

9.0 Selected Nontraditional Benefits

The following two sections present two methods for measuring benefits which traditionally have not been included in economic impact analysis. Section 9.1 describes benefits of reduced parking requirements due to the availability of transit. Section 9.2 describes transit-induced accessibility and agglomeration benefits. Both benefits can be substantial relative to the other types of benefits described in the previous sections of this Guidebook, as well as in absolute terms, especially over the life of the project. The reasons analysts omit these benefits vary, but the uncertainty of how to measure them probably contributes to this omission. The measurement methods themselves are not new; rather, their application and adaptation to measuring these specific benefits is unfamiliar to many analysts. Sections 9.1 and 9.2, therefore, devote considerable attention to explaining measurement methods and their correct application under a range of different conditions.

■ 9.1 Measuring Benefits of Reduced Parking Requirements

Introduction

Today, parking is as essential to a development project as are an entry lobby, elevators, and hallways. All of these facilities connect the user to an office, living room, or favorite coffee shop. While they are essential parts of the ultimate "usable" space (i.e., office, home, or shop), and account for a significant share of a building's cost, such facilities do not generate rent directly. The developer must balance the size and quantity of these non-revenue producing facilities against their cost and contribution to the success of a total project.

Since building and zoning codes specify minimum requirements for the size of entry lobbies, number of elevators, and number of parking spaces provided, the developer must decide whether to meet or exceed the minimum requirement. If a development project adjoins a convention center or a city park, a developer may sometimes undersize the common spaces since tenants have ready access to these public places. Such a substitution of public goods for private investment generates a benefit to the developer which, depending on other market conditions, may be necessary to make a project cost-effective, generate a windfall to the developer, or be passed on to tenants and sometimes to the general public. The same type of substitution occurs when private development can be accessed by public transit. When road capacity is at its limit, public transit can increase accessibility to the development. Transit, therefore, has the potential to supply a development with workers and customers. More importantly, as more people access a

development by public transit, transit may act to reduce demand for parking, thus reducing the number of parking stalls a developer needs to provide at the project's expense.

While parking reduction usually represents a benefit, estimating the size of the benefit and determining who ultimately receives it is not usually a straight-forward calculation. Finding the answers involves understanding the market and other forces in effect within a specific project area. These forces may be grouped into the following three categories:

1. **The requirements (supply) and demand for parking.** National surveys and case studies indicate that, in many areas of the United States, minimum parking requirements exceed demand by a considerable amount. While this is especially the case in suburban employment centers, many rapidly growing urban areas and central business districts (CBD) that currently do not have fixed guideway transit service also are oversupplied. Furthermore, these surveys report that developers usually build only the minimum amount of parking required.¹ Thus, a reduction in parking may involve two components: the first to eliminate the over supply and the second to account for transit ridership.
2. **The real estate market and the allocation of benefits.** The strength of the market determines who benefits from a reduced parking requirement and by how much. Low vacancy rates, high rents, scarce land, and a lack of alternative locations are usually good indicators of a strong real estate market, which would enable a developer to substitute leasable space for parking. If the developer had not yet purchased land for a project, these benefits may be captured by the land owner in higher land costs. In a weaker market, the developer likely would not replace the foregone parking with leasable space, thus the developer would simply not buy the land needed for the excess parking. In this weaker market, however, either the developer will benefit through lower land acquisition costs, or tenants might benefit from lower rents.
3. **The cost and price of parking.** The construction cost of parking depends on the type of parking being built. There are three types of parking (given in order of increasing cost): surface parking, multilevel or structural parking, and underground parking. As the cost of land increases, developers will use land for leasable space, and construct the more costly types of parking. The vast majority of surface parking is located in suburban job markets where land is relatively inexpensive compared to urban markets. In urban markets – especially in CBDs – developers must pay very high prices for raw land. In these markets, developers may choose to construct underground parking, which can cost between five to 10 times as much as surface parking, because they can recoup the cost of the parking through premium rents for leasable space.

This remainder of this chapter describes how to estimate the benefits of reduced parking at developments in the vicinity of transit stations within the context of the market forces described above. It provides a general methodology based on real estate pro forma analysis. An analyst must then apply the methodology to a specific development project or a

¹ Richard Willson, "Suburban Parking Requirements," *Journal of the American Planning Association*, Vol. 61, No. 1, Winter 1995.

particular study area to estimate the net benefits of reduced parking. In addition to the estimation of direct benefits, this section provides an overview of second order effects of reduced parking.

Estimating Parking Requirements from Demand

This section describes how an analyst may estimate parking requirements for urban versus suburban land use and areas with or without transit service. The general methodology is intended to determine how much parking really is required given likely demand. This analytic approach is essential if an analyst is to calculate a demand-based estimate of maximum parking requirements. The methodology presented is generic and therefore must be refined when applied to a specific transit project. Some important refinements involve adapting the methodology to the type of environment in which the project is planned: suburban, urban, or high density CBD.

The vast majority of parking requirements are based on zoning codes that have been written with only vague understanding of actual demand and little or no regard for an area's specific characteristics. Zoning codes in areas not served by transit typically require between 3.0 and 5.0 spaces per 1,000 gross square feet (gsf), with the lower end of the range for urban areas and the higher end for suburban areas. Surveys of both highly dense urban markets and low-density suburban markets revealed a common standard of approximately 4.0 spaces per 1,000 gsf, often without regard to building type.²³ In a survey of 117 urban and suburban jurisdictions in Southern California, for example, researchers calculated an average of 3.8 spaces per 1,000 gsf (the median was 4.0 spaces per 1,000 gsf).⁴ Many local jurisdictions adopt this universal standard to avoid the administrative complexity and the expense of conducting comprehensive parking demand studies.⁵

Nevertheless, sophisticated methods are used to estimate parking demand for large developments or areas where parking is scarce, expensive to provide, and the opportunity cost of land is great. Where transit exists, these methods often include detailed studies of the effects of transit service on parking demand. Although each situation requires some variation in methods, Figure 9.1 presents a general approach as a basis for estimating parking demand from a specific activity.

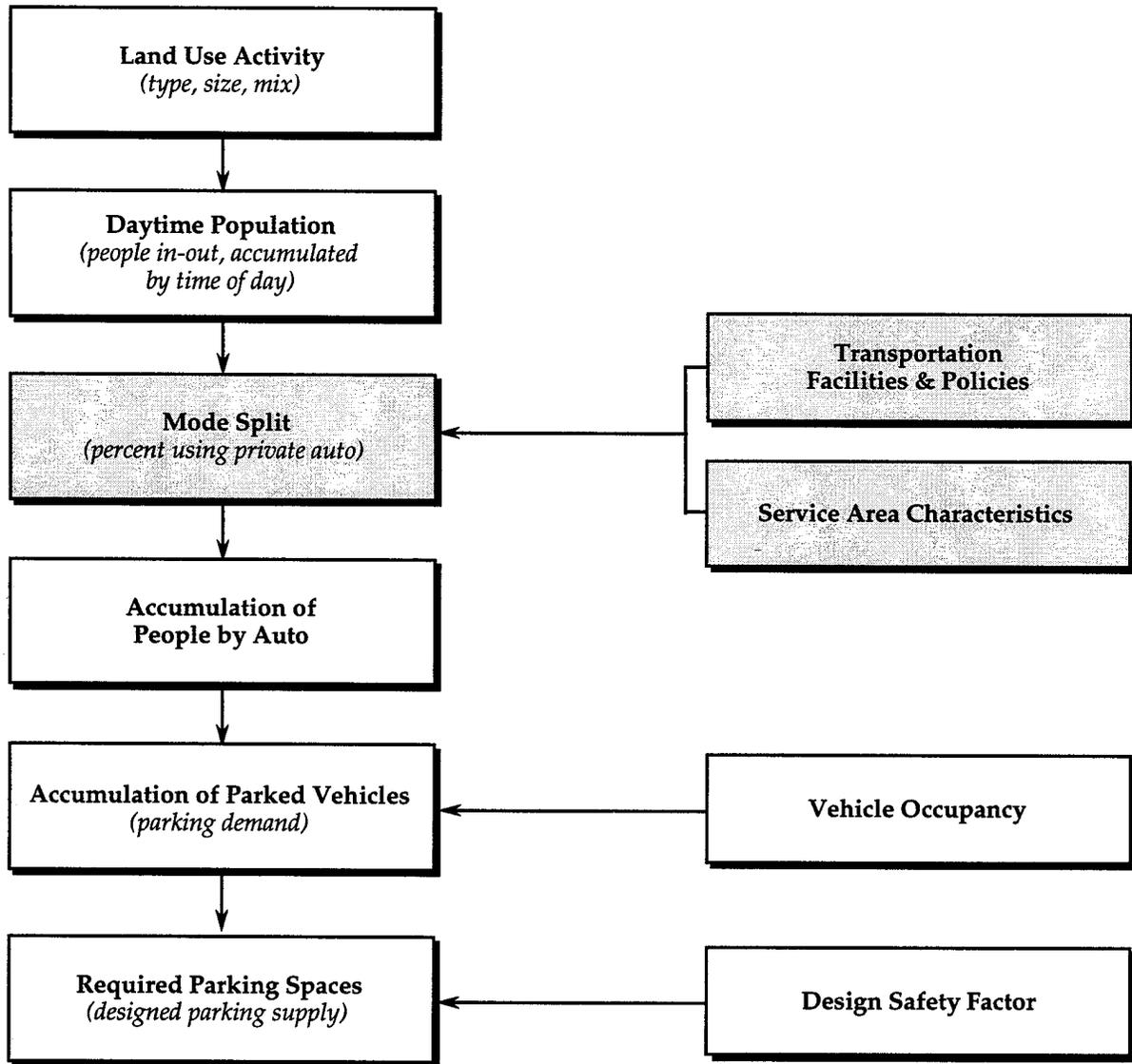
² Bergman, 1991; Gruen Gruen & Associates, 1986; *International Parking Design*, 1988; Cervero, 1984; Cervero, 1989; Shoup, 1993).

³ Many cities that are well-served by transit have much lower parking requirements, particularly in their CBDs. For example, in Boston, developers are required to provide only 0.3 parking spaces per gsf of office space. In New York City, only 0.25 spaces are required per gsf of office development.

⁴ An analysis of five special suburban office developments in five Southern California counties found an average requirement of 2.9 spaces per 1,000 gsf. Study authors deliberately selected jurisdictions with lower than average parking requirements. The average requirement for the five case studies in typical jurisdictions was 4.1 spaces per 1,000 gsf. (Willson, 1995).

⁵ Reed, C. 1984, *The Zoning Report* 2:1-8.

Figure 9.1 Estimating Parking Demand



Source: Robert Weant and Herbert Levinson, *Parking*, 1990, p. 93.

The process outlined in Figure 9.1 may be organized into two parts. The first, shown in the first four steps, provides an aggregate estimate of the person-accumulations (number of visitors and employees per square foot) generated by each type of land use for peak periods of activity. This aggregate is made up of separate estimates for each population group with dissimilar parking characteristics (i.e., length of stay, trip purpose, and inclination to use transit based on socioeconomic characteristics). These estimates depend on the mode split of the population, which are influenced by the transportation system and the characteristics of the transit service area. An investment in transit should not only decrease the number of vehicles accessing the development, but theoretically will induce more person trips to the area by attracting people who will only come via transit.

The second part of the process converts the person-accumulation estimates into a peak-hour accumulation of parked vehicles, given average vehicle occupancy rates and number of person trips. For multiple-use projects, separate estimates for peak-hour demand by land use type must be subtotaled to determine the aggregate peak-hour parking demand. This total parking demand is based only on demand generated from primary land uses. While there may be some complementary effects, secondary attractions derive most of their business from the draw of the primary activities (e.g., employment centers; major entertainment – movies, theater, stadium, etc.; regional retail; etc.); thus, the secondary uses (e.g., restaurants, news stands, business services, etc.) are not counted.⁶

In Figure 9.1, **Mode Split** is shown as an outcome of **Transportation Facilities and Policies and Service Area Characteristics**. Both of these are affected by the level of transit service. Although the expected influence on mode split must be determined through careful survey and model development, new or improved transit service within a specific area generally is expected to increase transit mode split and decrease demand for parking for the area. This area-wide change in mode split – and a corresponding decrease in parking demand – provides the basis for a reduction in parking requirements.

The specific number of spaces that can be omitted when transit provides good access to a development site requires a reasonably detailed analysis. This analysis must be tailored to a specific development project. Alternatively, it can be applied to a geographic area that is comprised of sites with similar transit characteristics. The following generic formula can serve as a starting point for this calculation, which presents the basic steps for estimating the effects of public transit on a new development's parking demand.

$$\sum_{u=1}^n \sum_{t=1}^{24} S_{t,u} = \left(\frac{U \times K_t \times D_{t/u} \times W_t}{O_t} \right) (1 - M_t)$$

where:

- S = Net reduction in parking demand when transit is provided during time period t .
- t = One hour during a 24-hour day and weighted for 85 percent of demand during peak season.
- u = Type of land use (e.g., office, industrial, retail, hospital, residential, amusement, etc.). Only necessary if development is mixed use or analysis covers more than one project (i.e., CBD, traffic analysis zone, etc.).
- n = Number of different land use types to be included in the proposed development project.
- U = Size of land use measured by units (e.g., square feet of floor space, number of employees, hospital beds, dwelling units, stadium seats, etc.).

⁶ Robert Weant and Herbert Levinson, *Parking*, 1990, p. 93.

- K_t = Proportion of total trips to the site that occur during time period t .
- $D_{t/u}$ = Person trips to the site per time period t per unit of land use u .
- W_t = Proportion of workers or visitors for which the site is the primary destination during time period t .
- M_t = Automobile mode share to the site during time period t when transit is available (i.e., percent of people coming to the site by car).
- O_t = Average occupancy rate for automobiles during time period t .

The formula calculates peak parking demand over a 24-hour day. This demand, however, will fluctuate seasonally. Thus, the variables should be weighted for seasonal demand, especially the person trips to the site (variable " D "). The formula can be applied to a specific project or to all development within a zone, provided transit ridership (i.e., mode split) is more or less constant across the zone.

The mode share for autos when transit is available is the critical variable and should be estimated using reliable data and a travel demand forecasting model. When data for a new development are input into this formula, an analyst may plot a curve showing demand for parking spaces with and without transit. The difference between these two curves at the peak period of demand represents the net number for parking spaces that may be eliminated from a development because of trips diverted to transit. Figure 9.2 shows a hypothetical case, where the maximum net parking reduction is estimated at the morning peak hour of demand.

Each individual municipality must determine the specific reduction in parking requirements it believes is appropriate given the availability of transit.⁷ The reduction depends on an individual project's proximity to transit stations and characteristics of their site design. The reduction may also be applied to an entire area as a special zoning condition. The City of Seattle, for example, has developed specific requirements for land use with high and moderate access to transit, as shown in Table 9.1.

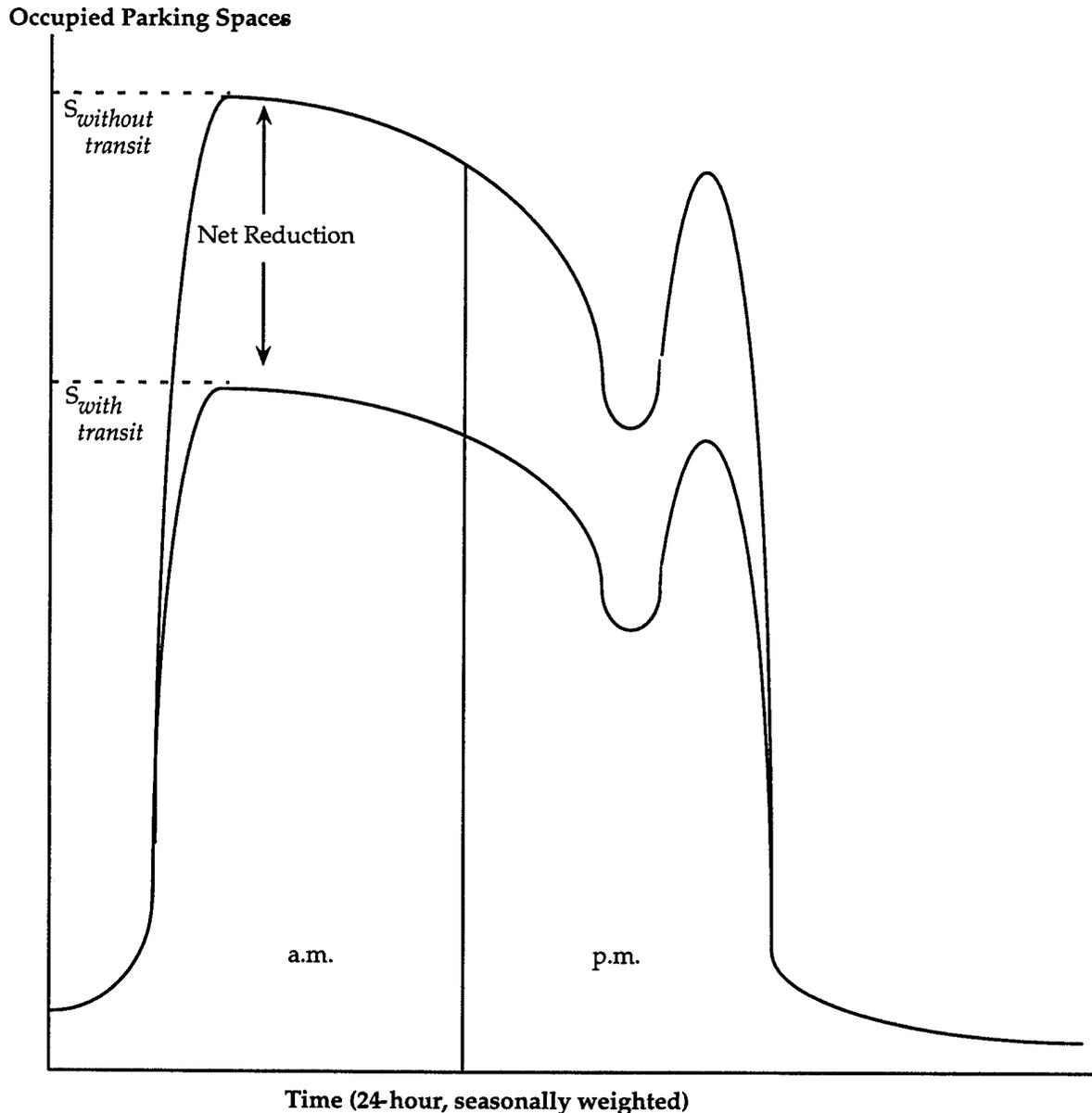
Table 9.1 shows that parking requirements for office development in high-transit-access areas are about 29 percent lower than the parking requirements for similar development in moderate-transit-access areas. For retail development, parking requirements in high-access areas are 52 percent of those in moderate-access areas.

The Boston Metropolitan Area provides another example of parking requirements indexed to transit accessibility. Over 20 years ago, the Massachusetts Department of Public Works in cooperation with the Federal Highway Administration (FHWA)

⁷ In theory, the provision of public transit effectively lowers the minimum demand for parking by some number of spaces. As a practical matter, however, the minimum amount of parking demanded by tenants is difficult to pin down. Stochastic fluctuations in demand for parking may cause some tenants to value some margin of surplus parking more than others. The value of surplus parking increases when alternative parking is unavailable or expensive.

prepared minimum and maximum parking requirements based on distance from transit stops. These requirements, shown in Table 9.2, are illustrative guidelines that may be applied to major transit corridors.

Figure 9.2 A Hypothetical Estimate of Reduced Demand for Parking Over 24 Hours when Transit is Available



Currently, many transit investments are being made in urban areas that either have no transit service or have limited, relatively new systems that are being expanded. Many of these areas (e.g., Seattle, Phoenix, Denver, Orange County (California), Salt Lake City, etc.) have relatively lower densities of development or are only recently achieving high-

density CBDs characteristic of older metropolitan centers with extensive fixed-guideway transit systems (e.g., New York, Chicago, Philadelphia, San Francisco, etc.).⁸ The former have high parking requirements (and relatively plentiful supplies of parking),⁹ reflecting heavy dependence on single occupant vehicle trips (i.e., an extremely low transit share). As a general characterization, these urban areas have evolved with auto dependent CBDs and must now retrofit transit systems into their cities.

Table 9.1 Parking Requirements for Downtown Seattle Expressed in Parking Spaces per 1,000 Gross Square Feet of Floor Area

	Office	Retail (except lodging)	Other Non- Residential	Lodging
Long-Term Requirements in Areas with High Transit Access				
Unrestricted Long-Term	0.54	0.32	0.16	1 space per 4 rooms
Carpool	0.13	0.08	0.04	1 space per 4 rooms
Total	0.67	0.40	0.20	1 space per 4 rooms
Long-Term Requirements in Areas with Moderate Transit Access				
Unrestricted Long-Term	0.75	0.56	0.16	1 space per 4 rooms
Carpool	0.19	0.14	0.04	1 space per 4 rooms
Total	0.94	0.70	0.20	1 space per 4 rooms
Short-Term Requirements in All Areas				
All Areas	0.1	0.5	none	none

Source: Robert Weant and Herbert Levinson, *Parking*, 1990, p. 48: Originally from the 1985 Seattle Parking Ordinance.

The high minimum parking requirements in these cities are often based on the common standard of four spaces per thousand square feet of leasable space, and an assumption that parking is provided free of charge or at a low fee. As a result, developers often provide the minimum number of spaces required by the zoning code. This minimum may be

⁸ There are a significant number of exceptions to this assumption of sufficient or oversupply: South Boston, Los Angeles, Minneapolis/St. Paul, Portland (Oregon) are examples of areas with recent or proposed transit investments that have reasonably dense CBDs with parking supply at or below demand. Analysis of the benefits of reduced parking, therefore, must be tailored to the specific parking supply and demand characteristics of the area.

⁹ An exception to this generalized situation is Portland, Oregon, which has experienced significant increase in CBD density. The city has capped CBD parking supply and invested heavily in transit. Thus, it represents an older CBD with a well established transit system.

