ubiquitous.

III. THE PROPERTY VALUE EFFECTS OF OTHER DURABLE, FIXED-LOCATION INFRASTRUCTURE

This section briefly examines studies on the property value effects of two other types of durable, fixed-location infrastructure: parks and public water/sewer connections. Before turning to the specific results of the empirical studies, it is worth considering whether and how these other types of infrastructure are different from the transportation facilities discussed in Part II. The logic of hedonic price modeling tends to elide differences between types of amenities. All locational characteristics are reduced to a single unit of measure: price. Transportation facilities, parks, and utility connections, however, perform different functions. Transportation facilities tie sites into the region as a whole; parks are generally neighborhood resources with very localized property value effects;[18] and utility connections affect only activities that occur directly on the sites served. These differences in scale may produce dramatic differences in the extent of capitalization effects.

The three types of infrastructure also have different spatial benefit patterns. Transportation facilities function as regional gateways, so there should be an inverse relationship between (1) site premiums and

(2) network distance or travel time to the facility. Negative externalities — congestion, noise, and vibration —may offset accessibility benefits for properties close to stations. Like transportation facilities, parks provide a benefit that decreases with distance, but they also generate potential view externalities that benefit only abutting properties (Weicher and Zerbst, 1973). The benefits of utility connections follow a third and completely different spatial logic. Any given parcel receives all of the benefits of utility connection or none of them. Benefit levels, however, are not identical for every site. The cost savings from sewer and water connections depend on topography and soil conditions (would development be possible without utility connections, and what would the cost be?), development pressures on the site (would utility connections facilitate more intensive development for which there is actual demand?), and the cost of obtaining the connections.

Finally, the cost distributions of the three types of infrastructure are different. As discussed above, most major transportation infrastructure is funded by a very broad population base, while property value effects are relatively localized. Although there is a similar mismatch in neighborhood park finance, it generally is less pronounced: jurisdictions that fund park construction and maintenance are often small, and they may try to spread parks uniformly throughout their area. In this context, there should be a much closer correlation between overall benefit levels and user cost. Since the two should offset one another to a certain extent, a smaller rent gradient may be observed. Utility connections are often financed through user fees, so that individual land owners and developers may be required to pay either the full marginal or embedded cost of infrastructure that serves their sites. The property value increment added by water and sewer connections, then, must be interpreted in light of the *cost* of obtaining these connections.

Unfortunately, the capitalization studies summarized in Tables 3 and 4 do not allow us to draw many general conclusions on how these differences affect the spatial distribution of property value effects. As with the transportation infrastructure studies, each examines a different land market. Correll et al. (1978), for example, found a large and statistically significant negative rent gradient associated with distance from Boulder's greenbelt. The magnitude and extent of the capitalization effect observed are larger than those documented in some of the transit studies. Correll et al., however, point out (at 216) that the increase in property values is produced by the relative scarcity of preserved open space: "As the public good of preserved open space becomes more common in the region, we expect that intra-area property value effects will diminish."

A couple of general patterns do, however, emerge. First, every study shows a relationship between property value and the availability of public water and sewer connections. This makes sense. As Chudleigh noted in his 1991 article, public sewer connections can decrease wastewater disposal costs and boost the development potential of sites by making more profitable, higher-density uses possible (Chudleigh: 222-24). So long as sewer and water connections for a given site are not compulsory, there is no way that offering this option could decrease property value.

Table 3. Property Value Effects -- Parks (see Appendix C for notes on studies)

Author (Date)	City/Region	Property Type	Accessibility Measure	Magnitude of Effect	Extent of Effect
Kitchen & Hendon (1967)	Lubbock, TX	SF homes	Distance to park	No significant effect	
		Land on which SF homes located	Distance to park	Significant negative correlation between distance and assessed value	0 to 2.5 blocks from park
Hendon (1971)	Dallas & Fort Worth, TX	SF homes & land on which those homes located	Access distance to park	Variable	Within ~5 blocks of park
Darling (1973)	Lake Merritt, Oakland	SF homes, apt bldgs, and vacant lots	Distance to shore	In some models tested, park proximity had a positive effect on value ($221/ft to $3174/ft)	0 to 3000 ft of park
	Lake Murray, San Diego	SF homes	Distance to shore	No significant effect	
	Santee Lakes, CA	SF homes	Distance to lake entrance	No significant effect	
Weicher & Zerbst (1973)	Columbus, OH	SF homes	Homes with view of park versus homes without a view	View premium of 7 to 23% of property value	Homes facing park
Blomquist (1974)	Suburban Chicago	Median value of SF homes in census block	Straight-line distance from park to center of census block	No significant effect	
Hammer et al. (1974)	Philadelphia, PA	SF homes	Distance to park on public streets	Proximity to park had positive effect on house values, equal to 4.2% to 30% of land value.	0 to at least 2500 ft from park
Hendon (1974)	Dallas, TX	Land on which SF homes located	Access distance to park	Significant correlation coefficients (from +0.275 to -0.226) between value and distance to park	Zone of value effect about the same as zone of use.
Correll, et al. (1978)	Boulder, CO	SF homes	Walking distance from greenbelt	-$4.20/ft rent gradient (aggregate); 3.4 to -10.2/ft for individual neighborhoods	0 to 3200 ft from greenbelt

Table 4. Property Value Effects - Sewer and Water Connections (see Appendix C for notes on studies)

Author (Date)	City/Region	Property Type	Magnitude of Effect
Weiss, et al. (1966)	NC Piedmont Crescent	Land	Availability of a public sewer connection had a statistically significant effect on value
Smith (1978)	Chicago	Land on which new SF home located	$1300/house for water and sewer connections
Chudleigh (1991)	CT	Commercial, Industrial, and Warehouse	Estimate of increase in assessed values from installation of sewers showed substantial value enhancement, equal to 3 times project cost.

Second, the property value effects of parks are ambiguous. Although several of the studies found positive effects, the magnitude seemed to depend on the specific design characteristics of each park and the surrounding land uses. In several of the studies, the authors documented both strong positive effects for some parks and strong negative effects for others (Hendon [1971, 1974]; Correll et al. [1978], who found that, when their data were broken down by neighborhood, individual neighborhood rent gradients varied between -10.2/ft and +3.4/ft; Darling [1973], who reported very different results for each of the three urban water parks he studied.)

IV. THE PUBLIC POLICY IMPLICATIONS OF PROPERTY VALUE CAPITALIZATION STUDIES

Property value capitalization studies have several potential policy applications. Three will be examined here: (1) evaluating the economic efficiency of public infrastructure projects; (2) identifying value-capture opportunities to fund public infrastructure; and (3) determining whether public transit infrastructure can stimulate land use changes that advance planning goals.

Evaluating the Efficiency of Proposed Public Investment

Capitalization studies can be used in benefit-cost analyses to evaluate the Kaldor-Hicks efficiency of proposed infrastructure projects. Weicher and Zerbst (1973), for example, calculated the total property value effect of an urban park on nearby properties, and then compared that figure to the value of the land if it were developed with single-family homes.

Even if the property market price effects of a particular piece of infrastructure can be measured accurately, however, it may be inappropriate to use them in an estimate of the facility's social value. In general, real property value changes are a *secondary* effect of public investment; it may be possible to measure infrastructure benefits more directly. Wheaton, for example, suggests that transportation improvements be evaluated by measuring the change in consumer surplus associated with the derived demand curve for transportation (Wheaton, 1977: 139). If this value is calculated properly, there is no need to consider real property value effects — indeed, including them in the estimate of social value would constitute double-counting (id.).

Even when properly included in benefit-cost analyses, capitalization effects should be interpreted with caution. Several factors suggest that property value changes will be less than the social value of infrastructure improvements. First, other markets, in addition to the real estate market, may be affected by public improvements. General equilibrium analysis, for example, suggests that transportation improvements will affect the wage rates paid to workers (see, e.g., Sullivan, 1990: 230-33). A sophisticated, low-user-cost metropolitan transportation network may decrease the general wage level necessary to attract labor to the region. If so, real property rent gradients will not reflect the full value of transportation infrastructure.

Second, because individual discount rates are different from the social discount rate, the sum of all land market effects may be substantially less than a facility's properly calculated social value. As discussed above, the property value premium for an amenity is equal to the present value of the associated benefit or savings stream. The implicit price revealed by an hedonic model, then, is based on individual property owners' discount rates. For evaluating the *social* value of infrastructure, however, those discount rates may be excessive. Because risk can be spread over a much larger group, and because societal investments can be more diverse, the discount rate appropriate for calculating social value arguably should be lower than that used by individuals.

Third, studies of land market effects will not capture the existence value of public facilities. Since this benefit does not vary with proximity, consumers will not bid-up the price of particular sites in an effort to realize it. The existence value of most local public infrastructure is probably quite limited. However, the factor highlights a more general concern: property value capitalization effects are based on the *private* benefits produced by public infrastructure; to the extent that public infrastructure produces a real *public good*, that benefit will not be reflected in property value prices.

These tendencies for land market changes to underestimate the social value of public infrastructure may be partially or completely offset by the market distortions created by government subsidies to real property ownership. Real estate is not just a consumption good. Home ownership, for example, functions as the primary savings instrument for many American families (Witte and Long, 1980: 135, citing Tucillo, 1978). The price of a dwelling unit, then, depends not only on the housing services it provides, but also on its value as a financial investment that provides attractive returns and allows indefinite deferral of tax obligations. The financial benefits of real property ownership may tend to encourage over-investment and over-consumption. If so, the private property value effects of public infrastructure could exceed the social value of the facility.

Various market imperfections may also unpredictably distort estimates of social value based on real property capitalization effects. The capitalization theory of value, for example, assumes perfect information: that consumers accurately recognize the presence of amenities and understand their benefits. This assumption may be incorrect. If it is, then the capitalized value of measurable benefit streams might not be properly reflected in housing price premiums.

Moreover, property value capitalization reflects consumers' beliefs about the stability of future benefit streams. In theory, consumers assess (1) the likelihood that benefits to a particular site will continue, increase, or decrease in the future; and (2) the comparative advantage of that site, *vis à vis* other locations in the future. The accuracy of these implicit calculations is questionable.

Finally, capitalization effects may be masked by high transaction costs. Because of the relatively high costs of moving and of identifying an "ideal" property, consumers' behavior might not reflect their full product preferences. If so, then the value of amenities would not be accurately reflected in sale prices (Yinger, Bloom, Börsch-Supan, and Ladd, 1988: 58).