Table 9.2 Boston Metropolitan Area Access Oriented Parking Strategy

Land Use	Activity	Criterion Unit	Number of Spaces per Unit by Distance from Transit Stop					
			0 - 500 Feet		500 - 1,000 Feet		1,000 - 1,500 Feet	
			Minimum Required	Maximum Allowable	Minimum Required	Maximum Allowable	Minimum Required	Maximum Allowable
Residential	Single family	Housing unit	0.5	1.0	0.7	1.0	0.8	1.3
	Multi-family	Housing unit	0.4	1.0	0.6	1.0	0.8	1.3
Commercial	General Office	GFA, 1,000 sq. ft.	-	2.0	1.0	2.0	1.7	2.9
	Medical - Dental Office	GFA, 1,000 sq. ft.	-	3.3	1.7	3.3	2.5	4.0
	Retail	GFA, 1,000 sq. ft.	2.0	3.3	2.5	3.3	3.3	5.0
	Restaurant	Seats	-	0.17	0.17	0.25	0.17	0.25
	Hotel - Motel	Rental units	0.7	1.0	0.7	1.0	0.7	1.0
Industrial	Manufacturing, warehouse, wholesale	Employees	0.2	0.33	0.25	0.33	0.33	0.5
Institutional ^a	Auditorium	Seats	0.13	0.2	0.13	0.2	0.14	0.25
	Hospital	Beds	0.80	1.0	0.80	1.0	1.0	1.4
	Church	Seats	0.14	0.2	0.14	0.2	0.14	0.25
Educational	Elementary & junior high school	Classroom & office	0.7	1.0	0.8	1.0	0.8	1.0
	Senior high school	Classroom & office	0.7 ^b	1.0 ^d	0.8 ^b	1.0 ^d	0.8 ^c	1.0 ^e
	College & university	Classroom & office	0.7 ^b	1.0 ^d	0.8 ^b	1.0 ^d	0.8 ^c	1.0 ^e

^a Where public use of an auditorium is likely, specific auditorium standards should apply.

^b Plus 1 space per 10-15 students, except where constrained by policy.

^c Plus 1 space per 8-10 students, except where constrained by policy.

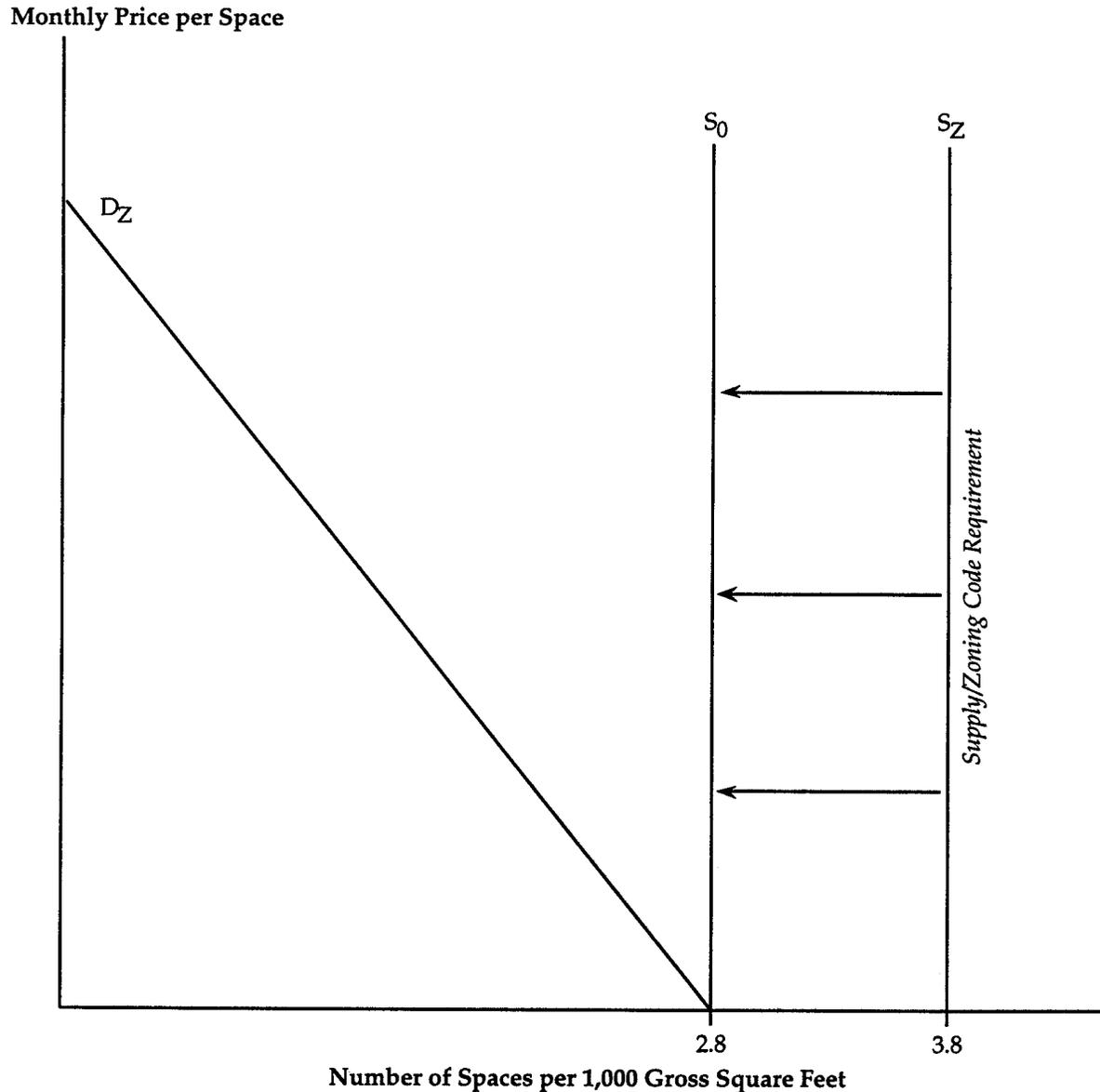
^d Plus 1 space per 8-10 students, except where constrained by policy.

^e Plus 1 space per 5-8 students, except where constrained by policy.

Source: Estimated by Wilbur Smith and Associates for *An Access Oriented Parking Strategy for the Boston Metropolitan Area*. Final report prepared by Massachusetts Department of Public Works in cooperation with Federal Highway Administration (July 1974). Table appears on page 49 in Weant and Levinson, *Parking*, 1990, page 49.

modeled as a vertical supply curve (S_z) shown in Figure 9.3.¹⁰ The downward sloping demand curve, D_z , shows that as the price of parking decreases, workers (and visitors)

Figure 9.3 Parking Demand and Supply in Suburban and Auto Dependent Urban Areas



Source: Cambridge Systematics, Inc.

¹⁰ A vertical supply curve is also consistent with a fixed short-term supply of parking, which is usually the case given a finite supply of land suitable for parking and the relative long lead time necessary for construction of new parking, especially structured or underground parking. The inelastic short-term supply contrasts with the high variability in short-term demand, which can fluctuate daily.

will use more parking. The adequate supply or oversupply of parking, however, means that the demand for parking either (D_z) intersects the supply curve (S_z) at the x-axis or it never intersects the supply curve. The market, therefore, will not indicate the most efficient quantity of parking at any price.

These requirements are often based on the common standard of four spaces per thousand square feet and assume parking is provided free of charge or at a low rate. As a result, developers often provide the minimum number of spaces required by the zoning code.¹¹ Thus, the minimum parking requirements may be modeled as a vertical supply curve (S_z) shown in Figure 9.3. The downward sloping demand curve, D_z , shows that as the price of parking decreases, workers (and visitors) will use more parking. The adequate or oversupply of parking, however, means that the demand for parking either never (D_z) intersects the supply curve (S_z) at the x-axis or it never intersects the supply curve; therefore, the market will not indicate the most efficient quantity of parking at any price.

Parking utilization surveys often show actual peak-demand levels between 2.0 and 3.0 spaces per 1,000 gsf.¹² Utilization rates for five Southern California case studies, for example, report parking occupancy at large suburban office parks averaged 56 percent of capacity at peak periods.¹³ Furthermore, the Institute of Traffic Engineers reports average parking generation rates of 2.8 spaces per 1,000 gsf for general office buildings and 2.5 spaces per 1,000 gsf for business parks, assuming parking has zero cost to the driver. Thus, the supply curve (S_z) may be shifted left to where it intersects the x-axis at 2.8 space (S_0). If parking requirements for new development are similarly changed, two important impacts will occur. First, developers will save on costs of constructing parking, including the cost of land. Second, because less land must be devoted to parking, developers will be able to provide more built space within the same lot dimensions. (This latter benefit is only possible when demand is strong enough to absorb the additional supply.)

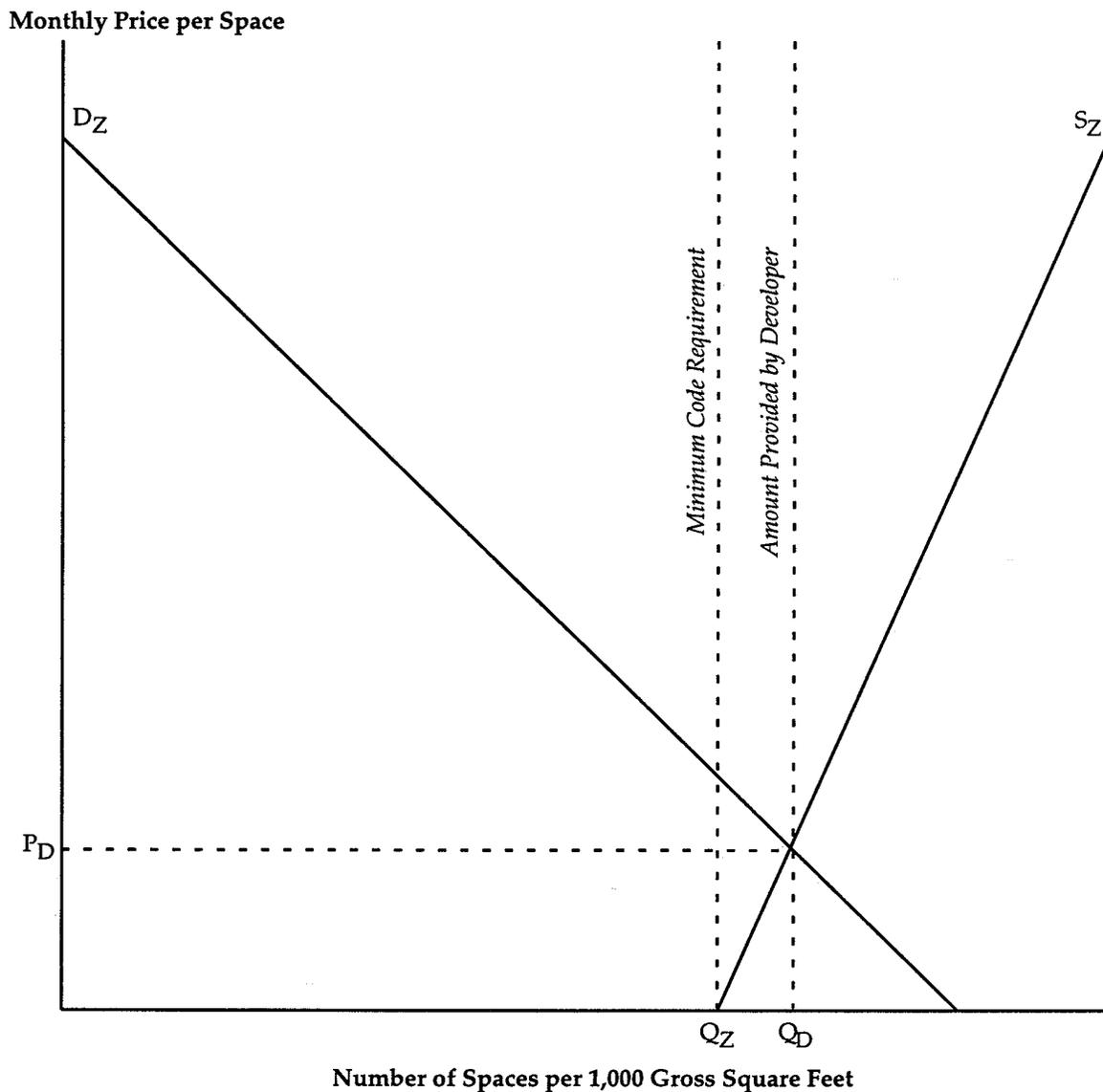
In Figure 9.4, parking requirements (Q_z) are lower than demand. Under one scenario, a developer might provide more than the minimum required parking (Q_b) and can charge a price (P_D) for parking. This situation would be most likely to occur in higher density urban areas and CBDs where the supply of parking is constrained. In this case, land costs would be high and developers would likely build expensive structured or underground parking in order to maximize leasable space on a finite amount of land. The supply curve (S_z) is slightly sloped and developers can collect a parking charge (P_D).

¹¹ Richard Willson, "Suburban Parking Requirements," *Journal of the American Planning Association*, Vol. 61, No. 1, Winter 1995, p. 34.

¹² Smith and Hekimian, 1985; Gruen Gruen & Associates, 1986; Institute of Transportation Engineers, 1987; Cervero, 1989. A utilization survey of Seattle suburbs reported an average surplus of 36 percent more spaces (Municipality of Metropolitan Seattle, 1991).

¹³ This average utilization rate was for five "typical" suburban sites in Southern California (Willson, 1995).

Figure 9.4 Parking Demand with a Constrained Supply of Parking



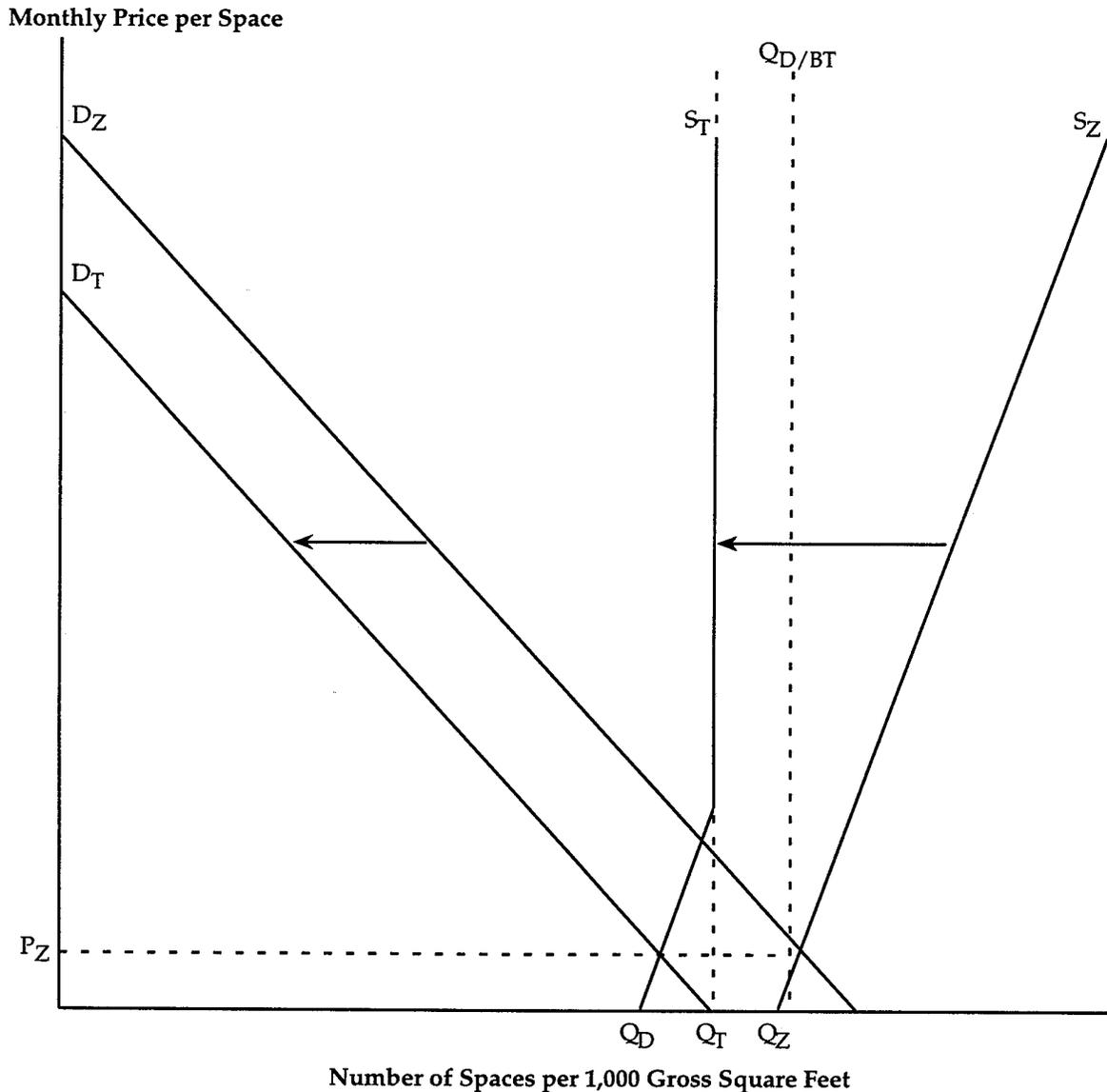
Source: Cambridge Systematics, Inc.

Figure 9.5 shows what happens when transit service is introduced. Demand for parking decreases from D_Z to D_T . In this case, the minimum amount of required parking before transit (Q_Z) is lowered (to Q_T) by imposing a maximum amount of required parking (S_T).¹⁴ This maximum is set at an amount proportional to the mode shift with transit. Thus, in

¹⁴ Alternatively, a reduction in the parking requirement could be accomplished by lowering the minimum requirement. In this case, the supply curve would be upward sloping along its entire length and parallel to S_Z .

the short-term, the downward-sloping supply curve (S_Z) shifts left to a vertical supply curve (S_T). Since the parking requirement is a maximum, the supply curve begins to slope at the intersection of new demand curve for parking with transit (D_T). The actual decrease in supply is from the quantity provided by developers before transit (slightly more than the minimum requirement, $D_{D/BT}$) to Q_T .

Figure 9.5 Parking Demand and Supply with the Introduction of Transit



In this hypothetical example, the price that developers can charge for parking remains at the pre-transit level (P_Z). Thus the entire benefit of reduced parking requirements is captured in the developers' savings in the foregone construction costs of parking and the opportunity costs of the additional leasable space that may be substituted for parking. If drivers did not switch to transit at the rate anticipated, prices would rise. If no drivers

shift to transit, the price would rise to where the pre-transit demand curve (D_z) intersects the after-transit supply curve (S_T).

Market Forces and the Allocation of Benefits

The beneficiary of lower parking requirements is determined by the markets for land and building space. While these two markets are closely linked, their relative scarcity, the knowledge of participants in the development process, and a host of other market forces will determine whether the land owner, the developer, or the tenant realizes some or all of the benefits. While an analyst may be relatively certain that reduced parking generates real benefits, who actually benefits from reduced parking requirements is difficult to determine, especially in the long term. This discussion is intended to summarize the major forces affecting who will enjoy the benefits of reduced parking.

- **Land owners** who know the value of the benefits to the developer capture the majority of benefit when raw land or underutilized sites that could be developed or redeveloped are scarce and low vacancy rates are encouraging developers to build more space. A shortage of land in a high-demand area drives the price of land up, thus increasing the market leverage of land owners holding the few available parcels. They may sell their land at a premium. In this case, the benefit of the reduced parking is high and the benefit tends to accrue to land owners. When the demand for land is weaker, the cost of the land is lower and parking itself becomes less costly for a developer to provide. In this case, the benefit of a reduced parking requirement tends to be less and it does not accrue to the land owner.
- **Developers** may garner most or all of the benefit if they know the value of the benefits. In addition, vacancy rates must be low (i.e., the supply of competitive building space must be scarce and tenants abundant), and sufficient land available to weaken the leverage of land owners. Under these conditions, developers may substitute leasable space for parking, and tenants (who are competing for scarce space) are more likely to forego cheaper, more abundant parking.
- **Tenants** may accrue the value of the benefits over the life of their lease if they know the value of the reduced parking benefit and vacancy rates are high. Under such circumstances, their gain may come at the expense of the developer or the land owner or both, depending on the other market conditions. High vacancy rates, for example, would force developers to lower lease rates, thus passing the benefits of reduced parking on to the tenant. The leverage of tenants, however, may be somewhat diminished by the attractiveness of building space with good access to transit.

Figure 9.6 shows a matrix of market forces affecting who in the development process accrues the benefits from reduced parking requirements. The table is general and does not provide an analyst with a template for a specific situation. Furthermore, it assigns benefits over one development cycle (i.e., from the beginning of one building boom to the beginning of the next). Many of these assignments will shift over the mid-term or long term.

Figure 9.6 Allocation of Benefits of Reduced Parking Requirements

Market Conditions	Benefits of Reduced Parking to:		
	Land Owner	Developer	Tenant
<i>Available land/high vacancy</i>	no benefit	modest benefit – reduced land cost ¹	large benefit – lower lease cost
<i>Available land/low vacancy</i>	no benefit	large benefit – reduced land cost and high lease	no benefit
<i>Scarce land/high vacancy</i>	moderate benefit – higher land prices	no benefit	moderate benefit – lower lease cost
<i>Scarce land/low vacancy</i>	large benefit – higher land prices	large benefit – higher lease cost and more leasable space ²	no benefit ³

Notes:

- ¹ Given high vacancy rates, developers would not be building significant amounts of space except as long term investments that will most likely encounter different market conditions. Thus, modest benefits only accrue to developers with projects underway.
- ² Assumes that the increase in leasable space due to substitution for parking does not significantly increase vacancy rates.
- ³ The substitution of leasable space for parking would only partially offset the low vacancy rate. On the margin, therefore, the benefits of reduced parking may accrue to the tenants of the additional space. In the long term, low vacancy rates would stimulate developers to building more space.

Source: Cambridge Systematics, Inc.

In a strong market (i.e., low vacancy), high demand for scarce building space would absorb all the square feet of space a developer could provide on a constrained supply of land. Thus, lower parking requirements would allow a developer to substitute leasable space for parking stalls. The benefit of a strong market is that the developer gains the marginal profit generated by the additional leasable space that would have been otherwise devoted to parking. In a strong real estate market, this foregone profit may be a substantial part of the benefit derived from the parking reduction.

An important exception to this scenario could occur where zoning restrictions limit the density in urban land markets. A maximum density zoning requirement could constrain a developer from substituting leasable space for parking. Under such circumstances, higher levels of parking may be profitable. Thus, a reduced parking requirement (imposed as a *maximum* number of allowed spaces) could set supply of parking stalls below market demand, imposing a cost rather than a benefit on a developer equal to the foregone profit on the disallowed spaces.

The residual benefit in a strong market depends on the profitability of the parking stalls in their own right. If the developer can charge parking rates that exceed the cost of the stalls' construction and maintenance/operation, then this profit must be subtracted from the profit of substitute leasable space. If parking stalls cost more to construct and maintain/operate than can be generated from their use, this foregone cost may be added to the marginal profits generated by substitution of leasable space for parking.

In a weaker market, a reduced parking requirement could lower development costs sufficiently to allow projects to proceed that would not otherwise have generated an adequate return to the developer. This improvement to a project's feasibility may come about in the following ways.

1. The cost savings due to reduced parking requirements may be applied to other project costs, allowing a project to move forward.
2. The space previously needed to provide parking may be used for (and the cost savings may be used to finance) additional amenities to enhance the marketability of the project. These amenities would attract more affluent tenants or accelerate absorption, thus increasing lease revenues to the developer or justify building more space on the land previously used for parking.
3. The cost savings may be used to lower rent or provide other concessions that would make the property more competitive.

The Cost and Price of Parking

The true cost of providing parking depends on the type of parking (i.e., surface, structured, or underground), the cost of land and construction, and the real estate market. This latter category may be the most critical. The real estate market determines the "opportunity cost" of using land for parking. Opportunity cost is measured as the value of the land used for parking if instead it could have been put to a higher and more profitable use. The opportunity cost of reduced parking may constitute the majority of the benefits in a strong real estate market.

Cost of Parking

The cost of parking may be broken into four components: land, construction, financing, and operations/maintenance. The per unit cost of each component – especially the first two – varies widely among regions and even adjacent parcels; thus, an analyst interested in the benefits from reduced parking must collect accurate cost data for each component. The following are break-even cost estimates needed to cover construction, operations, and maintenance. The cost estimates assume a land value of \$11 per square foot, 370 square feet per space, and \$1,000 per space construction costs with all capital costs amortized at 7.5 percent over 30 years and monthly operating costs of \$1.60 per space (all costs in 1992 dollars). The costs below are provided as rough comparisons among the component costs:

- **Surface lot stalls** cost roughly \$2,000 to build, not including the cost of land. As a very rough benchmark, the amortized cost of surface parking is \$37 per month (including \$29 per month for land). In a case study of suburban office developments in Southern California, monthly parking costs for six surface lots were on average \$48 per space with a range between \$28 and \$61, depending on the land costs and the efficiency of the lot's design.¹⁵
- **Multilevel structure stalls** cost roughly \$5,000 to build, not including the cost of land. For structured parking, the amortized monthly costs averages \$97 per space. The construction costs for the structure range between \$9,000 and \$12,000 per space.¹⁶
- **Underground stall** costs range roughly between \$20,000 and \$24,000 to build, depending on the seismic design requirements and subsurface soil conditions.¹⁷

Parking stalls – whether surface, structured, or underground – require roughly 400 square feet, including space for aisles and driveways. Two very general rules of thumb are that a developer 1) needs about one and one-half times as much space for parking as is needed for people using the leasable space¹⁸ and 2) will construct structured parking instead of surface parking at a floor-area-ratio (FAR) over 0.4.¹⁹ The choice between underground and multilevel structured parking is more complex and often dictated by the zoning code, subsurface soil conditions, and financing constraints.

Table 9.3 provides a set of aggregate cost categories for each of the three types of parking: surface, multilevel stand-alone structure, and underground (with building space above). The costs shown in Table 9.3 are generic and based on a set of assumptions constant across all three types of parking. Although the high and low figures represent national averages, actual values depend on a particular project. In dense urban areas with limited vacant land, for example, land costs may be far in excess of these average costs. The total break-even costs shown as the bottom line of the table represent an approximate range of costs that a developer can avoid by not building a parking stall. These numbers, however, do not represent a net savings. To calculate a net benefit, parking revenues (if any) must be subtracted from the break-even cost and compared to the net earnings on leasable space that may be substituted in place of the parking (if any).

¹⁵ These costs, however, are based on full occupancy of all spaces. Given that national occupancy rates for parking average 50 percent of capacity, the cost of a parking stall increases from \$37 per month to roughly \$74 per month. The Southern California case studies calculated an increase from \$48 per space per month to \$92 for suburban surface lots. (Richard Willson, "Suburban Parking Requirements," *Journal of the American Planning Association*, Vol. 61, No. 1, Winter 1995, p. 31).

¹⁶ Assuming a 50 percent occupancy rate, the cost of a parking stall increases from \$97 per space per month to \$161 for structured parking. (Richard Willson, "Suburban Parking Requirements," *Journal of the American Planning Association*, Vol. 61, No. 1, Winter 1995, p. 33).

¹⁷ Shoup, Donald. "The True Cost of Free Parking," *Parking Today*, August 1997.

¹⁸ This need should not be confused with parking requirements, which average roughly around four spaces per 1,000 square feet of office space and one space per 350 square feet of retail development.

¹⁹ A 0.4 FAR is equivalent to a 40,000-square-foot building on a 100,000-square-foot lot. (Joel Garreau, *Edge City*, Doubleday, 1991, pp. 118-121).

Table 9.3 Cost Estimates Per Parking Stall (1997 Dollars)

	Surface Lot		Above Ground Multi-Level Structure		Below Ground	
	low	high	low	high	low	high
	Land	\$600	\$12,000	\$500	\$1,000	\$0
Construction	1,500	4,000	8,800	20,000	16,000	40,000
Design, Engineering, & Contingency	200	800	1,800	5,000	3,200	10,000
Project Costs	\$2,300	\$16,800	\$12,100	\$26,000	\$19,200	\$50,000
Present Value of Annual Interest Payments	2,100	14,700	9,700	22,700	16,800	43,700
Present Value of Annual Operating Costs	700	2,800	2,800	5,600	2,800	5,600
Total Break Even Cost per Parking Stalls	\$5,100	\$34,300	\$24,600	\$53,300	\$38,800	\$99,300

Assumptions:

1. **Land costs** range between \$600 to \$12,000 per stall for surface lots; between \$500 to \$1,000 per stall for multilevel structures (average for three or more levels); and zero cost for underground parking.
2. **Construction costs** range between \$5 to \$10 per square foot for surface lots; between \$28 to \$50 per stall for multilevel structures; and \$50 to \$100 per stall for underground parking.
3. **Design, engineering, and contingency costs** range between 15 to 20 percent for surface lots and between 20 to 25 percent for multilevel structures and underground parking.
4. **Interest expense** is the present value for a 24-year loan at 9.0 percent discount rate.
5. **Operating cost** is the present value (discounted at 9.0 percent) over 24 years for monthly costs of \$0.25 to \$1.00 per stall for surface lots and between \$1.00 to \$2.00 per square foot for multilevel structures and underground parking. These include utilities, attendant, insurance, overhead, janitorial service, routine repairs, etc.

Sources *Parking*, Robert Weant and Herbert Levinson and Cambridge Systematics, Inc.

An estimate of the monetary benefits that result from reduced parking for a specific project requires a detailed pro forma analysis. Pro forma analysis is a standard financial planning tool in real estate development. It presents project costs and revenues over time and calculates a net profit (or loss) in each year (or month). In order to estimate the benefits of reducing parking at developments in close proximity to transit service, the analyst must prepare two pro forma analyses: 1) one that assumes no transit service and no reduction in required parking; and 2) one that assumes transit service is available and parking requirements are reduced. The net difference between the second and the first represents the benefits.

Figures 9.7 and 9.8 provide generic operating and investment templates itemizing parking costs and revenues that should be included in a general pro forma analysis. An actual pro forma may include line items specific to the type of development (e.g., office, amusement, industrial, big-box retail, etc.). Specific values depend on the particular project and have not been included here.

Ideally, these templates should be set up to analyze a parking facility as an integral part of a development's primary land uses, such as an office tower, retail mall, etc. Such a comprehensive pro forma analysis is a complex undertaking and requires access to confidential information that most developers would not be willing to make available to outside parties. An analyst, therefore, should expect to prepare a pro forma for the parking facility as a stand alone project.

This approach simplifies the analysis, but it ignores the very important financial consequences that would occur when leasable space is substituted for the reduced parking. Under this circumstance, it is important to estimate the profit a developer would earn on each increment of leasable space he or she can substitute for each increment of reduced parking. The necessary information may be obtained from interviews with the developer, asking real estate experts to make estimates, or examining the project proposal and approval documents on record at the local planning department.

To estimate the net annual benefits of reduced parking, an analyst would prepare two versions of an operating pro forma sheet modeled after Figure 9.7. The net annual savings would be the difference in Spendable Income (line 7) between the two pro formas. Taking the net present value (NPV) of the income stream provides a single cost that may be added to the investment savings calculated in the investment pro forma (Figure 9.8).

A second investment pro forma analysis must be completed for the construction period of the project (Figure 9.8). The investment pro forma itemizes all the capital costs of construction. It can usually be collapsed into a single column of costs unless construction is phased over a long period of time (i.e., five or more years). For a phased project, an analyst should determine if lower costs due to reduced parking occur evenly throughout the construction period or are grouped together during a specific phase.

To estimate the net one-time capital benefits of reduced parking, an analyst would prepare two versions of an investment pro forma sheet modeled after Figure 9.8. The net benefit would be the difference between the Total Investment (line 10) of the two pro formas. The total net benefits of reduced parking equal the NPV of the stream of operating savings (from Figure 9.7) and the NPV investment difference.

Figure 9.7 Generic Operating Pro Forma Analysis Template for Paid Parking Facilities

Operating Pro forma	1998	1999	2000	etc.
Gross Income Annual rent (#stalls x rate/day x 365 or 260, depending on land use ¹) Other income				
1. Total Gross Income				
Vacancy & Collection Loss Allowance (vacancy rate x annual rent) plus collection losses, etc.				
2. Total Vacancy/Collection Loss				
3. Effective Gross Income (#1 - #2)				
Operating Expense Property Management (payroll, legal, accounting, marketing, brokers, advertising) Utilities, Energy, Communications Repairs, Maintenance Contingency (to carry one year of operating costs and two months of financing costs)				
4. Total Operating Expense				
5. Net Operating Income (#3 - #4)				
Fixed Costs Property & Title Insurance Mortgage Interest/Debt Service Real Estate Taxes Replacement Reserve				
6. Total Fixed Costs				
7. Spendable Income (#5 - #6)				
8. Capitalization Rate (#5 ÷ #10)				
9. Cash on Cash (#7 ÷ Equity)				

¹ If a parking facility is used primarily during the work week (e.g., by employees of office buildings), 260 should be used, as there are approximately 260 work days in a year. If the parking facility is used seven days a week at full capacity (e.g., parking for a major retail development), it may be appropriate to use 365 days.

Source: Cambridge Systematics, Inc.

Figure 9.8 Generic Investment Pro Forma Analysis Template for Paid Parking Facilities

Total Investment	Construction Period ¹			
Hard Costs (includes parking)				
Land Cost				
Site Development (site preparation, earthwork, paving/ roads/parking, drainage, sewer, water, electricity/ phone, landscaping, site amenities)				
Parking Construction				
Signage, Revenue Control and Security Equipment				
Other Hard Costs				
Contingency				
10a. Total Hard Costs				
Soft Costs				
Architect Fee				
Other Fees (structural, mechanical, civil, landscape, etc.)				
Legal/Accounting				
Developer's Overhead & Fee				
Builder's Insurance				
Permits, Licenses				
Construction Loan Interest/Debt Service				
Financing Fees/Points				
Other Soft Costs				
Contingency				
10b. Total Soft Costs				
10. Total Investment (10a + 10b)				

Notes:

¹ Construction may last only one year or be phased, extending over a number of years.

Source: Cambridge Systematics, Inc.

Price of Parking

In a free or unregulated market, developers would provide the quantity of parking and charge a price that would maximize their profits.²⁰ Although determining this optimal supply and price involves a complex balance between many factors, it is basically a three-way tradeoff between: the willingness of tenants to lease the available space with a

²⁰ In a minority of cases when parking generates a profit, alternative uses are in some way regulated that leaves parking as the highest and best use of the available land. Parking on the abandoned piers along the San Francisco waterfront, for example, has been profitable to the Port of San Francisco because all other profitable uses are excluded by local and state laws.

minimum supply of parking, the cost of constructing parking, and the highest price that can be charged and still obtain full (or near full) occupancy.

In almost any situation where transit service is being proposed or exists, however, the supply of parking is almost always regulated. Thus, developers set the price of the parking such that they can recover some, all, or even more than the capital and/or operating cost of parking through some mix of the three following approaches:

- **Free Parking.** Parking is provided at no charge to the driver and the funding for its construction and operation are incorporated into the price of the lease for space. Depending on the strength of the real estate market and the availability of competitive space with sufficient "free" parking, a developer may recover the full cost of parking from the lease revenues. This approach usually involves lower-density development on low-cost land.
- **Break-Even Charges.** Parking rates (hourly, daily, or monthly) are set such that the capital and operating expenses of the facility are fully funded from the facility's revenue stream. This approach may be used also to supplement the revenue stream from an assessment district formed to repay the debt on a public parking structure.
- **Profit Maximizing Charges.** In areas of sufficiently strong demand or where parking is one of a few land uses allowed under the zoning regulations, paid parking can generate a profit. Some underground parking in high-density urban development, for example, offers such opportunities. Parking rates are set as high as the market will bear.

The average price of paid parking in North America ranges from less than a dollar per day in rural areas to over \$8 per day in urban areas with over 3,000,000 population. Figure 9.9 summarizes these findings.²¹

The amount a developer charges and the method he or she uses has a direct effect on the net benefits derived from reduced parking requirements. "Free" parking provides no incentive for drivers to use transit. Thus, the mode shift to transit for areas with free parking will be low compared to areas with only paid parking, and as the charge for parking increases, mode shift to transit should increase. The influence of parking prices and access to transit on mode shift, however, depends also on congestion, car ownership, travel demand management (TDM) incentives, and other non-price factors. A possible unintended side effect of increased parking prices, particularly for retail development, is that competing destinations with free parking available may become more popular.

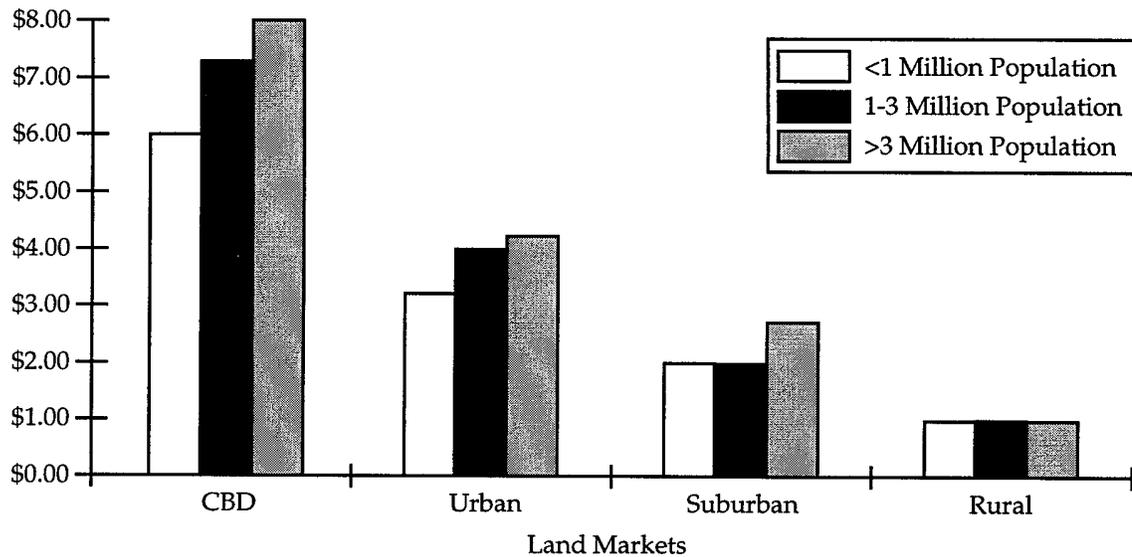
Increased parking revenues allow a developer to cover more of the cost of providing parking, and in some cases to generate a profit solely from the parking revenues. Under these conditions, the benefits to a developer of reduced parking requirements diminish as the gap between revenue and cost narrows. Reduced parking requirements

²¹ Don Pickrell, "Eliminating Employer-Subsidized Parking," in *Climate Change Mitigation: Transportation Options*. Volpe National Transportation Systems Center (Cambridge) for U.S. Environmental Protection Agency, 1993.

(implemented as a maximum allowable parking requirement) become a disbenefit to the developer at the price point at which that parking becomes profitable, if he or she cannot substitute a higher and better use for the parking. Nevertheless, the public will still benefit because higher parking prices or reduced parking supply will increase transit ridership, thus increasing farebox recovery, reducing congestion, improving air quality, etc.

Figure 9.9 Average External Parking Costs per Automobile Commuter

**Average Daily External Parking
Cost per Auto Commuter**



Source: Don Pickrell, "Eliminating Employer-Subsidized Parking," in *Climate Change Mitigation: Transportation Options*. Volpe National Transportation Systems Center (Cambridge) for U.S. Environmental Protection Agency, 1993.

Second-Order Impacts

The benefits described above accrue directly to the land owner, developer, or tenant; they are monetary and relatively short-term. In addition, second order impacts (both benefits and disbenefits) occur when parking requirements are reduced. These impacts are usually longer-term and more difficult to convert into monetary values. They also tend to accrue to the public at large. The following six impacts are examples of additional benefits and disbenefits conferred on the general public. For the most part, they are not quantifiable.

Parking Demand at Suburban Transit Stations

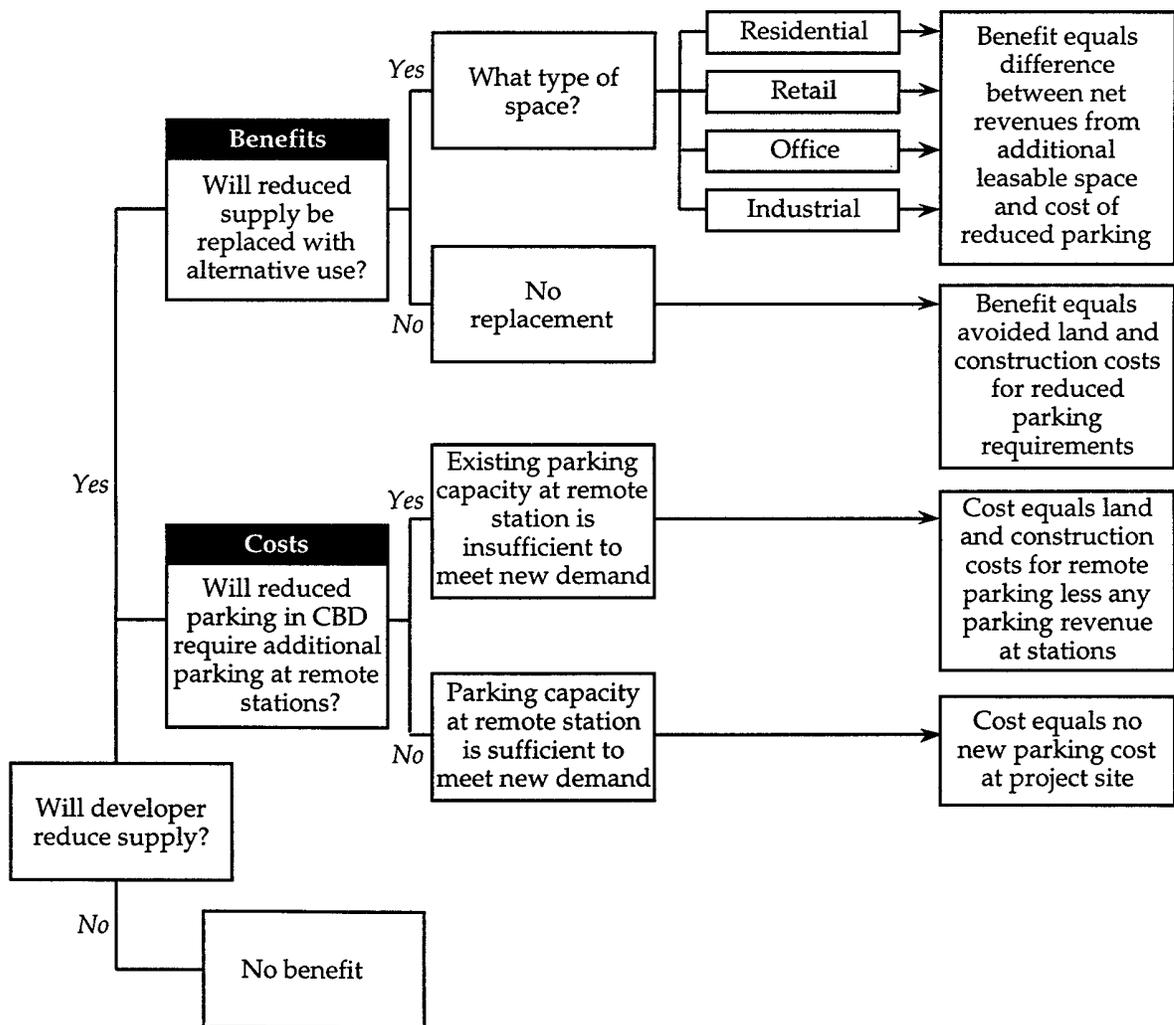
Most transit home-to-work trips to urban employment centers involve an automobile driver parking at a suburban transit station and then riding transit to work. These sta-

tions provide parking (sometimes free) for riders that drive their cars from their homes. When parking requirements are reduced at the work place (i.e., the CBD), the reduction is in *response* to the availability of transit and thus intended to reduce the supply of parking in the CBD.

Some transit systems, however, have extremely constrained supplies of parking at their suburban stations (e.g., BART in the San Francisco Bay Area). For these systems, a reduction in parking requirements for development near existing or new urban/CBD transit stations as service is extended (i.e., the job end of a trip) increases the demand for parking at the suburban transit station. As a result, the actual benefit of reduced parking requirements should be decreased by the cost of providing parking at the suburban transit station (home-end of commute trip).

Figure 9.10 shows the decision path an analyst should follow to determine the type of benefit a parking reduction may generate.

Figure 9.10 Net Benefits of Reduced Parking for Urban, Transit-Served Areas



Parking at suburban stations is generally less expensive than in urban employment locations because of lower land costs and the increased likelihood that surface lots can be built rather than structured or underground parking. The net benefit, therefore, still should be positive. Furthermore, not all new riders will require parking at the suburban station if feeder buses, carpools, and other alternative modes are available for the trip from home to a transit station.