Nevertheless, when other measures are unavailable, property value capitalization effects provide a useful starting point. Where the positive effects on private property values are larger than the costs of the facility, the total social benefits of the investment will likely outweigh its costs.

Value Capture

The Theory and Practice of Value Capture

Property value capitalization studies reveal the private benefits produced by public investment. Value-capture techniques seek to tax away that private windfall. In theory, they prevent landowners from collecting unearned premiums, and the revenues generated can be used to offset infrastructure costs.

Most commentators divide value-capture techniques into two broad categories: (1) fees or taxes assessed on benefiting properties; and (2) joint venture/joint investment techniques in which the government takes a direct ownership or development interest in benefiting properties (Zamora, 1988; Walther, Erskine, 1990). Techniques from the second category allow the public to recover any property value increment automatically. They require, however, substantial public resources, and there are legal restrictions on land development by public agencies. Moreover, many see them as excessive public participation and interference in the private land market.

Taxation and fee techniques, in contrast, have a long legal and institutional history. The key challenge they pose is technical: setting the proper level of taxation in each case. In theory, capitalization studies can make a valuable contribution here. Unfortunately, as discussed above, the studies reviewed in Parts II and III show a wide range of implicit prices associated with infrastructure proximity, and they provide relatively little guidance on how to predict the price effects of new investment.

Moreover, absent advance knowledge of property value effects, implementation poses significant difficulties. Capitalization theory implies that the full value of any private benefits expected from public infrastructure, over time, will be immediately reflected in the current market price for real property. Future purchasers will be willing to pay a premium, so the present owner at the time the public investment is made captures the entire windfall, unless she or he also bears the full, pro-rata share of program costs.

The problem is that this capitalization effect also reflects any anticipated value-capture programs. Capitalization can be empirically measured only if some original owners have already sold their property *with the belief that value capture will not be used.* If all prospective buyers and sellers know in advance that the state will ultimately claim any premiums generated by public infrastructure, then there will be no capitalization effect to measure. If the government wants to set an exactly accurate value capture tax, the state's only recourse is to experiment with different tax levels until a marginal increase in the tax would cause property values to fall— a formidable task for any public entity.[19]

Assuming that the state is able to identify and collect any property value premiums accurately, will there be an effect on land use patterns? In theory, so long as a tax on land is uniform and unavoidable, there should be no effects on land use. Land will still be dedicated to its highest and best use, based on its productivity and accessibility characteristics.

Practice diverges from theory, however, in two major ways. First, it is difficult to design a transit system value-capture tax that is uniform and unavoidable. If it is possible to enjoy some of the benefits of public infrastructure while avoiding the tax by siting just beyond a jurisdictional boundary, for example, it is likely that investment will be shifted across that border. Likewise, different land uses receive different amounts of benefit from public infrastructure. A tax based on some objective measure— such as square feet of building space — could encourage transition to uses that obtain more infrastructure benefit per square foot. Public policy decisions can also alter a uniform tax system. In Los Angeles, for example, the benefit assessment districts for the downtown stations of the Metro Rail system exclude residential properties (*SCRTD v. Bolen*, 3 Cal. Rptr. wd at 846).

Second, real property is not just a consumption good, it is an input into the development process. The presence of a value-capture system, then, will almost certainly have some effect on land use. In *Transit Station Area Joint Development: Strategies for Implementation* (1976), for example, the authors concluded (at 7), that "excessive use of value capture may discourage beneficial speculation":

> [A] serious problem is that it will never prove feasible to effect 100% value capture in situations where private developers are involved. The field of real estate development is very risky; windfall profits on some developments are not a luxury but a necessity for many developers. Past experience has indicated that recapture of more than 50% of land value windfalls may serve to discourage developer interest. An overly ambitious value capture policy is therefore likely to prove counterproductive.

(at 37, *citing* Grimes, 1975). Aggressive use of the property tax, however, might also encourage rapid development in strong markets:

> Taxes tied to increasing land values make it difficult to hold land out of production for speculative purposes. Rapid re-assessment procedures could make the property tax quite potent in this regard. It is possible for a speculator to reduce this effect somewhat by maintaining a low-level use on his property purely for "tax-paying" purposes. Nevertheless, incentives of this sort are likely to prove useful in transit station areas where market conditions are good and government seeks to encourage rapid development.

(Id. See also Bentick [1979], who provides an economic explanation of how tax systems based on land value will tend to encourage faster and often less-intensive development.)

The Empirical Support for Value Capture

Whether tax-based value-capture techniques can recover a substantial portion of infrastructure costs is an open question. Estimates of the value-capture potential for transit vary wildly. Allen, Chang, Marchetti, and Pokalsky (1986), for example, conclude that, in aggregate, a value-capture tax on single-family homes benefited by the Lindenwold High Speed Line would have yielded $279.5 million. This figure represents 115 percent of the actual costs of line construction, but if the costs of prior-existing infrastructure and rights-of-way used in the Lindenwold Line are considered, the percentage of costs recovered through a residential value capture tax would fall to about 33 percent. The lower figure developed by Allen et al. is relatively close to Anas's 1983 estimate that residential property value changes would equal nearly 36-40 percent of the capital cost of rail rapid transit alternatives that had been proposed for Chicago's southwest side. Both of these studies focused on the value capture potential associated with residential properties; if other land uses were also considered, the percentage might increase substantially.