Episodic or Unexpected Demand

Reducing parking requirements will force a developer to gamble that future events will not create frequent episodes of peak parking demand in excess of the available supply. As a general rule, parking supply is sized to accommodate 85 percent of the highest daily peak demand in a year. Thus, developers are already balancing adequate parking supply with cost-cutting design considerations, and the further reduction in parking due to transit service should not affect the demand for parking more on peak days than off-peak days. Nevertheless, a number of scenarios could generate more parking demand from transit riders. These scenarios include:

- Temporary or long-term transit service outages due to natural disasters (e.g., earthquakes, floods, power outages, etc.), strikes, maintenance problems, etc.
- General decline in transit service quality including reliability, safety, fewer operating hours, route restructuring, increased fares, and equipment attrition.
- Special events such as conventions (out-of-town visitors), sidewalk sales, concerts, etc., that encourage or require that people use their cars.
- Change in building tenants from one with more transit-oriented workers or clientele to one that is more auto-oriented.

The costs that these scenarios impose on a tenant or owner may be temporary or longer term. Consequences include illegal street parking, lost store or office patronage, higher vacancy rates, lower rental income, etc. In addition, excess parking demand frequently results in spill-over to on-street spaces, thus increasing traffic congestion, displacing shoppers, and disrupting neighborhoods. Given limited experience with these occurrences, they are difficult to quantify.

Increased Farebox Revenue

When transit is available as an alternative mode, a jurisdiction may reduce parking requirements by two increments. The first reduction is an amount equal to the voluntary mode shift. This assumes parking remains at the same general price level after transit is introduced. This first reduction is in response to drivers who decide to ride transit; thus, the minimum parking requirements are reduced as an acknowledgment that those requirements are too high given transit's mode share. This reduction, therefore, does not *cause* an increase in farebox revenues.

A second reduction in parking requirements (i.e., a parking maximum requirement) could induce more drivers to ride transit by making parking scarce. This scarcity means drivers must either wait for spaces to become available, walk to their final destination from remote parking lots, or pay more for the remaining spaces (or pay for previously free parking). Regardless of which option is available, this second reduction will cause more drivers to use transit (and some other alternative modes as well). Their ridership will increase farebox revenues and farebox recovery rates; thus fares are not increased (or not increased as much).²²

Land Conservation

This section identifies three types of land conservation that may result from reduced requirements for parking:

1. The creation (or conservation) of urban open space that would have otherwise been used for parking;
2. The conservation of suburban open space because suburban development is shifted to the urban or CBD areas; and
3. The lower consumption of suburban land for parking at suburban developments.

The first two cases involve more typical transit investments. The first case is a straight substitution of urban open space for parking. The open space may be required by the zoning code, but many developers are finding this amenity adds to the marketability of their property. In the second case, transit into the CBD improves access and reduces the need for developers to construct expensive structured or underground parking. Thus, development in urban areas or the CBD becomes more feasible and may attract development that would otherwise occur on suburban open space.

The last example involves less traditional transit systems that have been constructed in (or are being planned for) more suburban or low-density urban areas.²³ For most suburban office parks and retail malls, surface parking and stand-alone structured parking take up significant amounts of land. This is especially true for campus-style suburban office parks, which are generally surrounded by acres of surface parking at a rate of roughly four spaces per 1,000 square feet of building or approximately one and one-half times as much space for cars as people.²⁴ A developer who is required to build less surface parking, therefore, will purchase less land than he might otherwise have been required. The smaller purchase lessens the competition for raw land and hence exerts less upward

²² It must be acknowledged that this benefit would result in a reduction in the Highway Trust Fund revenues, but at the local level this loss would be insignificant.

²³ Examples include the light rail systems in Santa Clara County (i.e., Silicone Valley) and Sacramento, California, and planned systems in Salt Lake City and the western and southern extensions in Portland, Oregon.

²⁴ Richard Willson, "Suburban Parking Requirements," *Journal of the American Planning Association*, Vol. 61, No. 1, Winter 1995, pp. 30 and Joel Garreau, *Edge City*, Doubleday, 1991, pp. 118.

price pressure. A local government may then purchase the land for the lower price and preserve it as public open space. The savings accrue to local taxpayers, who would otherwise have to spend more for the same amount of land or who would have bought less land for the same amount of money. The price differential between the cost of acquiring land for public open space with and without the parking reduction provides a monetary estimate of the benefit from reduced parking.

Reduced Barrier Effect

A parking lot, especially large structured parking in urban areas and surface lots common in suburban office parks, impedes pedestrians, discourages would-be transit riders, and increases out-of-vehicle travel time for both auto and transit users. The amount of building set-back to accommodate parking is specified in site-design guidelines, which are used to promote more pedestrian and transit-oriented communities. The effect of an improved transit- and pedestrian-oriented environment on transit mode share has been quantified for Portland, Oregon, but a measurement of the specific effects of building set-back has not been estimated.²⁵ Nevertheless, the empirical evidence suggests that transit ridership will increase if distances between transit stations and buildings are short and more pedestrian-friendly.

Fiscal Impacts

Many local governments tax both business activity and parking. Parking, however, is frequently free (thus not taxed) and business activity (and housing) generate considerably more tax revenue per square foot than does paid parking. If a reduction in parking requirements allows for more commercial activity, local jurisdictions should collect a corresponding increase in tax revenues. Estimating the amount of the increase involves a straightforward calculation: the difference between taxes collected on the additional commercial or residential development and the foregone taxes on the paid parking.

Public vs. Private Benefits

Amidst all the analysis of how to estimate the amount of benefit from reduced parking requirements and who captures the benefit, it is easy to overlook the original source of the benefit: public transit. Were it not for the transit agency and the public moneys used to support it, parking requirements would not be possible to reduce. Thus, the direct benefit of reduced parking to a land owner, developer, or tenant is – in effect – a transfer of public spending to private profit. As defined in this study, an *economic* impact due to transit investment generally has been considered a generative impact to the general public, whether that term includes a neighborhood or an entire region.

²⁵ *The Interrelationships of Land Use, Transportation, and Air Quality (LUTRAQ)*, 1,000 Friends of Oregon, 1991. Cambridge Systematics investigated what effects land use, urban design, and transportation policies would have on future development, travel patterns, and air quality in the region using enhanced travel demand modeling capabilities.

Direct benefit to a specific private entity does not generate significant direct *economic* impact.²⁶ To create an *economic* impact, the transit agency or some other public jurisdiction must tax some portion (and possibly the full value) of the reduced parking benefits to the private entity and use the revenue to fund the transit improvements (or some other civic project). This approach, known as value capture, ensures that the benefits of transit are realized by the public and users who are ultimately paying for the system's construction and operation.

In many areas, however, transit systems are funded in some part by assessment district revenue. This approach, employing a direct form of value capture, requires landowners to pay either a one-time fee for the system's construction or an annual tax used to retire debt and/or fund operating expenditures. These fees or taxes are then distributed among the land owner, developer, and tenant depending on the market forces discussed in the previous section. When such assessment districts are in effect, and especially when the assessments are set at a rate sufficient to fund a significant amount of the system's capital and operating costs, further taxation of the benefits from reduced parking may not be necessary to recoup the benefits from the private sector.

■ 9.2 Transit-Induced Accessibility and Agglomeration Benefits: Estimation Based on Land Markets

Introduction

The land use impacts of transit investments are widely understood to be largely redistributive. It is well established that, under the right conditions, transit investments can induce shifts in land use activities, leading to compact station area development (Knight and Trygg, 1977; Cervero, 1984). This generally means that urban growth that might otherwise have been oriented around freeway interchanges and along highway corridors instead occurs around transit nodes.

The clustering of activities near rail nodes can mean real economic gains by virtue of the increased accessibility of nearby properties to transit services and the agglomeration economies that accrue. Accessibility gains translate to economic value because time and convenience are worth money. Residents, businesses, and firms bid for choice transitserved locations in a reasonably competitive marketplace. The value of agglomeration is more subtle. Agglomeration benefits represent the economic advantages of compact development. Having certain urban activities (e.g., business services) clustered around transit stations can increase firm productivity and profits through increased face-to-face contact, improved access to specialized skills, and easier external transactions, such as

²⁶ Indirect and substantially smaller benefits are generated when the beneficiary (land owner, developer, or tenant) spend the money gained from the reduced parking requirement in the regional economy.

subcontracting.²⁷ Certain goods and services that draw customers from a marketshed also tend to cluster in specific locations according to principles of central place theory; transit stations, for example, can function as nodes for the location of activities that cater to commuters, such as coffee shops, news stands, and dry cleaners.²⁸

Large-scale transportation and land use simulation models, like ITLUP and POLIS, are used in larger metropolitan areas to forecast the amount, types, and locations of land use shifts that result from introducing a new regional transit service.²⁹ These models, however, do not attempt to measure the economic benefits attached to these shifts. Measuring the economic value of concentrated land use activities prompted by transit investments is best accomplished by gauging the land value premiums associated with station area development.

The methods presented in this section involve applying fairly straightforward algebraic formulas that incorporate empirical evidence on the rates of land value premiums as functions of proximity to U.S. transit stations, stratified by different types of transit services, land uses, and urban environments. Given a certain amount of station area land use activity that has either already occurred or is forecasted, these techniques can be used to assign an economic value associated with the resulting accessibility and agglomeration gains.³⁰ As such, they can be thought of as providing an approach to extracting the generative economic component of concentrated land use development allowed and induced by transit investments. This notion of "nearness" to transit nodes, and the associated economic gain, incorporates concepts of both "accessibility" and "agglomeration." Since clustered development increases both ease and convenience of access and agglomeration-related economic productivity, no attempt is made to separate one from the other. Rather, they are treated jointly, as "accessibility/agglomeration" benefits, by the techniques presented.

²⁷ Traditionally, the economics literature has examined agglomeration benefits at the macro level as a basis for explaining the development of big cities and for measuring optimum city size. See Segal (1976) and Henderson (1986). A distinction should be made between "agglomeration" and "urbanization" economics. While agglomeration economies are enjoyed largely by private firms and interests, urbanization economies accrue mainly to the public sector. Urbanization economies represent economies of scale and scope that redound from compact, transit-oriented development, mainly in the form of reduced public outlays for infrastructure (e.g., roads, water trunklines, sanitation, sidewalks, etc.). See Frank (1989), Ewing (1994), and Burchell and Listokin (1995).

²⁸ Central place theory holds that urban goods and services locate so as to most efficiently serve a minimum threshold of customers, resulting in the formation of overlapping marketsheds whose sizes and ranges systematically vary according to the degree of product or service specialization.

²⁹ For a description of these models see: *A Technical Review of Urban Land Use-Transportation Models as Tools for Evaluating Vehicle Travel Reduction Strategies*, Frank Southworth, Center for Transportation Analysis, Energy Division. July 1995. Prepared for the Office of Environmental Analysis and Sustainable Development, U. S. Department of Energy. Prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831. See <http://www.bts.gov/smart/cat/ornl.html> for further information.

³⁰ As such, the techniques do not measure the degree to which transit investments induce land use changes. Rather, land use shifts are taken as givens. The aim is to assign economic values to these shifts.

This section presents a method for measuring economic benefits that accrue from the increased accessibility and agglomeration that occurs following the opening of a rail transit service. The method does this principally by applying empirical evidence on how transit investments increase urban property values. The methods and applications are limited to rail transit systems since only these investments have been shown in the past to materially increase land values. As such, the method likely will find most application to medium and large-size metropolitan areas that have built or are contemplating investment in light rail, heavy rail, and commuter rail systems.

In the first section below, how proximity to transit gets translated into land values is discussed, including a review of three methods – hedonic price models, matched-pair comparisons, and repeat sales ratios – for measuring land value premiums. Issues related to introducing proper statistical controls, measurement, timeframes of analysis, and contextual setting are also discussed.

Next, a straightforward and transparent method is presented for measuring accessibility and agglomeration benefits based on two inputs: 1) the amount of development occurring in station areas before and after the opening of a rail system; and 2) value premiums associated with specific land uses and defined over distance intervals. A more refined equation also is presented that allows measurement of benefits to be stratified by other dimensions, such as whether stations are located in a CBD or newer suburb. A hypothetical example is then presented that demonstrates the application of the method.

Because the methods presented rely on secondary data inputs, a third section presents the latest empirical evidence on the effects of rail transit investments on land values. Evidence is shown for the following land use categories: single-family/low-density residential; multi-family/medium-density residential; offices; and commercial-retail activities. A series of tables are presented that chronologically summarize the results of past studies, with information provided on measured land value premiums, the spatial extent of premium effects, and the structural form of how premiums vary with distances from stations.

The fourth section applies some of the empirical evidence from the section on rent premiums to demonstrate how methods can be applied to generate estimates of accessibility and agglomeration benefits. The San Francisco BART system is used in the demonstration. Sources of data inputs and additional assumptions needed to carry out the analysis are discussed. Data are then input into equations, and calculations are carried out. Based on the assumptions invoked, it is estimated that the accessibility and agglomeration benefits associated with BART's station area development (for 25 of the system's 36 stations) over the first 20 years of service amounted to around \$224 million.

A method of gauging the second-order benefits associated with station area development – namely, the increased ridership and revenues accruing to transit agencies is then described. The method measures how transit modal splits vary as functions of distances to stations. Continuing with the example from BART, the method is applied to arrive at an estimate of around 26,500 daily trips induced by station area development.

Finally, observations are made on the potential usefulness of applying empirical data on transit's land value and capitalization impacts as a basis for measuring accessibility and agglomeration benefits.

Measuring Benefits Based on Land Markets

A central tenet of urban land economics is that site-specific benefits get absorbed, or capitalized, into property values and rents in reasonably well-functioning and competitive land markets (Alonso, 1964; Muth, 1964). In the case of transit, the opening of a new rail station benefits nearby properties since they become more accessible to more places (served by rail transit) within a region. Since the numbers of benefiting parcels are finite, in a competitive marketplace, people and firms bid for these preferred locations, driving up the price of sites. For residential properties, this will mainly reflect accessibility benefits. All things being equal, most Americans want to avoid high-density living, so there likely are little if any agglomeration economies associated with residential growth.³¹ Indeed, residents might assign a disvalue to living in compact settings and being "too close" to transit facilities and the street traffic, noise, and fumes they often generate. Offices and commercial-retail activities, on the other hand, can be expected to enjoy both accessibility and agglomeration benefits as a result of compact station area growth.

Before turning to the matter of measuring land-related benefits, several caveats are in order. One, accessibility/agglomeration benefits, as reflected by land values, are generally only conferred by fixed-guideway systems – notably rapid rail (heavy rail), commuter rail, and light rail systems. And it is only around their access points, or stations, that these benefits accrue. (In fact, there may be disbenefit associated with being near a guideway line but not near a station.) As fixed permanent investments that provide relatively high-quality services, rail systems guarantee that properties near stations enjoy accessibility advantages. By operating on surface streets in mixed-traffic conditions, bus services, in contrast, are flexible (meaning services can be re-routed) and generally perceived to be of a lower quality (slower speeds, more random stopping). As a result, their impacts on land uses, and in particular property values, are thought to be more diffuse and in cases even inconsequential. A second caveat has to do with the spatial extent of impacts. It has become somewhat of a rule-of-thumb within the transit industry that the benefits of proximity to rail stations extend around a quarter of a mile radial distance from a station, roughly a distance that can be covered by foot in 5 minutes (Untermann, 1984; Bernick and Cervero, 1997). In reality, the spatial extent of impacts generally taper gradually with distance rather than following a step-like function or ending abruptly at a border. And as shown later, some studies have measured land value impacts well beyond a quarter-mile radius. Even less is known about the functional forms of how land value premiums taper as functions of distance to stations – e.g., whether linear, quadratic, or negative exponential in form.

In applying the techniques presented in this section to a particular metropolitan area and situation, there are at least four other factors that an analyst must consider: 1) controls; 2) measurement; 3) time line; and 4) setting.

³¹ Exceptions, of course, are places like Manhattan where high-rise residential development near centers of entertainment and culture, and which offer views, often command rent premiums. Outside of major commercial districts, however, residential densities are widely viewed as disamenities, all else being equal. Surveys consistently show, for example, that 90 to 95 percent of Americans prefer detached single-family homes to apartments. See Baldassare (1979).

Controls

It does not necessarily follow that if land values rise sharply once a rail transit station opens that the rail services *caused* this appreciation. Jumps in land values could be attributable to other factors, such as an upswing in the regional real estate market, improved highway access, better schools, and so forth. The challenge, then, is to control for these other influences so that the unique effects of transit proximity on land values can be isolated. Three approaches have largely been used to date to separate out the unique effects of proximity to transit on property values and rents: 1) hedonic price models; 2) matched pairs; and 3) repeat sales ratios.

Hedonic price models employ regression analysis to attach a monetary value to different attributes of a property and its surroundings, including the proximity of the parcel to transit. Cross-sectional or time series data, or both, are typically used.³² Hedonic price models normally follow a general linear form as:

$$P_{i,t} = f(I, N, L)_{i,t}$$

P = Price

I = Vector of attributes of the improvements on the parcel, such as measures of size (e.g., square feet, number of bathrooms), quality, height, age, landscaping, parking, etc.

N = Vector of attributes of the neighborhood, such as quality of public facilities and services (including schools) and socioeconomic composition.

L = Vector of attributes of the location of the parcel, such as distance to CBD, proximity to transportation services (including transit), gravity-based measures of accessibility to labor markets and employment, etc.

i = Cross-sectional observation, representing property transaction i.

t = Time series observation, representing time point t.

Hedonic price models tend to introduce the most rigorous controls. As such, they are widely viewed as providing the most accurate estimates of how access to transit gets capitalized into land values.³³

Matched pairs rely on finding comparable properties that are in every way similar except one is close to rail transit and the other is not. Finding suitable matches can be difficult.

³² Longitudinal, or time series, analyses are generally preferred since the effects of business swings and cyclical patterns can be explicitly controlled. When data for multiple parcels of land are pooled over multiple time periods, it is called a pooled cross-sectional/time series analysis.

³³ Hedonic price models are usually estimated in linear (absolute) and log-linear (proportional, or probability-based) forms. Estimation approaches range from ordinary least squares (OLS) to generalized least squares (e.g., reduced-form estimation).

Thus, comparison properties are rarely similar enough in all respects to suitably isolate the unique effects of proximity to transit. For this reason, matched pairs analyses are usually turned to when data and resources needed to support hedonic price modeling are not available (see Section 4.0).

Repeat sales ratios can also be used to gauge rent premiums. Here, changes in prices and rents between two or more sales transactions for the same transit-served property are recorded. These are compared to price changes for repeat sales of properties unserved by transit to produce a ratio. The differential can be attributed to transit proximity, controlling for other factors (since features of the house, neighborhood, etc. will normally remain constant across time periods).³⁴

Measurement

Sales transactions, reflecting what the market will bear, are normally used to gauge the value of land. While the Census reports median home values within tracts, most transaction data are obtained from proprietary local sources (e.g., Black's Guide). Sales transaction data, however, rarely separate the value of land itself from improvements (e.g., buildings).³⁵ Techniques like hedonic price modeling can be used to separate the marginal value of improvements versus land by including variables describing the size (e.g., square footage) and characteristics (e.g., presence of fireplace, presence of a view) of both improvements and land. Any measurement of the premiums associated with improved accessibility should, in theory, reflect increases in land values or site rents. Another source of information is county assessor records, which normally do distinguish between the values of land and improvements. Since land is usually reassessed only at times of sales transactions, however, assessor records can be spotty and woefully out of date.

Perhaps more problematic are the many discrepancies in the measurement of rents for office and commercial properties. Rents clearly reflect values imparted by both land and improvements as conjunct entities; however, since the interest lies with measuring rent premiums, differentials in rents (between transit-served and non-served properties) should express the capitalized site-related gains from accessibility improvements and agglomeration economies. Normally, only asking rents are reported by brokerage agencies. Asking rents might be expressed on a gross basis (all services included) or a net basis (some services paid for by tenants). Contract rents, which are the product of lease negotiations between individual tenants and landlords, are rarely reported, and can vary substantially from asking rents. Since revenues (and therefore profitability) are based not only on rents but occupancy rates as well, some studies report "effective rents" – average rents adjusted for occupancy rates.³⁶ Big differences in how rents are measured and

³⁴ Properties that have been substantially improved over time are usually excluded from the analysis since the improvements, rather than new transit services, could explain increases in real property values.

³⁵ In theory, the benefits of improved accessibility should be capitalized only into land, or what economists call site rents. In practice, these distinctions are not clearly made.

³⁶ An office building that rents for \$10 per square foot and is 90 percent occupied has an effective rent of \$9 per square foot ($\10×0.90).

reported can confound any analyses that try to attribute rent premiums to accessibility improvements. Because data are most readily available, asking rents has become the *de facto* standard used for expressing commercial rents. However, analysts need to be careful in distinguishing how rents are being measured when applying secondary data sources.

Time Line

The impacts of a rail transit investment can vary dramatically depending upon the time-frame. In some instances, the greatest appreciation in land values occurs prior to the opening of a new system, a consequence of rampant real estate speculation. Increases often occur after plans to site new transit stations are announced but prior to the actual station opening.

Near-term impacts (e.g., rents within the first year or two of opening) might be transitional and thus are not always reliable. A time period of at least five years after the opening of a rail system likely allows sufficient time for land market adjustments to work themselves out and institutional responses (e.g., zoning revisions) to take place. Intermediate and long-term time lines, like moving averages five to 10 years after a service starts, also tend to be less vulnerable to sharp swings and fluctuations in business cycles. While a growing number of studies report on the capitalization impacts of transit for an intermediate and longer-term time horizon, studies normally report results for particular time points rather than the moving averages for a multiyear interval.

Setting

Absolute values of rent and land value premiums (e.g., expressed in dollars per square foot) obviously reflect the particulars of a local real estate market – absolute premiums measured in Sacramento have little transferability to Chicago. For this reason, capitalized premiums are best reported in percentage terms – either as a result of estimating a loglinear hedonic price model (wherein coefficients represent elasticities) or by dividing premium estimates by median rent values (e.g., a \$2 per square foot premium in a market averaging rents of \$20 per square foot represents a 10 percent premium).

Because regional economies and land markets markedly differ, one should be cautious in applying premiums measured in a particular metropolitan area to another area. To the degree that findings are stratified by land use categories (e.g., residential, commercial-retail, office) and metropolitan setting (e.g., CBD, built-up urban, mature suburban, newer suburban, ex-urban), however, potential errors and biases in transferring findings across regions can be reduced. Stratifying findings across types of transit systems (e.g., heavy rail versus light rail) can also refine the analysis. Heavy rail systems, for example, are thought to exert stronger land use impacts than light rail because they typically serve larger areas, operate at higher speeds, are totally grade-separated, and are controlled centrally.