These optimistic projections must be contrasted to studies that identified small or insignificant property-value changes associated with proximity to transit stations (see Part II.A., above). If transit stations do not increase property prices, then there simply is no value to capture. If Gatzlaff and Smith are correct, then there is no significant value-capture potential associated with Miami Metrorail stations. Nelson's conclusion that MARTA stations decreased residential property values in certain neighborhoods suggests that, if anything, government compensation should be paid to land owners in affluent areas.

Finally, even studies that have identified substantial value capture potential acknowledge the political and ethical difficulties associated with collecting the increment. Allen et al. (1986), for example, stress (at v) that

> the time to capture the value is between when the line is announced and when the line becomes an operating reality. If the tax is instituted after the line has opened, it will only tax the windfall from those property owners who have continually occupied their homes. Anyone moving in after this time period has paid the capitalized savings to the seller of the house and taxing such individuals would tax them twice.

Likewise, the City of Los Angeles concluded in 1977 that politically feasible versions of the value-capture techniques studied would only recover a small portion of the cost of the transit stations— let alone the total cost of an entire transit system (City of Los Angeles, 1977: 2, 33).[20]

Given the current state of empirical research, it does not appear possible to propose practical, generic standards for setting benefit-based value-capture taxes. In contrast, joint development strategies, special benefit assessment districts, and user-charge systems directly tied to facility cost are alternatives that can be implemented today.

Using Transit Systems to Shape Urban Form

Classical theories of urban form model accessibility as the primary determinant of urban land value. Highly accessible locations will be occupied by the uses willing to pay the highest premium for that amenity —usually high-density housing and commercial development. Within this context, the property value capitalization effects of transit stations should provide a useful indicator of the stations' ability to promote land use change. If stations produce large increases in nearby land values, higher-density development could be expected in those locations; if not, then the potential for land use change is probably limited.

Existing capitalization studies, however, do not provide sufficient evidence to conclude when, if ever, transit investment will prompt land conversion. To complete this analysis, two types of information are required: (1) bid-rent curves for each land use in the jurisdiction; and (2) estimates of the regional-accessibility-related land price effects of transportation improvements.

None of the reviewed studies includes the first type of information. Moreover, many analyze only the small area immediately surrounding the transit stations. Such studies will reveal any localized land rent gradient. However, according to classical models of the relationship between land rent and land use, the key factor is whether the metropolitan accessibility of a parcel can support high-intensity land uses. In this framework, even a very steep local rent gradient around a transit station will not generate land use change if absolute metropolitan accessibility levels (and the associated accessibility premiums) are low. Without data from a larger area, there is no way of knowing what portion of the total land rents near the station is generated by regional accessibility.

Finally, if capitalization effects are to be used to predict land use change, it may be helpful to expand our empirical base beyond single-family homes. Virtually all of the recent transit capitalization studies model the price of single-family residences. This is due— at least in part— to the fact that single-family house sale data is well-suited to regression analysis. The number of house sales in any given time period is usually much larger than the number of sales of non-residential properties. Moreover, arms-length house sales are the norm; ownership, transfer, and payment arrangements for single-family homes are relatively standard; and house sale price is normally part of the public record.

Under the capitalization theory of value, however, the premium associated with accessibility for single-family homes reflects the private benefits realized by the occupants of those units. Given the small number of individuals who will benefit in each single-family home, the magnitude of that rent gradient can be expected to be small. Would other land uses in the same locations realize a larger accessibility benefit? In equilibrium, the accessibility premium paid by a single-family home buyer should at least equal the accessibility benefits that any other possible user could realize. Real-life markets, however, are sometimes distorted. Zoning might restrict conversion from single-family use. Because structures are so durable, there may be substantial barriers to land use change. Finally, theoretical models usually assume that the value of proximity will vary among different land uses, generating a kinked land rent gradient. If so, special care must be taken when extrapolating the rent gradient revealed by single-family home prices into areas dominated by other land uses.

V. CONCLUSIONS

In 1980, Witte and Long reviewed the literature on the property value capitalization effects of public policies. They noted that the studies used a wide range of explanatory variables (at 135-136), and they argued that additional research on non-residential land uses was necessary (at 155-156). Fourteen years later, those same general comments can be made about the literature on the property value effects of transportation improvements. While there seems to be a strong consensus that highway interchanges and public transit stations can have positive effects on land value, the estimates of that effect vary widely from study to study. Since the studies use a broad range of methodologies and models, it is difficult to compare their results. To date, there has been no effort to develop a systematic explanation for the variation in observed rent gradients aro

und transportation infrastructure in different cities. If anything, the research focus on residential land uses is even more pronounced than it was in 1980. Filling these gaps will require a two-part effort: a general investigation into the land market effects of accessibility, and a better understanding of the specific amenities and disamenities of transit stations.