Measuring Accessibility/Agglomeration Benefits

Land market measures of accessibility/agglomeration benefits can be carried out for both *ex ante* forecasts (of yet-to-be built systems) and *ex post* evaluations (of already completed systems). Two major inputs are needed: 1) *development* – the amount of development (in land area for owner-occupied units, and square footage for rental properties) occurring in station areas before and after the opening of a rail system, either measured or forecasted; and 2) *value premiums* – empirical measures of land value and rent premiums associated with specific land use categories defined over specific distance intervals.

Generalized Methodology

The following equation can be used for estimating accessibility/agglomeration benefits:

$$B = \sum_k \sum_d [(A_{kd} \gamma_{kd}) E_k] \quad (\text{Equation 1})$$

where:

B = Benefit (total, in dollars)

A = Amount of development (land area, floorspace)

γ = Land value or rent premium

E = Expansion factor (rent premiums expressed over benefit period)

k = Land use category

d = Distance category

The formula is applied to the entire impact zone affected by (or expected to be affected by) a rail transit investment. Based on past research or empirical evidence from a comparable area, for example, this might be viewed as the area encompassing half-mile rings around all (existing or planned) rail stations of a particular system.³⁷

Applying the Methodology: Inputs

The following inputs are needed to apply Equation 1:

³⁷ In reality, physical objects and barriers such as rivers and hillsides can affect the actual radius of land value impacts, and such considerations should be accounted for in specific situations. For the sake of simplicity, however, a standard catchment area of a quarter or a half mile radius is often adopted.

1. **Amount of development.** This ideally should be expressed in units for which land value and rent premiums are normally measured.³⁸ In the case of residential land uses, since premiums are capitalized into land values, the amount of development should be expressed in total square feet (or acreage) of residential land uses, perhaps stratified by single-family (detached) and multi-family (attached) parcels. If lot sizes are fairly comparable across classes of residential uses, development might instead be expressed in terms of total number of units (single-family, multi-family). For non-residential uses (e.g., office, commercial), premiums are normally capitalized into rents, and total rents are pegged to building area; thus, total development should be expressed in terms of floorspace.³⁹ Additionally, since agglomeration economies normally accrue only to non-residential activities, the amount of development needs to be expressed in terms of building area to reflect the "stacking up" of floorspace that often occurs on a site (e.g., construction of high-rises). When used for forecasting accessibility/agglomeration benefits (e.g., as part of an EIS), this method requires estimates to be made in advance of the amount of development induced by a proposed rail investment. As noted, this information would normally be obtained from a transportation-land use forecasting model, such as ITLUP (DRAM/EMPAL), or some assumptions about the future distribution of population and employment.⁴⁰
2. **Land value and rent premiums.** Premiums are expressed in real dollar terms based on empirical research that extracts the accessibility/agglomeration benefits associated with each land use category and distance interval, controlling for other factors. Land value premiums are used in measuring benefits associated with single-family residences, and rent premiums are used for most non-residential activities. Premiums, then, represent differences in land values and rents *with* versus *without* transit, all else being equal. Since rents are collected on a periodic basis, it is necessary to adjust premiums by an expansion factor that expresses the value for the timeframe of analysis. For example, if benefits are being measured over a 10-year period and rent premiums are expressed on a monthly basis, then these premiums (in constant dollars) should be multiplied by an expansion factor of 120 (12 months * 10 years).
3. **Land use categories.** Breaking down data by land use categories reflects differences in premiums across urban activities. A basic distinction is between residential and non-residential activities. Residential activities might further be stratified by single-family and non-single family. Non-residential activities would normally include two land uses that are thought to benefit from proximity and exposure to transit and

³⁸ Note that the amount of development used in calculating benefits should include both preexisting ("without") and transit-induced ("with") activities. That is, existing parcels also reap benefits, not just new ones, since in a competitive land marketplace all properties accruing accessibility and agglomeration benefits capitalize these gains.

³⁹ Net leasable floorspace ideally should be used; however, in practice, since the cost of constructing, operating, and maintaining unleaseable space is passed on to renters, building area is often expressed in terms of gross floorspace.

⁴⁰ ITLUP, or the Integrated Transportation-Land Use Program, is the most widely used long-range transportation-land use forecasting model in the United States. DRAM, or the Disaggregate Residential Allocation Model, is used to distribute future residential development across study areas (e.g., census tracts). EMPAL, or the Employment Allocation Model, distributes future employment growth. See Putman (1983).

agglomerations – offices and commercial-retail (e.g., shops, restaurants, consumer services, business services). Land rent theories would suggest, and empirical research largely confirms, that few other non-residential uses, such as industries, accrue benefits from transit-related proximity or agglomerations.⁴¹ Some activities, like hotels, no doubt reap some proximity benefits, though likely only at the high-quality end of the spectrum in specific quarters (e.g., downtown). In instances, airports might reap transit accessibility benefits (e.g., St. Louis's Lambert Field, Atlanta's Hartsfield); however, since these sites are generally publicly owned and are not subject to real estate transactions, no studies have ever measured the transit capitalization benefits redounding to airports. In general, empirical evidence on rent premiums for non-residential uses is almost wholly limited to offices and commercial-retail activities.

Refining the Estimates

The calculation of accessibility/agglomeration benefits might be further refined by information on the location of activities within a metropolitan area, area-wide land use densities, and types of transit technologies. This is because land value and rent premiums can significantly vary within these groupings. *Location of activities*, for example, might be broken down by: CBD; urban (e.g., traditional postwar city outside of CBD); mature suburbs (e.g., older suburbs outside of city that grew during early postwar era); newer suburbs (e.g., built on the fringes of metropolitan areas in the past two decades); and exurbs (e.g., satellites of a metropolitan area). While metropolitan rail systems normally impact CBDs, urban districts, and suburbs, commuter rail lines also serve (and thus potentially impact) exurban and rural areas as well. *Land use densities* might be expressed in categories. For residential uses, for example, densities might be trichotomized: low (<7 dwelling units per acre); medium (7-15 dwelling units per acre); high (> 15 dwelling units per acre). *Types of transit technologies* may be used to stratify data in areas with multiple types of transit system – e.g., heavy and light rail systems. Other breakdowns are conceivable, like whether a rail line is at grade or underground.

A dilemma in refining analyses is that redundancies are likely to be introduced. For example, single-family residential activities are found most often in low-density suburban areas. Thus, stratifying the amount of development and land value premiums by land uses, metropolitan location, and densities invariably introduces overlap. Moreover, as noted later, few empirical studies to date have tried or managed to refine measures of land value or rent premiums by metropolitan location or surrounding densities. Breakdowns by land use categories and transit technologies are about as refined as most capitalization studies get.

Should more refined data become available, however, Equation 1 can easily be extended. For example, say land value and rent premiums are available for the following:

- Land use categories: 1) residential; 2) office; 3) commercial-retail.
- Locational categories: 1) CBD; 2) urban; 3) mature suburb; 4) newer suburb.
- Transit technologies: 1) heavy rail; 2) light rail.
- Distance categories: 1) 0-500 feet; 2) 500-1,000 feet; 3) 1,000-1,500 feet

⁴¹ For a discussion of the land uses experiencing transit capitalization impacts, see Huang (1994).

Thus, the following extended equation could be used for measuring accessibility/agglomeration benefits:

$$B = \sum_{k=1}^3 \sum_{d=1}^3 \sum_{m=1}^4 \sum_{t=1}^2 [(A_{kdm} \lambda_{kdm}) E_k] \quad (\text{Equation 2})$$

where:

- B = Benefit (total, in dollars)
- A = Amount of development (land area, floorspace)
- g = Land value or rent premium
- E = Expansion factor (rent premiums expressed over benefit period)
- k = Land use categories (1,2,3)
- d = Distance categories (1,2,3)
- m = Location categories (1,2,3,4)
- t = Transit technology categories (1,2)

Example

Let's start with a simple hypothetical example. This will be followed later by a more realistic, albeit somewhat more complicated, real-world example. In this initial hypothetical example, say you have been asked to measure the capitalized accessibility and agglomeration benefits associated with a heavy rail transit system that has been in operation for five years. Let's set the base year, just before the rail system opens, at year zero, and our analysis date at year five. (In this case, then, you're studying accessibility/agglomeration impacts over an intermediate timeframe.) Assume you know the following:

- Impact areas extend up to 2,000 radial feet in all directions from rail station entrances.
- Land uses reaping accessibility and/or agglomeration benefits are limited to two: 1) residential; and 2) commercial.
- Land value and rent premiums are known for each land use category for four specific distance intervals from stations: 1) 0-500 feet; 2) 500-1,000 feet; 3) 1,000-1,500 feet; and 4) 1,500-2,000 feet.
- Before carrying out the calculation, we'll need two inputs: 1) amount of development; and 2) land value and rent premiums.

Amount of Development

For all affected station areas, the *amount of development* is distinguished "with" versus "without" the transit system. The simplest way to distinguish the two is to define the "without" time point as being before the system opened, and "with" as being after the system opened (in our example, five years after). (This approach assumes no development would have occurred in the impact zones in the absence of building and opening the system.) Alternately, one could estimate "without" amounts of development in year five based on either simulated outputs from transportation-land use models, or by extrapolating past trends.⁴² "With" amounts of development are known from land use inventories. In our example, the following "with" and "without" amounts of development shown in Table 9.4 (and also in Figures 9.1 and 9.4) were estimated.

Table 9.4 Total Amount of Development, With and Without Rail System

Distance Interval (ft.)	Residential (Land Area, 1,000 sf.)			Commercial (Floorspace, 1,000 sf.)		
	Without	With	Total	Without	With	Total
0 – 500	250	200	450	20	140	160
500 – 1,000	350	500	850	50	70	120
1,000 – 1,500	600	800	1,400	40	60	100
1,500 – 2,000	700	1,000	1,700	30	50	80

These amounts are reflective of how land development might occur around rail transit stops, barring zoning and other regulatory restrictions. Most residential development, in particular single-family housing, will occur in the outer rings of an impact zone partly because outer rings encompass larger land areas and partly because sites more immediate to stations will likely be occupied by commercial activities as the "highest and best uses."⁴³ Because of agglomeration economies and advantages of easy access, most commercial development will concentrate in the inner ring (in the form of higher rise buildings), even though the inner ring has just one-seventh the land area of the outer ring.⁴⁴ Note from Table 9.4 and Figure 9.11 that the greatest amount of transit-induced development is for

⁴² Assume, for example, that the base year (when the rail system opened) is year zero and the analysis is being conducted for five years after the base year. If the average annual increase in residential development was two percent in areas that are designated "impact zones," then the base amount of residential development "without" rail would be assumed to increase by 10 percent (5 * 2 percent), assuming growth occurs linearly (at a non-compounding rate).

⁴³ Each of the rings encompasses the following land areas: 0-500 feet = 18.03 acres; 500-1,000 feet = 54.09 acres; 1,000-1,500 feet = 90.15 acres; and 1,500-2,000 feet = 126.21 acres.

⁴⁴ However, since the absolute size of land area in the outer ring is so much larger than the inner one, the differential in total amount of commercial development is moderated.

commercial floorspace within the 500-foot ring of the station, reflecting the tendency for rail transit systems to attract concentrated office and retail development.

Figure 9.11 Example: Amounts of Residential Land Development by Distance to Transit Station

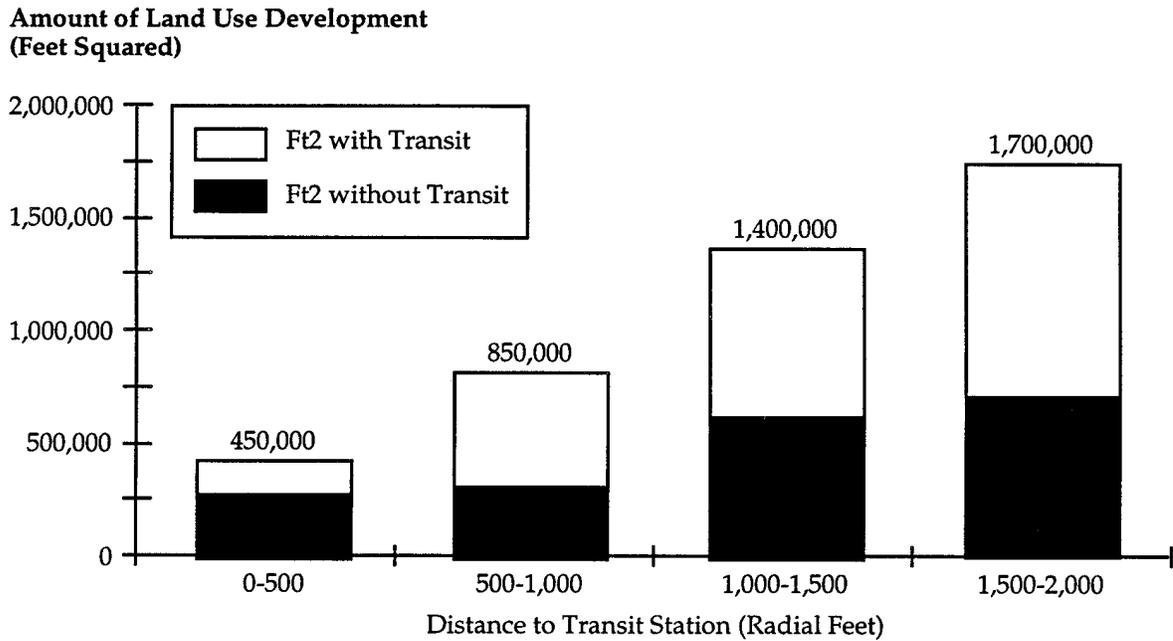


Figure 9.12 Example: Average Residential Land Values by Distance to Transit Station

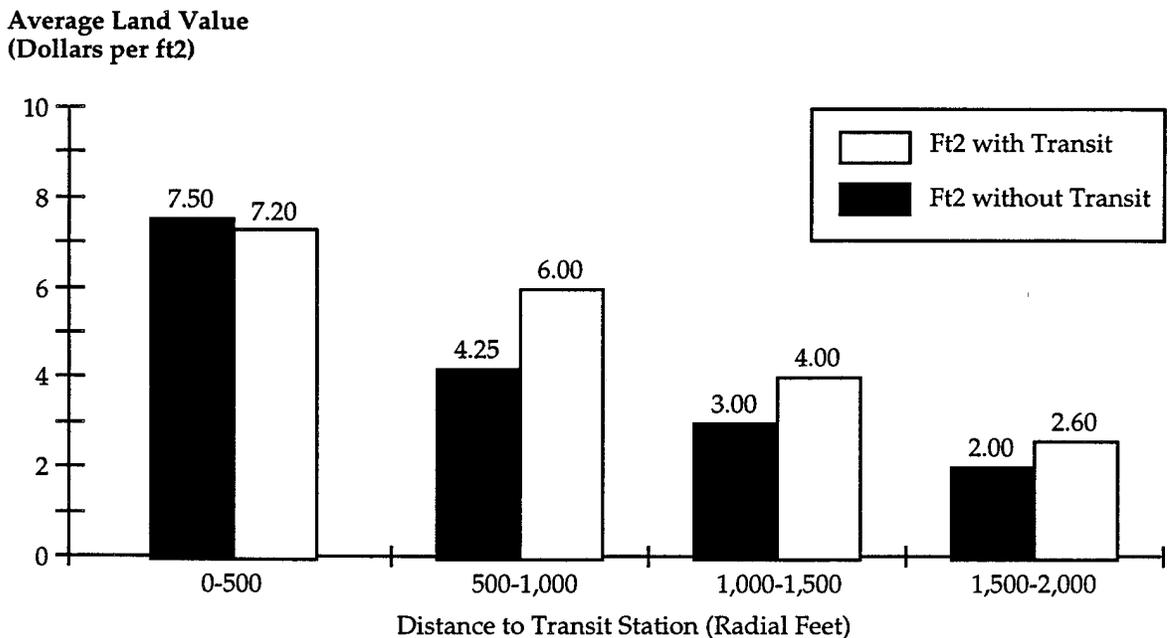


Figure 9.13 Example: Residential Land Value Premiums by Distance to Transit Station

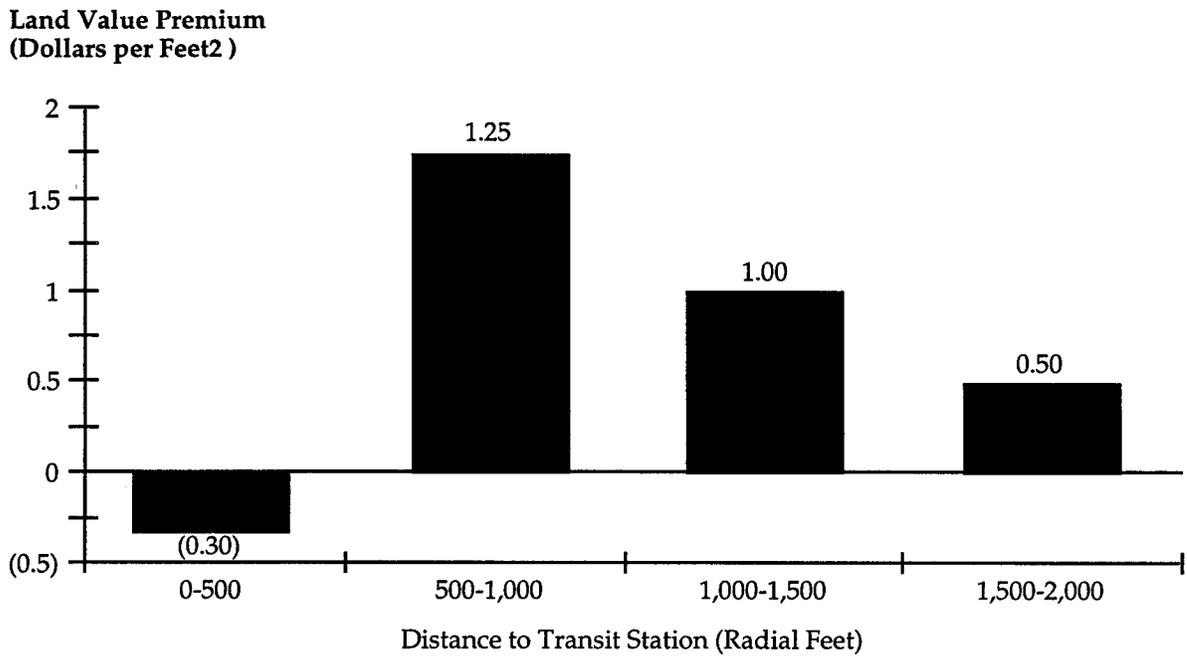


Figure 9.14 Example: Amounts of Commercial Land Development by Distance to Transit Station

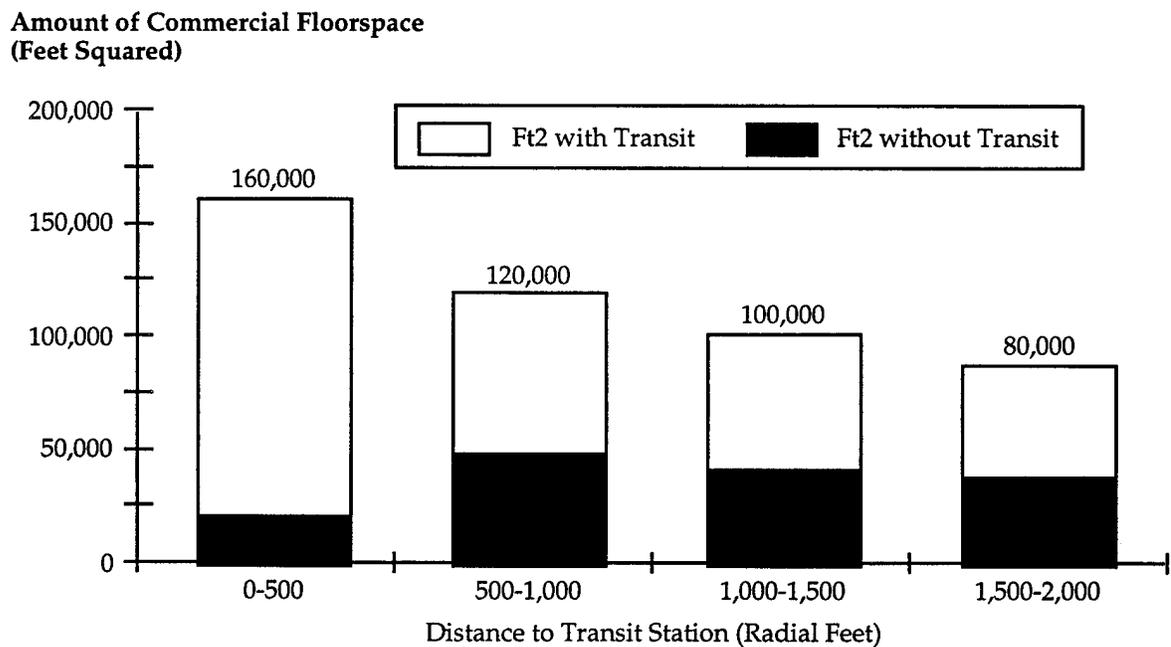


Figure 9.15 Example: Average Commercial Rents by Distance to Transit Station

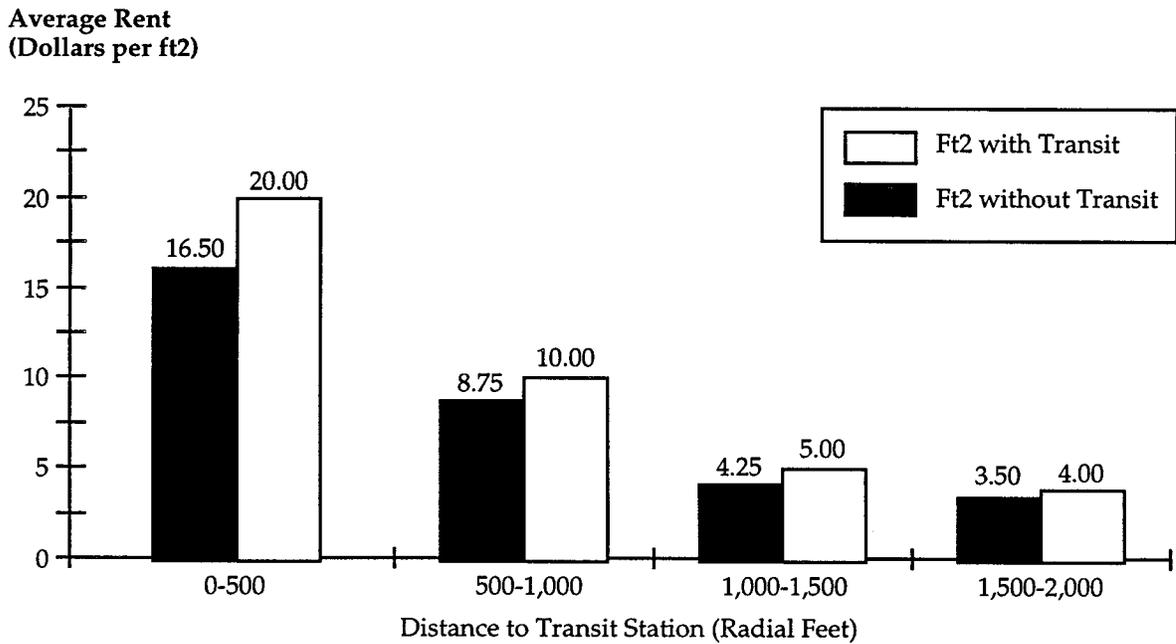
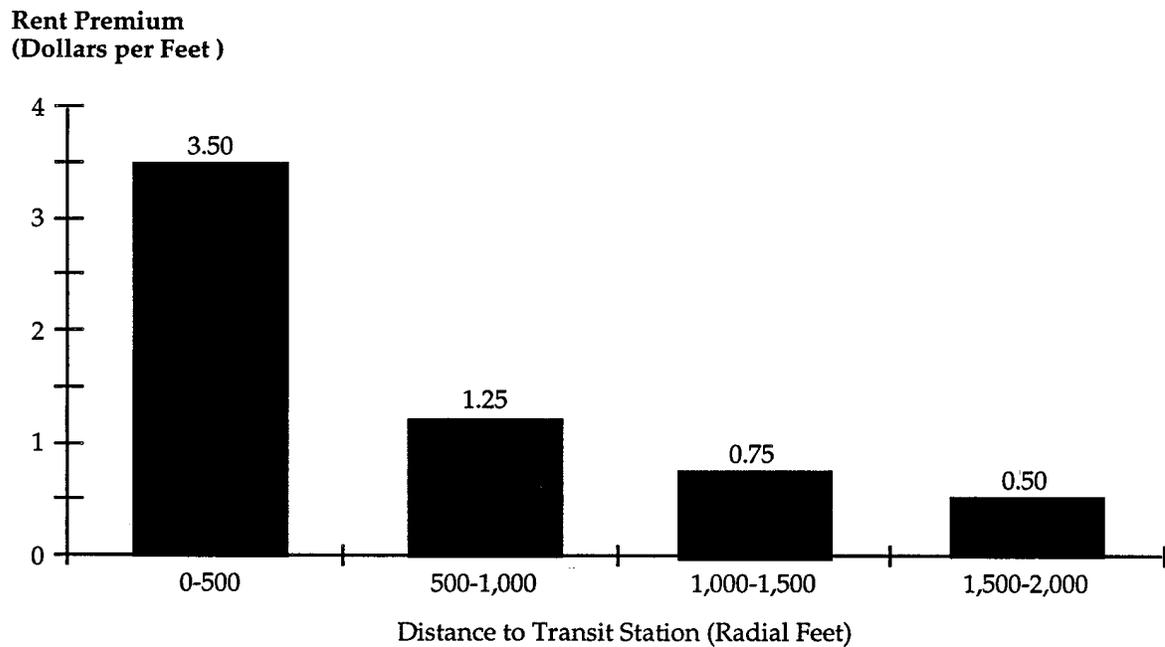


Figure 9.16 Example: Commercial Rent Premiums by Distance to Transit Station



Land Value and Rent Premiums

For our example, let's assume that past hedonic price models estimated for both residential and commercial land uses in our area successfully separated the unique effects of transit proximity on land values and rents, controlling for the influences of other explainers.⁴⁵ From these models, the average residential land values and commercial rents were estimated for each of the distance categories, shown in Table 9.5 (and in Figures 9.2 and 9.5).⁴⁶

Table 9.5 Average Land Value and Rent Premiums for Distance Categories, With and Without Rail System

Distance Interval (Feet)	Residential (Average Land Values, \$/SF.)			Commercial (Average Rents, \$/SF./mo.)		
	Without	With	Total	Without	With	Total
0 – 500	7.50	7.20	-0.30	16.50	20.00	3.50
500 – 1,000	4.50	6.00	+1.50	8.75	10.00	1.25
1,000 – 1,500	3.00	4.00	+1.00	4.25	5.00	0.75
1,500 – 2,000	2.00	2.60	+0.60	3.50	4.00	0.50

Figure 9.13 summarizes the average land value premiums for residential uses, and Figure 9.16 summarizes the average rent premiums for commercial activities. As shown in Figure 9.13, there is disvalue associated with residences being too near a rail transit station. In real dollar terms and controlling for other changes, properties within 500 feet of an existing station were worth, on average, \$0.30 more per square foot prior to the initiation of rail services. The highest land value premiums are shown to be within the 500-1,000-foot ring around rail stations – a distance sufficiently buffered from the noise and street traffic generated by rail services but still conveniently accessible by foot. Beyond the 500-1,000-foot range, premiums taper with distance from stations, at a fairly linear rate, and disappear beyond 2,000 feet. Figure 9.16 shows a different relationship for commercial uses. There is no disvalue associated with very close proximity; in fact, commercial buildings closest to rail stations average the highest rents, all else being equal. Rent premiums decline with distance from stations at a decreasing rate – i.e., rent premiums follow an exponential decay function in relation to distance from stations.

⁴⁵ Ideally, these would be the results of a pooled time-series/cross-sectional analysis, with data observations drawn from property transactions for times points before and after the opening of the rail transit system and in locations within, as well as beyond, the 2,000 foot impact zone.

⁴⁶ These represent the estimated values and rents based on observations (e.g., sales transactions) that include (e.g., "with") versus do not include (e.g., "without") nearby rail services, *ceteris paribus*.

Calculation

Applying data in Tables 9.4 and 9.5 to Equation 1 allows the accessibility/agglomeration benefits associated with the rail transit investment to be estimated. Again, benefits are being measured for an intermediate period – zero to five years after the opening of the rail system. No time adjustment is necessary for residential land uses, since for each parcel, the benefit is capitalized into land value as a one-time effect. In the case of commercial land uses, however, an expansion factor needs to be applied to adjust monthly rent premiums to a five-year period. If the amount of transit-induced land development that occurred month-by-month during the year zero to year five period was known, then monthly totals could be multiplied by premiums and accumulated over time to arrive at precise estimates. In practice, however, land use inventories are only gathered for two time points (e.g., before and after services start). As a result, an estimate needs to be made of the average length of time new (transit-induced) commercial floorspace has been in existence over the study period, in our case, from year zero to year five. In the absence of better information, one can assume that new commercial development occurred uniformly over the five-year, or 60-month, evaluation period, meaning that, on average, new station area shops and offices were on the market for 30 months of the 60-month study period. Thus, an Expansion Factor of 30 can be applied for commercial land uses in this example. Using this Expansion Factor with other inputs results in the following estimates:

$$\begin{aligned} \text{Benefit}_{\text{residential}} &= (450,000 \times \$0.30) + (850,000 \times \$1.50) + (1,400,000 \times \$1.00) + (1,700,000 \times \$0.60) = \$3,560,000 \\ \text{Benefit}_{\text{commercial}} &= (160,000 \times \$3.50) + (120,000 \times \$1.25) + (100,000 \times \$0.75) + (800,000 \times \$0.50) \times 30 = \$24,750,000 \\ \text{Total Benefit} &= \$3,560,000 + \$24,750,000 = \$28,310,000 \end{aligned}$$

Empirical Evidence on Rent Premiums

The methodology presented for estimating accessibility/agglomeration benefits relies on empirical evidence regarding transit's capitalization effects on land values and rents. Fortunately, a number of studies have been conducted over the past few decades that provide a reasonably reliable basis for applying these techniques, at least for some metropolitan areas of the country. Because measuring transit's effects on land values and rent premiums can be very data and time intensive, one should first look to borrow from the investments and findings of other researchers.

From an extensive literature review, it was found that past transit capitalization studies divided into two types of transit technologies and four types of land uses.⁴⁷ The two transit types are: 1) rapid rail/commuter rail/advanced light rail, representing fast, grade-separated, and geographically extensive services; and 2) conventional light rail, representing slower, sometimes shared right-of-way, and geographically more restricted

⁴⁷ Literature summaries of transit capitalization impacts can also be found in: Joint Center for Urban Mobility Research (1987); Huang (1994); and Cervero and Seskin (1995).

services.⁴⁸ In general, the capitalization effects of higher-performing rapid rail/commuter rail/advanced light rail services have been greater than those of light rail systems, as would be expected. (Note that no capitalization studies could be found for bus-based transit systems.) The four types of land uses are: 1) single-family/low-density residential; 2) multi-family/medium-density residential; 3) office; and 4) commercial-retail. Single-family residential represents detached units, mainly in low-density suburban settings (although many studies include older single-family homes in built-up urban areas as well). Multi-family residential consists of duplexes, townhouses, apartments, and condominiums; while most represent moderate density settings, it is difficult to generalize about their locations since empirical data come from all kinds of urban and suburban environments.

Overall, the literature failed to sort findings on land value and rent premiums into clear categories of metropolitan setting (e.g., downtown, urban, mature suburbs, new suburbs, exurbs). This is partly because most capitalization models were estimated using properties drawn from throughout a region. As noted, certain land uses are easier to associate with a metropolitan settings than others. While capitalization premiums measured for single-family homes generally represent suburban settings, for example, it is difficult to separate whether premiums measured for offices are for downtowns, built-up urban districts, or new suburbs. Hedonic price models for office capitalization rates are usually based on asking rents obtained from offices throughout a metropolitan area.

Tables 9.6 through 9.11 summarize key information and findings, including measured premium effects, from capitalization studies conducted for U.S. and Canadian rail transit services since 1970.⁴⁹ While capitalization studies were conducted prior to 1970, these were done largely for older (often turn-of-the-century) rail systems and did not always introduce suitable controls. All of the studies summarized in Tables 9.6 through 9.11 introduced statistical controls to some degree. Under each of the six combinations of transit and land use types, studies are listed in chronological order. In addition to the author, date of study release or publication, and system(s) studied, the following information is shown:

⁴⁸ Rapid rail transit, sometimes called heavy rail or metros, are high-speed, high-performance systems within urbanized areas that connect neighborhoods and major activity centers to downtowns. They are electrically propelled, usually from a third rail, and each car has its own motor. Commuter rail transit typically links outlying towns and suburbs to a region's downtown. These systems are characterized by heavy equipment (e.g., locomotives that pull passenger coaches), wide station spacing, and high maximum speeds that compete with cars on suburban freeways, though slow in acceleration and deceleration. Conventional light rail, sometimes also called streetcars and trams, often operates in mixed-traffic settings and obtains electricity from an overhead wire instead of a middle third rail. Light rail normally operates over a more limited geographic area. A hybrid of light and heavy rail is what is called advanced light rail, or intermediate capacity transit (ICT), represented by Vancouver's SkyTrain system. For more details on transit technologies, see Black (1995).

⁴⁹ The lion's share of capitalization studies to date have been for rail systems in the United States and Canada. While similar studies can be found for rail services in the United Kingdom and other parts of Europe, they are not reported here because of fundamental historical, social-cultural, and political differences between much of Europe and North America.

Table 9.6 Summary of Transit Capitalization Studies Transit Type: Rapid Rail/Commuter Rail/Advanced Light Rail Land Use Type: Single-Family/Low-Density Residential

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance	Control Variables/Comments
Davies (1970) San Francisco BART	RSR	SF home sales price	Pre-project	Linear ft. to station	New suburbs: 2 to 14%	800	Linear	No controls; comparison of average repeated sales price for properties near station versus within six- block area of station
Dornbush (1975) San Francisco BART	MP/BA	SF home sales price	First year of operations	Distance category	New suburbs: 0-400 ft : -4%	1,500	Binary	Comparisons with subregional markets; for newer suburban communities with P&R BART
Deweese (1976) Toronto	HP	SF home sales price	Post-construction; > 5 years	Time cost, converted to distance	Mature urban: +\$7,500, or +18%, per mile walk closer to station	1,750	Uniform within sphere	Rich array of housing quantity, quality, and neighborhood attributes; value of time weighted for travel, wait, walk
Falcke (1978) San Francisco BART	RSR		Post-construction; > 3 years	Linear ft. to station	Mature suburbs: +\$1.35/ft. ² for each ft. closer to some stations	1,000	Linear	Distances to shopping and BART tracks for some stations (not all)
Dyett et al (1979) San Francisco BART	MP	SF home sales price	First 1-2 years of operation	Distance category	Mature urban/residential 0-500 ft.: +17% 500-1,000 ft.: +5% 1,000-1,500 ft.: +3% 1,500-2,000 ft.: +2% 2,000-2,500 ft : +1% Mature urban/mixed-use: None	1,500	Negative exponential	Comparisons with subregional markets; for mature urban communities with limited parking
Damm et al. (1980) Washington Metrorail	HP	SF home sales price	Pre-project	Linear ft. to station	-0.06-.13 distance elasticity	2,500	Reciprocal straight-line distance	Neighborhood quality, densities, and socioeconomics; zoning compatibility

Table 9.6 Summary of Transit Capitalization Studies
Transit Type: Rapid Rail/Commuter Rail/Advanced Light
Rail Land Use Type: Single-Family/Low-Density Residential (continued)

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance	Control Variables/Comments
Bajic (1983) Toronto Spadina Line	HP	SF home sales price	Post- construction; > 10 years	Weighted commute time via rail to 5 destinations	Inner-urban:+\$5,370 per housing unit (single commuter)	Large catchment (no precise distance)	Linear	Array of housing, neighborhood, locational attributes; weighted commuting times to multiple locations; rich mix of controls
Allen et al (1986) Philadelphia-NJ Lindenwold High Speed	HP	SF home sales price	Post- construction; > 5 years	Commute cost savings to CBD	\$665/dollar commute cost savings; \$6,870 or +7.8% per unit	~10,000 (transit- served census tracts)	Linear	Lot size, building type and stories, property tax, dummies for housing amenities; distance to Camden and major bridges; for mainly suburban New Jersey development
Ferguson et al. (1988) Vancouver SkyTrain	HP	SF home sales price	Pre-project	Linear ft. to station	+\$14.70/sf for each ft. closer to station	2,400	Linear	Array of housing, neighborhood, locational attributes; interaction terms; secular time trend

Note: HP = Hedonic Price Model; MP = Matched Pair Comparisons; P&R = Park-and-Ride; RSR = Repeat Sales Ratios; SF = Single Family

Table 9.7 Summary of Transit Capitalization Studies
Transit Type: Rapid Rail
Land Use Type: Multi-Family/Medium-Density Residential

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect	Structural Form of Distance Effect	Control Variables/Comments
Falcke (1978) San Francisco BART	RSR	Monthly rents	Post-construction; > 5 years	Linear ft. to station	None, except Walnut Creek Station area	1,000	Linear	Comparable distances to BART tracks as a control
Damm et al. (1980) Washington Metrorail	HP	MF residential sales price	Pre-project	Linear ft. to station	-0.19 price elasticity relative to distance	2,500	Linear	Neighborhood quality, densities, and socioeconomics; zoning compatibility
Rybeck (1981) Washington Metrorail	MP	Condominium sales price	Post-construction; 1-3 years	Distance category	\$16.90 to \$18.60 per ft. ² within 1/4 mile	1,320	Binary	Comparably aged and sized suburban condominiums within versus beyond 1/4 mile. Examined for Arlington station areas
Bernick & Carroll (1991) San Francisco BART	MP/I	Monthly rents	Post-construction; > 15 years	Distance category	+5%	1,320	Binary	Rent comparisons of "comps" based on advice of local real estate brokers
Bernick et al. (1994) San Francisco BART	MP	Monthly rents	Post-construction; > 15 years	Distance category	\$0.05 per sf per month	1,320	Binary	Compared units within and beyond 1/4 mile of stations, matched by age, submarket, and bedroom-bathroom sizes. Suburban station areas
Cervero (1996) San Francisco BART	HP	Monthly rents	Post-construction; > 15 years	Distance category	\$42.30 per unit per month; \$0.04 per sf per month	1,320	Binary	Attributes of apartment complex and units; project age; city dummy

Notes: HP = Hedonic Price Model; I = Interview; MP = Matched Pair Comparisons; RSR = Repeat Sales Ratios; MF = Multi-Family

Table 9.8 Summary of Transit Capitalization Studies Transit Type: Rapid Rail Land Use Type: Office

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance Effect	Control Variables/Comments
Falcke (1978): San Francisco BART	RSR	Office rents	Post-construction; > 3 years	Linear ft to station	Oakland CBD: 0-600 ft: 10%; 600-1000 ft: 4%; > 1000 ft: None San Francisco CBD: 0-1% Walnut Creek: 0-200 ft: 6%; > 200 ft: None	Varies	Binary	Straightline distances to BART stations; Oakland impacts only for new office buildings; Walnut Creek impacts only for buildings adjacent to BART station.
Rybeck (1981): Washington Metrorail	MP	Office rents	Post-construction; 3-4 years	Distance category	(1) Downtown Washington: +\$3.60/ft ² or 9% (2) Montgomery County (Silver Spring): +\$3.25 per ft ² , or 14%	300	Binary	Matched pairs near and away from Metro stations based on interviews with real estate brokers and developers
Cervero (1993): Washington Metrorail; Atlanta MARTA	HP	Office rents	Post-construction; > 5 years	Distance category	+\$3.58/ft ² or 13.7%	300	Binary	Premium measured for joint development office projects adjacent to mature suburban Metrorail and MARTA stations.
Cervero and Landis (1993): Washington Metrorail; Atlanta MARTA	MP	Office rents	Post-construction; > 5 years	Distance category	(1) Metrorail: +\$4.24 to +\$5.35 ft ² , or +12.3% to 19.6% (2) MARTA: +\$2.80 to +\$4.59 ft ² , or +11% to 15.1%	300	Binary	Comparisons of rent premiums for offices that were jointly developed with rail stations. Premiums averaged over 12 year periods.
Landis and Huang (1995): San Francisco BART	RM	Sale price for office properties	Post-construction; > 10 years	Distance categories	None None	1300 2600	Binary	Lot and building area, city and transaction year dummies; measured for within 1/4 and 1/2 mile of East Bay stations.

Notes: HP = Hedonic Price Model; MP = Matched Pair Comparison; RM = Regression Model; RSR = Repeat Sales Ratio.

Table 9.8 Summary of Transit Capitalization Studies
Transit Type: Rapid Rail
Land Use Type: Office (continued)

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance Effect	Control Variables/Comments
Landis and Lotzenheimer (1995): San Francisco BART	HP	Office rents	Post- construction; > 15 years	Distance categories: 1/8 mi. intervals for 0 to 1/2 mi.	(1) Downtown San Francisco: None (2) Downtown Oakland: None (3) Walnut Creek (Suburb): None for 0 to 1/4 mile; +\$0.28 per ft ² , or 16%, for 1/4 to 3/8 mile	2000	Multinomial (4 ordinal distance categories)	Building variables, including size, age, heights, parking; market vacancy and rent variables.
Bollinger et al. (1996): Atlanta MARTA	HP	Office rents	Post- construction; > 10 years	Distance category	-\$0.95, or -4%, per ft ²	1300		Array of building, site, locational, socioeconomic, accessibility factors, including gravity measure of proximity to residences of worker classes; 190, 4994, 1996 time points.

Notes: HP = Hedonic Price Model; MP = Matched Pair Comparison; RM = Regression Model; RSR = Repeat Sales Ratio.

Table 9.9 Summary of Transit Capitalization Studies
Transit Type: Rapid Rail
Land Use Type: Commercial-Retail

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance Effect	Control Variables/Comments
Falcke (1978): San Francisco BART	RSR	Sale price for retail establishments	Post- construction; > 3 years	Linear ft to station	Mature urban: 0-500 ft: 1%; > 500 ft: None Suburban: 0-1000 ft: 8%; > 1000 ft: None	Varies	Binary	Straightline distances to BART stations and downtown San Francisco rail station.
Damm et al (1980): Washington Metrorail	HP	Sale price for retail establishments	Pre-project	Linear ft to station	-0.69 price elasticity relative to distance	2500	Linear	Neighborhood incomes, parking supply, degree of parcel upgrade, measures of employment densities.
Landis and Huang (1995): San Francisco BART	RM	Sale price for retail properties	Post- construction; > 10 years	Distance categories	None None	1300 2600	Binary	Lot and building area, city and transaction year dummies; measured for within 1/4 and 1/2 mile of stations.

Notes: HP = Hedonic Price Model; RM = Regression Model; RSR = Repeat Sales Ratio.