Appendix A: *Independent Variables Included in Table 1 Studies*

Author	Dependent Variable	Independent Variables/Comment
Al-Mosaind, Dueker, and Strathman (1993)	SF home sale price	(I) Model for all sales in study area includes: a dummy variable, 1 for all homes within 500 m walking distance from a station, and 0 otherwise; lot size in square meters; house size in square meters; dummy variable for presence of basement; number of bedrooms; age of house in years; dummy for single-family zoning; dummy for location in Portland; dummy for location in Multnomah County. (II) Model for sales located within 500 m actual walking distance from an LRT station includes: distance in meters of each home from the station; lot size in square meters; house size in square meters; dummy variable for presence of basement; number of bedrooms; age of house in years; dummy for single-family zoning; dummy for location in Portland; dummy for location in Multnomah County.
Allen, Chang, Marchetti, and Pokalsky (1986)	SF home sale price	Distance to the Ben Franklin Bridge; Distance to the Walt Whitman Bridge; lot size; property tax paid; garage dummy variable; fireplace dummy variable; house as only one-bathroom dummy variable; house has only 1.5 bathrooms dummy variable; Savings Variable.
Alterkawi (1991)	Land, assessed value per sq. ft	Straight-line distance from parcel to nearest Metro Station
Bajic (1983)	SF home sale price	Usable outdoor space in hundreds of square feet; floor area in hundreds of square feet; number of rooms; total, weighted commuting time using public transit from the house location to five chosen destinations on the subway system; auto in-vehicle time in minutes from the house location to the intersection of Bay and King Streets in downtown Toronto, weighted by the probability of choosing auto over public transit mode; composite, weighted auto in-vehicle time in minutes from the house location to five chosen interchanges on the Metropolitan Toronto expressway system; number of garage places; finished basement dummy variable; finished recreation room dummy variable; two-story building dummy variable; number of extras; excellent/very good house condition dummy variable; number of bathrooms; private driveway dummy variable; private or mutual driveway dummy variable; Toronto location with a private driveway dummy variable; stone or brick construction dummy variable; neighborhood locational dummy variables for eight regions in Metropolitan Toronto defined as relatively homogenous neighborhoods.

Author	Dependent Variable	Independent Variables/Comment
Damm, Lerner, Lerner-Lam & Young (1980)	SF home, MF residential, and retail sale price	SF home model: Reciprocal straight line distance to Metro variable; number of years to Metro station completion; distance by transit to Metro Center; % owner-occupied dwellings in neighborhood; % substandard housing in neighborhood; mean income in neighborhood; retail employment density (employees/sq. mile) in neighborhood; lot area (sq. ft.); zoning dummy variable (1 if parcel's zoning class and property type are identical). Multifamily housing model: straight-line distance to nearest Metro station; number of years to Metro station completion; distance by transit to Metro Center; % owner-occupied dwellings in neighborhood; % non-white in neighborhood; % substandard housing in neighborhood; mean income in neighborhood; retail employment density (employees/sq. mile) in neighborhood; population density (persons/sq. mile) in neighborhood; CBD dummy (1 if parcel is located in CBD); lot area (sq.ft.); dwelling unit dummy variable (1 if number of dwelling units on parcel actually recorded for observation); number of dwelling units on parcel. Retail model: straight-line distance to nearest Metro station; number of years to Metro station completion; mean income in neighborhood; difference between lot area and floor area (proxy for parking space availability); floor area of parcel's improvement; pre-1969 transaction dummy; ratio of retail employment density to population density in neighborhood; ratio of non-retail employment density to retail employment density in neighborhood; highrise dummy (1 if floor area of improvement was larger than lot area).
Davis (1970)	Property sale price	Comparison of changes in averages sales price, based on all sales within six blocks of the Glen Park Station site. Repeat sales of properties within 2 blocks of station also discussed.
Dewees (1976)	Low-density residential sale price	Floor space; number of rooms; number of 3 or 4 piece bathrooms; number of 1 or 2 piece bathrooms; number of garage parking spaces; number of type A extras; solid brick or stone; brick or stone facing; detached; fully attached or multiplex; condition; log of structure age in years; hot air heating medium; gas or electric fuel; single family only zoning; duplex allowed zoning; less than 40% of school children are native English speakers; light auto traffic only; average sale price of houses in the school district; weighted time cost to Bloor Street. (travel weighted as one, waiting at 1.5, and walking at 3).
Falcke (1978)	*Repeat sales ratios for*:	
	*Residential prices	Straight-line distance to BART station. Distance to shopping (Mission and 24th Street only); distance to tracks (South Hayward, only)
	*Residential rents	Distance to BART station; distance to tracks.
	*Office rents	Straight-line distance to BART station. Distance to Market St. (San Francisco CBD, only).
	*Commerical prices	Straight-line distance to BART station.

Author	Dependent Variable	Independent Variables/Comment
Ferguson, Goldberg, and Mark (1988)	SF home sale price in 1975 dollars	Dummy variable for presence of basement; basement-year interaction variables; ground floor area in square feet; area-year interaction variables; gas heating dummy variable; gas heat-year interaction variables; alterations dummy variable; alterations-year interaction variables; hardwood floor dummy variable; lot area in square feet; age of housing unit in years; number of plumbing connections; plumbing-year interaction variables; straight-line distance to CBD; distance to CBD-year interaction terms; straight-line distance to station; distance to station-year interaction terms; dummy variables for each year.
Gatzlaff & Smith (1993)	SF home sale price	Two methodologies used: (1) an analysis of repeat-sales indices, excluding substantially improved properties; and (2) an hedonic model using the following explanatory variables: total living area of the residence in square feet; lot size in square feet; age of the property in years at the time it sold; overall index of residential property appreciation; distance of the property from the Metrorail station measured in tenths of a mile; announcement dummy, 1 if after 1980, otherwise 0; an interactive variable set at distance for those properties selling after the rail development announcement; and an interactive variable set at distance for those properties selling before the rail development announcement.
Nelson (1992)	SF home sale price	South Side Home Sales: house size in square feet; lot size in square feet; basement dummy variable; location in Decatur City dummy variable; 1980 Census Tract Income; 1980 Census Tract % minority; distance from station (100 ft units); distance from station, squared. North Side Home Sales: house size in square feet; lot size in square feet; number of stories; adjacent to park dummy variable; foundation present dummy variable; central air conditioning dummy variable; corner lot dummy variable; number of fireplaces; basement dummy variable; number of full bathrooms; location in Decatur City dummy variable; 1980 Census Tract Income; 1980 Census Tract % minority; distance from station (100 ft units); distance from station, squared.
Pickett & Perrett (1984)	Quarterly District Assessors' Valuation	No regression analysis performed. Study based on matched pairs of "near" (within 200 m of Metro station) and "far" (1.5-3.0 km from the same Metro station) properties.
Voith (1991)	Median SF home value as reported in 1980 census	Station in or near tract, dummy variable; travel time in minutes from tract to the CBD by auto; average length of commute in minutes for each tract, regardless of destination; number of peak trains serving each tract; difference in CBD commute time between auto and train; average household income in tract; average household size in tract; % of population that is black; % of housing stock that is single-family detached housing; median age of the housing stock in tract; average number of rooms in a house in tract.

Appendix B: *Independent Variables Included in Table 2 Studies*

Author	Dependent Variable	Independent Variables/Comment
Adkins (1957)	Land sale price and assessed value (see comment)	No regression analysis performed. Dependent variable is land value. Therefore, for improved properties, land sale price calculated by subtracting the assessed value of improvements from the total sale price.
Allen (1981)	SF home sale price	Square feet of floorspace; age of house in years; lot size in square feet; number of baths minus 1; number of fireplaces; style of house dummy variable; type of basement dummy variable (Northern Virginia only); type of construction dummy variable (Northern Virginia only); house location within 70 dB(A) noise contour dummy variable; alternative, site-specific noise measures and/or functional forms.
Brown & Michael (1973)	See comment	No regression analysis performed. Dependent variable is change in land value, measured by comparing recent sales prices to assessed value of land prior to highway construction. For improved land, sales prices and assessed values are adjusted by subtracting the assessed value of improvements.
Buffington (1964a)	Land sale price, adjusted by CPI	No regression analysis performed.
Buffington & Meuth (1964b)	Land sale price, adjusted by CPI	No regression analysis performed.
Cribbins, et al. (1962)	Land sale price (per unit)	Size of parcel; year of sale; vacant/non-vacant dummy variable; rural/urban dummy variable; subdivision dummy variable; Interstate roadside location dummy variable; alternate roadway location dummy variable; straight-line distance to RoW; straight-line distance to CBD; straight-line distance to freeway access.
Langley (1981)	SF home sale price	No regression analysis performed. Time-series analysis comparing repeat-sales indices for three distance categories: (1) abutting properties; (2) impact area properties (within 343 m of roadway); and (3) non-impact area properties (beyond 343 m of roadway).
Palmquist (1982)	SF home sale price	Specific regression equations not presented in article.
Tomasik (1987)	SF home sale price	No regression analysis performed. Rate of appreciation in study area sale prices compared to overall Maricopa County resale housing appreciation rate. Within study area, appreciation rates of Impact Area (0 to 0.5 mi. from freeway) compared to Control Area rates (0.5 to 1.0 mi. from freeway).

Appendix C: *Independent Variables Included in Tables 3 and 4 Studies*

Parks

Author	Dependent Variable	Independent Variables/Comment
Blomquist (1974)	Median value of SF homes in census block	Average number of rooms per house; distance to power plant (kinked regression line formulation); distance to Lake Michigan; distance to railroad tracks; distance to park; distance to local commercial district; percentage black; Glencoe dummy; Kenilworth dummy; and Wilmette dummy. Note: final reported model did not include all of these variables.
Correll, et al. (1978)	SF home sale price	Walking distance (in feet), using most direct public access to Greenbelt; age of house in 1975; number of rooms; finished square footage of house; dummy variable for average lot size; dummy variable for above-average lot size; urban distance ((2/3)*(avg. distance from neighborhood to center of city) + (1/3)*(avg distance from neighborhood to nearest major shopping center))
Darling (1973)	Sale price and assessed value for SF homes, apt bldgs, and vacant lots	For Lake Merritt: distance to the Lake; lot area in square feet; year sold; year built; square feet of residence; number of bathrooms; average crime rate; number of units (for apartment buildings, only); zone dummies; census tract dummies; and other unidentified variables (vacant lots, only). For Lake Murray: distance to lake; year sold; year built; lot area in square feet; square feet of residence; view dummy; census tract dummies. For Santee Lakes Area: distance to lake entrance; year sold; year built; square feet of residence; number of bathrooms; view dummy distance to CBD; zone dummies.
Hammer, et al. (1974)	SF home sale price	Distance to park on public streets and ways (reciprocal form used: [1/(D+200)]); corner dummy variable; abutting park dummy variable; side-to-park dummy variable; house type dummy variables (16); year of sale dummy variables.
Hendon (1971)	SF home assessed value and land assessed value	Simple correlations with access distance to park
Hendon (1974)	SF home assessed value and land assessed value	Simple correlations with access distance to park
Kitchen & Hendon (1967)	SF home assessed value and sale price; land assessed value	Simple correlation with access distance from park.

Author	Dependent Variable	Independent Variables/Comment
Weicher & Zerbst (1973)	SF home sale price	Number of rooms in house; age of house at time of sale; size of lot in square feet; sale in 1966-67 dummy variable; sale in 1968-69 dummy variable; property adjacent to and facing park dummy variable; property adjacent to and backing onto park dummy variable; property adjacent to park and facing area of heavy recreational use or park building dummy variable.

Public Sewer and Water Connections

Author	Dependent Variable	Independent Variables/Comment
Chudleigh (1991)	Assessed value, all property types	No regression analysis performed. Each improved property analyzed individually, using a discounted cash flow technique that compared the cost of maintaining a septic system with a sewer-use charge. Analyses also considered possible land use changes made possible by the availability of a public sewer connection (e.g., more intensive land development in parcels where the capacity of on-site septic systems was constraining development).
Smith (1978)	Location Premium for new home (see comment)	Distance to Chicago CBD; distance to O'Hare Airport; gravity model index of accessibility to employment; distance from major commuter rail transportation; compatibility of neighborhood land uses to proposed use (dummy variable); availability of public water and sewer (dummy variable); current property tax rate; school expenditures per pupil; reported crimes per 1000 people; approximate average pollution rate; % nonwhite in census tract. The Location Premium dependent variable for unit (i) is the premium purchasers are willing to pay (above value of land at urban frontier) for location (i). Calculated from total sales price, appraised land values, and lot size.
Weiss (1966)	Assessed land value	Accessibility to work areas; availability of public sewerage; distance to major street; distance to nearest elementary school.

NOTES

[1]See, e.g., Gatzlaff & Smith (1993), who describe (at 54) Miami's efforts to use Metrorail to encourage growth and revitalize certain areas of the city, instead of aligning the system to serve growth areas.

[2]This literature review focuses on U.S. and Canadian studies. The bias is partly due to limited access to reports from other countries. However, it also may reflect differences in infrastructure finance systems. Outside of the U.S., public agencies often have the power to acquire substantial amounts of land around transit stations for future development. This allows transit agencies to coordinate land uses around stations, and revenues from land development can be used to fund transit. Value capture, then, is automatic: because the government owns both the infrastructure facility and the affected land, any benefits from the infrastructure are internalized.

In contrast, constitutional and statutory limits generally prevent U.S. transit agencies from taking land substantially in excess of that required for system construction. Value capture, in this context, must be implemented through taxation and user-charge programs. Since there are legal constraints on the power of localities to impose additional taxes or charges on particular parcels or new development, there has been a greater need for studies in the United States that can empirically demonstrate and quantify the private property value effects of public infrastructure.

A few fee-based value-capture programs were identified in other countries. Ridley and Fawkner (1987) report the results of a survey on value-capture techniques sent to the 51 members of the *Comité international des métros*. In addition to station-leasing and joint-development techniques, they list methods to measure and capture benefits from employers, store owners, automobile drivers, and owners of real property, including a range of taxation and development impact fees. Their survey, however, provides little discussion of how the specific taxes or charges described in their non-U.S. case studies were linked to the measured benefits provided by transit systems.

Two studies on the property value effects of urban railroad construction in Japan were also identified. Kuribayashi (1986), for example, examines four different techniques for calculating the "development profits" associated with urban railroad construction. Tsukuda and Kuranami (1990) describe the various value-capture techniques that have been used in Japan to finance urban rail systems.

[3]Indeed, in the cobweb model of lagged supply adjustment response, it is theoretically possible for housing markets never to reach equilibrium (Goldberg and Chinloy, 1984: 257-58).

[4]The construction of other transportation facilities, for example, can increase the accessibility of competing locations, thus driving down the premium for accessibility in the market.

[5]The hedonic price model also showed a negative —and statistically insignificant —price gradient of $21.75/meter for houses within a 500m radius of the stations. This translates to $6,939 at the mean distance of 319 meters (Al-Mosaind et al., 1993: 11-12).

[6]Al-Mosaind et al. (1993) note (at 11) that "[i]n an auto-dominated city like Portland, transit's role in people's travel behavior is minor . . . . Therefore, the housing market may not be noticeably influenced by transit users' locational decisions." This pattern suggests that some factor other than reduced household transportation costs affected single-family home values near LRT stations.

Although speculative premiums associated with possible land use conversion are one possibility, their models also showed (at 16-170) that single-family zoning had a strong positive effect on value. This suggests that anticipated land use conversion may not be the critical factor.

[7]A few of the studies used longitudinal data. Davis' 1970 analysis of land prices around the Glen Park BART Station, for example, examines changes in residential property values during the period from 1960-67. He presents only descriptive statistics. Likewise, Gannon and Dear (1972) use descriptive statistics to show that the Philadelphia-Lindenwold line has facilitated the suburbanization of the office sector. Pickett and Perrett (1984) conducted a time-series analysis of changes in assessor valuations of property close to Metro stations in Tyne and Wear County.

[8]Gatzlaff and Smith, for example, use an exponential form (Gatzlaff and Smith, 1993: 62). Damm et al. (1980) use a logarithmic formulation for its multi-family building model (at 327) and a log-log form for their retail property

model (at 331). Falcke (1978) uses an inverse distance formulation for each of his models. Nelson (1992) combined both simple distance and distance squared in his model.

[9]Three studies included information on land use controls. Al-Mosaind et al. (1993) and Dewees (1976) include a dummy variable for whether or not the parcel is in a single-family-only zone. Dewees also includes a dummy variable indicating whether or not duplex zoning is permitted on the site. Damm et al. include a zoning dummy variable equal to 1 if the parcel's zoning and actual use are identical (at 324).

[10]Falcke (1978) asserts (at 26) that "[p]revious experience has shown that little can be gained by expressing the various distances in walking distances, time intervals, and so forth, as compared to plain straight-line distance" (citing Louis Berger, Inc., *Methodology to Evaluate Socio-Economic Benefits of Urban Water Resources*, prepared for the U.S. Department of the Interior, Office of Water Resources Research [1971]).

[11]This result has two important implications. First, as Bajic notes, it suggests that residents' travel cost savings were completely capitalized into real property values. This is substantially different from Dewees' study, which found a much lower rent gradient (Bajic, 1983: 155); if correct, Bajic's conclusion implies that consumers are capable of making extremely accurate bids on single-family homes. Second, Bajic's interpretation of the capitalization effect implies that the possibility of profitable land use change (or any other possible benefits of station proximity) did not affect households' bids. Of course, Bajic's results are also logically consistent with (1) partial capitalization of commute cost savings and (2) capitalization of other proximity benefits.

[12]In contrast, Bajic (1983) used a similar methodology to show a close correspondence between the capitalized value of time saved and the housing price premium associated with the Toronto Subway's Spadina Line.

[13]As Nelson notes (at 131), "[i]t is possible that some or all of [the negative effect observed for affluent neighborhoods] is associated with distance from minority-dominated neighborhoods."

[14]A couple of methods on how to isolate these effects come to mind. First, studies that examine the extent to which measured commute cost savings are reflected in site premiums suggest one way of isolating the two effects. If property value changes are greater than the capitalized commute cost savings stream, the increment may reflect the speculative premium associated with the parcel. Second, it might be possible to examine the ongoing investment behavior of homeowners in a given area. If a pattern of low maintenance spending and high land values is found for residential land uses, then the possibility of conversion to a higher-intensity use seems more likely.

[15]Nelson (1992) used data from neighborhoods near a portion of the East Line of Atlanta's MARTA system. He developed an hedonic price model with two distance variables: (1) simple distance from the nearest transit station; and (2) distance squared. According to Nelson (at 129), this functional form

> allows one to detect convex or concave relationships. For the south subarea, the functional relationship between transit station proximity and sales price is hypothesized to be concave; the first-order sign will be negative and the second-order sign will be positive. For the north subarea, the functional relationship is hypothesized to be convex; the first-order sign will be positive and the second-order sign will be negative.

The regression results showed the distance variables performing as hypothesized. According to Nelson, this implies that: (1) for low-income households, there is a strong positive price effect on value; and (2) for high-income households, proximity to transit stations is a nuisance that depresses value.

Contra Gatzlaff and Smith (1993), who suggest that for the Miami Metrorail system, "to the extent that accessibility is improved by the Metrorail, the capitalization of these improvements is of greater net benefit to higher-income households." This is because positive value changes were associated with stations located in safer, more affluent neighborhoods, WHile there were negative changes associated with proximity to stations in poorer areas.

[16]Langley notes (at 20) that the findings of his study are consistent with theories of capital asset pricing —i.e., that "each yearly deflated housing price actually represents the present value of the stream of anticipated housing services and locational amenities." According to Langley, the difference between the impact and non-impact areas reflects either (1) changes in the level or degree of an externality, or (2) changes in consumer attitudes toward an externality. Although Langley does not mention it, there is a third possibility: a change in the supply of a given amenity (e.g., accessibility to the CBD), such that the value of the property's locational advantage changes.

[17]The four most recent studies we reviewed all focus on the effects of highway construction on residential properties. Tomasik (1987) briefly discusses multi-family and commercial land uses, but the core of his analysis relates to the effect of highways on single-family homes.

[18]Some of the reviewed park studies, however, examine the effects of regional parks. See, e.g., Correll et al. (1978).

[19]Special benefit assessment districts allow the state *and* private property owners to share the burden of setting the proper tax level. Under California's Public Utility Code, for example, the relevant transit agency estimates the benefits to the district, and private property owners in the district are given an opportunity to challenge that figure. *Southern California Rapid Transit District v. Bolen*, 3 Cal. Rptr. 2d 843, 845-846, describes the process by which benefit assessment districts for Los Angeles's Metro Rail system were established.

[20]Los Angeles has since established benefit assessment districts around the Phase I stations of its Metro Rail system. The assessments from these districts were designed to recover over 10 percent of the Phase I construction costs (*SCRTD v. Bolen*, 3 Cal Rptr. 2d at 846-847).

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