Table 9.10 Summary of Transit Capitalization Studies
Transit Type: Light Rail
Land Use Type: Single-Family/Low-Density Residential

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance Effect	Control Variables/Comments
VNI Rainbow (1992) San Diego Trolley	MP	SF home sales price	Post-construction; > 3 years	Distance category; adjacency or not	2%	200 (adjacent to station)	Binary	Comparison of properties very near versus within 2,600 ft. of stations that are otherwise similar
Al-Mosaind et al. (1993) Portland MAX	HP	SF home sales price	Post-construction; > 5 years	Distance category	\$5,360 or 10.6% per unit	1,500	Linear	Array of housing and locational attributes; no neighborhood controls except zoning
Landis et al. (1995) (1) Sacramento Light Rail	HP	SF home sales price	Post-construction; 1-2 years	(1A) Linear ft. to station	\$806, or 0.4%, for every 1,000 ft. closer to station	~25,000	Linear	Various housing size, age, and amenity attributes; tract income and socioeconomics; highway distance Wide variations across light rail systems; adjacency premiums in Sacramento, and adjacency disamenities in San Diego and Santa Clara County
				(1B) Distance category	+\$11,990, or 6.2%, per unit within 900 ft. of station	900	Binary	
(2) San Diego Trolley	HP	SF home sales price	Post-construction; >3 years	(2A) Linear ft. to station	\$337, or 0.1%, for every 1,000 ft. closer to station	~25,000	Linear	
				(2B) Distance category	-\$10,410, or -4.1%, per unit within 900 ft. of station	900	Binary	
(3) Santa Clara County Light Rail	HP	SF home sales price	Post-construction; 1-2 years	(3A) Linear ft. to station	\$324, or 0.1%, for every 1,000 ft. closer to station	~25,000	Linear	
				(3B) Distance category	-\$38,970, or -10.8%, per unit within 900 ft. of station	900	Binary	

Note: HP = Hedonic Price Model; MP = Matched Pair Comparisons

Table 9.11 Summary of Transit Capitalization Studies
Transit Type: Light Rail
Land Use Type: Other Land Uses

Author (Date)/ System	Analysis Technique	Dependent Variable	Time Context	Transit Accessibility Measure	Premium Effect (1997 US\$)	Spatial Extent of Effect (ft.)	Structural Form of Distance Effect	Control Variables/Comments
<i>Multi-Family Housing</i>								
VNI Rainbow (1992) San Diego Trolley	MP	Apartment rents	Post-construction; > 3 years	Distance category; adjacency or not	0 to \$3,475 per unit, or 0 to +5%	200 (adjacent to station)	Binary	Rent premium from higher occupancy rates in La Mesa project adjacent to trolley line
<i>Offices</i>								
VNI Rainbow (1992) San Diego Trolley	MP	Office rents	Post- construction; > 3 years	Distance category; adjacency or not	None	200 (adjacent to station)	Binary	Comparison of per square foot rents with control property; suburban offices
Landis and Huang (1995) San Diego Trolley	RM	Sales price for office properties	Post- construction; > 3 years	Distance category	(1) None (2) None	(1) 1,300 (2) 2,600	Binary	Lot and building area, lot and transaction year dummies; measured for within 1/4 and 1/2 mile of downtown and suburban stations from 1987-1993
<i>Commercial-Retail</i>								
VNI Rainbow (1992) San Diego Trolley	MP	Retail rents	Post- construction; > 8 years	Distance category; adjacency or not	+\$1.35 per sf, or +167%	200 (adjacent to station)	Binary	Comparison of per square foot rents with control property 1/2 block away; downtown shops

Note: MP=Matched Pair Comparisons; RM=Regression Model.

- **Analysis technique:** The major tools used for measuring capitalization effects have been hedonic price models, matched pairs, and repeat sales ratios. As noted in the last column of each table, studies vary markedly in approach and degree of sophistication with regards to introducing controls.
- **Dependent variable:** Most studies of single-family homes have measured premiums based on market prices, recorded through sales transactions. Premiums for apartments and other multi-family housing are normally based on monthly rents. Office values are also usually expressed on the basis of monthly rents (per square foot), though some studies have been based on sales prices. For commercial-retail activities, values have usually been expressed on the basis of sales transaction prices.
- **Time context:** Studies vary quite a bit in terms of the length of time capitalization effects were measured following the opening of a system. For several studies of single-family sales, effects were measured pre-project – i.e., before the system opened. The majority of capitalization studies, however, have been conducted for intermediate to long-term time spans, periods over which market adjustments to new rail services should have stabilized.
- **Transit accessibility measures:** Most studies have measured accessibility to rail stations on the basis of either straight-line (linear) feet to a station entrance, or by using a distance category (e.g., a dummy variable signifying whether or not a property lies within 1,000 feet of a station). Several studies have expressed transit accessibility on the basis of travel time or commute cost savings.
- **Premium effects:** Premium effects have been reported in numerous forms, making generalizations difficult. Many studies have simply reported premiums (or disvalues) on a dollar per square foot or per housing unit basis. To make findings more comparable, rent premiums have been converted to 1997 U.S. dollars by using the consumer price index (CPI), where possible.⁵⁰ Ideally, premiums are reported in percentage terms (relative to mean property values), thus facilitating the transfer of findings to other areas. Premiums reported in dollar values have been converted to percentage terms where possible, using mean values reported in studies or by the U.S. Census Bureau. Some premiums are expressed in elasticity terms – percentage change in rents per unit increase in distance from stations. As noted, most capitalization studies fail to distinguish the metropolitan settings for which the findings were measured. Where the settings are defined or can be discerned, they are presented in these tables. Also, many studies fail to measure rent or land value premiums for multiple distance intervals, thus it is difficult to infer any kind of distance-from-station gradient from many capitalization studies. The best information on premium gradients as functions of distances from stations come from San Francisco's BART system. For some other systems, like MARTA, capitalization effects across distance categories can be imputed by

⁵⁰ The CPI, estimated by the U.S. Bureau of Labor Statistics, is for all goods and services, not just real estate. The CPI is assumed to increase by 3 percent in calendar year 1997. Canadian dollars are expressed as U.S. currency depending on the exchange rate for the years encompassing the analysis of capitalization effects.

inputting data into estimated hedonic price models and comparing value estimates with median prices of housing units.⁵¹

- **Spatial extent of effects:** The catchment areas of recorded capitalization impacts also vary markedly across studies. Many define the capitalization effects of transit proximity within 1,000 to 1,500 feet of a station, or roughly within a quarter-mile distance or five-minute walk. Nevertheless, some have found impact areas to extend a number of miles away from a station – what one might expect for suburban and terminal station areas where park-and-ride lots draw customers from a large catchment. The land value premiums associated with large catchments, however, are mostly limited to residential uses and are generally thought to erode to inconsequential levels beyond several miles from a station.
- **Structural form of distance effect:** Because distances from stations are normally measured in linear feet or in terms of categories, premium effects have generally been measured in simple linear or binary forms. With the exception of several studies of single-family housing values associated with San Francisco's BART and Atlanta's MARTA (that explicitly fit negative exponential or quadratic curves to data), most nonlinear forms have been implicitly captured by measuring average premiums for distinct distance categories.
- **Control variables:** Studies have varied substantially in the degree to which control variables are used for other possible explainers of land values and rents, besides proximity to transit. Hedonic price models of land value premiums for the Philadelphia Lindenwold line, Toronto's Metrorail, Atlanta's MARTA, and San Francisco's BART, in particular, have been vigorous in their use of control variables, and thus provide some of the most reliable evidence available. Studies of light rail's impacts on non-residential rents (Tables 9.8 and 9.9) have generally been the least successful in controlling for other possible explainers.

⁵¹ In the case of Nelson's 1992 evaluation of MARTA's impacts on single-family home prices, for instance, capitalization impacts were estimated as follows. Quadratic expressions of distance to stations as predictors of sales prices were used to determine the "break-even" distance at which mean sales prices would be equivalent to the price of a housing unit situated exactly at the station site, all else being equal. In the case of the lower-income, minority-populated southern sections of the elevated East Line, it was determined that the concave quadratic expression produced a zero value at about 6,700 feet, or one and a quarter miles, from the station entrance. (This is based on coefficients of -1,045.6 for distance, expressed in 100 foot units, and +15.56 on distance-squared: $[-1,045.6*67] + [15.56*67^2] \approx 0$.) For distance intervals within this range, land value differentials were inferred by comparing mean values between properties located at the break-even point and those within distance intervals.

Real-World Example: Measuring BART's Accessibility and Agglomeration

Benefits

Given the current state of knowledge, it is difficult to generalize about transit's capitalization effects because studies vary so widely in terms of methodologies, measurement units, time contexts, spatial extents of measurements, levels of sophistication in controlling for other possible predictors, and findings. For these reasons, empirical evidence on transit's capitalization impacts should generally be applied only for the same area where the evidence is drawn. One should be cautious in attempting to transfer evidence across metropolitan areas, not only for the problems mentioned above, but also because real estate market dynamics differ so much across regions of the country.

Empirical evidence is probably best suited to imputing accessibility and agglomeration benefits in some of the larger rail-served metropolitan areas that have been the subject of considerable past research. In the San Francisco Bay Area, for example, a number of studies, most related to the original BART Impact Study and the recent 20-year update, provide evidence on BART's capitalization effects as a function of distances for different classes of stations across distinct land use classes. As a clear-cut example of applying empirical evidence to estimate accessibility and agglomeration benefits, one can use the evidence on BART's land use and capitalization impacts.

In this example, we will measure the value-added from accessibility/agglomeration gains for the four land use categories for which BART has been shown to have yielded capitalization benefits: single-family residential (Table 9.6); multi-family residential (Table 9.7); offices (Table 9.8); and commercial-retail (Table 9.9). For these land uses, past studies provide some evidence on how premiums (and disvalues) have changed over distance categories within defined impact zones. In the absence of better information, one can average across the findings of separate studies, or perhaps choose the findings from the most recent work. We also need a time context to carry out the work. Here we can borrow from the recent findings of the "BART @ 20" study that documented the amount of development that occurred around 25 of BART's 34 stations during the 1973-1993 period (see Cervero, 1995). To carry out the analysis, we need to first obtain basic inputs, and then apply them to an adapted version of Equation 1.

Amount of Development

From the BART @ 20 study, Table 9.12 presents inventory summaries of land use development that were recorded for impact zones, defined as half-mile rings around stations, except downtown San Francisco and Oakland, wherein quarter-mile ring impact areas were used. Data are further stratified by metropolitan location of station areas: CBD, urban, and suburban.⁵²

⁵² Office development is shown only for private offices. Government and institutional offices are excluded from this analysis.

Land Value and Rent Premiums

From Tables 9.6 through 9.9, we see that since 1970 there have been the following number of studies on the capitalization effects of BART: single-family residences – 5; multi-family residences – 4; offices – 3; and commercial-retail – 2. As noted, the relationship between capitalization effects and distance from stations has been fairly well documented in the case of BART relative to most other North American rail systems. Some BART impact studies also stratify findings by metropolitan location. In general, study findings are fairly consistent. The only notable discrepancy is with respect to capitalization impacts on single-family residences close to BART stations. Early work by Dornbush (1975) recorded disvalue for residences in newer suburban settings that were situated within 400 feet of stations; other work, such as by Davies (1970), found no such disvalues, although his work did not concentrate on blocks immediately surrounding BART stations. Dyett et al. (1979) also found no disamenities associated with being near BART stations, although their work concentrated mainly on mature urban station areas as opposed to newer suburbs. More recent work by Landis et al. (1995) found that residences near East Bay BART stations in Contra Costa County, a fairly new suburban setting, actually commanded rent premiums. These more recent findings on capitalization impacts on nearby single-family residences will be used here.

For purposes of estimating accessibility/agglomeration benefits, empirical findings from past BART studies that were expressed in terms that were most compatible with how land use inventories were reported in the BART @ 20 study (shown in Table 9.12) were used. In the case of single-family residences, the work of Dyett et al. (1979) was mainly used to represent premiums, supplemented by work by Landis et al. (1995) that provided more complete information for suburban settings. The value added per unit is based on the mean value of single-family residences for each metropolitan setting reported in these two studies, expressed in 1997 dollars. For multi-family housing, findings from Bernick et al. (1995) and Cervero (1996) were adopted. For offices, findings from Falcke (1978) and Landis and Lotzenheimer (1995) were merged; premium estimates were based on averages computed from these two studies. And for commercial-retail, Falcke's 1978 results were relied upon. Estimated premiums, shown in Tables 9.13 through 9.17, are expressed for distance intervals that are most commonly used in these studies.

Additional Assumptions

In addition to these inputs, several assumptions need to be adopted to carry out the calculations. These assumptions can be dispensed with in instances where data are available or can be readily compiled. The necessity to make assumptions can be overcome given enough resources – namely the budget needed to fully compile and organize needed input data. In the absence of such resources, however, reasonable assumptions can be made. What is important is that analysts be *explicit* about the assumptions invoked. One can easily change assumptions, say based on inputs from a Delphi process or a focus group session. Indeed, the very nature of sensitivity analysis involves perturbing assumptions to trace effects on outcomes. It is in this spirit that assumptions should be drawn.

Table 9.12 Inventory of Land Uses Around 25 BART Station Areas, 1973 and 1993

Land Use Category	Units	Amount of Development							
		1973 (pre-BART)				1993 (20 years after)			
		CBD	Urban	Suburban	Total	CBD	Urban	Suburban	Total
Single-Family Residential	No. of units	220	2,680	6,030	8,930	205	2,750	6,915	9,870
Multi-Family Residential	No. of units	2,455	9,535	6,490	18,480	3,420	10,085	11,255	24,760
Office	Building, sf. (1,000)	18,425	2,700	1,805	22,930	34,655	2,770	7,065	44,490
Commercial-Retail	Building, sf. (1,000)	11,205	2,895	2,720	16,820	14,830	3,070	6,155	24,055

Source: Cervero (1995).

Table 9.13 Premiums for Single-Family Residences Within Half-Mile Impact Areas of BART Stations, for Distance Intervals (Expressed in 1997 Dollars)

Distance Interval (ft.)	Average Premium per Unit (1997\$)	
	CBD/Urban	Suburban
0 – 500	48,960	9,140
500 – 1,000	14,400	7,930
1,000 – 1,500	8,640	3,040
2,000 – 2,500	5,760	5,500

Note: Premiums reported in Dyett et al. (1979) for urban settings (and also assumed to apply to CBDs) are: 0-500 feet – +17 percent; 500-1,000 feet – +5 percent; 1,000-1,500 feet – +3 percent; 1,500-2,000 feet – +2 percent; 2,000-2,500 feet – 1 percent. Median single-family house in urban parts of the BART-served Bay Area are assumed to be valued at \$288,000, in 1997 dollars. Premiums reported in Landis et al. (1995) for suburban settings are based on: a decline in value of \$2.43 (in Contra Costa County) for every foot distance from station, using midpoint values for distances for each interval (e.g., values at 250 feet for the 0-500-foot interval). A proximity premium of \$9,750 (based on Alameda County findings) is used for dwelling units within 1,000 feet of stations (i.e., for the 0-500 and 500-1,000-foot interval categories).

Source: Dyett et al. (1979) and Landis et al. (1995).

Table 9.14 Premiums for Multi-Family Units Within Half-Mile Impact Areas of BART Stations, for Distance Intervals (*Expressed in 1997 Dollars*)

Distance Interval (ft.)	Average Premium per Unit (1997\$)	
	CBD/Urban	Suburban
0 – 1,300	\$50.00	\$42.30
1,300 – 2,500	\$ 0.00	\$ 0.00

Note: Premiums reported in Cervero (1996) are used for suburban settings (based on Pleasant Hill and Fremont station areas). For CBD/urban settings, premiums (\$0.05 per square foot) reported in Bernick et al. (1994) are used. Assuming an average size of 1,000 square feet for urban multi-family unit yields a gross premium of \$50 per unit.

Source: Cervero (1996) and Bernick et al. (1995).

Table 9.15 Premiums for Offices Within Half-Mile Impact Areas of BART Stations, for Distance Intervals (*Expressed in 1997 Dollars per Square Foot*)

Distance Interval (ft.)	Average Premium per Square Foot (1997\$)	
	CBD/Urban	Suburban
0 – 1,300	\$0.13	\$0.00
1,300 – 2,000	\$0.07	\$0.28
2,000 – 2,500	\$0.00	\$0.00

Note: Insignificant or no rent premiums were recorded for San Francisco and Oakland CBDs by Landis and Lotzenheimer (1995) and Landis and Huang (1995), anywhere within a half-mile catchment. Falcke (1978) found more significant impacts in downtown Oakland, and fairly inconsequential capitalization effects in San Francisco's CBD. A weighted-average estimate of premiums was computed for CBD/urban settings (based on the shares of office space in the CBDs of San Francisco and Oakland). Based on 1993 mean rents in CBDs (expressed in 1997 currency) of \$1.60 per square foot (for the 0–1,300-foot distance interval) and \$1.40 per square foot (for the 1,300–2,000-foot interval), and a weighted-average premium of eight percent for the 0–1,300-foot distance interval and five percent for the 1,300–2,000-foot interval, proximity to BART is assumed to raise office rents per square foot by \$0.13 for the 0–1,300-foot interval and by \$0.07 for the 1,300–2,000-foot interval. For suburban BART station areas, premiums were recorded only for the 1/4-to 3/8-mile ring (roughly 1,300 to 2,000-foot distance from station), based largely on the experiences around the Walnut Creek station. Since the Walnut Creek station area, and the nearby Pleasant Hill and Concord station areas, constituted the bulk of suburban office development that took place around BART during the 1973–1993 period (Cervero, 1995), the recorded premium for Walnut Creek is assumed to apply for all suburban station areas.

Sources: Falcke (1978) and Landis and Lotzenheimer (1995).

Table 9.16 Premiums for Commercial-Retail Activities Within Half-Mile Impact Areas of BART Stations, for Distance Intervals (Expressed in 1997 Dollars per Square Foot)

Distance Interval (ft.)	Average Premium per Square Foot(1997\$)	
	CBD/Urban	Suburban
0 – 500	\$0.07	\$0.24
500 – 1,000	\$0.00	\$0.24
1,000 – 2,500	\$0.00	\$0.00

Note: Premiums based on findings of Falcke: One percent for urban retail within 500 feet of stations and none otherwise; and eight percent for suburban retail within 1,000 feet of stations and none otherwise. Percent premiums were monetized based on assumed monthly retail rents of \$7 per square foot in CBD/urban settings, and \$3 per square foot in suburban settings, expressed in 1997 dollars.

Source: Falcke (1978).

The following assumptions were adopted to carry out this analysis.

- The monthly rent premiums associated with multi-family housing, offices, and commercial-retail development need to be spread out over the 20-year time horizon (1973 to 1993). The amount of development that occurred over this period can be assumed to have come on line at a uniform rate. This is equivalent to assuming that, on average, new development occurred midway, or in the tenth year, of the 20-year period. Since rent premiums are expressed on a monthly basis, we'll assume station area development over the 1973-1993 period existed, on average, for 120 months (10 years × 12 months). Thus, an expansion factor of 120 will be used for measuring rent premiums.
- In order to apply Equation 1 to the BART data, one must also know the total amount of development within each distance interval, using the distance intervals by which premiums are broken down in Tables 9.13 through 9.16. The BART @ 20 study did not stratify land use inventories by distance intervals within impact zones, thus some assumption must be made on how development within these zones is spread across distance intervals. This must be done for each of the four land uses.

The simplest assumption is that development is evenly spread within distance rings. This is equivalent to saying that land uses are distributed within each distance interval according to that interval's share of total land area within an impact zone. For example, Table 9.14 shows that rent premiums for commercial-retail activities vary according to whether the activities are within any one of the three distance rings: 0-500 feet; 500-1,000 feet; and 1,000-2,500 feet. The impact zone of 2,500 radial feet from a station constitutes a

450-acre land area (assuming the impact catchment takes the form of a perfect sphere around the station).⁵³ The land areas of 500 radial foot and 1,000 radial foot circles are 18 acres and 72 acres respectively. This, then, tells us that the area of each distance ring is: 0-500 feet = 18 acres; 500-1,000 feet = 54 acres (72 minus 18); and 1,000-2,500 feet = 378 acres (450 minus 72). Thus, the share of commercial-retail development that is assumed to exist in each ring is the following percents of total development within the impact zone: 0-500 feet – 4 percent; 500-1,000 feet – 12 percent; 1,000-2,500 feet – 84 percent. Invoking the same assumption, development can be apportioned among distance rings for the other three land uses as follows:

- Single-family residential:
 - 0-500 feet: 4 percent
 - 500-1,000 feet: 12 percent
 - 1,000-1,500 feet: 20 percent
 - 1,500-2,000 feet: 28 percent
 - 2,000-2,500 feet: 36 percent

- Multi-family residential:
 - 0-1,300 feet: 27 percent
 - 1,300-2,500 feet: 73 percent

- Office:
 - 0-1,300 feet: 27 percent
 - 1,300-2,000 feet: 37 percent
 - 2,000-2,500 feet: 36 percent

While the above assumptions are simplest to employ, in most instances they would fail to capture how urban development actually occurs around rail stations. In the case of single-family housing, development farther from stations would likely tend to be on bigger lots, so the proportion of single-family housing in the outer rings of BART impact zones (e.g., 2,000-2,500 feet) is probably somewhat smaller in reality.⁵⁴ Likewise, we would expect multi-family housing in the inner ring (0-1,300 feet) to be denser, in the form of mid-rises, four-plexes, and three-story walk-up garden apartments. In the suburbs, zoning often restricts the amount of multi-family housing that is built away from major transportation nodes, such as rail stations. Thus, the share of apartments and condominiums built in the inner distance ring is likely larger. And in the cases of office and commercial-retail activities, we know that in a competitive land market, they will generally outbid other uses for choice sites near transit stations. From casual observation, it is clear that the share of commercial-retail development within the 0-500-foot ring of BART

⁵³ Given that the area of a circle equals πr^2 , where r equals the circle's radius in linear feet, and that there are 43,560 square feet per acre, the acreage of a 2,500 radial-foot impact zone can be computed as: $[(3.1416) * (2,500^2)] / 43,560 = 450$.

⁵⁴ This is probably offset somewhat by the tendency for locations closer to stations to be zoned for and occupied by non-residential activities, with more outlying areas characterized by traditional housing development.

stations is more than four percent of the commercial-retail development within 2,500 radial foot impact zones. This is especially so in CBD and urban settings. For these reasons, the distributions of development for each land use were adjusted, and assumed to be as follows (for both CBD/urban and suburban settings):

- Single-family residential:
 - 0-500 feet: 4 percent
 - 500-1,000 feet: 12 percent
 - 1,000-1,500 feet: 20 percent
 - 1,500-2,000 feet: 32 percent
 - 2,000-2,500 feet: 32 percent

- Multi-family residential:
 - 0-1,300 feet: 40 percent
 - 1,300-2,500 feet: 60 percent

- Office:
 - 0-1,300 feet: 40 percent
 - 1,300-2,000 feet: 40 percent
 - 2,000-2,500 feet: 20 percent

- Commercial-retail:
 - 0-500 feet: 30 percent
 - 500-1,000 feet: 30 percent
 - 1,000-2,500 feet: 40 percent

Merging these apportionments with Table 9.12 produces Table 9.17, showing estimates of development within each distance interval for the 25 BART stations, as of 1993.⁵⁵

⁵⁵ Recall that calculations are made for the total development in the "after" or "with" period of analysis, since all development (old and new) capitalize accessibility and agglomeration benefits.

Table 9.17 Estimates of Development Within Distance Intervals of 25 BART Station Areas, 1993

Land Use Category (Measurement Units)	Distance Interval (ft.)	Amount of Development, 1993		
		CBD/Urban	Suburban	Total
Single-family residential (number of units)	1) 0 – 500	118 units	277 units	395 units
	2) 500 – 1,000	355	830	1,185
	3) 1,000 – 1,500	591	1,383	1,974
	4) 1,500 – 2,000	946	2,213	3,159
	5) 2,000 – 2,500	946	2,213	3,159
Multi-family residential (number of units)	1) 0 – 1,300	5,402 units	4,502 units	9,904 units
	2) 1,300 – 2,500	8,103	6,753	14,856
Office (thousands of square feet)	1) 0 – 1,300	14,970 sf. (000)	2,826 sf. (000)	17,796 sf. (000)
	2) 1,300 – 2,000	14,970	2,826	17,796
	3) 2,000 – 2,500	7,485	1,413	8,898
Commercial-Retail (thousands of square feet)	1) 0 – 500	5,730 sf. (000)	1,847 sf. (000)	7,577 sf. (000)
	2) 500 – 1,000	5,730	1,847	7,577
	3) 1,000 – 2,500	7,160	2,462	9,622

Calculations

With the inputs from Tables 9.13 through 9.17 and the assumptions invoked above, we are ready to calculate the accessibility/agglomeration benefits associated with BART station area development over the 1973-1993 period. Adapting Equation 1 to the data at hand, the following formula for carrying out this calculation is used:

$$B = \sum_{k=1}^3 \sum_{s=1}^2 \sum_{d=1}^{n_k} [(A_{ksd} \lambda_{ksd}) E_k] \quad (\text{Equation 3})$$

where:

- B = Benefit (total, in dollars)
- A_{ksd} = Amount of development in land use category k (1, 2, 3, 4), setting category s (1, 2), and distance interval d for land use category k
- λ_{ksd} = Land value or rent premium in land use category k , setting category s , and distance interval d
- E_k = Expansion factor for land use categories k (2, 3, 4 – i.e., multi-family housing, offices, commercial-retail); $E_k = 2, 3, 4 = 30$
- k = Land use category (1 = single-family residential; 2 = multi-family residential)

- 3 = Offices, (4 = commercial-retail)
- d = Distance category; for $k = 1$: 1=0-500 feet; 2=500-1,000 feet; 3=1,000-1,500 feet;
- 4 = 1,500-2,000 feet; 5=2,000-2,500 feet; for $k = 2$: 1=0-1,300 feet; 2=1,300-2,500 feet; for $k = 3$: 1=0-1,300 feet; 2=1,300-2,000 feet; 3=2,000-2,500 feet; for $k = 4$: 1=0-500 feet; 2=500-1,000 feet; 3=1,000-2,500 feet
- s = Setting category (1 = CBD/urban; 2 = suburban)
- n_k = Number of distance intervals in land use category k ; for $k = 1$, $n_1 = 5$; for $k = 2$, $n_2 = 2$; for $k = 3$, $n_3 = 3$; for $k = 4$, $n_4 = 3$

Inputting appropriate data from Tables 9.13 through 9.17 into Equation 3 produces the following estimate of accessibility/agglomeration benefits for the 25 BART stations over the first 20 years of service (broken down for each land use category k and setting category s):

Single-Family Residential ($k=1$), CBD/Urban ($s=1$):

$$[(118^*48,960) + (355^*14,400) + (591^*8,640) + (946^*5,760) + (946^*2,880)] = \quad \mathbf{\$ 24,169,000}$$

Single-Family Residential ($k=1$), Suburban ($s=2$):

$$[(277^*9,140) + (830^*7,930) + (1,383^*3,040) + (2,213^*5,500) + (2,213^*4,280)] = \mathbf{\$ 34,961,000}$$

Multi-family Residential ($k=2$), CBD/Urban ($s=1$):

$$[[(5,402^*50) + (8,103^*0)] ^* 30] = \quad \mathbf{\$ 8,103,000}$$

Multi-family Residential ($k=2$), Suburban ($s=2$):

$$[[(4,502^*42.30) + (6,753^*0)] ^* 30] = \quad \mathbf{\$ 5,713,000}$$

Offices ($k=3$), CBD/Urban ($s=1$):

$$[[(14,970,000^*0.13) + (14,970,000^*0.07) + (7,485,000^*0)] ^* 30] = \quad \mathbf{\$ 88,740,000}$$

Offices ($k=3$), Suburban ($s=2$):

$$[[(2,826,000^*0) + (2,826,000^*0.28) + (1,413,000^*0)] ^* 30] = \quad \mathbf{\$ 23,738,000}$$

Commercial-Retail ($k=4$), CBD/Urban ($s=1$):

$$[[(5,730,000^*0.07) + (5,730,000^*0) + (7,160,000^*0)] ^* 30] = \quad \mathbf{\$ 12,033,000}$$

Commercial-Retail ($k=4$), Suburban ($s=2$):

$$[[(1,847,000^*0.24) + (1,847,000^*0.24) + (2,462,000^*0)] ^* 30] = \quad \mathbf{\$ 26,597,000}$$

$$\mathbf{TOTAL = \quad \$24,169,000 + \$34,961,000 + \$8,103,000 + \$5,713,000 + \$88,740,000 + \$23,738,000 + \$12,033,000 + \$26,597,000 = \quad \mathbf{\$224,054,000}$$

In summary, based on the methods, data inputs, and assumptions presented, it is estimated that the 25 BART station areas studied generated nearly \$225 million in accessibility and agglomeration benefits.⁵⁶ The accessibility benefits of BART likely far exceed this total since properties beyond impact zones, which are far greater in number than properties included in this exercise, no doubt accrue accessibility benefits to some degree, however infinitesimally small they might be. Even if most past studies have not successfully measured capitalization benefits beyond half-mile impact zones, this is likely more an artifact of data limitations than the absence of BART's accessibility benefits being geographically dispersed.⁵⁷ Still, given the data inputs and assumptions made, \$224 million is likely a reasonable estimate of the accessibility/agglomeration benefits associated with station area development for these 25 BART stations.

It appears that downtown offices have reaped the greatest accessibility/agglomeration benefits – roughly 40 percent of the total. The second most benefiting activity has been suburban single-family homes, followed by suburban retail and urban single-family housing. Station area apartment-dwellers and condominium owners appear to reap the fewest accessibility benefits, in large part because they are less prevalent. With current BART efforts to promote transit villages around selected stations, however, this could change over time (see Bernick and Cervero, 1997).

Second-Order Impacts

Compact mixed-use development around rail transit stations can set into motion a series of second-order impacts. The additional transit ridership resulting from more compact transit-oriented development, for example, will benefit society at large (e.g., less traffic congestion) and transit agencies (e.g., more farebox revenues).

Estimating Ridership Impacts of Rail-Induced Growth

Given sufficient input data, second-order ridership impacts of station area growth can be estimated by borrowing from past research. To get at ridership impacts, one can compare the likely modal split differentials between development within versus beyond a walking distance (quarter- to half-mile) of a transit station. Particularly good data on transit modal splits as functions of distances to transit stations are available from metropolitan Washington, DC, Toronto, Edmonton, and several rail-served regions of California (San

⁵⁶ It should be recalled that accessibility benefits accrue to all land use categories, while agglomeration benefits accrue primarily to offices and commercial-retail land uses, and perhaps secondarily to transit-oriented multi-family housing. None of the measured benefit for single-family housing, however, likely includes any agglomeration benefit component. Rather, it exclusively reflects the capitalized value of accessibility benefits.

⁵⁷ It should be noted that some studies found accessibility benefits that extended beyond half-mile impact zones. Landis et al. (1995), for example, estimated that BART-induced capitalization benefits for single-family homes extended more than 10 miles beyond many East Bay stations.

Francisco-Oakland, San Diego, and Sacramento).⁵⁸ Findings on how modal split gradients taper with distance for residential land uses in these three settings are summarized in Figure 9.17.⁵⁹ Findings for office land uses are summarized in Figure 9.18.

Using empirical evidence from Figure 9.17 or other sources, and other data inputs, the second-order ridership benefits of station area development might be estimated using Equation 4:

$$R = \sum_{k=1} \sum_{d=1} [(A_{ksd(w)} A_{ksd(wo)}) T_{kd}] (\gamma_{ksd(w)} - \gamma_{ksd(wo)}) \quad (\text{Equation 4})$$

R = Ridership increase from compact, transit-oriented development for land use category k

$A_{kd(w)}$ = Amount of development of land use category k and distance interval d , with rail transit services

$A_{kd(wo)}$ = Amount of development of land use category k and distance interval d , with rail transit services

T_{kd} = Trip generation rates for land use category k and distance interval d (e.g., daily motorized trips per 1,000 square feet)

$\gamma_{kd(w)}$ = Transit modal split capture rate for land use category k and distance interval d (e.g., percent of motorized trips by transit), with rail transit services

$\gamma_{kd(wo)}$ = Transit modal split capture rate for land use category k and distance interval d (e.g., percent of motorized trips by transit), without rail transit services

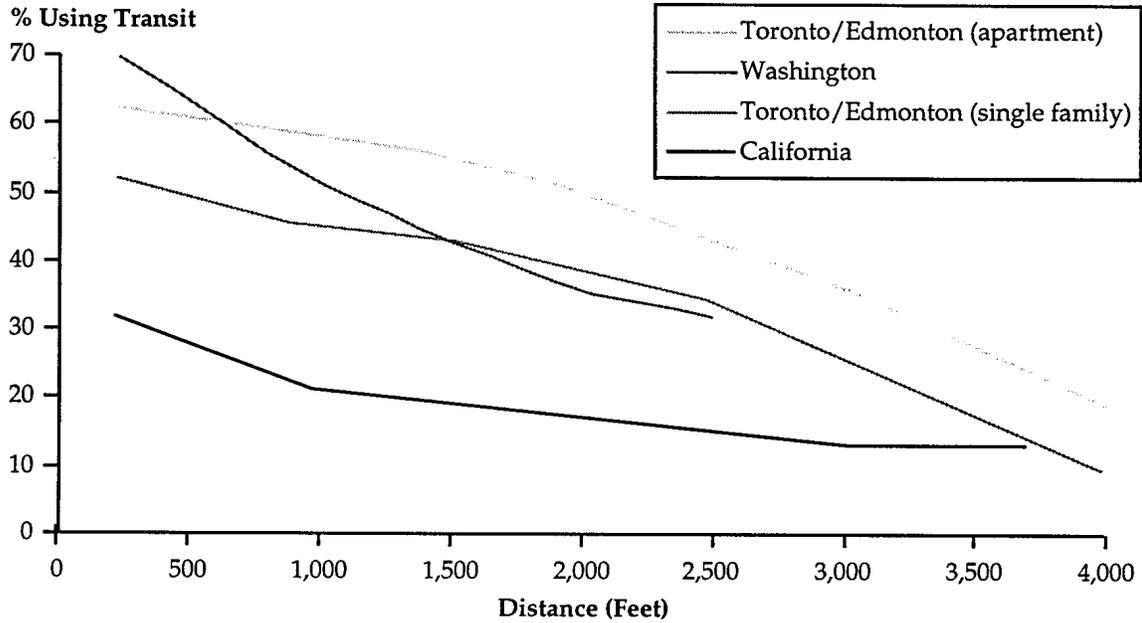
k = Land use category

d = Distance interval

⁵⁸ See JHK and Associates (1987, 1989); Cervero (1993); and Stringham (1982). In California, rail's modal shares fell by about 1.1 percent for every 1,000 foot increase in walking distance to rail stations. Higher rates in metropolitan Washington, DC (mainly based on experiences in Arlington, Virginia) and Toronto/Edmonton, Canada likely reflect the following characteristics of these areas (relative to California): higher residential densities; higher primacy (e.g., larger shares of the regional workforce in downtowns); better feeder bus connections; more extensive and more frequent rail services; and perhaps even better quality station area walking environments.

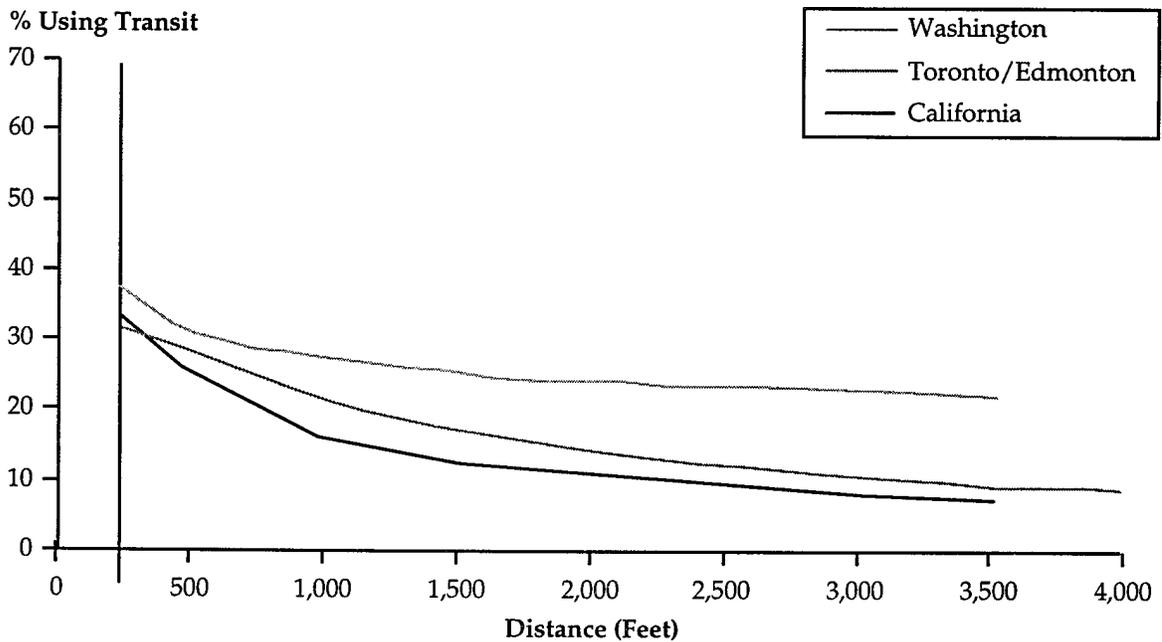
⁵⁹ Findings from California and metropolitan Washington, DC are for multi-family residences. Canadian findings are for all residential types.

Figure 9.17 Transit Modal Shares for Station Area Residences by Distance to Stations: Comparison of Experiences in Toronto/Edmonton, Metropolitan Washington, and Rail-Served Parts of California



Source: Cervero (1993) and Bernick and Cervero (1997).

Figure 9.18 Transit Modal Shares for Station Area Office Workers by Distance to Stations: Comparison of Experiences in Toronto/Edmonton, Metropolitan Washington, and Rail-Served Parts of California



Source: Cervero (1993) and Bernick and Cervero (1997).

Example: Measuring Ridership Impacts

Assumptions and Inputs

Data from the BART @ 20 study, Figures 9.17 and 9.18, and trip generation references can be applied to Equation 4 to estimate the ridership induced by station area growth. To compute an estimate, let's assume the following:

- Ridership gains associated with station area growth only accrue to two land uses: multi-family residential and offices. In the case of BART, this is largely supported by empirical evidence (Cervero, 1993).
- Motorized trip generation rates from the ITE (1991) Trip Generation manual are assumed to apply. A daily rate of 6.5 trips per multi-family household is assumed.⁶⁰ A daily rate of 10 trips per 1,000 square feet of office is also assumed.⁶¹ For both land uses, trip rates are not thought to vary by distance from stations.
- Transit-induced growth is represented by the differences in development "before" (in 1973) and "after" (in 1993) BART. This assumes no new development would have occurred in these half-mile radius station areas between 1973 and 1993 without BART being built.⁶²
- Transit modal splits for station area residents in the "without" scenario are assumed to match the regional 1991 average transit modal split (for all trips) of three percent, as reported from the 1991 Bay Area Travel Survey (BATS). Because of the tendency of offices to be in more compact transit-served settings (i.e., relatively good bus services in the absence of BART), a higher modal split of five percent is assumed for offices in the "without" scenario.
- No distinctions are made in trip generation rates and transit modal splits between CBD/urban and suburban settings (since little is known about these variations and empirical results shown in Figures 9.17 and 9.18 do not make such distinctions). Thus, total amounts of single-family and office development for both 1973 (pre-BART: "without") and 1993 (20 years after: "with") shown in Tables 9.12 and 9.17 are used.
- Distance intervals are expressed according to how land use inventories were reported in the BART @ 20 study for the two land uses. Thus, average transit modal splits are imputed from Figures 9.17 and 9.18 based on midpoint values for the distance intervals used.

⁶⁰ This is the average weekday vehicle trip rate for apartments (ITE land use category 220).

⁶¹ This is the average weekday vehicle trip rate for general office buildings (ITE land use category 710), based on an assumed average office building size of 400,000 square feet.

⁶² This is likely a liberal assumption in the sense that some new development would have probably occurred in these areas, although the amount would surely have been far less than with BART and it would have not been physically oriented to BART. Alternately, one could assume that a certain percentage of station area growth would have occurred anyway, based, say, on the amount of growth for a land use that took place during the 1973-1993 period for the city in which a station resides. For simplicity sake, the assumption that all new growth is induced by BART is adopted.

- Modal split experiences reported in Figures 9.17 and 9.18 for California are representative of the BART system.

Given these assumptions, the data inputs can be organized as follows to facilitate the use of Equation 4. Table 9.18 summarizes the amount of 1993 multi-family and office station area development "with" and "without" BART for the 25 stations under study. The difference is assumed to be induced growth. Table 9.19 summarizes the assumed transit modal splits for each distance interval, using midpoint values from Figures 9.17 and 9.18.

Table 9.18 Assumed 1993 Single-Family and Office Station Area Development With and Without BART (for 25 Station Areas)

Land Use Category (Measurement Units)	Distance Interval (ft.)	Amount of Development	
		Without ¹	With ²
Multi-family residential (number of units)	1) 0 – 1,300	7,392 units	9,904 units
	2) 1,300 – 2,500	11,088	14,856
Office (thousands of square feet)	1) 0 – 1,300	9,172 sf. (000)	17,796 sf. (000)
	2) 1,300 – 2,000	9,172	17,796
	3) 2,000 – 2,500	4,586	8,898

¹ Represents amount of development in 1973, prior to BART's opening. These values were derived in a similar manner to how the figures in Table 9.17 were produced. The same prorations of land development across distance intervals, used in calculating 1993 totals in Table 9.17, were assumed to apply in 1973.

² Represents amount of development in 1993, 20 years after BART's opening and that is assumed to be induced by BART. Values are from Table 9.17.

Table 9.19 Assumed Transit Modal Splits With and Without BART (for 25 Station Areas)

Land Use Category	Distance Interval (ft.)	Transit Modal Splits (%)	
		Without ¹	With ²
Multi-family residential	1) 0 – 1,300	3	22
	2) 1,300 – 2,500	3	16
Office	1) 0 – 1,300	5	20

¹ For multi-family residential, assumed to represent the 1991 regional transit modal split of around three percent for all trips. A higher modal split for office workers is assumed based on the tendency of offices to be in more compact settings better served by bus and other forms of transit.

Sources: Cervero (1993).

Calculation

Using data from Tables 9.18 and 9.19, and invoking the assumptions, the average daily ridership impacts of transit-oriented growth around the 25 BART stations can be computed using Equation 4, stratified by the two land use categories:

$$\text{Benefit (residential)} = [(450,000 * -\$0.30) + (850,000 * \$1.75) + (1,400,000 * \$1.00) + (1,700,000 * \$0.60)] = \quad \mathbf{\$ 3,820,000}$$

$$\text{Benefit (commercial)} = [(160,000 * \$3.50) + (120,000 * \$1.25) + (100,000 * \$0.75) + (80,000 * \$0.50)] * 30 = \quad \mathbf{\$24,750,000}$$

$$\mathbf{\text{TOTAL BENEFIT: } \$3,772,500 + \$24,750,000 = \quad \mathbf{\$28,570,000}}$$

$$\text{Multi-family Residential (k=1): } \{ [(9,904-7,392) * 6.5] * (.22-.03) \} + \{ [(14,856-11,088) * 6.5] * (.16-.03) \} = \quad \mathbf{6,286}$$

$$\text{Offices (k=2): } \{ [(17,996-9,172) * 10] * (.20-.05) \} + \{ [(17,996-9,172) * 10] * (.11-.05) \} + \{ [(8,898-4,586) * 10] * (.09-.05) \} = \quad \mathbf{20,255}$$

$$\mathbf{\text{TOTAL: } 6,286 + 20,255 = \quad \mathbf{26,541}}$$

Thus, based on the assumptions and empirical data used, it is estimated that some 26,500 daily trips are a result of transit-oriented, multi-family housing and office development around 25 BART stations. Around three-quarters of this total is attributable of station area office growth. This estimated 26,500 daily growth-induced BART trips constitutes around 10 percent of BART's current total daily ridership.

From the perspective of many transit agencies, the bottom-line benefit of transit-induced growth is increased farebox revenues. Applying an average fare per trip, the revenue implications of transit-induced growth can be estimated. In BART's case, the average fare per trip in 1993 was around \$2.⁶³ Thus, the estimated amount of additional daily fare revenues generated in 1993 by transit-induced growth around the 25 stations is: 26,541 daily trips * \$2/trips = \$53,082.

Conclusion

Using empirical evidence from land markets is one of the most promising and straightforward approaches to getting at transit's accessibility and agglomeration benefits. Simple algebraic formulas can be used to generate estimates, drawing from available empirical data and intuitive assumptions. By defining the spatial extent of transit's capitalized land value and rent premiums, and by capturing the relationship between price and distance, one can easily multiply premiums by land use quantities and integrate the

⁶³ BART uses distance-based fares. Transbay fares, between the East Bay and San Francisco, are the highest. Since Transbay trips constitute a large share of daily journeys, especially for office workers, average fares per trip tend to be relatively high.

results across distance categories to arrive at plausible estimates. And given knowledge of how transit modal splits vary with distances from stations, a topic that has gained increasing research attention in recent years, one can extend the analysis to measure second-order impacts – namely how ridership and farebox revenues might increase as urban growth clusters around transit stops.

For the most part, there is sufficient empirical evidence to carry out these analyses for some of the larger metropolitan areas of the country with relatively new rail systems. While some assumptions will likely have to be adopted in applying these methods, as is the case with virtually any method, the assumptions themselves can be perturbed to allow for sensitivity analyses. Also, qualitative approaches, such as Delphi and focus group techniques, can be used to set and refine assumptions. As empirical evidence on transit and land use relationships continues to mount, we can expect the methods presented in this section to have even broader applicability in years to come.

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation