Evaluation of the Accessibility Effects and Proximity Related Externalities of Commuter Rail Service

by

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Abstract

The impact of commuter rail service upon communities is examined via the analysis of single-family residential property values, with both beneficial and deleterious impacts evaluated. The primary motivations for this research are threefold: the growth of commuter rail services throughout the U.S., the ongoing debate in a number of U.S. metropolitan areas concerning the existence and extent of impacts from commuter rail facilities upon residential properties, and the current lack of adequate empirical evidence concerning the capitalization effects of commuter rail facilities.

Revealed preference hedonic price models are utilized in conjunction with quasi-experimental approaches and paired data analysis, with the resulting analytic framework applied to a case study of commuter rail service in metropolitan Boston, Massachusetts. Results of the paired data analyses indicate that variations in accessibility to commuter rail stations within a given community do have a statistically significant but small impact upon single-family residential property values. Quasi-experimental hedonic price models yield inconsistent findings, with statistically significant property value premiums of 3.0 percent and 9.9 percent observed for homes within walking distance of commuter rail stations in two of the five study areas.

At the regional level, there is some evidence that commuter rail accessibility to downtown terminals has a statistically significant appreciative impact upon single-family residential property values. Estimates of the elasticity of single-family residential property sales price with respect to commuter rail line haul travel time range from -0.16 to -0.18. A statistically significant sales price premium of about 3.8 percent is also observed for single-family residential properties by virtue of their being located within a community directly served by commuter rail.

Regarding proximity related externalities, both paired data analyses and hedonic price models reveal no consistent statistically significant reductions in the value of properties in proximity to rail rights-of-way. For the grade crossing analyses, there were no statistically significant effects upon property values identified.

The implications of the findings of this research, and the potential development of appropriate policy responses to the impacts that have been examined, are discussed in the context of the planning, design, and operation of new commuter rail facilities.

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Title: Professor of Civil and Environmental Engineering

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Chapter 1
Introduction

In recent years, there has been a renewed interest in commuter rail throughout much of North America. However, despite broad mobility, air quality, and economic benefits that often result from commuter rail service, recent attempts by transit agencies to introduce or expand commuter rail services have often met with significant local opposition. This thesis is focused upon the development and application of an appropriate analytic framework for measuring the various impacts of commuter rail service, with the goal of evaluating the nature and extent of both the beneficial and deleterious impacts of commuter rail systems upon communities and property owners. A greater understanding of these impacts may aid in the development of policy responses aimed at mitigating the negative impacts of commuter rail, while helping to maximize both public support of and the benefits derived from commuter rail services. Thus, it is hoped that these findings will benefit both the affected public as well as transit agencies engaged in the planning, design, and operation of new or expanded commuter rail facilities.

1.1 History and Current Status of the Commuter Rail Mode

The use of passenger railroads for dedicated commuter rail service is said to have begun in 1843 by the Boston & Worcester Railroad, although several years prior to this time, local and regional travel on intercity passenger trains at "commuted" or reduced rates was available in a number of U.S. metropolitan areas, including Philadelphia (1832), New York (1833) and Boston (1838).[1,2] Throughout the mid and late 1800's, the number of commuter passengers grew steadily as a result of post-Civil War industrialization and population growth. Ridership reached its zenith in the mid-1920's at 6.7 million passengers daily. However, by the 1930's, the expansion of suburban railroading was brought to an end by increased federal aid for road and highway improvements, increasing automobile ownership, and the Great Depression.[3]

World War II provided some relief for railroads, with ridership rebounding as a result of full employment, and shortages and rationing of gasoline and rubber making automobile use

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[1] Vuchic, Vukan R. *Urban Public Transportation Systems and Technology*. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1981. pg. 42.
[2] Grow, Lawrence. *On the 8:02 - An Informal History of Commuting By Rail in America*. New York, New York: Mayflower Books, Inc., 1979.
[3] Smerk, George M. *The Federal Role in Urban Mass Transportation*.. Bloomington, Indiana: Indiana University Press, 1991.

difficult. However, following World War II, having made major expenditures to replace passenger rolling stock weary from years of wartime use, railroads found themselves with heavy debt and few riders. By this time, air and automobile travel proved to be overwhelming competition for passenger rail travel. Freight operations too suffered substantial declines during this period resulting from competition with truck and air travel. Thus, where railroads had in the past been able to mitigate losses from passenger trains by cross-subsidization from freight operations, declining freight revenues now prevented the industry from following this course.

Although declines in passenger rail patronage continued, unprofitable passenger services endured because of onerous regulatory procedures. Railroads lobbied for regulatory relief, and Congress provided it in the form of the Transportation Act of 1958, which allowed railroads to more easily discontinue unprofitable passenger service. Taking advantage of the legislation, many railroads gave prompt notice of the elimination of several commuter rail lines in major metropolitan areas. To avoid the serious disruption of the transportation system in these metropolitan areas that would have likely resulted from such service reductions, a $75 million federal mass transit assistance program was passed as part of the Housing Act of 1961, and thus federal assistance to mass transit began in an effort to preserve unprofitable passenger commuter rail lines.[4]

As the 1960's progressed, increased federal support for all transit modes continued with further legislation including the Urban Mass Transportation Act of 1964. Federal money for transit expanded substantially in the 1970's, with the Highway Act of 1973, the National Mass Transportation Assistance Act of 1974 and the Surface Transportation Act of 1978 providing continued support. Many commuter rail properties took advantage of this opportunity and proceeded with rebuilding and replenishment of worn out infrastructure and rolling stock.

With the advent of the 1980's, there was considerable concern among transit supporters regarding the new philosophy of government that arrived with the Reagan administration and what impact this would have upon federal transit programs. However, despite the best efforts of the Reagan administration, the federal transit program received surprisingly strong bi-partisan Congressional support, in large part shielding the program and helping it to survive largely intact into the late 1980's.

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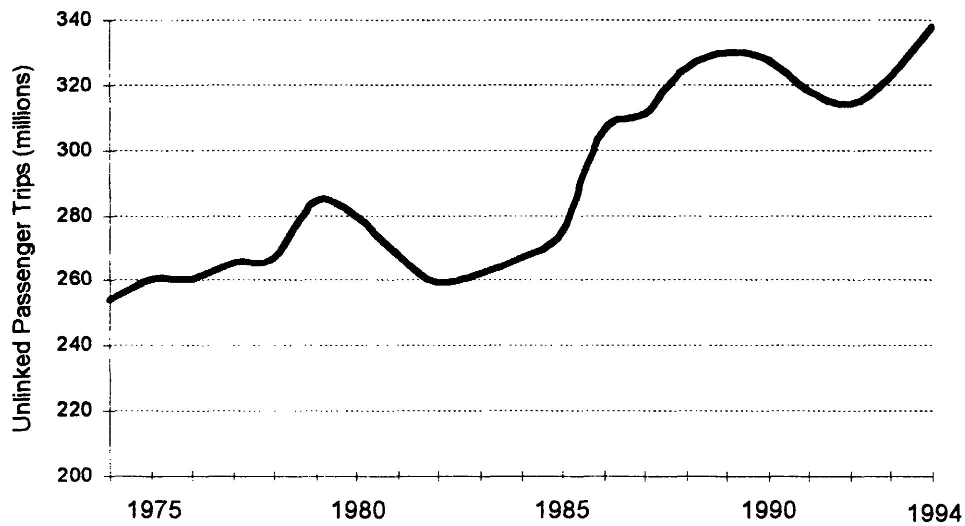
[4] *Ibid.* pp. 78-81.

Figure 1.1: Historical Trends in U.S. Commuter Rail Ridership



Source: American Public Transit Association, Transit Fact Book, multiple editions.

Commuter rail services in North America have experienced a revival in recent years, with an impressive increase in commuter rail activity that has continued almost unabated since the early 1980's but for the recessionary period of the early 1990's (see Figure 1.1). This period has seen existing services expand, as well as new services be introduced in a number of locations including Florida (Tri-Rail), New Haven (ConnDOT), Washington D.C. (Virginia Railway Express), and Los Angeles (Metrolink). As of the end of 1995, commuter rail services operated in fourteen metropolitan areas in North America (see Table 1.1).

Throughout much of the past decade commuter rail has also been one of the fastest growing segments of the transit industry in the U.S., with renewed interest brought about in part by air quality concerns, increasing traffic congestion, and regulatory and financial limitations placed upon the expansion of highway capacity (see Table 1.2). In some regions, commuter rail has experienced robust ridership growth while at the same time growth in other transit modes remained stagnant. Although light rail has experienced a greater overall average annual percentage growth in unlinked trips during the period shown in the table, the considerable number of light rail new-starts that have occurred throughout the period has contributed to this advantage, with almost a doubling in the number of light rail systems (from 12 to 22) between 1985 and 1994. Commuter rail experienced more modest growth in the number of new-starts, increasing from 13 to 16 systems during the same period. The

Table 1.1: U.S. and Canadian Commuter Rail Systems - 1995[(1)]

Metropolitan Area Served	Transit Agency	Service Mark	Date of Initial Operation for New Systems
New York, NY	Metropolitan Transportation Authority	Long Island Railroad (LIRR)	
New York, NY	Metropolitan Transportation Authority	Metro-North Railroad (MN)	
New York, NY	New Jersey Transit Corporation	New Jersey Transit (NJT)	
Chicago, IL	Regional Transportation Authority (RTA), Commuter Rail Service Board	Metropolitan Rail (Metra)	
Chicago, IL	Northern Indiana Commuter Transportation District (NICTD)	South Shore Line	
Washington, D.C.	Maryland DOT, Mass Transit Administration	Maryland Rail Commuter (MARC)	
Washington, D.C.	Northern Virginia and Potomac and Rappahannock Transportation Commissions	Virginia Railway Express (VRE)	June 1992
Boston, MA	Massachusetts Bay Transportation Authority (MBTA)	MBTA	
Philadelphia, PA	Southeastern Pennsylvania Transportation Authority (SEPTA)	SEPTA	
Los Angeles CA	Southern California Regional Rail Authority (SCRRA)	Metrolink	October 1992 [(2)]
San Diego, CA	North San Diego County Transit Development Board	Coast Rail Express (Coaster)	February 1995
Miami, FL	Tri-County Commuter Rail Authority	Tri-Rail	January 1989
San Francisco, CA	Peninsula Corridor Joint Powers Board	CalTrain	
New Haven, CT	Connecticut DOT (ConnDOT)	Shore Line East	May 1990
Syracuse, NY	The New York, Susquhanna & Western	On Track	September 1994
Toronto, ON	Government of Ontario	GO Transit	
Montreal, PQ	Montreal Urban Community Transit Corporation (MUCTC)	MUCTC	
Vancouver, BC	BC Transit	West Coast Express	November 1995

(1) Sources: 1994 National Transit Database; *1996 Transit Fact Book*, American Public Transit Association. PennDOT service not shown in table.

(2) Orange County Transportation Authority (OCTA) commuter rail service operated by Amtrak commenced April 1990 between San Juan Capistrano and Los Angeles on what is currently the Metrolink Oceanside Line

Table 1.2: U.S. Transit Industry Service Utilization Trends - Unlinked Passenger Trips (all systems by mode)

Calendar Year	Commuter Rail	Heavy Rail	Light Rail	Trolley Bus	Motor Bus	Demand Response
1984	267	2,231	135	165	5,908	62
1985	275	2,290	132	142	5,675	59
1986	306	2,333	130	139	5,753	63
1987	311	2,402	133	141	5,614	64
1988	325	2,308	154	136	5,590	73
1989	330	2,542	162	130	5,620	70
1990	328	2,346	175	126	5,677	68
1991	318	2,172	184	125	5,624	71
1992	314	2,207	188	126	5,517	72
1993	322	2,209	188	121	5,371	75
1994	338	2,206	203	118	5,402	87
Avg. Annual Growth for the Period	2.5%	0.0%	4.3%	-3.2%	-0.9%	3.7%

Source: American Public Transit Association. *1996 Transit Fact Book*. Table 36.

significant average annual growth in demand response services is in large part the result of Americans with Disabilities Act compliance efforts.

Shifting the focus to absolute gains in ridership, comparing 1984 with 1994 one sees that the absolute gain in ridership was greatest for the commuter rail mode at 71 million unlinked passenger trips, followed by light rail at 68 million unlinked passenger trips, and demand response at 25 million trips. Heavy rail, motor bus, and trolley bus all experienced net decreases in ridership over this same period. Thus, for the past decade commuter rail has experienced greater absolute growth in unlinked passenger trips than any other transit mode, even while experiencing the fewest number of new-starts of any transit mode other than trolley bus, making it a strong candidate for the fastest growing transit mode of the past decade.

A review of metropolitan area population growth trends and the capital costs of new rail transit systems provides some insight into why commuter rail has experienced such growth in recent years. Since the 1920's, the data reveal that suburban population has grown faster than urban population, substantially so following World War II (see Table 1.3). Urbanized land area nearly tripled between 1950 and 1970."[5]

Along with these changes in the size and geographic distribution of metropolitan area populations, changes in work related travel patterns have also occurred. Average vehicle trip length in miles for work trips has grown from 8.5 miles in 1983 to 11.0 miles in 1990, a 29.4%

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[5] Cervero, Robert, et. al. *Efficiency and Equity Implications of Alternative Transit Fare Policies*. DOT-I-80-32. September 1980. pg. 5.

Table 1.3: Metropolitan Population Growth Trends in the U.S. - 1910 to 1990[1]

Decade	Central City Growth Rate	Suburban Growth Rate	Percent Total SMSA (2) growth in Suburbs
1910-1920	27.7%	20.0%	28.4%
1920-1930	24.3%	32.3%	40.7%
1930-1940	5.6%	14.6%	59.0%
1940-1950	14.7%	35.9%	59.3%
1950-1960	10.7%	48.5%	76.2%
1960-1970	10.0%	37.8%	78.2%
1970-1980	16.6%	25.7%	64.7%
1980-1990	13.7%	13.8%	56.2%

(1) 1910-1970 city population data is for central cities only. 1980 and 1990 city population data is for all U.S. cities of 50,000 or greater population.
(2) SMSA: Standard Metropolitan Statistical Area
Sources: 1910-1920 to 1950-1960 data from Muller, Peter O. "Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis," pg. 38. In *The Geography of Urban Transportation*, Edited by Susan Hanson. New York, NY: The Guilford Press, 1986. 1960 & 1970 data from *Historical Statistics of the United States. Colonial Times to 1970. Part I*. Bicentennial edition. pg 30, Series A 264-275. U.S. Department of Commerce, Bureau of the Census. 1980 and 1990 data from *Statistical Abstract of the United States 1992*. 112th Edition. U.S. Department of Commerce, Bureau of the Census. Table No. 30, Table No. 37.

increase.[6] Mean travel time to work has grown from 21.7 minutes in 1980 to 22.4 minutes in 1990, an increase of 3.2%.[7] Although inconsistencies in the data may account for the apparent discrepancy between the substantial growth in trip length for work trips of 29.4% and the more limited growth in the mean travel time to work of only 3.2%, it may also be that growth in suburb-to-suburb work trips may account for a portion of this apparent incongruity. Indeed, some researchers have suggested that the apparent "commuting paradox" of more congestion, as is commonly reported both in the literature and in the media, but relatively stable commuting times, as observed in the Nationwide Personal Transportation Study, may reflect an increase in suburb-to-suburb commuting and faster speeds often associated with suburban travel. The location adjustments of rational commuters, involving changes in residence and/or workplace, keep commuting times within tolerable levels, and help to prevent the extra time costs of increasing congestion from having a significant impact on average commuting times. Thus, there still may be increasing congestion per unit of road capacity, but this may not be resulting in higher average commuting times.[8]

Growth in suburb-to-suburb work trips is apparent in Table 1.4, which shows that work trips by all modes between suburban residential zones and suburban employment zones

[6] U.S. Department of Transportation, *National Transportation Statistics, Annual Report*, September 1993. DOT-VNTSC-BTS-93-1. Table 96, pg. 198. Original source data, *1990 Nationwide Personal Transportation Survey (NPTS)*.
[7] U.S. Department of Transportation, Volpe National Transportation Systems Center, *National Transportation Statistics: 1995*. Table 130, pg. 231.
[8] Gordon, Peter, Harry W. Richardson, and Myung-Jin Jun. "The Commuting Paradox: Evidence from the Top Twenty." *Journal of the American Planning Association*, Vol. 57, No. 4, Autumn 1991. pp. 416-420.

Table 1.4: Percentage Changes in the Geographic Distribution of Travel to Work Within U.S. Urban Areas (SMSAs) - 1970 to 1980

	Employment Zone		
Residence Zone	Central City	Suburban Ring	Entire SMSA
Central City			
All Work Trips	-16.3%	+22.5%	-10.7%
Transit Work Trips	-31.9%	-33.0%	-32.1%
Suburban Ring			
All Work Trips	+7.9%	+33.6%	+24.1%
Transit Work Trips	+4.6%	-21.5%	-4.0%
Entire SMSA			
All Work Trips	-8.8%	+31.5%	+7.1%
Transit Work Trips	-24.7%	-26.5%	-24.9%

Source: Pickrell, Don H. "Rising Deficits and the Uses of Transit Subsidies in the United States." Journal of Transport Economics & Policy, Vol. XIX, No. 3., pg. 290.

experienced the largest increase of any work trip geographic distribution category between 1970-1980, with growth over this period of 33.6%. More significantly, this same table shows that the only type of transit work trip that experienced an increase was transit work trips from suburban residences to central city employment locations, with all other types of transit work trips experiencing substantial declines. It is exactly this type of suburb-to-CBD transit work trip that commuter rail is designed to serve. Note also that transit work trips within central cities declined by 31.9% during this same period. This is consistent with the declines in heavy rail, light rail, and motor bus ridership that many metropolitan areas experienced during this time.

Capital costs for heavy rail and light rail transit systems are often substantial, averaging \$20 million per route mile for light rail and over \$100 million per route mile for heavy rail systems built during the late 1970's and 1980's (see Table 1.5). Commuter rail systems, however, often operate on existing shared rights-of-way with freight rail or intercity passenger rail service, and therefore metropolitan areas hoping to establish new service can often minimize the costs associated with land acquisition and construction, as incremental upgrades of existing infrastructure and acquisition of rolling stock are sometimes all that is needed to initiate service. It is generally recognized in the literature that transit requires high-density urban land development to be cost effective (e.g. Meyer, Kain, and Wohl, 1965). However, as is evident from the above discussion of metropolitan population growth trends, some metropolitan areas may no longer have the population and employment densities necessary to support the effective operation of heavy rail rapid transit systems such as the Washington Metro, the Bay Area Rapid Transit (BART) system, and the Metropolitan Atlanta Rapid

Table 1.5: Capital Cost per Route Mile of Heavy Rail and Light Rail Transit Systems

Heavy Rail Transit		Light Rail Transit	
City	Millions of 1988 dollars	City	Millions of 1990 Dollars
Atlanta	$101.49	Portland	$18.59
Baltimore	$169.61	Sacramento	$10.28
Miami	$63.86	San Jose	$16.83
Washington, D.C.	$131.70	Los Angeles	$36.56

Source: U.S. Department of Transportation, Characteristics of Urban Transportation Systems, September 1992, DOT-T-93-07. Tables 2-11 and 2-15.

Transit Authority (MARTA) system in Atlanta. With the continued decentralization of population in many metropolitan areas (itself in part a reflection of past transportation technological changes), commuter rail service is seen by an increasing number of metropolitan areas as a means of providing transportation from increasingly remote suburban communities to urban employment centers in a relatively comfortable, economical, and energy efficient manner.

With commuter rail new-starts being considered in almost two dozen metropolitan areas in both the U.S. and Canada, it is apparent that the expansion of commuter rail services in North America is far from finished. All indications are that commuter rail will continue to experience robust growth and associated new starts and expansions of existing service, enjoying promising future prospects even at time when many foresee substantial reductions in operating and capital assistance for the transit industry as a whole.

1.2 Commuter Rail - An Urban Transportation Panacea?

Commuter rail service is capable of providing a broad array of benefits, with recipients including not only commuter rail riders but also society as a whole. Although difficult to quantify with accuracy, there is consensus among most transportation planners and economists that the transit related benefits discussed herein do exist. However, even though these benefits are often discussed at length in the literature, there are few detailed benefit-cost analyses that provide strong empirical findings either supporting or refuting assertions as to the nature and extent of commuter rail and rail transit benefits. Thus, transit critics often argue that the magnitude of these benefits does not outweigh the substantial public expenditures for transit capital and operating subsidies. Regardless, even many transit critics do not take issue with the nature of transit benefits, only with their extent and their relation to transit expenditures. What follows is therefore a primarily qualitative discussion of the nature of transit benefits, supported with empirical findings where possible.

1.2.1 Accessibility Related Benefits

Commuter rail can often provide significant accessibility and mobility advantages over other travel modes. As the extensive literature review presented in Chapter 4 reveals, there exists substantial research and empirical evidence concerning the accessibility and mobility benefits of rail transit. Although there is only limited evidence related specifically to commuter rail service, the few existing studies suggest that commuter rail does in fact produce measurable accessibility benefits, which is consistent with the findings concerning other modes of rail transit. Accessibility benefits often manifest themselves as increases in land value for both residential and commercial properties surrounding rail transit stations. The introduction of commuter rail service may result in increases in housing demand in areas to be served, and thus increases in the price of residential properties. Residential locations having favorable access times to stations and those within walking distance are thought to be more desirable, sometimes making it possible for households to reduce auto ownership and operating costs. Other documented indications of accessibility benefits have included retail sales increases for retail development near transit stations, and higher rates of occupancy for commercial development near transit stations.[9,10,11]

The accessibility and mobility benefits of commuter rail have certainly been a contributing factor in the growth in commuter rail travel in recent years. In August 1996, for instance, Metra introduced new "North Central" commuter rail service to the Chicago metropolitan area, running service along a 41-mile segment of the Wisconsin Central Railroad between Chicago's central business district and Antioch, just south of the Wisconsin state line in Lake County. The first new commuter rail service in the region since 1928, reports indicate that the service was eagerly anticipated by those communities to be served, so much so that communities along the route willingly contributed $20 million to acquire land and to build stations and parking at 12 planned stations.[12] Metra, meanwhile, funded the remaining $51 million for engineering work, signal and track improvements, platform construction, rolling stock rehabilitation, and land acquisition and construction of a storage yard.

1.2.2 Rationalized Development

Another benefit made possible by rail transit, but one that is not always realized in practice because of insufficient planning and exogenous political and financial factors, is the

[9] Waters, David C. "Use of Ensemble Averaging and Differential Comparison to Detect Retail Sales Increases by the Bay Area Rapid Transit System." *Transportation Research B*, Vol. 21, No. 1., 1987, pp. 41-58.
[10] U.S. Department of Transportation. *The Economic Impacts of SEPTA on the Regional and State Economy*. June 1991. DOT-T-92-02. pp. 5-10 - 5-14.
[11] Cervero, Robert. "Rail Transit and Joint Development: Land Market Impacts in Washington, D.C., and Atlanta." *Journal of the American Planning Association*, Vol. 60, No. 1, Winter 1994.
[12] Transit Connections. *1995-1996 Transit Planner's Deskbook*. pg. 45.

ability to rationalize both residential and commercial development. By facilitating more compact land use patterns, transit oriented development practices can help in minimizing auto travel and roadway congestion, as well as the amount of land necessary for parking. Through this and other mechanisms, transit service can thus help in meeting broader environmental, economic, social, and energy policy goals such as improved air quality, improved roadway safety, reduced consumption and dependence upon fossil fuels, and improved mobility for the economically and physically disadvantaged. Underlying many of the above issues are broader notions of "quality of life," and the ability of transit service to maintain and enhance it. Although less tangible, quality of life issues may be no less important than the other more discrete and quantifiable elements of social benefit discussed above that contribute to it.

1.2.3 Transit Subsidies

Despite the robust ridership growth throughout much of the commuter rail industry in recent years and the many potential benefits of commuter rail service as documented above, there are various problems associated with the operation of commuter rail service. One shortcoming that commuter rail transit shares with other transit modes is the substantial subsidies required to meet both capital and operating expenses.

As shown earlier in Table 1.5, capital costs for heavy rail and light rail transit systems are often substantial, having been made even more so in part by gross underestimates of the costs of design and engineering, construction, and vehicle purchases that have plagued many new rail transit projects during the last two decades.[13] Although many new commuter rail services have been introduced at relatively modest cost in recent years (see Table 1.6), for instance the new North Central commuter rail service in Chicago, in other instances costs for new commuter rail lines have been substantially greater, for example the proposed MBTA Greenbush Line in Boston. As for the source of these capital funds, the basic matching ratio for federal transit capital assistance is a maximum of 80% federal assistance to 20% state and local assistance, however in practice only about 44% of transit capital funding came from the federal government in 1994, since many projects are funded at more than the minimum 20% local match and sometimes entirely at the state and local level.[14] State and local jurisdictions rely heavily upon sales taxes, property taxes, and income taxes to provide their share of transit capital assistance.

[13] Pickrell, Don H. "A Desire Named Streetcar: Fantasy and Fact in Rail Transit Planning." *Journal of the American Planning Association*, Vol. 58, No. 2, Spring 1992. pp. 158-176.
[14] American Public Transit Association. *1996 Transit Fact Book*. Washington, D.C., January 1996. pg. 12.

Table 1.6: Capital Cost per Route Mile of New Commuter Rail Service

Metropolitan Area	Transit Agency/ Commuter Rail Service	Date of Initial Operation	Route Miles	Total Capital Cost Millions of 1995 US$	Capital Cost per Route Mile Millions of 1995 US$
Chicago, IL(1)	METRA	August 1996	41	$71	$1.73
Boston, MA(2),*	MBTA	December 1999	18	$202	$11.22
Boston, MA(3),*	MBTA	December 1999	18	$395	$21.94
Boston, MA(4)	MBTA	September 1994	23	$83	$3.62
Washington, D.C.(5)	VRE	June 1992	73	$152	$2.08
Miami, FL(6)	Tri-Rail	January 1989	67	$351	$5.24
Los Angeles, CA(7)	Metrolink	October 1992	334	$861	$2.58
Vancouver, BC(8)	BC Transit	November 1995	40	$82	$2.04
San Diego, CA(9)	Coaster	February 1995	43	$150	$3.49

* Planned. Included to show the substantial capital costs of some new lines requiring extensive reconstruction and environmental mitigation.
Notes: Costs inflated at 4% per year to 1995 dollars. Capital costs shown include design and engineering, the procurement, rehabilitation, and/or construction of right-of-way where relevant, construction of layover yards, vehicle acquisition and/or rehabilitation, and land acquisition and construction of stations and parking

(1) North Central Service on former Wisconsin Central Railroad. *Transit Connections*, 1995-1996 Transit Planner's Deskbook, pg 45.
(2) Greenbush Line, fully at-grade alternative. *Supplemental Draft Environmental Impact Statement/Report*, March 1995.
(3) Greenbush Line, deep bore tunnel alternative, with 9,125 ft. deep bore tunnel in the vicinity of Hingham Square. *Supplemental Draft Environmental Impact Statement/Report*, March 1995.
(4) Worcester extension from Framingham. *Railway Age*, 1995 Regional/Commuter Rail Planner's Guide. November 1994.
(5) Railway Age, September 1992 pg. 64
(6) Tri-County Commuter Rail Authority, *1992-1993 Annual Report*. $264 million was paid for 81 miles of CSX track in 1989 ($3.26 million per mile). An additional $59 million was spent for track improvements, rolling stock, and station construction. Note that the capital cost figures in the table only only $218 million or the original $264 million cost, since the system currently only utilizes 67 miles of the 81 right-of-way.
(7) *Railway Age*, December 1992, pg. 17, and 1993 Regional Passenger Railroad Planner's Guide, November 1992. $500 million was paid to Sante Fe for 340 miles of rail lines in July 1992. Also, $80 million for initial capital improvements for commuter service, $46 million in other commuter rail related capital improvements. $96 million for 70 passenger coaches in 1991, and $38 million for locomotives.
(8) *Railway Age*, 1996 Regional/Commuter Rail Planner's Guide, November 1995. pg. G8. Currency exchange rate of C$1.00 to $0.741 US.
(9) *Railway Age*, September 1994, pg. 28.

Although recent capital cost estimates for the MBTA Greenbush Line, which for one alternative is upwards of $22 million per mile, still compare favorably to those of the heavy rail and light rail transit costs per route mile shown in Table 1.5 (inflated to 1995 dollars), these costs are formidable compared to past experience with other commuter rail projects. If unit capital costs of this magnitude are repeated elsewhere for other commuter rail projects, there may be cause for concern regarding the escalation in costs and the impact upon project feasibility in coming years.

In 1994, sources of operating funding for U.S. transit systems included fares (38%), local assistance (31%), state assistance (21.5%), federal assistance (5%), and various other types of assistance (4.5%).[15] As these numbers indicate, although the matching ratio for federal transit operating assistance can be as much as 50% of net operating costs, in practice overall federal operating assistance to the U.S. transit industry is a relatively small proportion of operating funding, and has been in decline in recent years due to federal budget constraints.[16] As in the case of transit capital expenditures, after fare revenue the balance of

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15 American Public Transit Association. *1996 Transit Fact Book*. Table 1. pg. 15.
16 U.S. Department of Transportation. *Intermodal Surface Transportation Efficiency Act of 1991: A Summary*. FHWA-PL-92-008. pp. 21-25, and Table 2, pg. 42.

capital and operating expenses is usually provided by state and local jurisdictions with some combination of sales taxes, property taxes, and income taxes.

As mentioned earlier, commuter rail systems have the highest operating subsidies per passenger trip, making it an irresistible target for many critics. In defense of these high per passenger operating subsidies, it should be noted that many researchers have documented the "hidden" subsidies and full costs of auto use, which itself is highly subsidized by all levels of government. In a recent study of travel in Boston, MA, the Conversation Law Foundation found that when considering the costs travelers impose upon government, the environment, and the economy, the user fees, fares, and taxes paid by travelers during peak periods amount to only 9-18% of costs imposed for solo drivers, but 21-88% of costs imposed for commuter rail riders.[17] However, until adequate methods are developed and implemented on a widespread basis to charge users of other modes the full cost of travel and to translate some of the social benefits of transit into actual revenue (which, although implemented in some cases as value capture and related policies, does not seem likely in the near future), the large operating and capital subsidies required by commuter rail will continue to be an issue of contention.

1.2.4 Distributional Equity

Although the sheer magnitude of per trip subsidies is reason enough for many critics to condemn commuter rail service, an equally compelling focus of critics are the equity effects related to the distribution of both transit benefits and tax costs used to provide transit subsidies. Commuter rail transit, a mode general used by the affluent, receives substantially larger per trip subsidies than other modes such as bus transit that are more frequently used by those who are poor. At a time when politicians have come under attack for reducing funding for social programs that benefit the truly disadvantaged, commuter rail subsidies are perceived by some as welfare for middle and upper class professionals.

In addition to the equity impacts resulting from the differential subsidization of transit modes, there exist a number of implicit cross-subsidies within each mode and each route that in general benefit higher income groups. It is widely recognized that long-distance riders are more subsidized that short distance riders, that peak-period riders are more subsidized than off-peak riders, and that riders from outlying suburban portions of networks are more subsidized than riders from more urbanized areas.[18,19] Therefore, high income commuter rail

[17] Conversation Law Foundation. *Road Kill: How Solo Driving Runs Down the Economy*. May, 1994. pg. 28.
[18] Pucher, John. "Equity in Transit Finance: Distribution of Transit Subsidy Benefits and Costs Among Income Classes." *Journal of the American Planning Association*, October 1981. pp. 388-390.
[19] Cervero, Robert, et al. *Efficiency and Equity Implications of Alternative Transit Fare Policies*. U.S. Department of Transportation. September, 1980. DOT-I-80-32.. pp. 1-21.

riders, typically being long-distance, peak-period and from outlying suburban areas, are again the prime beneficiaries of these within-mode cross-subsidies.

The financing mechanisms by which revenues are raised by federal, state, and local governments in order to provide transit subsidies typically include some combination of sales taxes, property taxes, or income taxes. The limited empirical evidence suggests that subsidies financed by federal, state, and local income taxes are in generally quite progressive, while those financed by general sales taxes are regressive. The findings for property taxes are inconclusive, and depend in part upon the assumptions made regarding incidence.[20] Even under the most regressive incidence assumptions, the overall burden of transit taxation has been found to be progressively distributed among income classes.[21] Therefore, a comprehensive view of not only transit subsidies but the transit tax burden as well suggests that the distribution of transit benefits, net the transit tax burden, is not as inequitable as is generally perceived. In addition, although the progressive redistribution of income can contribute to the overall desirability of transit service and transit subsidization particular when considered in conjunction with other social, environmental, and economic benefits of transit, general income assistance programs and other welfare in-kind programs are likely far more efficient in achieving income redistribution than transit subsidy programs.

1.3 Motivation and Statement of the Problem

Despite its benefits, commuter rail is not considered by all to be an environmental "good neighbor." The environmental impacts associated with the proximity of sensitive and often incompatible residential and commercial land uses to commuter rail facilities are of particular concern to many communities. Opposition groups typically present a range of arguments in an attempt to support their position, many of which revolve around actual or perceived threats to property values, neighborhood amenity, and personal security. Although there is only limited empirical evidence, arguments related to possible threats to property values are understandable, since the investment in a single family residence is in many cases one of the largest single real property investments that an individual or family makes in their lifetime. Rail transit project opponents also sometimes profess concern over loss of neighborhood amenity and fear of transit related crime, although here too there is little empirical evidence to support many of these assertions.

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[20] Pucher, John. "Equity in Transit Finance: Distribution of Transit Subsidy Benefits and Costs Among Income Classes." *Journal of the American Planning Association*, October 1981. pg. 398.
[21] *Ibid.* pp. 400-410.

Recent attempts by transit agencies to introduce or expand commuter rail services have often met with significant local opposition as a result of these concerns. In many areas of the U.S., those living in suburban communities have waged impassioned campaigns against commuter rail and other transit projects for a variety of reasons, some pragmatic, others prejudicial. Past experience has shown that local officials and community groups opposed to transportation projects, including the introduction of commuter rail service, are often successful in delaying or requiring substantial modification to these otherwise desirable transportation improvements, often at great additional cost to the project. In some cases, these additional costs and the many years that are sometimes required in responding to legal and other challenges to a project can ultimately result in it being abandoned entirely.

It is apparent that the actual and perceived property value impacts of commuter rail service, and the consequent public reaction to such impacts, are a significant contributing factor in the transportation planning process. The misperceptions of such impacts by both property owners and by transportation agencies can lead to the significant redesign or delay of millions of dollars worth of transportation improvements. Although transportation agencies generally support the idea that transportation improvements enhance accessibility and by doing so increase property values, there is limited empirical evidence concerning the property value impacts of commuter rail service upon which to base any of these propositions. The claims of both opponents and proponents of commuter rail projects regarding potential property value impacts resulting from both accessibility improvements and proximity impacts are in fact largely unsubstantiated by empirical evidence, as is made apparent by the extensive literature review presented in Chapter 4. It is this lack of existing research, combined with the continued growth nationwide in commuter rail and the contentious debate that exists in many areas regarding the impacts of commuter rail service, which are the primary impetus for this thesis.

It is hoped that the empirical findings of this research will provide additional insights into the nature and magnitude of commuter rail impacts that will in many ways be applicable to commuter rail systems throughout the U.S. Specific issues to be addressed will include, among others: To what extent is any accessibility advantage provided by commuter rail service capitalized into single family residential housing values? Does physical proximity to commuter rail facilities including rights-of-way, grade crossings, and stations have a significant impact upon single family residential housing value, and if so, what is the nature and extent of that impact? Does freight rail traffic on rights-of-way to be shared with commuter rail service affect the magnitude of this impact and if so, to what extent? What physical and socio-economic factors influence the extent to which these impacts are present? What analytical methods are available for measuring these impacts, and what are their particular strengths and weaknesses? What are the planning and legal contexts within which these impacts occur, and what types of policies and strategies might be developed within these contexts to minimize the negative impacts of commuter rail service while maximizing the benefits derived?

Other contributions of this thesis include a comprehensive review of the existing empirical literature, detailed in Chapter 4. In addition, this thesis will be one of only a handful of capitalization studies to examine both the accessibility benefits of a rail transit mode, as well as its proximity impact related costs. Advanced geographic information system (GIS) techniques are used extensively in both developing measures of accessibility and proximity, with high resolution digital aerial photography used to ensure reliable and precise positional accuracy in developing proximity measures. Finally, both quasi-experimental and multivariate analytic techniques are used, and the results from using these two approaches are compared for consistency and cross-validation.

1.4 Thesis Outline

This thesis begins with an overview of the distinguishing characteristics of the commuter rail mode and a detailed discussion of both its beneficial and deleterious impacts upon communities in Chapter 2. Chapter 3 then reviews the relevant theoretical literature, and provides a rationale for the evaluation of both accessibility related and proximity related commuter rail impacts. The strengths and weakness of various possible analytical approaches are also presented here. In Chapter 4, an extensive review of the existing empirical literature concerning the impacts of various types of transportation facilities as well as other major types of infrastructure and facilities is presented, and insights of particular relevance to this thesis are discussed. Chapter 5 provides the framework for a detailed case study of commuter rail service operated in the Boston metropolitan area by the MBTA. An analytical framework is developed, and data relating to the region's economy, housing market, and transportation services are presented. Study areas and corresponding control areas are then selected. In Chapter 6, an extensive parcel-level data set for the study and control communities is developed for use in the ensuing empirical analysis. In Chapter 7, models are specified and empirical analyses of commuter rail impacts in the Boston area are carried out. Finally, in Chapter 8, implications related to the empirical findings are examined. The planning and legal context within which commuter rail impacts occur in the U.S. is discussed, and possible strategies and policy alternatives aimed at both minimizing negative impacts and maximizing positive impacts of commuter rail service are explored. Insights from practice and experience in other countries are also discussed.

Chapter 2
Characteristics and Environmental Impacts of Commuter Rail

Throughout its recent period of growth, the commuter rail industry has experienced various degrees of innovation and change in numerous aspects of its planning, operations, and management practice. In order to place the analysis of commuter rail impacts presented in subsequent chapters in context, this chapter reviews the status of commuter rail in the U.S., providing an overview of the history and distinguishing characteristics of the commuter rail transit mode, an introduction to the beneficial and deleterious impacts of commuter rail service, and a summary of the planning process within which these impacts are typically considered.

2.1 Characteristics of the Commuter Rail Mode

A concise but limited definition of commuter rail service is as follows: local and regional passenger train service that operates within metropolitan areas between a central city and its suburbs, with typically only one or two stations located in the central business district. Commuter rail service typically operates as part of a regional system that is publicly owned although it is sometimes operated under contract by an independent operator, on rights-of-way that are usually shared with freight rail service and intercity passenger service.

Although commuter rail is also sometimes referred to as "suburban rail" or "regional rail," regional rail often refers specifically to commuter rail services offering off-peak service, as well as through-routed service between terminals located in the CBD. Although many view regional rail as utilizing traditional commuter rail technology, regional rail may be more appropriately thought of as a service concept, independent of the rail technology used, and integrating suburban, urban, and downtown travel functions.[22] For this reason, as well as for sheer simplicity and consistency, the term "commuter rail" will be used solely throughout the remainder of this thesis.

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[22] Schumann, John W., and S. David Phraner. "Regional Rail for U.S. Metropolitan Areas: Concept and Applications." *Transportation Research Record 1433*, 1994, pp. 83-88.

2.1.1 System and Technical Characteristics

Commuter rail service typically operates on rights-of-way that are shared with intercity passenger rail service or freight rail service, and often have a mix of grade separation and at-grade crossings with automobile traffic. Unlike heavy rail rapid transit systems, commuter rail rights-of-way do not necessarily consist of a double track right-of-way. Sometimes a single track is used, supplemented by passing sidings to allow for bi-directional movement of train sets.

Since the majority of commuter rail services utilize existing rights-of-way, new systems can often minimize the costs associated with land acquisition and construction. Use of shared rights-of-way, although no guarantee of environmentally benign operations, can also often minimize disruption to the environment caused by right-of-way generated proximity impacts including noise and ground-borne vibration. In addition, track and signal improvements that are often necessary for operation of commuter rail service over freight rail rights-of-way can benefit freight shippers as well, providing for faster movement of freight trains.[23]

The utilization of shared rights-of-way, however, is not without its problems. For instance, the commencement of Virginia Railway Express (VRE) commuter rail service in the summer of 1992 required several years of planning and negotiations with no less than four separate railroads over whose tracks VRE would be operating in order to resolve complex liability insurance issues.[24] Existing systems attempting to expand service often experience similar difficulties. For example, the recent extension of MBTA commuter rail service in Eastern Massachusetts to Worcester required what was viewed as a "landmark" liability agreement between Conrail and the MBTA.[25]

Also, a variety of operational issues can arise, such as who will have priority in the case of a route conflict: the commuter train or the freight train? With more and more freight movements involving high priority intermodal services for which freight railroads are unwilling to compromise service quality, the issue of track priority in cases of shared rights-of-way is of increasing importance. As a recent example, the Maryland Department of Transportation operates MARC commuter rail service over trackage that it leases from CSX in Maryland. While many railroads view the leasing of trackage rights to commuter rail operators as an opportunity to obtain revenue from underutilized freight lines, CSX now believes that commuter rail service is inhibiting the growth of its core freight business.[26] As a possible solution, CSX hopes that more federal assistance will be made available for transit

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[23] Seinfield, Keith. "Commuter Rail Likely Would Aid Freight Trains," *Seattle Times*, 14 May 1996.
[24] Middleton, William D. "Off to a good start." *Railway Age*, September 1992. pg. 64.
[25] "Conrail and MBTA: A landmark liability agreement." *Railway Age*, October 1994. pg. 6.
[26] Barnes, David. "Snow: CSX wants commuter trains off its tracks." *Traffic World*, July 22, 1996. pg. 11.

Table 2.1: U.S. Transit Modal Comparisons - 1993

	Transit Mode					
	Light Rail	Heavy Rail	Commuter Rail	Trolley Bus	Motor Bus	Demand Response
System and Technical Characteristics						
Number of Systems (1)	20	14	16	5	1,934	3,917
Average Station Spacing (miles) (2)	0.8	0.7	2.7	n/a	n/a	n/a
Typical Line Capacity (passengers per hour) (3)	6,000-20,000	10,000-72,000	8,000-60,000	2,400-12,000	2,400-12,000	n/a
Active Vehicles (1)	1,025	10,261	4,494	851	64,850	23,527
Ridership and Market Characteristics (1)						
Average Passenger Trip Length (miles)	3.7	5.0	21.5	1.6	3.8	6.9
Unlinked Passenger Trips (millions)	188	2,046	322	121	5,381	81
Passenger Miles (millions)	705	10,231	6,940	188	20,247	562
Financial Characteristics (4)						
Operating Cost per Unlinked Passenger Trip	$1.68	$1.79	$6.49	$1.09	$1.88	$9.79
Operating Cost per Passenger Mile	$0.45	$0.36	$0.30	$0.70	$0.50	$1.41
Average Fare Revenue per Unlinked Pass. Trip	$0.55	$0.94	$3.09	$0.43	$0.58	$1.16
Average Fare Revenue per Passenger Mile	$0.15	$0.19	$0.14	$0.28	$0.15	$0.17
Net Cost per Passenger	$1.14	$0.86	$3.39	$0.66	$1.30	$8.63
Farebox Recovery Ratio	32.4%	52.2%	47.7%	39.7%	30.8%	11.8%
Revenue Vehicle Hours per $1,000 Operating Cost	6.6	7.4	3.2	13.6	16.4	38.5
Service Effectiveness and Characteristics						
Unlinked Passenger Trips per Vehicle Mile (4)	6.8	3.9	1.4	8.9	2.4	0.2
Unlinked Pass. Trips per Revenue Vehicle Hour (4)	89.5	75.2	48.8	67.2	32.4	2.7
Average Operating Speed (MPH) (1)	13.6	20.4	33.9	8.1	13.0	13.5
Average Seated Passenger Capacity (5)	59.1	55.7	127.7	52.8	43.7	12.9
Space per Seated Passenger (sq. ft.) (6)	3.0-5.0	3.0-5.0	4.0-6.0	n/a	n/a	n/a
Avg. Total Pass. Capacity per Vehicle (7)	119	182	154	70	70	14

(1) American Public Transit Association. *1996 Transit Fact Book*. Table 5. Operating speed is in revenue service only.
(2) Various sources, including system specific data, U.S. Department of Transportation data, various issues of *Railway Age*, *Jane's Urban Transport Systems*, Jane's Information Group, Inc., various editions, various issues of *Transit Connections*.
(3) Gray, George E., and Lester A. Hoel. *Public Transportation*, 2nd edition. Englewood Cliffs, New Jersey. Prentice-Hall, 1992. pg. 102.
(4) Calculated from data in *1996 Transit Fact Book*. American Public Transit Association. Table 5.
(5) American Public Transit Association. *1996 Transit Fact Book*. Table 45.
(6) U.S. Department of Transportation, Federal Transit Administration. *Characteristics of Urban Transportation Systems*. Revised Edition, September 1992. DOT-T-93-07.
(7) Includes seated and standing passengers. American Public Transit Association. *1996 Transit Fact Book*. Table 5, pg. 25, note (c).

solution, CSX hopes that more federal assistance will be made available for transit improvements, including the construction of additional tracks paralleling existing freight tracks within the same right-of-way.

As can be seen in Table 2.1, the commuter rail transit mode features considerably greater average distances between stations than other rail transit modes. Average station spacing often varies, however, depending upon whether diesel or electric electric power is used. For instance, in Chicago, electric powered commuter rail service on three lines have an average station spacing of .75 miles per station, whereas diesel powered service operated on nine other lines averages 2.2 miles per station.

Commuter rail station design also varies considerably, from modestly sized and economical facilities, to much more extensive and elaborate facilities. In many cases, requirements for a station having relatively low ridership may include little more than paved low-level platforms, a small shelter and signage. Larger and more elaborate commuter rail stations serving greater ridership may feature extensive park-and-ride and drop-off facilities, public address systems, ticket vending and newspaper vending machines, and longer high-level platforms. Although low level platforms from which passengers enter and exit passenger coaches directly from grade level are still in widespread use, high-level platforms allowing passengers to enter and exit coaches at car floor level are becoming more common. This is due in part to the handicapped accessibility requirements of the U.S. Americans with Disabilities Act, as well as to improve the quality of service and provide operational advantages such as reduced dwell times. Although high-level platforms provide considerable accessibility and operational advantages, freight equipment clearances required on shared rights-of-way can present a problem for the provision of high level platforms.

While in the past many commuter rail services were operated with traditional railroad equipment that had been used previously in main line service, the use of locomotives and passenger coaches designed specifically to meet the needs of commuter rail service is now more common. Commuter rail vehicles and train sets can consist of a variety of types of vehicles, with either diesel or electric power sources. Propulsion can be provided by a variety of sources, including locomotives combined with passenger coaches in push-pull operations, or multiple unit configurations whereby individual passenger coaches, "married pairs", or "triplets" are utilized, each providing its own motive power. In either case, diesel or electric power sources may be used, or in some instances both may be utilized in a dual power configuration as with dual power locomotives. With an increasing focus upon air quality concerns, some properties have begun to use low emission locomotives, such as those used by the Southern California Regional Rail Authority (SCRRA).[27] Although electric traction provides superior air quality benefits, acceleration characteristics, and higher operating speeds, because of the high cost of electrification there have been no new commuter rail electrification projects of any significance in North American in recent years.

Some developments of note concerning commuter rail vehicles include the use of a.c. traction motors for both electric locomotives and electric multiple unit (emu) vehicles, and renewed interest among North American commuter rail providers in rail diesel cars, otherwise know as diesel multiple unit (dmu) vehicles. For systems that are electrified, savings in both maintenance and operating costs may be realized with the utilization of new a.c. traction motors.[28] Likewise, for systems dependent upon diesel operations, the use of dmu vehicles offers the potential for savings in equipment acquisition costs, operating costs, and

[27] Middleton, William D., contributing editor. "New directions for rolling stock." *Railway Age, 1994 Regional/Commuter Rail Planner's Guide*, November 1993. pg. 37.
[28] *Ibid*. pg. 40.

maintenance costs.[29] However, to date, dmu use has proven more widespread in Europe, Japan, and Australia than in North America.

One final development in commuter rail vehicle design is the increased use of bi-level passenger coaches. As commuter rail ridership has grown in recent years throughout North American, so too has the use of bi-level passenger coaches, which provide for seating of passengers on two separate levels in either a gallery car layout or a true multi-floor design. Prior to 1990, only four commuter rail services operated bi-level passenger coaches, the rest relying entirely upon more traditional single-level equipment. Since then, however, six more properties have begun operating or are planning to operate bi-level equipment. Of these ten properties, all but one chose true multi-floor designs over bi-level gallery cars.[30]

The vast majority of bi-level designs are for use in diesel locomotive powered push-pull operations.[31] The advantages of bi-level coaches over single-level coaches include lower operating cost per seat, resulting from higher passenger loads per vehicle and minimization of crew size and cost resulting from the use of shorter train consists in achieving equivalent passenger capacity per train. Reductions in train length also improve the utilization of existing platforms, thereby avoiding costs associated with platform lengthening projects. At the same time, dwell times are also not adversely affected. For instance, a recent analysis of MBTA commuter rail dwell times revealed that loading and unloading times for bi-level coaches and single-level coaches were remarkably similar, even though bi-level coaches had much greater numbers of passengers onboard.[32] Overall train weight as well as the tare weight-to-passenger ratio can be minimized, thereby improving locomotive utilization and reducing fuel consumption. Total passenger coach fleet size can be minimized, thereby reducing accompanying storage and layover facility requirements. Although there are few disadvantages seen to the use of bi-level designs, for some properties limited vertical clearances at bridges and in tunnels preclude the use of bi-level coaches.[33]

Possible provision of service arrangements for commuter rail operations include direct operation, contract operation, or a combination of both. While many of the larger and older commuter rail systems including LIRR, Metro North, New Jersey Transit, and SEPTA rely almost exclusively upon direct operation of services, other systems such as Metra use a combination of direct operation on some lines and contract operation on other lines, and still

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[29] Middleton, William D. "Diesel railcars: On the comeback trail?" *Transit Connections*, December 1994. pp. 18-20.
[30] Massachusetts Bay Transportation Authority. *North-South Rail Link Project Equipment Engineering Study. Technical Report*. Draft, November 8, 1995. Appendix J.
[31] Bowen, Douglas John. "The bi-level breakthrough." *Railway Age*, October 1990. pg. 44.
[32] Massachusetts Bay Transportation Authority. *North-South Rail Link Project Equipment Engineering Study. Technical Report*. Draft, November 8, 1995. pp. 2-11 - 2-14.
[33] Bowen, Douglas John. "The bi-level breakthrough." *Railway Age*, October 1990. pg. 44.

other systems such as the MBTA utilize contract operation exclusively. Meanwhile, all of the recent new-start commuter rail systems since the 1989 commencement of the Tri-Rail service in Florida have elected to utilize some type of contracted service or purchase of service agreement to operate their commuter rail services.[34]

Benefits of direct operation include greater direct control by the agency over employees and operations, thus providing the foundation for a possible strong commitment to quality of service. However, most operators, being public agencies, have employment procedures that can be rather inflexible, and many agencies would also prefer to avoid the complexities associated with being subject to the Railroad Labor Act and the Railroad Retirement Act.[35] Also, many agencies wish to avoid making a long term commitment to a service until successful operations have been firmly established. Therefore, contract operation is often utilized for new start systems.

One potential shortcoming of contract operation is the paucity of qualified contract operators from which an agency can choose. In the recent past Amtrak has been the only major player in commuter rail contract operations, except for a few operators providing contract services locally on railroads that operate primarily freight service as in the Chicago area. With such a limited number of contract operators from which to choose, competition may be limited to such an extent that the possible cost and service quality benefits of contract operation may be diminished. There has been some change occurring in the industry more recently, however, with contract operators including Herzog Transit Services, Inc. (previously UTDC) and ATE Management & Service Co. becoming more active, as well as local contract operators such as Burlington Northern, CSX, Southern Pacific, and Union Pacific having more interest in competing for contracts.

Additional possible shortcomings of contracting include the cost to the agency of developing and maintaining procedures for continued monitoring of the performance of the contract operator. Many contracts can be characterized as cost-plus-fee, or fixed compensation contracts based on competitive procurement and negotiation. However, the trend in contracting of services appears to be towards provision of more incentives and penalties in the contract, based not only on traditional performance measures, but also on factors such as customer satisfaction and the maintenance and growth of ridership.[36] Some recent contracts, such as Southern California's Metrolink service contracted with Amtrak, go a step further by not offering explicit incentives, but rather assuming that superior performance

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[34] Middleton, William D. "1995 Regional/Commuter Rail Planner's Guide." *Railway Age*, November 1994.
[35] *Ibid.*
[36] *Ibid.*

should be the norm, and imposing penalties for performance levels below this norm. Although this effort towards greater responsibility and accountability for superior performance on the part of contractors certainly indicates a move in the right direction, care must be taken in developing cost effective monitoring programs so that gains from contracting will not be significantly diminished by the cost of monitoring activities. Despite these difficulties, the overwhelming proportion of recent new starts choosing to use contract operators suggest that this method of service provision yields real and significant benefits that will likely make it the preferred choice for other new start operators, and perhaps even for existing systems that currently use direct operation.

2.1.2 Ridership and Market Characteristics

As Table 2.1 shows, commuter rail transit can be a high capacity transit mode, with commuter rail lines providing a range of passenger capacity from approximately 8,000 passengers per hour up to a maximum of approximately 60,000 passengers per hour, higher than all other transit modes except heavy rail transit. Although comprising only 4% of all transit mode unlinked passenger trips in 1993, commuter rail represented 18% of all transit mode passenger miles in 1993. This reflects the much greater average passenger trip lengths characteristic of commuter rail service, which for U.S. commuter rail properties in 1994 ranged from between 15.8 miles to 33.3 miles (see Table 2.2). Lines often extend well beyond the immediate urban area into lower density suburbs, and often extend 30 to 50 and in some cases more than 70 miles from downtown terminals. Figure 2.1, from a recent study of rail transit and land use conducted for the Transit Cooperative Research Program, shows the characteristic pattern of commuter ridership as it relates to trip length, as well as the dependence of commuter rail ridership on levels of CBD employment given the radial orientation of most systems to downtown terminals located in or near the CBD.

Ridership is usually heavily peaked, and in some areas service is provided during peak periods only. In recent years, many operators have focused marketing efforts on off-peak riders in an attempt to increase ridership levels, with some success. However, even significant growth in off-peak ridership often translates in only modest gains in the total number of riders since the vast majority of ridership continues to be home-based work trips during peak periods.

Ridership is also usually highly directional, with most systems having a radial orientation and serving a limited number of downtown stub terminals located in the CBD. In recent years, more operators have considered offering through-routed services. A rail link between North Station and South Station in Boston is currently under consideration, and in

Table 2.2: Summary Characteristics of U.S. Commuter Rail Systems - 1994 [1]

	Average	Range Low - High
System and Technical Characteristics		
Average Route/Line Length (miles)	50.4	11.7 - 77.0
Average Station Spacing (miles)	2.7	0.8 - 8.1
Financial Characteristics		
Operating Cost per Unlinked Passenger Trip	$6.67	$4.30 - $8.06
Operating Cost per Passenger Mile	$0.27	$0.20 - $0.46
Average Fare Revenue per Unlinked Passenger Trip ‡	$3.09	$1.71 - $4.26
Average Fare Revenue per Passenger Mile ‡	$0.13	$0.05 - $0.17
Net Cost per Passenger ‡	$3.78	$2.09 - $5.60
Farebox Recovery Ratio ‡, (2)	41.1%	13.0% - 56.0%
Revenue Vehicle Hours per $1,000 Operating Cost	3.0	1.8 - 5.3
Revenue Vehicle Hours per Vehicles in Max. Service	1,377	507 - 2,436
Revenue Vehicle Hours per Total FTE Employees (3)	393	262 - 571
Ridership and Market Characteristics		
Average Passenger Trip Length (miles)	23.6	15.8 - 33.3
Peak-to-Base Ratio (4)	2.3	1.4 - 3.9
Service Effectiveness and Characteristics		
Unlinked Passenger Trips per Vehicle Mile (5)	1.4	0.6 - 2.1
Unlinked Passenger Trips per Revenue Vehicle Hour	49.6	27.5 - 67.9
Average Systemwide Speed (MPH) (6)	36.1	27.5 - 50.4
On-Time Performance ‡, (7)	94.7%	92.8% - 97.1%
Space per Seated Passenger (sq. ft.) †	n/a	4.0 - 6.0

† 1992 Data. U.S. Department of Transportation, Federal Transit Administration. *Characteristics of Urban Transportation Systems.* Revised Edition, September 1992. DOT-T-93-07.

‡ 1993 Data. 1993 National Transit Database, except On-Time performance data from various sources including recent annual reports from specific properties. Note that use of 1993 data and 1994 data yield results that appear internally inconsistent for some data items (e.g. net cost per passenger, which in the above table appears not to equal operating cost per unlinked passenger trip minus average fare revenue per unlinked passenger trip. This occurs because these two values are not temporally consistent. However, net cost per passenger is calculated using 1993 operating cost data such that this data item is correct as it is based solely upon 1993 data)

(1) Data is from the 1994 National Transit Database unless otherwise noted. Properties include: LIRR, MN, NJT, Metra, NICTD, MBTA, Septa, MARC, Tri-Rail, VRE, Metrolink, Caltrain, and Shoreline East. Some categories of characteristics omit data for certain properties that were either unavailable, suspect, or otherwise unrepresentative (e.g. data for some recently initiated commuter rail services)

(2) Total farebox revenue divided by total operating cost

(3) Includes transportation, maintenance, and general and administrative full time equivalent (FTE) employees

(4) Maximum number of vehicles operated in average PM peak period divided by the maximum number of vehicles operated in average base period

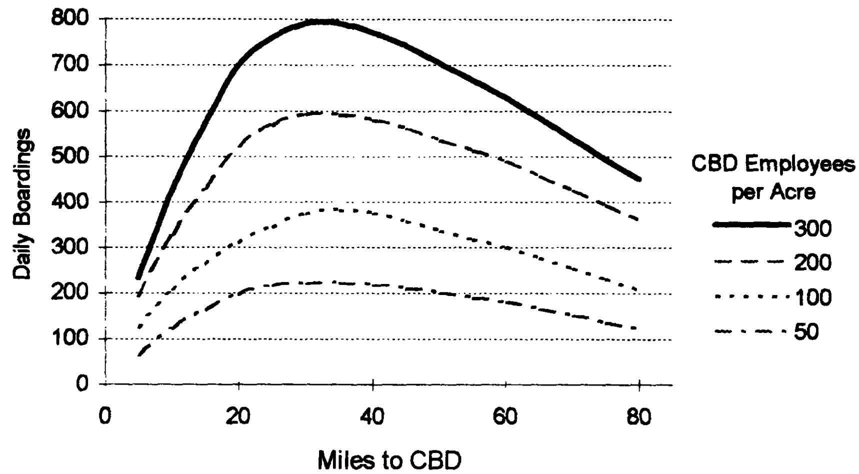
(5) Note that one vehicle mile represents one car mile, not one train mile

(6) Calculated as annual actual vehicle revenue miles divided by annual vehicle revenue hours

(7) Although "on-time" is typically defined as trains that arrive with 0-5 minutes of the scheduled arrival time at a station, the exact threshold value for determining if a train is on-time often varies between commuter rail properties, thus caution is urged in utilizing and interpreting this data

Philadelphia the completion of the Center City Commuter Tunnel allowed through-routing of commuter rail service. Even where the capability to offer through-running exists and is used as such by intercity passenger service, as in the case of Penn Station, New York, and Union Station, Washington, D.C., it may not be offered as a commuter service because of conflicting physical standards, or separate and sometimes conflicting institutional domains.

Figure 2.1: Commuter Rail Station Boardings, Trip Length, and CBD Employment



Source. *Commuter and Light Rail Transit Corridors: The Land Use Connection*. Transit Cooperative Research Program, 1996. Based on data from 550 stations on 47 commuter rail lines in Boston, Chicago, Los Angeles, San Francisco, Philadelphia, and Washington, D.C..

Although transit riders overall have considerably lower incomes on average than do auto users, income distributions vary substantially by transit mode. Table 2.3 clearly shows that of all travel modes, commuter rail passengers have the highest income profile of any group, even auto and taxi users. In contrast to commuter rail transit passengers, bus passengers have the lowest income profile of any group.

2.1.3 Financial Characteristics

Virtually all major North American commuter rail services utilize a traditional distance-based zone fare structure, with a variety of payment instruments typically available including weekly or monthly passes, and single and multiple-ride tickets. With commuter rail service having higher levels of service quality than other transit modes, as well as much longer average trip lengths, commensurately higher fares are charged for commuter rail travel. As shown in Figure 2.2, commuter rail fares can range from between just under $1.00 to over $11.00 for the longest of one-way trips on some systems. Fare collection is usually accomplished with a traditional system of on-board ticket collection by a trainman, although there has been some automation of ticket vending in recent years. Many new commuter rail services, as well as some older systems, are now beginning to adopt barrier-free, proof-of-payment ticketing systems that have generally proven to be successful in their applications to several new light rail systems in North America.

Table 2.3: Household Income Distribution and Travel Mode

	Income Class								
Travel Mode	Less than $10,000	$10,000-$19,999	$20,000-$29,999	$30,000-$39,999	$40,000-$49,999	$50,000-$59,999	$60,000-$69,999	$70,000-$79,999	$80,000+
Auto (1)	6.1%	13.2%	16.2%	17.9%	13.4%	11.9%	6.7%	4.7%	9.9%
Transit (Total)	15.0%	21.3%	17.9%	12.8%	8.4%	7.4%	5.3%	3.4%	8.6%
Bus	20.0%	25.3%	17.8%	12.6%	7.2%	5.7%	4.0%	2.5%	4.8%
Subway (2)	4.9%	15.5%	16.8%	14.9%	12.1%	11.5%	8.1%	5.3%	10.9%
Streetcar/Trolley	16.0%	20.0%	40.0%	16.0%	0.0%	0.0%	0.0%	0.0%	8.0%
Commuter Rail	3.8%	7.0%	17.8%	8.9%	8.5%	10.8%	8.0%	5.6%	29.6%
Taxi (3)	19.3%	9.4%	13.0%	10.9%	6.8%	8.3%	3.1%	4.7%	24.5%
Bicycle	12.1%	13.9%	18.2%	20.1%	10.8%	8.4%	6.1%	3.1%	7.4%
Walk	18.8%	17.9%	17.4%	15.3%	8.0%	6.9%	5.6%	3.6%	6.5%

Source: Calculated from the *1990 Nationwide Personal Transportation Survey*. BTS-CD-09, U.S. Department of Transportation, Bureau of Transportation Statistics

Note: Each value represents the percentage of each mode's riders in each household income class, with each row adding to 100%.

(1) Includes station wagons

(2) Includes elevated rail

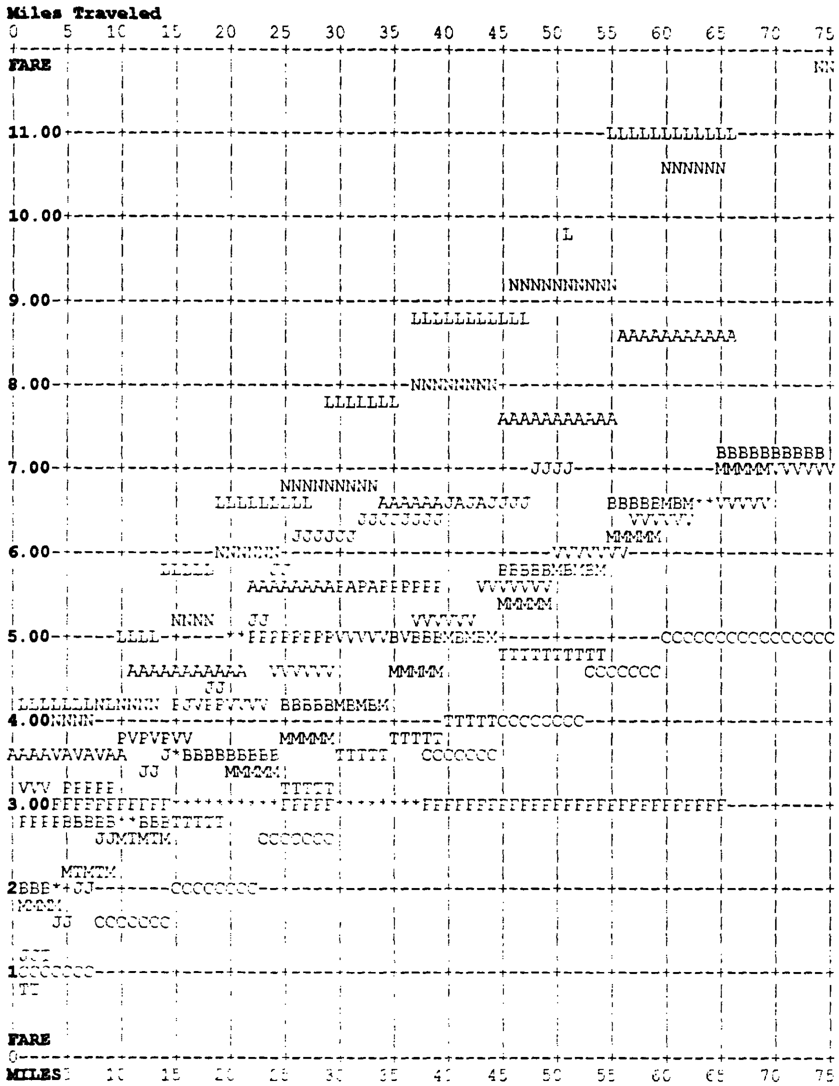
(3) Commercial use

Although there is limited empirical evidence regarding commuter rail fare elasticities, indications are that overall commuter rail ridership is more elastic with respect to changes in fares than are other transit modes.[37] This is generally consistent with evidence suggesting that the elasticity of demand for transit use generally increases with income, due primarily to higher rates of auto ownership. Thus, commuter rail riders being a higher income group are more fare elastic than patrons of other transit modes.

Recalling Table 2.1 and Table 2.2, although the average fare per one-way trip is much higher for commuter rail than for other transit modes, the average fare revenue per passenger mile is similar among transit modes because of the longer average commuter rail trip lengths. Similarly, although operating cost per unlinked passenger trip, at $6.49 per one-way passenger trip in 1993, is much higher for commuter rail than for most other transit modes, operating cost per passenger mile for commuter rail is actually the lowest of all transit modes, at $0.30 in 1993. The average net cost per passenger for commuter rail service of $3.39 in 1993 has also drawn the attention of some critics, who focus upon the potential equity implications of such large per-trip subsidies for a rail transit mode with ridership having the highest income profile of any urban travel mode. Bus transit, in contrast, having the lowest income profile of all travel modes, received a per trip subsidy of $1.30 in 1993, less than half that of commuter rail. Although the per trip subsidies for commuter rail do appear disproportionately large, the net cost per passenger mile of commuter rail, at $0.16 in 1993, is the lowest of all transit modes,

[37] Mayworm, P., A.M. Lago, and J.M. McEnroe. *Patronage Impacts of Changes in Transit Fares and Services. Executive Summary*. U.S. Department of Transportation, Urban Mass Transit Administration, RR 135-1, September, 1980. pp. 7-18.

Figure 2.2: Fare Structure of U.S. Commuter Rail Systems - 1995



Codes: A-Metrolink, B-MARC, C-SF CalTrain, F-Tri-Rail, J-NJ Transit, L-LIRR, M-Metra, N-Metro-North, P-SEPTA, T-MBTA, V-VRE, *-multiple operators

Source: Delaware Valley Association of Railroad Passengers, Inc. (DVARP), http://www.libertynet.org:80/~dvarp/docs/farechrt.txt

whereas the net cost per passenger mile for bus in 1993 was more than double that of commuter rail at $0.35.

Since commuter railroad employees are often members of railroad unions, the resulting work rule limitations can result in higher operating expenses than one might otherwise anticipate for commuter rail operations.[38] Even so, the commuter rail industry performs admirably with respect to its ability to meet operating expenses with passenger farebox

[38] Gray, George E., and Lester A. Hoel. *Public Transportation*, 2nd edition. Englewood Cliffs, New Jersey: Prentice-Hall, 1992.

revenues, achieving a farebox recovery ratio of 47.7% in 1993, besting all transit modes other than heavy rail transit, which had a farebox recovery ratio of 52.2%.

2.1.4 Service Characteristics

Commuter rail systems typically operate with headways of about one half hour during peak periods, with less frequent service during off-peak periods. Operations are also sometimes limited primarily to daytime hours, unlike many heavy rail transit systems which operate late into the night albeit with reduced frequencies. In many urban areas, commuter rail terminals are shared with rail rapid transit stations, allowing direct commuter rail to rail rapid transit connections.

Service quality is a key element of commuter rail service, perhaps more so than for any other transit mode, and can have a significant impact upon the maintenance and growth of ridership. The high income profile of commuter rail passengers makes the provision of high quality service of paramount importance, since higher rates of auto ownership among higher income groups suggest that there are non-transit alternatives often readily available. As shown in Table 2.1, commuter rail has a significantly higher average operating speed (34 mph in 1993) than all other transit modes. Use of continuously welded rail is now commonplace among newer and rehabilitated commuter rail lines, further contributing to ride quality by reducing noise and vibration caused by conventional jointed rail.

The ability to adhere to scheduled arrival and departure times is an important component of service reliability and an important element of quality for commuter rail service. Schedule adherence is of particular importance to passengers in the morning peak period when many are counting on arriving at the terminal station at the scheduled time in order to arrive at their workplace on time. Also, with headways typically being greater than ten minutes even during peak periods, passenger arrival times at stations are based upon the departure of a specific train. Although the exact determination of an "on-time" arrival or departure varies somewhat from property to property, Table 2.2 shows that on-time performance in the commuter rail industry is generally quite good, with an average of 94.7% trains on-time in 1994.

Passenger comfort is a particularly important element of service quality, especially given the much longer average trip lengths of commuter rail passengers. Most commuter rail operators make considerable efforts to provide each rider with a seat, and the average space provided per seated passenger for commuter rail is between 4 and 6 square feet, as compared to 3 to 5 square feet for heavy rail transit.[39] Recently, commuter rail operators have even begun to solicit substantial amounts of customer input during the equipment procurement process. For example, in New York, the Long Island Rail Road (LIRR) systematically obtained input from 150 riders and employees about the features and amenities found in new prototype passenger equipment. The feedback obtained during this process has resulted in many changes to the final design of the equipment.[40]

Finally, the provision of adequate park-and-ride facilities at suburban commuter rail stations, sometimes considered a passenger comfort and/or a reliability issue, is becoming increasingly problematic for some agencies, given the growth in commuter rail ridership in recent years. Although inadequate parking is often cited by riders as a serious problem, easy solutions are not often available. Providing additional parking capacity often requires long term planning and interaction with many local communities and more importantly, land surrounding many of these stations is often already well developed, severely restricting the ability to expand surface lot capacity.

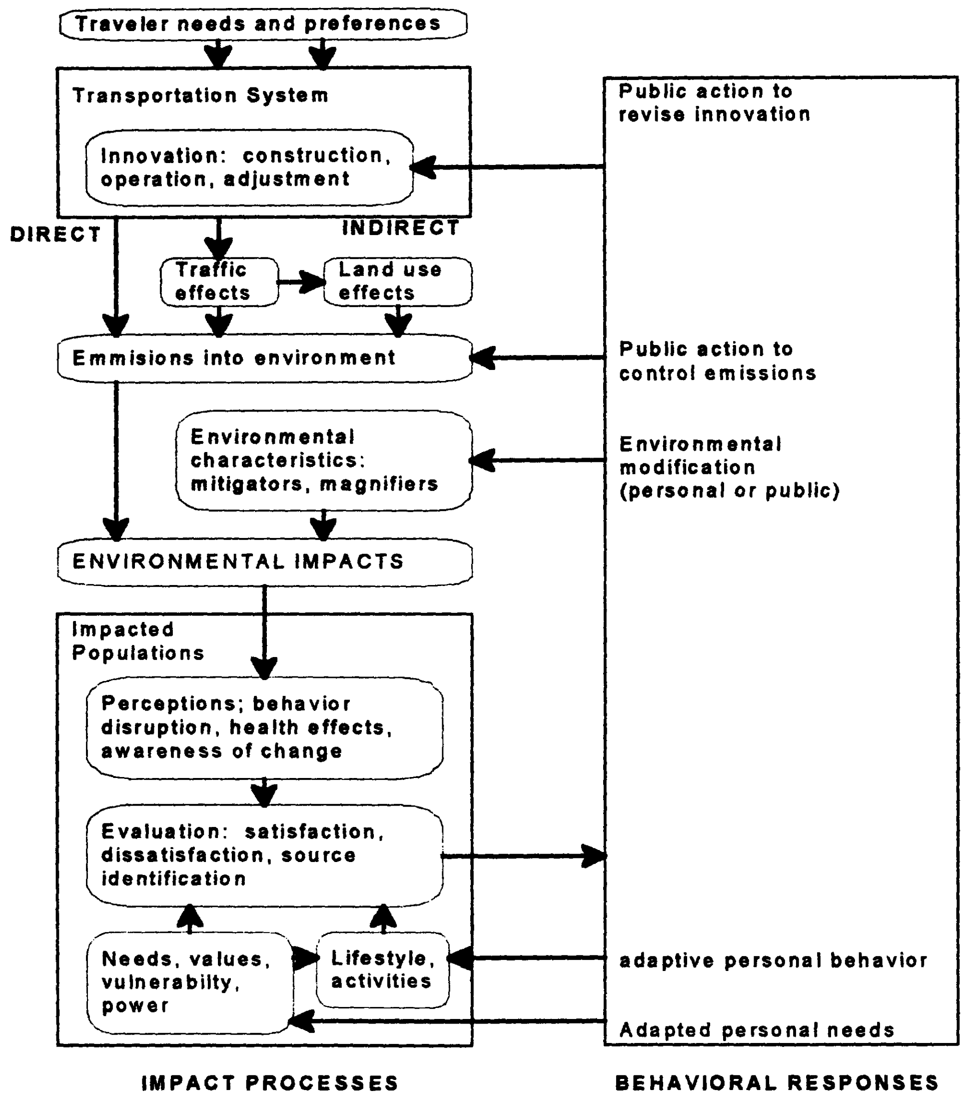
2.2 Environmental Impacts of Commuter Rail Facilities

Of greater concern, perhaps, than the debate over the economic feasibility and distributional equity implications of commuter rail service discussed in Chapter 1 are the environmental impacts associated with the proximity of sensitive and often incompatible residential and commercial land uses to commuter rail facilities. By their nature, many commuter rail and other transit facilities are located close to residential and commercial development. Therefore, it should come as no surprise that proximity related impacts generated by the operation of new commuter rail facilities have been of particular concern in recent years to communities and property owners. Figure 2.3 presents a conceptual overview of the impact process. Typical proximity impacts generated by commuter rail include noise, ground-borne vibration, and to a lesser extent, airborne pollution, visual intrusion and aesthetic impacts, the source of which is the operation of commuter rail equipment and facilities, and the receivers of which include those located within a given distance of these facilities.

Commuter rail noise source-type categories include fixed guideway sources (e.g., train passbys, horns and whistles, and crossing signals on rights-of-way), stationary sources (e.g., idling locomotives at layover yards), and highway/transit sources (e.g., automobile and transit bus activity at stations).[41] Commuter rail facilities most likely to generate significant noise and

[39] U.S. Department of Transportation, Federal Transit Administration. *Characteristics of Urban Transportation Systems*. Revised edition. September 1992. DOT-T-93-07.
[40] Vantuono, William C. "Riders help write the specs." *Railway Age*, April 1996. pp. 61-66.
[41] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. April 1995. pg. 2-3.

Figure 2.3: The Impact Process



Adapted from: Appleyard, Donald, and Robert L. Knight. *Environmental Impacts of Transit Systems*. Reprint No. 179. University of California at Berkeley, Institute of Urban and Regional Development. January 1979.

vibration proximity impacts are the rights-of-way over which trains operate, the grade crossings through which trains pass, and the stations at which patron arrivals and departures occur. The nature of the above types of impacts at each of these types of facilities are discussed briefly below, and in somewhat more detail in Chapter 6.

2.2.1 Rights-of-Way

Along commuter rail rights-of-way, noise and vibration are generated by commuter rail vehicles (locomotives and passenger coaches) in motion along the guideway. Locomotives tend to be the dominant noise source. The two major components of commuter rail noise are wheel/rail interaction, and diesel exhaust and cooling fans on diesel-hauled trains.[42] Wheel/rail noise consists both of rolling noise due to rolling contact, and impact noise when a wheel encounters an irregularity in the running surface such as a rail joint, turnout, or crossover. Because of wheel/rail noise, noise source strength increases with train speed, however this dependence is less for commuter rail than for other rail transit modes, particularly at low speeds where locomotive exhaust noise dominates. Sound levels and noise exposure also depend upon the vehicle acceleration and throttle setting, train length, the type and condition of the running surfaces, number of vehicles per train, and the number of train passbys per day.

Ground-borne vibration generated by commuter rail operations is associated with train wheels rolling on the steel rails, creating vibration energy that is conveyed through the track support system and into the supporting structure. This vibration then excites the adjacent ground and causes vibration waves to propagate through the soil and into the foundations of nearby buildings. The vibration then propagates from the foundation throughout the remainder of the building. Associated with ground-borne vibration is ground-borne noise, which is generated when ground-borne vibration causes a building to move or vibrate, and noise then radiates from the floors, walls, and contents (e.g. dishes, windows) of a room. Although the movement of both locomotives and passenger coaches result in vibration, locomotives usually generate the highest vibration levels.

Right-of-way noise and vibration impacts can occur up to a maximum of 750 feet from the centerline of the right-of-way, however many factors including ambient noise levels, local geology, intervening buildings and terrain, and the number and type of operations conducted over the right-of-way typically limit major impacts to within a much more modest distance from the rail line.[43] Although the use of currently active or former freight rail rights-of-way for new commuter rail service can help in minimizing environmental impacts, the introduction of new commuter rail operations in areas where rights-of-way have long been abandoned often results in significant community opposition. Even on currently active freight rail lines, the perceived marginal contribution of newly introduced commuter rail operations to noise and vibration has resulted in community opposition.[44] Although at-grade crossings are technically considered a fixed guideway noise source and a component of the right-of-way, the particular nature of noise impacts from these facilities are considered separately below.

[42] *Ibid.*
[43] *Ibid.* pg. 4-3.
[44] Phone interview, Robert Fitzpatrick, New Jersey Transit, September 1995. Proposed NJT commuter rail service on the New York, Susquehanna & Western, and proposed service to Ocean and Monmouth counties have encountered some opposition from residents.

Visual impacts typically result when existing views are blocked or lessened by new commuter rail facilities such as noise barriers and bridges. Also, if the bulk or mass of a facility is out of scale with its surroundings, this could diminish the visual character of an area.[45] Impacts of a somewhat more intrusive nature may also occur, such as shadow effects caused by facilities blocking the path of previously available sunlight, or bright lighting at stations interfering with normal nighttime activities in residential areas near stations.[46] These impacts are generally limited to the impact areas of both noise and ground borne vibration, and is therefore not considered in subsequent analyses.

Airborne pollutants include both particulate matter and emissions such as carbon dioxide, carbon monoxide, and hydrocarbons, generated by the operation of commuter rail. Diesel exhaust from train locomotives has impacts primarily only at the regional level, if at all, because the primary components of diesel exhaust have an air quality impact only after they have undergone photochemical oxidation.[47] Their impact at the local level is therefore insignificant, and is not considered in subsequent analyses. Although automobile related carbon monoxide concentrations increase due to station generated vehicular traffic, any proximity impact from these increases is likely to be obscured by the even greater impact of station generated traffic upon noise levels.

2.2.2 Grade Crossings

Although the number of public highway-rail grade crossings has decreased substantially in the past two decades due to rail abandonments, grade crossing closings, and grade separation projects, as of 1993 there were still over 160,000 highway-rail grade crossings in the U.S..[48] Although the approximately 600 deaths annually resulting from highway-rail accidents are minimal when compared to the approximately 40,000 traffic fatalities annually in the U.S., highway-rail accidents tend to be high profile and thus attract a heightened level of public and political awareness. Grade crossings can be a significant source of noise along a rail right-of-way, with major components of this noise including grade crossing protection equipment such as crossing gate bells, and the sounding of train whistles and bells. The approximate maximum sound level (L_{max}) for crossing signals is 73 dBA at a distance of 50

[45] U.S. Department of Transportation, Federal Transit Administration, and the Massachusetts Bay Transportation Authority. *Supplemental Draft Environmental Impact Statement/Report and Section 4(f) Evaluation for Transportation Improvements in the Greenbush Line Corridor*. March 1995. pg. V-90.
[46] Appleyard, Donald, and Robert L. Knight. *Environmental Impact of Transit Systems*. Reprint No. 179. Institute of Urban and Regional Development, University of California at Berkeley. January 1979.
[47] U.S. Department of Transportation, Urban Mass Transit Administration, and the Massachusetts Bay Transportation Authority. *Final Environmental Impact Statement/Report, Old Colony Railroad Rehabilitation Project from Boston to Lakeville, Plymouth, and Scituate, Massachusetts*. Volume 1, March 1992. pg. V-21.
[48] "Grade Crossing Systems - Refining, Improving: A never-ending climb." *Railway Age*, April 1996, pg. 54.

feet.[49] For commuter rail trains, grade crossing bells will typically ring for a period of approximately 12 seconds.[50] Certain noise sources, such as bells on crossing signals and train whistles, also contain pure tones that can be particularly annoying to people, thus they are assessed a 5 dBA penalty during noise assessment.[51]

Federal Railroad Administration (FRA) and Association of American Railroads (AAR) operating rules dictate that the whistle blowing pattern used at grade crossings consist of two long blasts, one short blast, and one long blast.[52] This whistle pattern typically takes between 45 and 60 seconds to complete, and in many states (including Massachusetts[53]) is required to start at distance of at least ¼ mile from the crossing and continue until the locomotive has cleared the crossing. Therefore, with train operations in both directions, grade crossing impacts related to train whistles can extend for a total distance of ½ mile along the right-of-way, centered on the location of the crossing where impacts are most severe. The approximate maximum sound level for locomotive horns or whistles is 105 dBA at a distance of 50 feet.[54] The train bell on MBTA commuter rail locomotives and cab cars has been measured at 82 dBA at a distance of 50 feet.[55] Because of their primary use as a safety device, locomotive horns and whistles are exempt from noise emission standards established by the U.S. Environmental Protection Agency and enforced by the FRA. Although recent Federal Transit Administration (FTA) documents concerning rail transit noise do not specifically address the issue of what screening distance should be used in attempting to assess the maximum possible extent of grade crossing noise impacts to the surrounding community, the Massachusetts Department of Public Utilities has on occasion used a distance of 500 feet in its practice of assessing noise impact and evaluating possible whistle blowing bans.[56] However, given the intensity of train whistle noise, its tonal nature, and the geographic extent of impact resulting from the requirement to sound the horn beginning ¼ mile from the crossing, 500 feet would appear to be a conservative value.

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49 U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. April 1995. pg. 6-17. L_{max} measures the loudest level of a noise event.
50 U.S. Department of Transportation, Federal Transit Administration, and the Massachusetts Bay Transportation Authority. *Supplemental Draft Environmental Impact Statement/Report and Section 4(f) Evaluation for Transportation Improvements in the Greenbush Line Corridor*. March 1995. pg. III-41.
51 U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. April 1995. pg. 6-26.
52 Rule 19(b), formerly rule 14L.
53 See Massachusetts G.L. c. 160, §138.
54 U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. April 1995. pg. 6-10.
55 U.S. Department of Transportation, Federal Transit Administration, and the Massachusetts Bay Transportation Authority. *Supplemental Draft Environmental Impact Statement/Report and Section 4(f) Evaluation for Transportation Improvements in the Greenbush Line Corridor*. March 1995. pg. III-41.
56 *Town of Acton*. DPU 89-160. Massachusetts Department of Public Utilities. October 3, 1991. pg. 7.

Although noise levels at grade crossings can often be quite disturbing to those who live nearby, safety considerations typically prevail over concerns about noise. Even so, nationwide in 164 cities and towns in 24 states there are approximately 2,100 grade crossings which are subject to local ordinances curtailing whistle blowing.[57,58] Although these bans are usually isolated instances, in Florida a special interest group calling itself "Project Whistle Stop" successfully lobbied the state legislature in 1984 to enact a legislative ban allowing local jurisdictions to ban whistle blowing at specially equipped grade crossings on intra-state rail lines. Eight counties and a number of individual cities soon followed with bans that met state requirements, and by 1990 the Florida East Coast Railway Company (FEC) was prohibited from using train whistles at 537 of its 600 hundred public at-grade crossings.[59] An FRA study of these crossings showed a strong correlation between the whistle bans and a 195% increase in the number of accidents at these grade crossings. Citing this significant decrease in safety, in 1991 FRA issued an order that overturned these local ordinances and required FEC to sound whistles at all 600 public grade crossings.[60]

In Massachusetts, the Department of Public Utilities (DPU) regulates warning systems at grade crossings and operating conditions, including speeds, on intra-state commuter rail lines. As of 1996, there were 107 at-grade crossings that had either full or partial (e.g. night only or one direction only) whistle bans. In the past, whistle blowing bans have been granted to cities and towns on a case-by-case basis by the Department of Public Utilities (DPU). Recently, however, after having their requests for whistle bans turned down by the DPU, local officials in three towns were successful in filing "home rule" petitions in the state legislature, which subsequently granted authority to the towns to enact the whistle blowing bans.[61]

The issue of whistle blowing bans has now taken center stage at the federal level, with the passage of the Swift Rail Act in 1994. One provision of the Act requires that train whistles be used at all highway-rail grade crossings throughout the U.S., regardless of and superseding local ordinances to the contrary. Although the Act attracted little attention when first passed by Congress in 1994, as more details became known about the whistle blowing provisions, the Act caused a nationwide outcry from those communities that had fought hard-won battles with state and local regulatory agencies to obtain their whistle bans. The Act would allow the FRA to issue waivers, however no direction was given as to what the basis for these waivers would

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[57] Walsh, Edward. "Illinois officials oppose law requiring trains to blow whistles," *Boston Globe*, 31 December 1995. pg. 4.
[58] "Hear That Loathsome Whistle Blow." Chicago Metra's On the (Bi)level, Cyberspace World Railway. September, 1995. URL <http://www.mcs.com/~dsdawdy/cyberroad.html>
[59] U.S. Department of Transportation, Federal Railroad Administration, Office of Safety. *Florida's Train Whistle Ban*. September 1992.
[60] *Ibid*.
[61] "Home rule" refers to the extent of municipal autonomy under state delegation of authority.

be, or who would pay for the improvements in crossing warning systems and gates that would likely be necessary to obtain these FRA waivers. Although the Act directed the FRA to promulgate and implement regulation by November, 1996, this deadline was not met due to the intense controversy surrounding the issue. Many industry observers have suggested that the FRA should simple request that Congress repeal the whistle blowing provisions of the Act, and by late 1996, the issue remained unresolved.

Anecdotal evidence suggests that grade crossings result in reductions in residential property values for nearby homes. In Palo Alto, CA, a group of residents living near the CalTrain commuter rail line calling themselves "HALT" (Home Owners Against Loud Trains) assert that real estate agents in the area have estimated that homes near the line can experience a loss of 10% or more in sales price over comparable properties elsewhere in Palo Alto.[62] In Franklin, MA, witnesses at a public hearing concerning grade crossing noise along the Franklin commuter rail line in 1990 stated that the train "whistling makes it difficult for realtors to sell homes in Franklin."[63] The implementation of the Swift Rail Act could potentially have widespread impacts throughout the U.S.. In Massachusetts alone, there are 107 existing commuter rail grade crossings with whistle bans located in 30 cities and towns, and an additional 85 grade crossings in 16 cities and towns on the three branches of the soon to be opened Old Colony Railroad that would potentially be eligible for whistle bans were it not for the provisions of the Swift Rail Act. Assuming a 500 foot area around each grade crossing would be effected by renewed whistle blowing, these 192 grade crossings would in total impact an area of approximately 5.4 square miles, representing .74% of all land area in these 46 communities. In fiscal year 1994, these communities encompassed a total of more than 200,000 single family residential parcels, with a combined assessed valuation of over $53 billion, or about $250,000 each. Assuming that both the location and value of these parcels are evenly distributed (admittedly a gross oversimplification), the provisions of the Swift Rail Act could potentially affect over 1,500 single family residential parcels, with an assessed value in 1994 of almost $390 million. Arbitrarily assuming a loss in property value of 4%, for instance, this would result in a combined loss in value of $15.5 million. Even under various other sets of assumptions, it becomes clear that nationwide, the magnitude of the potential impact from the Swift Rail Act regarding the effect of whistle blowing on residential areas needs to be considered.

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[62] Gauvin, Peter. "Train whistles steam residents," *Palo Alto Weekly*, 28 December 1994.
[63] *Town of Franklin*, DPU 89-92. Massachusetts Department of Public Utilities. November 6, 1990. pg. 9.

2.2.3 Stations

Commuter rail stations can be another source of significant proximity impacts. Stations, considered stationary sources, generate noise that primarily consists of automobile noise resulting from the ingress and egress of passengers, particularly in early morning hours, and in some cases can also include transit buses and auxiliary equipment such as public announcement systems. Even so, the potential impacts of most stations and parking facilities is approximately 200 feet at a maximum, and can be less if there are intervening buildings.[64] In addition to these possible negative impacts, homes in proximity to stations, and in particular those within walking distance, may in fact benefit because of the accessibility advantage.

One drawback to the growth that commuter rail has experienced in recent years is that, with some systems and lines experiencing double-digit growth at times, and with park-and-ride the dominant station access mode in suburban areas, the demand for parking at many stations has reached or exceeded capacity. Easy solutions to this problem are not often available, since land surrounding many of these stations is often already well developed, severely restricting the ability to expand surface lot capacity, and the construction of structured parking facilities is often not cost effective or compatible with the residential character of surrounding neighborhoods. Under these conditions, automobiles may overflow onto local streets, or if feeder bus service is introduced, the noise impact from the buses (80-85 dBA while pulling out from a stop) may also affect the community.[65]

For some commuter rail systems, the establishment of new commuter rail stations has become a task requiring not only sound planning, but extraordinary patience and diplomatic skills as well. In contrast to the enthusiastic moral and financial support provided by local communities in the Chicago area for the new "North Central" service as mentioned earlier, other communities in the U.S., although aware of the potential accessibility benefits of commuter rail, believe that a new station within their community may attract too many riders from nearby towns, resulting in unacceptable traffic on what are often local residential streets and collector roads. Other communities are concerned that special assessments levied by the state upon towns with transit access will be increased substantially. For example, in the Boston area, a 23 mile extension of commuter rail service west from Framingham to Worcester, MA, sparked controversy precisely for the reasons cited above. Officials and residents from three of the five towns to receive new stations have rejected various proposals for station sites because of traffic concerns. Some possible solutions have included proposals

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[64] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. April 1995. pg. 4-3.

[65] U.S. Department of Transportation, Urban Mass Transit Administration. *Guidelines for Transit Sensitive Land Use Design*. Final Report, July 1991. DOT-T-91-13.

to limit parking capacity at stations in order to discourage riders from nearby towns from using a station, and including at least one station in every town along the extension so that riders will be compelled to use a locally available station.[66] Other concerns, relevant to other communities in Metropolitan Boston that are to receive new commuter rail service in the next few years, are related to the special assessment levied by the state on towns that are within the MBTA district. Seventy-eight cities and towns currently within the MBTA district must pay an annual assessment to help the MBTA meet its operating deficit. However, many of these communities do not receive direct service. As the commuter rail system has grown and extended beyond the geographic limits of the MBTA district, some towns now receive frequent, high quality commuter rail service, but are not charged any assessment by the state. As a condition of allowing a project to proceed smoothly, many communities want to be assured protection from future MBTA assessments that the state legislature may wish to impose as the state's share of MBTA costs increases. Although many observers agree that the current system is not equitable, little progress has been made in developing a more equitable system.

2.3 Commuter Rail Impacts and the Planning Process - Recent Experience

Few public projects are without controversy, and several recent commuter rail projects have yielded significant local opposition. Past experience has shown that local officials and community groups opposed to transportation projects, including the introduction of commuter rail service, can often be successful in bringing about the delay or substantial modification of otherwise desirable transportation improvements, often at great additional cost to the project. In some cases, these additional costs and the years that are sometimes required in responding to legal and other challenges to a project can ultimately result in it being abandoned entirely.

Generally speaking, urban transportation planning is conducted by state and local agencies, with the role of the federal government being to set national policy, provide financial support (and by doing so influence local planning by attaching requirements that certain conditions be met for the receipt of these funds), technical assistance and training, and conduct research. The transportation planning process utilized in the 1950's and 1960's had various shortcomings, not the least of which was the lack of an in depth analysis of the social and environmental impacts of transportation facilities and services. As a result, throughout the 1960's, there were many notable controversies throughout the U.S. involving federally funded transportation projects, including highways, airports, and mass transportation facilities. By the early 1970's, the process had begun to change, as federal and state legislation and policies

[66] Higgins, Richard. "Commuter station gets second chance," *Boston Globe*, 4 February 1996, pg. 4.

related to transportation and environmental planning expanded both in number and in the breadth and depth of their content. Over time, the result was a more open form of planning and decision making that incorporated greater opportunities for the public to have a direct role in the planning and decision making process , and had a greater concern for the social and environmental impacts of projects and the opinions of those affected by these impacts.

One major piece of federal legislation that had a widespread impact on the transportation planning process is the National Environmental Protection Act (NEPA) of 1970. Under NEPA, all construction projects receiving federal funds must comply with existing federal environmental regulations prior to the release of federal funding. NEPA requires that a detailed environmental impact statement (EIS) be completed in order to assess all potential impacts resulting from such projects, and analyze alternatives in an attempt to avoid any adverse environmental impacts. Furthermore, NEPA requires that the EIS be fully disclosed to interested parties, including elected officials and private citizens. Although NEPA does not directly prohibit the development of projects that produce adverse environmental impacts, it does have a tremendous ancillary impact on projects through the resulting political and legal actions that can be taken as a result of information provided in the EIS. Since the early 1970's, several hundred legal challenges based on NEPA have been filed by groups or organizations objecting to proposed federal actions.[67] In general, at issue in these lawsuits is the sufficiency of information disclosed in an EIS, or that an EIS should be prepared where it has not been.

A common motivation in filing a NEPA lawsuit is to delay a project, often in the hopes of "papering" it to death either with continuous legal maneuvering or further, and sometimes seemingly endless, analysis and review. Many years may pass pending the outcome of preliminary hearings, a decision at the trial level, and appeals. During this time, the defendant agency is precluded from approving the disputed action until final resolution or settlement is reached. This delay can add significantly to the cost of the project, both because of the costs of the litigation itself and because of substantial modifications to the project that may be required for eventual approval. Other regulatory legislation that can have a major impact upon the planning of new transportation facilities include Section 4(f) of the Department of Transportation Act of 1996 (limiting use of preserved open spaces for DOT funded projects), Section 106 of the National Historic Preservation Act of 1966 (taking into account project impacts upon historic properties), and Section 404 of the U.S. Clean Water Act (regulating wetlands impacts). Eventually, the additional costs as well as the pressures that may be

[67] Platt, Rutherford H. *Land Use Control: Geography, Law, and Public Policy*. Englewood Cliffs, New Jersey: Prentice-Hall, 1991. pg. 305.

brought to bear on the agency by politicians, the media, citizens groups and others may even result in the project being abandoned.

Certainly, many citizens and elected officials who take issue with a project on environmental or other grounds are sincere and genuine, however others are more self-interested and obstructionist in nature. Although the more enlightened environmental and planning laws of the past three decades have helped to prevent much of the environmental degradation and negative social impacts upon communities that were more widespread during the 1950's and 1960's, in recent years it has become increasingly difficult and in some cases impossible to build facilities that are often highly desirable for cities and regions. Transit projects, including commuter rail, have not been immune to this phenomenon, and in many areas of the U.S., transit projects have for a variety of reasons been the focus of impassioned campaigns presented in opposition. So pervasive has this phenomenon become that it has spawned a virtual nomenclature of terms describing various aspects of it, the mostly widely recognized of which is NIMBY. NIMBY refers to the protectionist and exclusionary attitudes and oppositional tactics of community groups facing what they consider to be an unwelcome development in their neighborhood.[68] Another term related to NIMBY, sometimes used to describe the extreme nature of some NIMBY sentiments, is CAVE (citizens against virtually everything). Finally, NIMTOO (not in my term of office) refers to politicians who increasingly yield to those with NIMBY attitudes, regardless of the merits of a project.

NIMBY related controversy can encompass a range of land-use and development proposals, including but not limited to human service facilities, landfill sites, hazardous waste facilities, low-income housing, nuclear facilities, and transportation facilities including airports, highways and rail transit. As mentioned earlier, NIMBY related controversy can also lead to substantial modification of a project, often achieved at a significant premium in cost, or even abandonment of a project. For instance, in Los Angeles, planning for the Red Line encountered heavy NIMBY opposition, for the most part preventing even a discussion of any surface or elevated segments. Thus, the entire system is being built underground, at significantly greater cost than might have otherwise been realized if at-grade or elevated alignments had been considered.[69]

Opposition groups typically offer a range of arguments in an attempt to support their position, most revolving around actual or perceived threats to property values, personal security, and neighborhood amenity. Arguments related to possible threats to property values

[68] Dear, Michael. "Understanding and Overcoming the NIMBY Syndrome." *Journal of the American Planning Association*, Vol. 58, No. 3, Summer 1992. pp. 288-289.
[69] Kunz, Richard. "Is Urban Rail in America's Future?" *Mass Transit*. March/April 1996. pp. 63-68, 100, 104-105.

are understandable, since in the U.S. owner-occupied homes represent the principal asset for most individuals and families, and spending on housing comprises more than 40 percent of total consumption.[70] The investment in a single family residence is in many cases one of the largest single real property investments that an individual or family makes in their lifetime, with housing assets in the U.S. and the mortgages used to finance these housing purchases both valued in the trillions of dollars.[71] Therefore, for many households the largest debt is the mortgage. Expenditures on owner-occupied housing are also the primary savings instrument for many families.[72] With these considerations in mind, concern over potential loss of property value appears quite reasonable from the perspective of the property owner concerned with maintaining his or her property value. Project opponents usually disregard, however, the possible increases in property value that may result from the improvements in accessibility that the new service may provide. Planning agencies, on the other hand, often support the claim that property values will improve accessibility and by doing so increase property values.

In addition to property value arguments, rail transit project opponents often profess fear of transit related crime, although there is little empirical evidence to support this stance.[73] This issue is often particularly relevant in the case of commuter rail service to suburban communities, where in extreme cases opponents attempt to conjure up visions of pillaging hordes of urban dwellers descending upon the vulnerable and unsuspecting suburbs.

Neighborhood amenities, although often related to possible changes in the visual character of a neighborhood as mentioned earlier, also often focus on possible changes to the "character" of a community or the "way of life" in a community. Often, these types of arguments are somewhat vague in what their specific meaning, particularly in light of local zoning ordinances that regulate the type of land use, the density of population, and the bulk of buildings for both residential and commercial development. Unfortunately, in some cases these arguments are meant to conceal veiled intentions of a more insidious nature, such as attempts to impede development of affordable housing in a community, or promote a type of xenophobic paranoia and the exclusion of racial minorities from a community.

As NIMBY battles grow more common and intense, arguments have become increasingly creative, and in some cases perhaps overly imaginative. In Kingston, MA, where planning and construction of the Plymouth Line of the MBTA Old Colony Railroad

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[70] Nicholson, Walter. *Microeconomic Theory: Basis Principles and Extensions*. 5th edition. Forth Worth, TX: The Dryden Press. 1992. pg. 185.
[71] Megbolugbe, Isaac F. "Editor's Introduction." *Journal of Housing Research*, Volume 6, Issue 3, 1995. pg. 371.
[72] Witte, Ann D., and Sharon K. Long. "Evaluating the Effects of Public Policies on Land Prices in Metropolitan Areas: Some Suggested Approaches." In *Urban Land Markets: Price Indices, Supply Measures, and Policy Effects*. ULI Research Report No. 30, J. Thomas Black and James E. Hoben, eds., Washington, D.C.: Urban Land Institute.
[73] Plano, Stephen L. "Transit-Related Crime: Perception Versus Reality - A Sociogeographic Study of Neighborhoods Adjacent to Section B of Baltimore Metro." *Transportation Research Record 1402*. pp. 59-62.

Rehabilitation project has been underway, the head of the local conservation commission was concerned with the potential damage to the hearing systems of small animals caused by train noise, and noted that although the EIS extensively studied the noise impacts of commuter rail service upon humans, there could potentially be harmful impacts to the hearing systems of raccoons that warranted additional study.[74] Ultimately, the MBTA and FTA did not pursue such an analysis however.

Recent experience continues to show that political and legal action resulting from the environmental review process can significantly delay and increase the cost of otherwise desirable commuter rail projects. For example, in the Boston metropolitan area, the Old Colony Railroad Rehabilitation Project has encountered significant community opposition in certain areas. This project, first proposed in 1983, aims to rehabilitate three rail lines south of Boston terminating in Scituate, Plymouth, and Lakeville, which up until the late 1950's carried commuter passengers to and from Boston on a regular basis. Although most of the Old Colony system will operate along existing rights-of-way shared with either existing freight rail operations or heavy rail transit operations within the same right-of-way, the Greenbush Line to Scituate will be operating through residential areas along a right-of-way which has not seen any activity for most of its length since 1959. After more than thirty years, there were few remaining visual reminders of the once active rail line, which in parts of Hingham, Cohasset, and Scituate was by then nothing more than an unimproved trail, overgrown and largely impassable in many locations. Over time, residential and commercial land uses have encroached upon this former right-of-way, such that there is now the potential for significant impacts at a number of locations along the line.

Public reaction concerning the potential impacts of the Old Colony Lines has been significant, for the Greenbush Line in particular. Some 1,193 comments of the total 1,938 comments received on the Old Colony Draft Environmental Impact Statement/Report (DEIS/R) concerned the Greenbush Line.[75] Although anecdotes have a tendency to oversimplify a complex reality, the excerpts of public opinion presented below demonstrate at a minimum that opposing points of view exist concerning the potential property value impacts of commuter operations. The following are just a few of the comments concerning property value impacts received by the MBTA during its public review process:

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[74] Moroney, Tom. "Invoking Indians: A primer on how to delay builders," *Boston Globe, West Weekly Section*, 27 June 1993, pg. 1.

[75] U.S. Department of Transportation, Urban Mass Transit Administration, and the Massachusetts Bay Transportation Authority. *Final Environmental Impact Statement/Report, Old Colony Railroad Rehabilitation Project from Boston to Lakeville, Plymouth and Scituate, Massachusetts. Volume IV*, December 1991. Section 10.9.

"My wife and I have owned the property ... for the last 13 years ... I feel that the quality of life ... and the property values ... will be lessened if the Old Colony Railroad is restored."[76]

"The project will ruin the quality of life with its noise and pollution rambling by the house - also decrease the valuation. I never hear of any consideration about reducing the noise or pollution for the thousands of homes and businesses along the railroad bed."[77]

"As a family whose home abuts the railroad, we know that the proposed project is going to have a very negative impact on our property values..."[78]

"The affect [sic] on the local economy caused by making Boston and easier commute will have a drastic affect [sic] on property values."[79]

"I'm a businessman, real estate owner and I live only 200' from the tracks ... but the trains are good for the area."[80]

In addition to these comments received by the MBTA, reaction in the local newspapers and media have included such comments as:

"In Hingham, dozens of homes abut the tracks. They pass within a few feet of buildings as they cross three streets in the business district. Welch says the train line would reduce the value of the local homes."[81]

"Our townspeople want it ... and those who don't are the ones who live closest to the track."[82]

"Hingham Center residents also said that property values would likely plummet on homes located near the commuter line."[83]

"The Hingham Journal recently reported that business people conducted a study of the Old Colony's impact on property values and concluded their properties would depreciate 30 to 40 percent with the railroad's return to Hingham."[84]

The reactions from residents of the affected region concerning possible economic, environmental and other impacts from the Greenbush Line ultimately led to the postponement of construction of the line, as final design and construction for the remainder of the Old Colony Project including the Main Line, Middleborough Line, and Plymouth Line proceeded and is now scheduled for a September 1997 start of revenue operations. After the DEIS/R for the entire Old Colony Project was completed in May 1990, the Federal Transit Administration and

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[76] *Ibid.* Public at large comment PL-938.
[77] *Ibid.* Public at large comment PL-67.
[78] *Ibid.* Public at large comment PL-823.
[79] *Ibid.* Public at large comment O-12.
[80] *Ibid.* Public at large comment PL-583.
[81] Mehegan, David. "Some residents oppose commuter rail plan," *Boston Globe*, 9 May 1986, pg. 18.
[82] Mehegan, David. "Commuter rail service revival splits region," *Boston Globe*, 5 August 1986, pg. 18.
[83] McGrory, Brian. "Hingham marshals forces to stop trains." *Boston Globe, South Weekly Section*, 29 July 1990, pg. 8.
[84] Rosenberg, Ronald. "Old Colony line inspires a petition duel," *Boston Globe*, 30 July 1990, pg. 18.

the Massachusetts Secretary of Environmental Affairs determined that further analysis of the Greenbush Line corridor would be required in order to fully address unresolved issues concerning the proposed Greenbush Line commuter rail service. Therefore, a Supplemental Draft Environmental Impact Statement/Report (SDEIS/R) was published in March 1995. In this supplemental analysis, a number of alternatives incorporating cut-and-cover or deep bore tunnels were put forth to reduce impacts to the Lincoln National Register Historic District in the Hingham Square area.

These alternatives range in cost from an estimated $262 million (1993 dollars) for a short cut-and-cover tunnel alternative to $365 million (1993 dollars) for a longer deep bore tunnel. This is in sharp contrast to the fully at-grade alternative having an estimated cost of $186 million (1993 dollars), fully half the cost of the deep bore tunnel alternative and about 70% of the cost of the short cut-and-cover alternative. In response to continued opposition to the rail alternatives after release of the SDEIS/R, in June 1995 the Weld administration said that it now favored a guided busway system to operate over the former Greenbush Line right-of-way. After five months of more detailed analysis, however, the MBTA and the Weld Administration announced its intention to proceed with the at-grade Greenbush Line commuter rail alternative. A Supplemental Final Environmental Impact Statement/Report (SFEIS/R) for the Greenbush Line is expected sometime in 1997, with final design and construction to begin later that year.

Throughout the time during which preparation of the SDEIS/R was underway, opposition to the Greenbush Line became more intense as well organized opposition groups began to form. Anti-rail campaigns by groups such as the Coastal Coalition, representing residents of South Shore towns through which the line will run, became more aggressive as a final decision on whether to proceed with a SFEIS/R and final design and construction approached. The debate has been contentious, and compromise has been elusive, with alternatives presented in the SDEIS/R for a tunnel under Hingham square being summarily rejected by many commuter rail opponents. When asked about support for the project if a tunnel is built, one Coastal Coalition member responded, "That is not what the Coalition is about. We are trying to stop it.", indicative of the acrimony present throughout the debate.[85] A number of legal challenges to the project have been threatened, with the town of Hingham setting aside $100,000 for possible litigation against the Greenbush Line.

In response to activism on the part of anti-rail groups, proponents have also attempted to organize and rally public support around their position, forming groups such as Back on

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[85] Preer, Robert. "Rail dispute entering critical stage." *Boston Globe*, 19 March 1995, pg. 4.

Track, and the Scituate Committee for Commuter Rail. Proponents believe that widespread support for the project is simply being overshadowed by a vocal and aggressive activist anti-rail minority, and that the repeated non-binding referendum votes in towns throughout the region, which after several years had began to show a majority opposed the project in some towns along the line, were not fully representative of public sentiment. The results of a region-wide survey conducted in September 1995 by a professional market research firm at the behest of the South Shore Chamber of Commerce would seem to support proponents' positions, showing that overall, 61% of those polled supported the restoration of the at-grade commuter rail service alternative, with 18% opposed and the remainder having no opinion. 86% of those polled said that with the existing transportation system there was a problem with getting to and from Boston from the Greenbush Line region.[86]

Although existing commuter rail service in the metropolitan Boston area has received widespread public support, made evident by strong ridership growth in MBTA commuter rail service, residents in towns along other recently proposed commuter rail lines have expressed sentiments similar to those expressed by opponents to the Greenbush Line. Proposals for Fall River/New Bedford commuter rail service, the construction of the Framingham to Worcester extension, and discussions about rehabilitating the Central Massachusetts Line from Hudson to Waltham all have been met with overall support tempered with concerns about possible impacts. As with the Greenbush Line, residents in towns along rights-of-way to be used for the Fall River/New Bedford service have formed opposition groups such as Citizens Concerned about Tracks and SmartRail, and have even looked to the Coastal Coalition's experience in opposing the Greenbush Line to help them organize more effectively.[87] Although interim service has been operated between Worcester and Framingham since 1994, five stations planned for the 23 miles along this route have met with substantial opposition from towns concerned about possible traffic impacts of these stations.[88] Towns along the long dormant Central Massachusetts Line, although generally supportive of the idea of restored commuter rail service, have expressed concerns about the possible impacts on homes that are near the right-of-way.[89]

The seemingly endless debate concerning the Greenbush Line has resulted in one of the lengthiest planning processes for a commuter rail project in recent history, and one that may yet have several years until resolution. Being public agencies, transit properties are often subject to political influence and the vagaries of public opinion, thus it is no wonder that

[86] Layton, Lyndsey. "Commuter rail widely favored." *Patriot Ledger*, 13 September 1995, pg. 8.
[87] Preer, Robert. "Rail fights gain speed." *Boston Globe, South Weekly Section*, 19 November 1995, pg. 1.
[88] Moroney, Tom. "Commuter rail plan on track, MBTA says." *Boston Globe, West Weekly Section*, 7 May 1995, pg. 1.
[89] Moroney, Tom. "Plans afoot to revive railroad line." *Boston Globe, West Weekly Section.*, 21 January 1996, pg. 1.

projects of this magnitude often take years to complete. However, most would agree that the time that has transpired since the beginning of the planning process for the Greenbush Line has been excessive, perhaps to the point of jeopardizing the potential implementation of commuter rail service in this corridor.

Throughout the debate over the Greenbush Line and other new service proposals, the MBTA and other agencies have had little empirical evidence with which to respond to opponents. Transportation agencies generally support the idea that transportation improvements such as the Old Colony Rehabilitation Project and the Greenbush Line improve accessibility, and by doing so increase property values. In discussing the socio-economic and environmental impacts expected from the Greenbush Line, the Supplemental Draft Environmental Impact Statement/Report (SDEIS/R) states:

> "Improving accessibility to the downtown Boston job market would make the Old Colony area a more attractive residential location, and would be expected to lead to a greater demand for housing and to higher housing costs in the vicinity of stations. Realtors, developers, and planners in the Old Colony study area communities agree that reinstitution of commuter rail could cause an increase in housing demand and raise the price of existing homes."[90]

The SEIS/R further notes that evaluations of changes in residential property value resulting from commuter rail service have been limited in number, and this conclusion is indeed supported by the literature review conducted for this thesis and presented in Chapter 4. Throughout the intense debate that has been present during the planning process for the Greenbush Line, few of the claims made by opponents and proponents of the project regarding potential property value impacts resulting from both accessibility improvements and proximity impacts have been based on empirical evidence.

[90] U.S. Department of Transportation, Federal Transit Administration, and the Massachusetts Bay Transportation Authority. *Supplemental Draft Environmental Impact Statement/Report and Section 4(f) Evaluation for Transportation Improvements in the Greenbush Line Corridor*. March 1995. pg. V-10.

Chapter 3
Theoretical Basis for the Evaluation of Commuter Rail Impacts

This chapter reviews the theoretical literature and analytical methods that provide the basis for the evaluation of the accessibility effects and the proximity related externalities of commuter rail service. The analysis is rooted in a behavioral and economic framework in which observable marketplace behavior between the participants of the real estate market is used to derive the values of accessibility and proximity related externalities that are implicit in this behavior. Residential housing is treated as a complex multiattribute good, with accessibility and proximity related externalities being just a few of the many attributes embodied within a single-family residential property. These attributes are not themselves exchanged in explicit and observable market transactions. Rather, the value of these individual attributes is inferred by analyzing the willingness to pay for each unique bundle of characteristics represented by each single-family residential property. The strengths and weakness of possible analytical methods for estimating these implicit attribute prices are then reviewed.

3.1 Accessibility

An overview of urban land use theory is presented here in an attempt to offer some insight into how transportation can affect property values. Many of the empirical studies reviewed in Chapter 4 proceed directly to the measurement of variations in property values with respect to changes in the transportation system. Such an ad hoc approach is, however, incomplete. Many of the methods used in examining these effects provide little more than measures of the statistical correlation. When considered in the absence of any underlying theory, these approaches offer little insight into the deterministic and causal interactions between the transportation and land use systems. This may lead to misguided inferences and conclusions concerning the true nature of the impacts.

Before proceeding further, an attempt is first made to characterize and clarify the nature of accessibility and the role it plays in this thesis. In much of the literature, accessibility broadly refers to the extent of separation of activities, for instance employment, retail shopping, and home-based activities. From an economic perspective, accessibility can be defined as the economic benefits derived from the interaction between activities, or the net benefit obtained from making contact with other activities, less the interaction or transport cost. Viewing households as rational entities which attempt to maximize net benefit or utility, households will attempt to locate so as to maximize the net utility gained from these activities that are distributed throughout space, given various constraints and limitations such as income and the availability of information. For the purpose of this thesis, accessibility can be conceived of as the relative advantage of one location over another in its ability to provide for ease of movement to and from locations at which activities occur. Assuming that the availability of commuter rail service in a community provides for ease of movement or a reduction in the interaction cost between two activities, then the net benefit derived from these activities will be greater than would otherwise be the case in the absence of commuter rail service.

In the context of this thesis, one must next consider whether accessibility refers to actual trip making behavior, or whether accessibility also refers to the *potential* to travel between selected activities. In light of the actual level of commuter rail usage in the Boston area as reviewed in Chapter 5, this issue is of particular relevance to this thesis. For any sample of residential property sales chosen for analysis, only a small portion are likely to represent households that actually use commuter rail service, even if these sample property sales are restricted to being within close proximity to a commuter rail station. Do the potential benefits of commuter rail service (as reflected in property values) accrue only to those single family residential properties owned by commuter rail users? If so, it is not likely that any relationship between property values and commuter rail access will be observed. Few of the empirical studies reviewed in Chapter 4 consider this issue. This thesis adopts a fundamental premise that accessibility refers to the set of activities to which a person has the potential to travel, even if such a trip is not actually made. The assumption inherent in this viewpoint is that people view an opportunity, even if unused, as better than or at least equivalent to having no opportunity. Therefore, unchosen options are considered as having value.

Thus far, access has been characterized as the net benefit obtained from making contact with other activities, less the interaction or transport cost, with households attempting to maximize net benefit by locating so as to maximize the net utility gained from these spatially distributed activities. Land rent theory, as first postulated by von Thünen (1826) in the context of agricultural markets, and later refined in urban location models by Haig (1926), Alonso (1964) and others is now used to derive the expected impact of accessibility on land rents and property values.

Much of traditional urban land use theory either directly or indirectly owes its origin to an agricultural land rent model developed by von Thünen in the early 1800's.[91] Given a central market, von Thünen argues that agricultural land use patterns will depend upon the distance to the central market, the selling price of the product in that market, and the land rent, which in this context refers to the economic rent, that is the return to any factor of production which is in fixed supply (in this case land). Transportation costs are assumed to increase with increasing distance to market. Within the context of several limiting assumptions, including rational economic behavior, perfect competition, uniformity of topography, and uniformity of accessibility among others, agricultural production having higher transportation costs would exhibit a preference for locations nearer to market, thus bidding up the rent for these sites. Those having lower transportation costs would bid less for these sites, and so be forced to locate further from the market. With land allocated to the highest bidder, concentric zones of agricultural production thus develop around the central market, with the land rent differentials being determined by variations in transportation cost savings. The bid rents for various products dictate the use of land at particular locations, with that bidding the highest being produced at that location.

Haig (1926) applied similar reasoning in an urban context.[92] In addition to the assumptions in the agricultural model, in the urban model proposed by Haig all activities are assumed to exist at the CBD, with a homogenous population and invariate building costs. Under these assumptions, with transportation costs also assumed to increase with distance, the sum of transportation costs plus site rents is constant across the entire city. People willing to pay the highest price for locations having superior access (least transportation cost) will out-bid rivals, with the outcome being that the highest site rents will be obtained at the most accessible locations. Alonso (1964) further refines this model of urban location, showing that such a model can extend beyond analyses of residential land rent in isolation, to include other land uses such as industry as well as different classes of households.[93] These different land uses trade off purchases of accessibility to the CBD, land area, and other attributes. The land uses offering the highest bid rent end up with control of a parcel of land. Therefore, commercial and industrial land uses are often located at central sites where they are able to benefit from agglomeration economies. Poorer people who cannot afford high transportation costs and place a relatively low priority on large sites are willing to bid higher rents for inner

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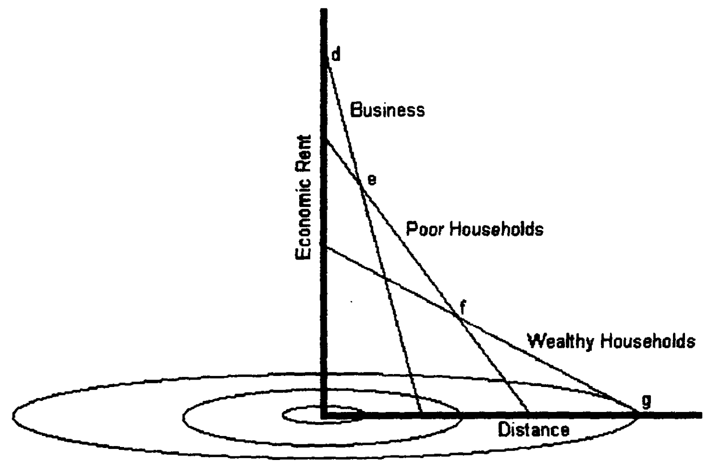
[91] Hall, P., ed., *von Thünen's Isolated State: An English Version of "Der Isolierte Staat.* 1966. English translation of von Thünen, J. H, *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalokonomie*, 1826.

[92] Haig, R.M. "Towards an Understanding of the Metropolis." *Quarterly Journal of Economics*, 40, 1926. pp. 179-208.

[93] Alonso, William. *Location and Land Use: Toward a General Theory of Land Rent.* Harvard University Press. Cambridge, MA. 1964.

Figure 3.1: Urban Bid-Rent Gradient and Land Use Pattern



area locations, while the wealthy will be more inclined to bid a higher rent for suburban locations. The outcome of this process can be seen in the characteristic observed rent-bid curve *defg* presented in Figure 3.1.

The many limiting assumptions of these urban location models make their practical application questionable, and the land use patterns described by their application obviously deviate from the more complex organization of actual cities. It is not the purpose of this thesis, however, to employ and empirically test these theories in their pure form, but rather to utilize the theory as a source of general a priori guidance concerning the basic causal and statistical relationships between transportation and property values. The methods discussed later that are generally employed to measure the magnitude of the relationship between transportation and property values serve primarily as accounting relationships that, if considered in isolation as they often are in many empirical studies, offer little insight into the underlying interactions between the transportation and land use systems.

3.2 Proximity Related Externalities

As with accessibility, many existing empirical studies proceed directly to the measurement of variations in property values with respect to changes in noise or other externalities. As before, such an ad hoc approach is incomplete. An attempt is made here to characterize the proximity related externalities of commuter rail from an economic perspective, and then illustrate how proximity related externalities are reflected by variations in single-family residential property values.

The environmental impacts of commuter rail service, as viewed from a physical perspective, are reviewed earlier in Chapter 2, and further discussion related to the physical nature and measurement of the environmental impacts of commuter rail is deferred until Chapter 6. Because noise is often considered to be the primary environmental impact of commuter rail service, it will be the focus here. In relation to its impacts upon property values, noise from commuter rail can be characterized as an externality. Externalities exist when the activities of one entity affect the welfare of another entity without any payment or compensation being made. In the context of this thesis, noise from commuter rail can be characterized specifically as an external diseconomy of production, with the operation of commuter rail resulting in uncompensated costs to others in the form of noise imposed upon nearby residences. Commuter rail noise can be further characterized as a technological externality, since it directly enters into the utility function of affected residents. This is in contrast to a pecuniary externality, which does not involve resource costs in an aggregate sense but often has distributional implications.

Commuter rail externalities are largely local in their effect, occurring in proximity to facilities such as rights-of-way, grade crossings, layover yards, and stations. Given this, noise can be viewed as a neighborhood disamenity, whereas quiet or freedom from noise can correspondingly be viewed as a neighborhood amenity or local public good. As will be seen later in Chapter 6, attitudinal surveys have consistently revealed a strong correlation between higher noise levels and higher levels of annoyance. Because commuter rail noise is an annoyance, it enters the utility function of affected residents. Since higher noise levels at a given property location will diminish the utility derived by the residents of that property, there is a corresponding reduction in the willingness to pay for a noisy home as compared to a quieter home having otherwise similar structural, site, and other attributes. A noise discount arises because residents are willing to pay to avoid the noise externality. Strictly speaking, the nuisance cost of noise is negatively capitalized into the value of residential property, and represents the present value of the future stream of noise costs to the resident. A priori, one would expect a resident's willingness to pay for quiet to depend upon income. Thus for low income people, the marginal willingness to pay for quiet is expected also to be low. As the literature review in Chapter 4 will show, this is supported by empirical evidence.

3.3 Analytical Approaches and Value Estimation Methods

Having now provided some theoretical insights into the manner in which accessibility and externalities are reflected in residential property values, this section proceeds with a more detailed review of the particular analytical methods that are available for estimating the value of commuter rail accessibility and proximity related externalities. The methods reviewed are categorized as being either revealed preference techniques based on the observation of actual behavior in a market, or stated preference techniques based not on actual behavior but on survey responses to particular situations. The strengths and weakness of each are briefly reviewed here, with the focus of attention being those methods that are most applicable to this thesis and are utilized extensively for the case study in Chapter 7.

3.3.1 Stated Preferences and Contingent Valuation Methods

Stated preference techniques, often referred to as contingent valuation methods, are often utilized in estimating "non-use" values related not to the use or consumption of a resource, but merely to its existence and its intrinsic value. Therefore, by definition, there is no behavioral evidence that can be utilized in estimating such non-use values, and surveys are instead used to elicit information on the various trade-offs people would make given a particular situation. Stated preference techniques can be utilized for estimating use values as well. For instance, a group of residents could be surveyed concerning how much compensation would be required to allow them to maintain their current level of welfare if a commuter rail related environmental impact were to occur, or what amount would they be willing to pay to avoid such an impact. Factors such as questionnaire design and the characterization of particular scenarios and contexts are crucial in obtaining relevant value estimates. The use of stated preference techniques would require the expert design and implementation of a survey, which is well beyond the means of this thesis. Furthermore, the existence of sales transactions for single-family residential properties provides sufficient behavioral data for the use of a revealed preference technique, thus forgoing the need for any stated preference techniques in this thesis.

3.3.2 Revealed Preferences and Averting Behavior

One revealed preference technique, particularly relevant to the measurement of externalities such as noise, is referred to as "averting behavior." This technique involves estimating the cost of an environmental externality by equating it with the cost of measures utilized to avoid any impact from this externality. Thus, one might infer from a household's expenditures upon noise mitigation measures (e.g. double-glazed windows, improved insulation, air conditioning) the cost of the noise that otherwise would have affected the property. This technique, however, suffers from several shortcomings, not the least of which is that obtaining such detailed data concerning specific homes would be virtually impossible in the context of this thesis. Also, benefits other than just noise avoidance often accompany such expenditures on these types of measures, for instance a more comfortable room temperature during hot weather from air conditioning, or lower heating bills because of improved windows and insulation. In practice, it is difficult to isolate the specific expenditures that are made to avoid the environmental externality only. Also, except perhaps in the case of the construction of noise barriers, noise mitigation measures do not address the impacts to residents when they are outside their house, which also will affect their level of utility but is not reflected in the averting behavior. For these reasons, this method is not utilized for this thesis.

3.3.3 Revealed Preferences and Hedonic Price Models

Another more widely utilized revealed preference technique is known as the hedonic method or hedonic models. Single-family residential properties are best characterized as complex heterogeneous goods, each consisting of an inseparable bundle of homogenous attributes of varying quantities and qualities. These attributes can include not only structural and site attributes, but also measures of local service quality, locational attributes such as accessibility, and environmental amenities such as freedom from noise. Although each attribute is not individually exchanged in an explicit market transaction, implicit prices for these attributes can be inferred by observing the willingness to pay for each unique bundle of characteristics represented by each single-family residential property. The method is rooted in a behavioral and economic framework in which observable marketplace behavior between the participants of the real estate market is used to derive the implicit prices of these attributes. The use of hedonic models is well established, relatively uncontroversial, and is generally a well accepted practice in evaluating the implicit prices of the component attributes of complex goods.

It should be noted that a full implementation of the hedonic methodology requires two steps, the first in which a hedonic price schedule is estimated, and a second in which demand functions are estimated. Therefore, the first stage hedonic price model does not represent a demand function for any given attribute. This first stage hedonic price model simply represents an equilibrium locus of prices, and as such is the result of the interaction of the participants in the real estate market. If further information is required concerning individual behavior and the underlying demand for the attributes, a second stage is required in which demand or bid functions are derived. It is at this second stage that substantial theoretical and econometric difficulties arise, among the most difficult of which is that of identification when dealing with simultaneously determined price and quantity variables. It is for these reasons that the vast majority of empirical studies employing the hedonic methodology rely solely on the first stage hedonic model.

As Palmquist (1992) notes, use of a first stage only hedonic modeling methodology is acceptable, as long as one assumes that the equilibrium hedonic price schedule remains unchanged.[94] Again, the first stage hedonic model represents an equilibrium locus of prices reflecting the outcome of the interactions in the real estate market. Different real estate markets with differing participants would be likely to generate differing equilibrium price schedules. For instance, as indicated in the Chapter 4 literature review, previous studies of the effect of noise on property values have obtained a wide range of values. Although some interpret this as meaning that some or all of the estimated values are somehow flawed, in fact one should expect that in different real estate markets having different participants, willingness to pay for quiet would be different. Because this thesis will rely solely upon a first stage hedonic model, empirical findings must be considered within this framework, and caution should be utilized in the direct application of the findings from the models estimated in Chapter 7 to other regions or market areas.

The implicit price of each individual housing attribute is an equilibrium outcome of the supply of the attribute (determined by producer costs) and the demand for the attribute (determined by consumer tastes). The equilibrium price of a residential property can therefore be expressed as a function of the many attributes of the property, stated formally:

$$P = f(Z)$$

where P represents the equilibrium price of a property, and Z represents a vector of attributes for that property. The basic empirical relationship to be investigated typically is of the general form:

$$P_i = \alpha + \sum_k \beta_k X_{ik}$$

where P_i is the sales price of the *i*th house, X_{ik} is a vector of property attributes, β_k are the estimated implicit marginal prices for each attribute, and α is the intercept term which, in addition to being interpreted as the mean effect on the dependent variable of all excluded relevant independent variables, may also be interpreted as representing the fixed start up costs of housing production. The hedonic price relationship is, by itself, rather unexceptional and amounts to little more than a simple accounting identity between housing price and expenditures on individual housing attributes. It should be emphasized here that the use of

[94] Palmquist, Raymond B. "Valuing Localized Externalities." *Journal of Urban Economics* 31. 1992. pp. 59-68.

various statistical or experimental techniques to estimate the implicit prices in a hedonic price relationship does not ensure that a causal relationship exists between the level of an attribute and property values, but only reveals the presence of correlation between these variables. To establish causality, one must defer to sound theoretical principles and other a priori considerations, and should not infer a causal relationship based solely upon the data itself.

Estimating the implicit marginal prices of attributes of a single family residence involves the implementation of a hedonic price model by means of ordinary least squares (OLS) regression. Linear here refers to a model which is linear in the parameters, and not necessarily in the variables. Three basic forms of the sample regression function with potential applicability to this analysis include the general linear additive model such as

$$Y_i = \beta_0 + \beta_1 X_{1i} + u_i$$

a general exponential model such as

$$Y_i = e^{\beta_0 + \beta_1 X_1 i + u_i}$$

and a general multiplicative model such as

$$Y_i = \beta_0 \, x_{1i}^{B_1} \, e^{u_i}$$

with the latter two models being intrinsically linear, since a straightforward logarithmic transformation of these models results in what is referred to as a semi-log transformation of the exponential model:

$$lnY_i = \beta_0 + \beta_1 X_{1i} + u_i$$

and a log-log or log-linear transformation of the multiplicative model:

$$lnY_i = \ln\beta_0 + \beta_1 lnX_{1i} + u_i$$

In addition to these intrinsically linear models, other more flexible model frameworks such as Box-Cox transformations are sometimes presented in the literature on hedonic models.

Although these types of transformations impose fewer restrictions on the functional form of the hedonic relationship than do the more traditional forms presented above, they involve more elaborate computational procedures and also make coefficient interpretation more difficult since the implicit price of amenities in such a model is dependent on the levels of other amenities. For these reasons, the intrinsically linear exponential and multiplicative model specifications are utilized in thesis.

Because of the complexity of the market for residential housing, the general linear additive model specification is rarely used and will be avoided here. Referring back to the logarithmic transformations of the exponential model, the estimated parameters of this model when multiplied by 100 can be interpreted as the percentage change in the dependent variable (housing price) for an absolute change of one unit in the independent variable. An exception to this is when the independent variable is a dummy variable. While the above interpretation is correct for continuous independent variables, for dummy variables the correct interpretation of the estimated parameter involves the use of the following adjustment:

$$g^{*} = \exp\left(\hat{c} - \frac{1}{2}\hat{V}(\hat{c})\right) - 1$$

in which g is the proper interpretation of the relative magnitude of the effect of a change in the dependent variable for a given absolute change in the independent variable, c is the estimated dummy variable coefficient, and V is the sample variance of the estimated dummy variable coefficient c. [95] Although often overlooked in much of the existing empirical research related to hedonic models, this distinction is important since the errors involved in incorrectly assuming that c is equal to g can be substantial depending upon the estimate of c.

In practice, the logarithmic transformation of the multiplicative model is attractive because the estimated parameters can be interpreted as the elasticity of the dependent variable (housing price) with respect to the independent variable, or the percentage change in housing price for a given percent change in the independent variable. It should be noted that because the noise metrics described in more detail in Chapter 6 are based on a logarithmic scale, the logarithmic transformation of these metrics for use in a log-linear model transformation should be avoided. Such a manipulation changes the noise metric from a subjective noise annoyance

[95] Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1981. pg. 801.

measure into a sound intensity or energy equivalence level, whose interpretation is somewhat ambiguous. If, however, distance to a facility is used as a proxy for noise, note that noise levels are linear in the log of distance, thus, the use of log-linear transformation is warranted.

The following assumptions apply when estimating the models presented above using OLS.

1) The mean value of the stochastic disturbance term, u_i, is zero.
2) The u_i error terms are uncorrelated or independent
3) The u_i terms are homoscedastic, that is, identically distributed.
4) There is zero covariance between u_i and X_i.
5) The regression model is correctly specified and there is no specification bias.

Furthermore, if these assumptions hold, the resulting least square estimators are

1) linear
2) unbiased
3) have minimum variance among the class of all such linear unbiased estimators, and are therefore efficient estimators

Estimators with these qualities are said to be best linear unbiased estimators (BLUE). This fact has significance regarding the inferences to be made concerning the true population parameters based upon the estimated sample regression parameters. If the sample regression parameters are not BLUE, then inferences concerning the true population parameters may be erroneous.

In practice, complex multivariate models of the type required for the estimation of a hedonic price function often violate these OLS assumptions to varying degrees, or exhibit other problems which can affect the ability to draw reliable inferences concerning the true value of the population parameters from the estimated sample parameters. One of the major problems associated with the estimation of hedonic models is that of multicollinearity. Strictly speaking, multicollinearity is present when some or all of the independent variables are linearly correlated. In practical applications, however, the presence of nonlinear as well as linear relationships among the independent variables will also present a similar problem. For instance, although the inclusion of interaction terms such as quadratics in a model specification will not, strictly speaking, result in a linear relationship between these variables, by design these regressors will be nonlinearly correlated, which in practice will make it difficult to estimate the parameters with a larger degree of precision. It should be noted that if the objective is the accurate prediction of the dependent variable only, for instance housing price, then the presence of multicollinearity does not pose a serious problem. In such a case, the explanatory power of the model, as indicated by R^2, may in fact be quite high, regardless of the high standard errors of the parameter estimates that typically result in the presence of multicollinearity. However, if the objective is the reliable estimation of the model parameters, as it is in this thesis, then the presence of multicollinearity may pose a significant problem since, as shown above, it can lead to large standard errors and insignificant *t*-values.

The problem of multicollinearity is one of degree more than one of its presence or absence. It is rare for perfect multicollinearity to exist, and when it does, it is often the result of improper design. This can occur, for instance, when using of a set of dummy variables that is exhaustive or nearly exhaustive of all categories of the attribute in question. The total absence of multicollinearity is similarly rare.

A common guideline for determining whether multicollinearity is a serious problem is to compare the pair-wise or zero-order correlations among the regressors in a model to the value of R^2 for a model. If any pair-wise correlations exceed the R^2, then multicollinearity may present a significant problem. High pair-wise correlations are, however, only a sufficient but not a necessary condition for the presence of multicollinearity, because the interaction of multiple regressors means that multicollinearity can exist even if these pair-wise correlations are relatively low. Auxiliary regressions of various combinations of regressors upon each other can be utilized in an attempt to ascertain the relationships that exist among the regressors, however this may be of little value if there exist a number of complex associations among the independent variables in the model. Although strictly speaking multicollinearity violates no regression assumptions since unbiased consistent estimates will still occur, it is difficult to obtain estimates with a small standard error when multicollinearity is present. The practical implications of this are that the ordinary least square estimators will have large variances and covariances, wider confidence intervals around them, and thus more insignificant *t* values. One indication of multicollinearity is in fact the existence of insignificant *t* values in combination with a high R^2. Although the inclusion of a large number of independent variables often exacerbates the problem of multicollinearity, excluding variables in an attempt to mitigate the effects of severe multicollinearity may itself impart a significant specification bias, and should therefore be avoided when at all possible. A better and more benign remedial measure for multicollinearity is simply to increase the sample size, since doing so is likely to decrease the standard error and variance of the parameters, thus helping to combat the effect of increasing standard errors resulting from multicollinearity.

Another problem that can arise in the estimation of hedonic models is that of autocorrelation, violating the OLS assumption of independently distributed error terms.

In practice, this appears to be a lesser problem than that of multicollinearity. Most often, autocorrelation arises in the analysis of time series data, where dependencies occur among successive chronologically ordered dependent variables. In this thesis, however, all time series effects associated with the sampling of property sales data over time are controlled for by utilizing a housing price index to normalize all sale price values to a single point in time, and therefore time series dependencies are not expected to present a problem. Spatial autocorrelation, in which spatial dependencies occur among dependent variables, is also a potential problem considering the spatial nature of the analysis presented in Chapter 7. Given the paucity of guidance available in the literature regarding both the presence of spatial dependencies, its effects and their implications, and because the estimation of spatially autoregressive model specifications that account for such spatial dependencies is highly complex, autocorrelation is assumed not to present a problem in the context of this analysis.

One final consideration concerning the estimation of hedonic models is that of heteroscedasticity, which violates that OLS assumption of identically distributed error terms. The use of log transformed models, such as those discussed earlier and proposed for use in this thesis, serves to reduce heteroscedasticity in many cases because it in effect compresses the scale in which the variables are measured. It may also be prudent to segment the housing transaction data by price class, most likely based on market price segmentations readily available from local real estate analysis firms. Separate models estimated for three different market segments (low, medium, and high price) may help to reduce heteroscedasticity, and since these three segments can be viewed as operating almost as three different sub-markets, this approach may also be warranted for other reasons.

Extensive amounts of data regarding the various attributes for each property are required in order to estimate a hedonic model. Although in the past this extensive data requirement was a significant impediment to the application of hedonic models, advances in the availability of detailed real estate, demographic, and geographic data sources in machine-readable formats now makes the application of the hedonic methodology significantly more feasible.

None of these problems associated with hedonic model estimation is easily solved. In addition to the mitigation measures suggested, another practical method of ensuring the models are robust is to attempt to obtain consistent results with the use of an experimental or quasi-experimental approach, in addition to the multivariate approach typically utilized for hedonic models. In the parlance of real estate appraisal and research practice, this approach is sometimes referred to as paired data analysis (PDA). In this thesis, the effect of commuter rail proximity impacts and commuter rail related accessibility are of primary interest, and thus can be considered the primary attributes. Other factors affecting property values are of secondary interest, in as much as these factors must be controlled for while attempting to isolate the separate influences of commuter rail proximity impacts and accessibility upon property values, and thus will be called secondary attributes.

Paired data analysis and multivariate hedonic models differ in two major respects. First, the two methods have different data structure requirements, and secondly, both methods deal with the contribution of secondary attributes to property values in a different manner. Regarding the first difference, in principle, paired data analysis requires pairs of property values matched in every respect except the primary attribute. In practice, however, perfectly matched or even well-matched pairs seldom exist. In contrast, hedonic models, do not require this type of matching process, making data selection simpler and usable observations more readily available.

The second difference between the two methods is the way in which they account for differences in attributes that affect value other than the primary attribute, referred to as secondary attributes. Paired data analysis achieves this by matching pairs of properties as closely as possible on all determinants of selling price except for the primary attribute. However, in paired data analysis secondary adjustments are usually needed to correct for leftover differences in the attributes of a matched pair. If paired sales are different in some attribute other than the primary attribute, a secondary adjustment corrects the sale price of one sale by adding or subtracting the net value of this unwanted difference. Sources of secondary data adjustment values often include other paired data, cost data, survey data, or regression estimates.

In contrast, the multivariate hedonic model uses statistical techniques such as multiple regression analysis to account for the attributes that affect value. The hedonic model decomposes the overall sales price into individual elements, each of which is explained by variations in these separate attributes including the primary attribute, and controls for the secondary attributes statistically. Thus, paired data analysis requires a paired data set while hedonic models do not.

In paired data analysis, a pair of sales is identified, each being similar in all major respects except for a primary attribute for which a value estimate is required. The sale price difference between the properties in this otherwise perfectly matched pair can therefore be attributed to the presence of the primary attribute in one of the paired properties. Paired data analysis provides a number of advantages. By matching properties as closely as possible through judicious design of the study area and sampling procedure and selection of control and experimental observations, the effects of the matched variables are considered without having to specify the form of their impact on the sale price, thus avoiding potential specification errors. Therefore, in the event of perfect matches, paired data analysis is essentially a model-free approach, avoiding a host of possible biases that may be introduced at this stage. Even in those cases where the matches are not exact, the bias introduced by adjusting out the remaining small differences may be smaller in many instances than the bias due to incorrect model specification that might be introduced by hedonic models. The use of experimental methods such as paired data analysis, as well as other more quasi-experimental techniques to measuring the various impacts of commuter rail service upon property values, can be both more efficient and more robust than alternative multivariate techniques for this type of analysis, in turn making empirical findings more defensible. This is an important consideration given both the contentious and public nature of the debate that exists in many communities concerning commuter rail impacts. Therefore, paired data analysis is in many ways a more efficient and robust approach, and where possible will be the primary methodology employed in this thesis.

In the analysis of how proximity to commuter rail facilities including stations, rights-of-way, and grade crossings impacts property values, many of the other attributes affecting property values can be controlled for experimentally. Regional accessibility can be controlled for simply by limiting observations to one community for each analysis. Local accessibility within a given community can also be controlled for by choosing properties that are equidistant from the commuter rail station, yet vary only in their proximity to the right-of-way or grade crossings. Commuter rail accessibility would need to be differentiated either in a discrete binary fashion or in a continuous fashion. Both approaches should be investigated. With the analysis limited to a single community, local service provision and cost variables, for example school quality, public safety, and property tax rates, would be controlled for.

To supplement the paired data analysis approach, structural attribute variables and site attribute variables could be included explicitly in a quasi-experimental hedonic model, where all secondary characteristics except for site and structural characteristics are controlled for experimentally. This may be necessary, since the likelihood of obtaining perfectly matched pairs in every analysis is small. Alternatively, assessed value, reported in the Banker & Tradesman COMPReports, could be used to control for the differing characteristics among properties. In order to evaluate the property value impact of the primary variable, it is necessary to account for all secondary attributes as well. This can be done by evaluating individual site and structural attributes, attempting to match each one separately, however this would dramatically reduce the ability to obtain an adequate number of matched pairs. Viewing the assessed value as being representative of the sum total of all secondary attributes allows this single value to be used to control for all secondary attributes. The specific magnitude of individual secondary attributes is unimportant, as long as the sum total of these attributes yields the same measure of value between two properties that have different combinations of attributes, but combinations that in total provide the same level of utility to the consumer. In this manner, pairs of properties that are similar in all respects except for the primary attribute can be selected and compared on the basis of the differences in their sales prices, assuming of course that the valuation method used by the local assessor does not already explicitly consider the presence or absence of the primary attribute. This assumption is addressed further in Chapter 6.

Because both the assessed values and sales prices are in effect continuous variables, it is assumed that there is a zero probability that the two properties in any pair will have exactly the same sales price. In each pair, then, either one property or the other will have the greater sales price. Under these assumptions, the n pairs of properties thus matched on the basis of assessed value can be viewed as representing n Bernoulli trials. Treated in this manner, the pairs can be evaluated using a variety of available nonparametric inference procedures to determine whether the primary attribute, for instance accessibility to commuter rail stations, has a statistically significant effect upon sales price.

The simplest of nonparametric procedures, such as the *sign test*, consider only the sign of the difference between values of each pair. Letting $p = P(Y_i > X_i)$, where $i = 1,\ldots,n$ and where Y_i represents the sales price of properties exhibiting the primary attribute, for example accessibility to commuter rail, and X_i represents the sales price of properties lacking the primary attribute, for example having poor accessibility to commuter rail, p denotes the probability that for the ith pair of properties, the more accessible properties will exhibit a greater sales price than the non-accessible properties. In terms of p, the null hypothesis is

$$H_0: p = \tfrac{1}{2}$$

and the one-sided alternative hypothesis is

$$H_0: p > \tfrac{1}{2}$$

The number of pairs in which accessible properties sell at a greater sales price than properties that are not accessible to commuter rail, or the number of plus signs, will have a binomial probability density function, with parameters n and p. Given n, the number of plus signs, and p (which under the null hypothesis is ½) inspection of the binomial distribution yields the corresponding cumulative probability. At any level of significance greater than or equal to this probability the null hypothesis should be rejected, indicating that the primary attribute does have a statistically significant effect upon property values.

Using the sign test, the decision to accept or reject the null hypothesis is based only on the number of positive differences in the pairs, with no consideration given to the magnitudes of these differences. In practice, if the size of the difference for each pair can be measured, as they can be here, it is useful to apply a test procedure which not only considers the signs of the differences but also recognizes the relative magnitudes of the differences. One of the most widely used nonparametric procedures of this type, the Wilcoxon signed-rank test, will be used in the analyses presented in Chapter 7. Continuing with the same notation as with the sign test above, $D_i = Y_i - X_i$ represent the differences between the sales prices of properties exhibiting the primary attribute and the sales prices of properties lacking the primary attribute. Because the n differences $D_1,\ldots,D_n$ pertain to different pairs of properties, the differences will be independent random variables, which are assumed also to come from the same continuous distribution which is symmetric with respect to some unknown point θ.

The null hypothesis H_0 that properties having accessibility to commuter rail do not sell for more than properties that do not have access to commuter rail is equivalent to the statement that $\Pr(D_i \leq 0) \geq ½$, which is equivalent to the statement that $\theta \leq 0$. Likewise, the alternative hypothesis that properties having accessibility to commuter rail do sell for more than properties that do not have access to commuter rail is can be represented by the statement $\theta > 0$. The Wilcoxon signed-rank test is used to test these hypotheses. To implement this test, first the absolute values of the differences $|D_1|,\ldots, |D_n|$ are arranged in ascending order. Next, each absolute value is then assigned a rank corresponding to is relative position in this ordered set of absolute values. Then, each of these rank values is assigned either a plus sign or a minus sign based upon the sign of the original difference D_i. Finally, the statistic S_n is defined as the sum of the ranks assigned a positive value, and the Wilcoxon signed-rank test is based upon the value of S_n. When $\theta = 0$, the expected value of S_n can be shown to be

$$E(S_n) = (n(n+1))/4$$

and the variance of S_n can be shown to be

$$Var(S_n) = (n(n+1)(2n+1))/4$$

It can also be shown that as $n \to \infty$, the distribution of S_n can be adequately approximated by the normal distribution with mean and variance as shown above. In practice, for $n > 12$, a normal distribution can be used to approximate the distribution of S_n. When $\theta = 0$, the random variable

$$\mathbf{Z_n = (S_n - E(S_n))/ \text{s.d.} (S_n)}$$

will have an approximately normal distribution. The null hypothesis would then be rejected, for instance, at a 0.05 level of significance if $Z_n \geq 1.645$, indicating that the primary attribute does have a statistically significant effect upon property values.

Chapter 4
A Review of Existing Empirical Literature and Evidence

There exists a substantial base of empirical literature that explores the various impacts of transportation facilities upon their surrounding environs. This chapter draws upon this great wealth of information with a comprehensive review of this literature. The methodological approaches employed in these previous research efforts are reviewed, as are their specific empirical findings regarding the nature and extent of possible impacts. A paucity of commuter rail related research is found to exist, providing additional justification for the empirical analysis contained later in this thesis. By necessity then, the majority of the studies reviewed here focus upon other transportation modes and facilities, including other rail transit modes as well as highways and airports, that have for various reasons received more extensive attention by researchers in recent decades. A discussion of additional empirical literature drawn from other disciplines such as the housing appraisal practice is deferred until Chapter 6, where it is reviewed to provide additional insights and guidance related to the determinants of housing value.

4.1 Commuter Rail Transit

In examining the transit literature review summary presented in Table 4.1, it becomes evident that very few studies concerning commuter rail impacts have been performed during the past three decades. One of the earliest references specifically concerning the impacts of commuter rail service is provided in an annotated bibliography of early highway and commuter rail impact related literature by Onibokum (1975).[96] Although this work initially appeared promising and is sometimes cited in other literature reviews, it focuses almost entirely upon highway related research, with only brief references made to a limited number of ridership surveys and other statistical reports pertaining to the GO commuter rail system in Toronto. The sole reference to the evaluation of the impact of GO service, by Robinson (1966), is a

[96] Onibokum, Adepoju G. *Socio-Economic Impact of Highways and Commuter Rail Systems on Land Use and Activity Patterns - An Annotated Bibliography*. Chicago, IL: Council of Planning Librarians, June 1975.

proposal for research of the effect of GO upon property values and land use, and provides no quantitative or qualitative evaluations of GO service.[97]

In a widely cited and comprehensive study of the land use impacts of rail transit, Knight and Trygg (1977) review commuter service in six North American cities.[98] The study relies primarily on previously published reports, interviews, aerial photos, and other secondary sources available at the time in each of the metropolitan areas studied, as opposed to more detailed empirical studies. In Toronto, GO service was found to have resulted in a very limited amount of new development in selected station areas. In particular, the authors note that other factors such as supportive local land use policies played an important role in facilitating the limited development that did occur. In addition, the heavy use of auto and feeder bus in GO station access suggests that development impacts would tend to be more widely dispersed throughout the area surrounding GO stations, making it more difficult to identify and measure these impacts than if they were more focused in the immediate vicinity of stations. In Philadelphia, Knight and Trygg found evidence that the then proposed Center City Commuter Tunnel linking the downtown terminals of SEPTA commuter rail service had a significant impact upon the scale of redevelopment efforts in the Market Street East area of Philadelphia, expanding the scale of the redevelopment beyond that which would have otherwise taken place. In suburban areas of Philadelphia, large multi-unit apartment complexes were built near stations in a number of communities at the time of the study in the early 1970's, and a limited amount of commercial office development also occurred near some suburban station sites. Commuter rail service was found to be a significant asset in many suburban communities, contributing to the prestigious character and stability of areas such as Chestnut Hill, Radnor, and Bryn Mawr for example. Post WWII improvements in the quantity and quality of commuter rail service in Philadelphia appear to have contributed not only to ridership gains but the extent of land use impacts as well. In Chicago, improvements in commuter rail service were generally found to have little impact on land use in the vicinity of suburban stations, however development potential around downtown terminals appeared to be enhanced by the overall vitality of commuter rail service on most routes in the Chicago area.

In Boston, Knight and Trygg generally found that declines in the level and quality of commuter rail service that occurred throughout the 1960's and into the 1970's, combined with the relative stability of many of the communities served by commuter rail at the time, resulted

[97] Robinson, R. A. *Assessing the Impact of the Lakeshore Commuter Rail Service on Real Estate Values and Land Use.* Metropolitan Toronto and Regional Transportation Study. November 1966.
[98] Knight, R. and J. Trygg. *Land Use Impacts of Rapid Transit: Implications of Recent Experience. Final Report.* Washington, D.C.: Office of the Assistant Secretary for Policy, Plans, and International Affairs, U.S. Department of Transportation. DOT-TPI-10-77-29. August 1977.

in no measurable development impacts related to commuter rail service. In Montreal, the findings were similar, with no gains in ridership or commuter rail related development despite significant suburban population growth. In New York, although commuter rail services were modernized to a greater extent than in Boston or Montreal, the long-established nature of the suburban areas served generally resulted in little or no measurable development impacts associated with commuter rail service.

One of the earliest empirically based studies of the impact of commuter rail access upon property values appears to have been performed by Diamond (1980) (see Table 4.1).[99] Although his analysis focuses more generally upon income and residential location in the Chicago area, Diamond utilizes the appraised value of single-family residential land obtained from home mortgage applications still outstanding in 1976 for 414 parcels sold between the years 1969 to 1971 to estimate the marginal value of various urban amenities, including access to commuter rail, which he measures simply as the straight-line distance to the nearest commuter rail station for each of the parcels. Multiple regression models estimated with ordinary least squares (OLS) methods are utilized, in which a set of land price differentials estimated from the data set are regressed upon the corresponding set of amenity differences, one of which is the difference in commuter rail access among the parcels under analysis.

Diamond finds that the marginal value of each additional mile of proximity to a commuter rail station, evaluated at the sample mean appraised lot value of $21,700 in 1970 dollars, is $460, which is an increase of approximately 2.1% for each additional mile. The corresponding elasticity of property value with respect to distance to a commuter rail station, evaluated at the sample mean distance from a commuter rail station of three miles and the sample mean appraised lot value of $21,700, is .0635. Thus, as an example, a typical property located three miles distant from a station would sell at a premium of approximately 6.35% as compared to one that was six miles distant but similar in all other respects. Furthermore, in looking at how the value of access varies with income levels, Diamond uses household income information derived from the mortgage application data to estimate the income elasticity of commuter rail access to be 2.88, indicating that the value of greater commuter rail access increases more than proportionately with income. Thus, one might anticipate the value of commuter rail access estimated for higher income areas to be greater than that estimated for lower income areas, which must be considered either implicitly or explicitly through the use of statistical or quasi-experimental controls.

[99] Diamond, Douglas B. "Income and Residential Location: Muth Revisited." *Urban Studies* 17, 1980. pp. 1-12.

Table 4.1: Review of Selected Transit Impact Studies

Author(s)	Study Area (Facility)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Davis (1970)	San Francisco (BART heavy rail), Glen Park Station	repeat sales data and descriptive statistics	sales price	n/a	positive effect on single-family property values found within 6 blocks of Glen Park BART station
Boyce, et. al. (1972)	Southern New Jersey and Philadelphia (PATCO Lindenwold heavy rail line)	analysis of variance (ANOVA), and multiple regression models	sales price	lot size, dummies for no. of stories, dummies for building description (e.g. brick, metal, etc.), no. of garages, land use, year of sale dummies, neighborhood dummies	increase in single-family sales price of $149 for each $1 of daily travel time savings after the line opened; little evidence of pre-service property value impacts; some evidence of a transfer of value from nearby unserved areas
Lee (1973)	San Francisco Bay Area (BART heavy rail)	multiple regression model	asking price, sales price, and assessed value used in alternative models	no. of rooms, no. of baths, no. of bedrooms, age of structure, lot size, distance along BART, distance to station, tax rate	cross-sectional data in Contra Costa County reveal that BART stations had little or no effect upon the prices of nearby single-family homes; findings using longitudinal data from Alameda County sugggest that BART may have had some positive effect on value
Dornbusch (1975)	San Francisco Bay Area (BART heavy rail)	multiple regression model			reduced residential property values were found around some station areas.
Dewees (1976)	Toronto (Bloor Street heavy rail line)	multiple regression model	sales price	living area, no. of rooms, no. of full & half baths, no. of garages, extras, brick or stone construction, detached/attached, condition, age of structure, heating, fuel, zoning, traffic on street, weighted time cost to Bloor St. Toronto	transit access increases residential property values by $2,370 per hour of weighted travel time units (where transit time =1, waiting time = 1.5, and walk time =3)
Damm, et. al. (1978)	Washington, D.C. (Metro heavy rail)	multiple regression model	sales price	station distance, within 0.1 mi. of station, above ground station, park-and-ride lot, % owner-occupied, % non-white, mean income, employment density, pop. density, lot area, floor area, assessed value, zoning, no. of units, distance to Metro Centre	proximity to the station increases sales price; the model results suggest that the Metro system has had a much greater impact in the retail property sector than in either of the single or multi-family property market
Falcke (1978)	San Francisco (BART heavy rail)	repeat sales index model	residential sales prices, residential rents, office rents, and commercial rents	straight line distance to BART station (an inverse distance formulation), distance to shopping mall, distance to tracks (for South Hayward only in the residential price model)	a small positive effect upon property values was found near some stations; no distance-senstive effect was found; a small postive impact upon office rents within 100 feet of stations in San Francisco CBD, and within 1,000 feet of Oakland and Walnut Creek
Poon (1978)	London, Canada (interurban railway)	multiple regression model	sales price	age, no. of rooms, no. of bathrooms, dummies for recreation room, basement, fireplace, single family, garage, and type of siding; no. of stories, lot size, corner lot, distance to arterial road, distance to railway in units of 100 feet	residential sales price increase with distance from the railway; elasticity of distance with respect price is .05; impacts terminate at 800-900 feet from the track; a home 800 feet from the track sells from $2,151 more than a home 100 feet from the track
Smith (1978)	Chicago (heavy rail)	multiple regression model	relative location premiums	distance to CBD, distance to airport, gravity model index of employment accessibility, distance to major rail transit, water & sewer availability, property tax rate, expenditures per pupil, crime rate, pollution rate, % non-white in census tract	a positive impact of $1,400 per house was found for water and sewer connections; for rail transit, a premium of about $600 per mile was found; high income households experience a higher property value premium than lower income households
Baldassare, Knight & Swan (1979)	San Francisco Bay Area (BART heavy rail)	descriptive statistics using data from surveyed homeowners	n/a		a reduced preference for homes near some BART stations was found

n/a: not applicable

Table 4.1: Review of Selected Transit Impact Studies (continued)

Author(s)	Study Area (Facility)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Dyett. et. al (1979)	San Francisco Bay Area (BART heavy rail)	multiple regression model	sales price and contract rent		pre-service impacts of 8% to 25% on single-family homes within 200 to 2,000 feet of stations at Glen Park, 24th Street, and South Hayward; premiums disappeared after service began; no measurable decline in values from proximity to BART tracks
Diamond (1980)	Chicago, over 50 different suburban communities (commuter rail)	multiple regression model	appraised lot value	lot size, family income, auto access distance to CBD, straight line distance to nearest commuter rail station, dummy for within 5 miles of Lake Michigan, violent crime rate per 1,000 persons, air quality, topography	the marginal value of each mile of proximity to commuter rail station is $460 (1970$) (evaluated at the mean single-family home value of $21,700); the income elasticity of the marginal value at the mean for commuter rail access is estimated to be 2.88
Bajic (1983)	Toronto (Spadina heavy rail line)	multiple regression model	sales price	outdoor space sq. ft, floor area, no. of rooms, public transit time, auto time to CBD, garages, basement, recreation room, stories dummy, house condition, extras, no. of bathrooms, stone or brick construction, driveway, neighborhood dummies	residential values were $2,237 higher near the rail line than elsewhere
Allen, et. al (1986)	Southern New Jersey and Philadelphia (PATCO Lindenwold heavy rail line)	hedonic price model	sales price	distance to Ben Franklin Bridge, distance to Walt Whitman Bridge, lot size, property tax, garage, fireplace, bathroom dummies, transit travel cost savings	for every dollar of daily travel cost savings, $443 was added to the value of the house, the average daily savings was $10.34 which, for the mean sales price, indicates a 7.34% increase in value ($4,581)
Ferguson, Goldberg & Mark (1988)	Vancouver, BC (light rail)	multiple regression model	sales price	basement, floor area, gas heat, hardwood floor, lot area, age of structure, plumbing connections, straight line distance to CBD, straight line distance to station, and various Interaction variables	single-family property values decline C$4.95 per foot from the station, with the impact diminishing at about 1,800 feet and nonexistent at 2,400 feet from the line; no negative externality effects from noise, etc., were found
Nelson & McCleskey (1990)	DeKalb County, GA (MARTA heavy rail, East Line)	multiple regression model	sales price	living area, lot size, no. of rooms, no. of stories, presence of basement, foundation, enclosed porch, garage, central air conditioning, age of house, zoning, corner lot, adjacent to non-residential land use, distance to station	distance from station has a negative realtionship with single-family property values indicating that accessiblity advantages seem to outweigh negative impacts of noise and traffic; corner lot status was not desirable, and age of house increased value
Bernick & Carrol (1991)	San Francisco (BART heavy rail, CalTrain commuter rail), and Santa Clara County, CA (light rail)	paired data analysis of comparable projects based on surveys of developers and residents	contract rent	n/a	6 of 9 mutli-family developers state station proximity increased value; comparables show a slight rental premium for transit based developments; surveys show a high willingness-to-pay for station proximity
Voith (1991)	Philadelphia (SEPTA commuter rail), and southern New Jersey (PATCO Lindenwold heavy rail line)	model for percent working in the CBD is estimated using a Tobit; median housing value and auto ownership models are multiple regression	median census tract house value owner estimates	commuter rail service dummy, auto travel time to CBD, avg. commute time for each tract, no. of peak trains, commuter rail vs. auto differential CBD commute time, census tract hh income, hh size, % black, % detached housing, housing age, avg no. of rooms	% of a census tract's labor force working in the CBD is 10% higher for tracts with commuter rail service nearby, and auto ownership is 4.5% lower; premium of 6.4% of avg house value found for the pooled data set (3.8% for SEPTA service, and 10% for PATCO)
Nelson (1992)	DeKalb County, GA (MARTA heavy rail, East Line)	hedonic price models	sales price	sq ft of house and lot, no. of bathrooms, no. of stories, presence of basement, foundation, fireplace, central a/c, corner lot, adjacent to park, distance to station, location inside city of Decatur, household income, census tract minority status in 1980	findings show that in the low-income area, proximity to a station has positive price effects upon single-family homes, and that in the higher income areas, proximity to a station has a negative price effect

n/a. not applicable

Table 4.1: Review of Selected Transit Impact Studies (continued)

Author(s)	Study Area (Facility)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Al-Mosaind, Dueker & Strathman (1993)	Portland, OR, MAX light rail	hedonic price model	sales price	walking distance from nearest station (dummy in one model, continuous variable in 2nd model), lot size, house size, presence of basement, no. of bedrooms, age of house, single family zoning, location in Portland or Multnomah County	an increase of $4,324 for a home within 500 meters walking distance of a station (10.6% of the mean house value); continuous variable indicates a statistically insignificant decline of $21.75 for each meter from a station
Anas & Armstrong (1993)	New York City, excluding Staten Island (heavy rail and commuter rail)	hedonic price model	land value per square foot of land	walk distance to station, parks and water; station passenger volume, on-time times of station, transit time to Downtown & Midtown, train crowding, % new/rehab rail cars, local/express service, station type (elevated), crime, employment by place of work	negative rent gradients were found with increasing walking distance from stations for all but elevator apartments and retail uses; the steepest land value gradient is found for office uses, with vacant land, walk-up apartments, and single-family uses next
Gatzlaff & Smith (1993)	Miami (Metrorail heavy rail)	repeat sales index model, and hedonic model	sales price	in the hedonic models, variables include living area, lot size, age of house, price index, distance to nearest station, project announcement dummy (before/after 1980)	station and overall MSA single-family home price indices are not significantly different during any period of the 18 year time frame; widely varying findings for individual station models suggest that neighborhood characteristics influence price
Cervero and Landis (1993)	Washington, D.C. (Metro heavy rail) and Atlanta (MARTA heavy rail)	quasi-experimental analyses of study and control areas using ANOVA	n/a	proximity to transit station	overall findings are mixed, with only some of the transit oriented office developments commanding a rent premium; other indicators of office market perfmance such as vacancy rates and density were also similarly mixed
Bernick, Cervero & Menotti (1994)	San Francisco Bay Area (BART heavy rail)	matched-pair comparisons, and hedonic price model	contract rent	within 1/4 mile of station, unit size (sq ft), no. of bedrooms, no. of bathrooms, age of building, playground, weight room, project density (units/acre), project age, laundry room, Concord dummy	residential units within 1/4 mile of the Pleasant Hill BART station rented for about $34 more per month than otherwise comparable units; a number of amenity variables such as pool, rec. buildings, and spas are insignificant
Cervero (1994)	Washington, D.C. (Metro heavy rail) and Atlanta (MARTA heavy rail)	multiple regression model	office rents, vacancy rates, absorption rates, and total square footage of commercial floor space	ridership, service frequency, fares, metropolitan employment totals, regional avg. comercial rents, absorption rates, new office construction, and vacancy rates served as control variables, zoning, maximum floor area ratios, joint development initiative	presence of joint development projects at stations raised office rents by about $3 per sq. ft.; controlling for rents and building size, vacancy rates were about 11% lower in station areas; office density also appears to be higher near stations
Landis, Guhathakurta & Zhang (1994)	San Francisco (BART), San Mateo County (commuter rail), & Sacramento, San Diego, & Santa Clara County (light rail)	hedonic price model	sales price	living area, lot area, age, no. of bedrooms, no. of bathrooms, census tract median hh income, % owner-occupied, racial composition., road distance to station, road distance to highway interchange, within 300 meters of rail right-of-way or a freeway	access premiums near stations of $2.29 per meter in Alameda county for BART, and $1.96 per meter in Contra Costa county; accessibility to CalTrain did not increase values; homes with 300 meters of CalTrain sold at discount of $51,011 in 1990 (about 15.3%)
Armstrong (1995)	Boston (MBTA Fitchburg commuter rail line)	hedonic price model	sales price	no. of bedrooms, no. of bathrooms, age, garages, lot size, per pupil $, crime rate, property tax rate, time to hwy interchange, auto time to CBD, auto & walk station access time, rail time to CBD, located within 400 ft of rail ROW, town has station	premium of 6.7% is found for homes located in towns having a commuter rail station, homes within 400 ft of the right-of-way are shown to sell for 20% less than otherwise comparable homes; walking time to station is not signficant
Landis, et al. (1995)	San Francisco (BART heavy rail) and San Diego (light rail)	ANOVA, and hedonic price model	sales price	building square footage, lot area, transaction year dummy variable, city/commercial market dummy variables, and BART proximity dummy variables for properties within 1/4 mile and 1/2 mile of BART stations	in Alameda County, office, retail, & industrial uses sold at higher values closer to stations; in Contra Costa County, no increases in sales prices were found; in San Diego County, office & retail uses sold at higher values closer to stations

n/a: not applicable

One of the first studies to consider the impact of rail right-of-way externalities such as noise and visual intrusion upon residential property values was performed by Poon (1978), who focuses exclusively upon railway externalities and their effects upon property values.[100] Poon examines the proximity related externality effects of interurban railways in London, Canada. Although no mention is made by Poon regarding the level and composition of rail traffic in the area studied, it is assumed that it consists of a mix of interurban passenger and freight rail traffic. Poon utilizes multiple listing service (MLS) property sales data for a total of 285 observations (85% single-family, 15% multi-family) sold during the period of 1967 to 1972. Multiple regression models using linear additive, multiplicative, and quadratic model specifications are utilized, and are estimated with OLS methods. In all cases, sales price inflated to 1972 dollars is the measure of value used, and straight-line distance from the railway measured in 100 foot intervals serves as the primary independent variables in conjunction with several other structural and site specific control variables.

The quadratic model specifications indicate that property value impacts terminate at about 800 to 900 feet from the right-of-way, which is notable in that this distance is also largely consistent with noise screening distances suggested by the U.S. Federal Transit Administration (FTA) for commuter rail mainlines. Poon finds that residential sales prices increase with distance from the right-of-way, with the quadratic model specification indicating that a home within 50 feet of the right-of-way sells at a discount of $2,161 as compared with a property located greater than 850 feet from the right-of-way. Because no summary statistics including the sample mean property value are given for the data set, no judgment can be made concerning what percentage of value this would be for a typical home in the study area. However, the coefficient for railway proximity in the multiplicative model specification suggests that the elasticity of housing value with respect to distance to the right-of-way is 0.05. This suggests that a property located 200 feet from the right-of-way would sell at a discount representing approximately 15% of the sales price of an otherwise similar property located 800 feet from the right-of-way.

In a comprehensive analysis of SEPTA commuter rail service upon residential location and house values in the Philadelphia area, Voith (1991) utilizes 1980 census data for 571 census tracts in the metropolitan Philadelphia area.[101] Census tracts are designated as having rail service based on the presence or absence of a station located within the tract, or in the case of densely populated areas, within an adjacent tract as well. In examining the existence of

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100 Poon, Larry C.L. "Railway Externalities and Residential Property Prices." *Land Economics* 54, No. 3, May 1978. pp. 218-227.

101 Voith, Richard. "Transportation, Sorting and House Values." *Journal of the American Real Estate & Urban Economics Association*, Volume 19, No. 2, Summer 1991. pp. 117-137.

residential sorting or choice of residential location based on employment location, Voith concludes that the percentage of a census tract's labor force working in the CBD is 12.0% higher for tracts with commuter rail service nearby. To estimate the impact of commuter rail access upon housing values, Voith uses a multiple regression model, estimated with OLS methods using a linear additive model specification, in which median census tract housing values (which for the 1980 census represented owner-occupied single-family homes or condominium units) are regressed upon a number of census tract housing and socioeconomic characteristics, as well as measures of auto travel time from each tract to the CBD and a dummy variable indicating the presence of a station within the tract or a nearby tract. Also, in addition to the CBD-oriented accessibility measures typically included in housing price models, Voith uses the 1980 Census journey-to-work average travel times for all work commutes to control for non-CBD oriented accessibility. Although often overlooked in many empirical studies, non-CBD access is an important consideration with the increasingly decentralized employment patterns evident in many U.S. metropolitan areas. Voith suggests that after controlling for access to the CBD, higher average journey-to-work times should serve as an effective proxy for poor accessibility to other employment centers. His empirical findings indicate that this variable is insignificant in all cases, most likely because there is little variation across tracts in these average journey-to-work times, suggesting that most areas are for the most part equally convenient to employment.

Voith finds evidence that rail transit access is capitalized into house values, with a premium of $3,437 found for tracts served by SEPTA commuter rail. This represents 3.8% of the 1980 median house value of just over $90,000 for the study areas. These house value premiums are then used in combination with other estimates of house value premiums related to other rail service in southern New Jersey to estimate an aggregate increase in suburban Philadelphia housing values associated with rail service of about $1.45 billion. According to Voith, these findings regarding the house value impacts of rail service imply that despite the continued decentralization of the region, over 40% of the residents of the suburban Philadelphia metropolitan area appear to have a direct interest in the quality of public transportation and the economic health of the CBD, regardless of whether they themselves actually make use of the rail service or are employed in the CBD. Although Voith's use of census tract median property values allows him to adequately examine the impacts of rail transit accessibility, it does not allow for a more geographically disaggregate analysis, and more importantly, it does not allow for the examination of possible impacts related to commuter rail externalities such as noise and ground-borne vibration. His approach also ignores certain local variables such as school quality and property tax rates that have been found to be significant determinants of housing value in other empirical studies. If correlated with the presence of commuter rail access, the influence of these omitted variables may in part be reflected in the rail transit access premiums measured by Voith.

A more recent study by Landis, et. al, (1995) examines the relationship between CalTrain commuter rail service and its impact upon property values and land use change in San Mateo County.[102] Both the impacts of commuter rail access as well as the possible negative impacts of commuter rail related externalities such as noise are examined. A total of 233 sales of single-family homes in San Mateo County during 1990 are used. To estimate the impact of commuter rail access upon housing values, Landis uses a hedonic house price model, estimated with OLS methods using a linear additive model specification, in which the sales price of single-family homes are regressed upon a set of home characteristics, neighborhood characteristics, and locational characteristics. In addition, dummy variables are used to represent the different municipalities in which the observations are located in an attempt to control for variables at the municipal level such as tax rates, school quality, and other public service quality measures. Roadway distance from each home to the nearest CalTrain station is used as the commuter rail accessibility measure, while a dummy variable indicating whether a house is located within 300 meters (approximately 1,000 feet) of the CalTrain right-of-way serves as the proximity impacts measure. Approximately 11%, or 26 of the 233 observations, are within 300 meters of the CalTrain right-of-way in San Mateo County. Both measures are calculated using Arc/INFO, a widely used Geographic Information Systems (GIS) software package.

Landis finds that accessibility to CalTrain commuter rail stations has no significant impact upon residential property values, and suggests that the lack of adequate park-and-ride facilities (19 of 26 CalTrain stations have parking, however their total capacity is only 3,438 spaces) and relatively infrequent service (particularly when compared to other types of rail service in the Bay Area such as BART) are at least partially responsible for this outcome. These findings are consistent with those of Bernick and Carroll (1991), who in a survey of developers in the San Francisco area, found mixed results regarding the perceived impacts of CalTrain stations upon rents in nearby multi-family housing developments, with one developer stating that proximity to the Mountain View CalTrain station had increased rental prices, and

[102] Landis, John, and Subhraijit Guhathakurta, William Huang, and Ming Zhang. *Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems*. Monograph 48. University of California at Berkeley, Institute of Urban and Regional Development. July 1995.

another stating that proximity had no impact upon rental prices at a project near the Palo Alto CalTrain station.[103]

As for the effect of proximity to the CalTrain right-of-way, Landis finds that being within 300 meters of the CalTrain right-of-way results in a discount of about $51,000, which represents 15.3% of the mean sales price for San Mateo County of $334,195 in 1990. This too is generally consistent with anecdotal evidence along the CalTrain line in Palo Alto, where residents assert that real estate agents have estimated that homes near the line can experience a loss of 10% or more in sales price over comparable properties elsewhere in Palo Alto, although train whistle blowing at grade crossings is thought to be responsible for much of this impact.[104]

One shortcoming of the study by Landis, in fact, is that housing values near the CalTrain right-of-way may vary more as a function of distance from grade crossings than as a function of distance from the right-of-way in general. Even more significantly, the CalTrain right-of-way is shared with Southern Pacific freight trains that serve a number of industries in San Carlos, Redwood City, and Lawrence. While CalTrain operated a total of 54 trains per weekday in 1990, Southern Pacific freight service consisted of six or seven trains per day operating at night between 6 PM and 5 AM, with lengths typically between 10 to 40 cars. Therefore, although freight trains comprise only about 11% of the total trains operated daily, their substantially longer consist length combined with their operation during nighttime hours when residential land uses are more responsive to noise impacts suggests that the proportion of total daily noise exposure from freight trains along the CalTrain right-of-way is greater than the relatively modest 11% total operations that freight trains represent. Therefore, it is likely that Landis' estimate of a $51,000 discount for residential properties located in proximity to the CalTrain right-of-way is a substantial overestimate of the impact that is directly attributable to CalTrain commuter rail service.

Another recent study of commuter rail impacts by Armstrong (1995) also examines both the relationship between commuter rail accessibility and property values, as well as the impact of proximity to commuter rail rights-of-way upon property values.[105] Armstrong uses a hedonic house price model to estimate the impact of commuter rail access upon housing values, estimated with OLS methods using a multiplicative model specification. A total of 451 observations of sales of single-family homes from a suburban area northwest of Boston are used, with sales prices regressed upon a set of structural attributes, site attributes, local service

[103] Bernick, Michael, and Michael Carroll. *A Study of Housing Built Near Rail Transit Stations: Northern California.* Working Paper 546. University of California at Berkeley, Institute of Urban and Regional Development. October 1991.
[104] Gauvin, Peter. "Train whistles steam residents," *Palo Alto Weekly*, 28 December 1994.
[105] Armstrong, Robert J., Jr. "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values." *Transportation Research Record* 1466. 1995. pp. 88-98.

provision and cost variables, locational and accessibility variables, and environmental impact variables. Many of the locational, accessibility and environmental impact variables are calculated using TransCAD, a widely used transportation GIS software package.

Commuter rail accessibility is measured as a function of three continuous variables including auto access time to stations, walking access time to stations, and commuter rail main line travel time to the CBD. Commuter rail access is also represented in a dichotomous fashion with a dummy variable indicating the presence of a commuter rail station within the same municipality in which the home sale observation is located. Armstrong hypothesizes that this approach is consistent with the manner in which single-family residential properties are often marketed by real estate firms, where often the fact that the home is located within a community with commuter rail access may be extolled, and whether the property is 3 minutes from the station or 8 minutes from the station, for instance, is not focused on. The empirical findings support this contention, with the continuous variable for station access time by auto statistically insignificant. The dummy variable representing commuter rail access, however, indicates a premium of 7.1% for homes located within communities that have commuter rail service. Walking distance is found to be statistically insignificant, perhaps because any accessibility benefits associated with being close to a station are negated by the presence of proximity related externalities including automobile noise from station ingress and egress.

Property value impacts resulting from proximity to the commuter rail right-of-way are represented with a dummy variable indicating whether a house is located within 400 feet of the Fitchburg commuter rail line right-of-way. Armstrong finds that homes located within 400 feet of the MBTA Fitchburg commuter rail line experience a discount of 18.9%, but notes that since the right-of-way was shared with light to moderate amounts of freight service at the time of the study in 1990, it is likely that commuter rail operations account for only a portion of this total impact.

After an extensive review of the literature, it appears that very few studies concerning commuter rail impacts have been accomplished during the past three decades, and even fewer still have considered the negative externalities of commuter rail service in conjunction with the beneficial accessibility effects. Although the studies reviewed above provide valuable insights into the impact of commuter rail upon property values, they still exhibit a number of shortcomings.

Some studies, such as that by Voith (1991), use data at a level of geographic detail (e.g. census tracts) that is too broad to draw useful insights related to the more localized effects that many commuter rail transit systems are likely to have. Also, grade crossing noise externalities have never been analyzed, despite that fact this issue is currently one of great interest at the local, state, and federal levels, nor have any of the commuter rail studies to date considered the impact of station externalities. Of the only two studies that have considered right-of-way externalities, both appear to have used digital geographic data including the U.S. Census TIGER/Line files whose level of accuracy is not suitable for the types of analyses for which they have been used. The U.S. Census TIGER/Line files and commercial derivatives of these publicly available geographic files are based upon source data that for most part consists of USGS 1:100,000 scale Digital Line Graph (DLG) data for coverage of rural, small city, and suburban areas, and the Census Bureau's GBF/DIME-Files and to a lesser extent USGS 1:24,000 scale quadrangles for other areas.[106]

The Census Bureau specifically notes that its data products are designed only to show the relative position of features, and thus do not require positional accuracy. The positional accuracy of the information based on DLG data is no greater than the established National Map Accuracy standards for 1:100,000 scale maps from the USGS, which is approximately +/- 167 feet, suggesting that even at best, the positions of features are likely to contain errors of 167 feet.[107] In addition to the positional accuracy of the GIS data, the Census Bureau notes that the accuracy of the address ranges assigned to road features in TIGER/Line files is also limited, and may contain address range overlaps, gaps, odd/even reversals and other errors.[108] Therefore, the interpolation routines used by GIS software packages for so-called "roof-top" geocoding are likely to assign locational coordinates to a given street address that may contain substantial errors, further compounding the positional inaccuracies, and making relative distance measures used for the analysis of proximity impacts highly suspect. Given the highly localized nature of noise and other externality effects of rail transit facilities, and their non-linear relationship with distance from the facility, positional accuracy is a key element that has in the past been overlooked.

Further diminishing the usefulness of their findings, the studies that do examine externality effects have typically relied upon an approach that utilizes independent variables representing noise impact that enter the house price model in a dichotomous fashion as dummy variables indicating whether properties are located within a buffer zone of a given distance from a right-of-way. This approach results in findings that are actually quite ambiguous for a variety of reasons. It reveals nothing about the actual geographic distribution of properties, which if not evenly distributed throughout the buffer zone area may result in biased estimates of the actual impact, either over or under estimating the true impact depending upon whether

[106] *TIGER/Line® Files, 1994 Technical Documentation*. Prepared by the Bureau of the Census. Washington, D.C.: The Bureau. pg. 5-1.
[107] *Ibid.* pg. 5-3.
[108] *Ibid.* pg. 5-5.

the properties tend to be closer to, or further from, the right-of-way on average. Secondly, the use of a dummy variable creates measurement errors, yielding no insights into the differential impacts of externalities as they vary with distance from the facility of interest. This is particularly important given the non-linearities inherent in various noise exposure metrics, and the fact that impacts typically vary more than proportionately with distance from the facility.

About half of the studies reviewed above use linear model specifications, even though much of the theoretical and empirical literature regarding property value impacts and their measurement using hedonic methods suggests the use of non-linear model specifications. Besides introducing possible specification bias, the use of a linear specification may also make the model more susceptible to heteroscedasticy, whereas a log transformed model aids in reducing possible heteroscedasticity by compressing the scale in which the model variables are measured.

Few of the studies that utilized hedonic price models recognize or address the potential complexities and drawbacks involved in using this method as discussed earlier in Chapter 3, nor have any of the studies used experimental or quasi-experimental methods in an attempt to support or refute the findings obtained using the hedonic price model approach.

Despite these problems, the limited empirical findings to date are surprisingly, however, in general agreement as to the magnitude of commuter rail property value impacts, although the varied methodologies and data types used (e.g. census tract median value data, individual housing sales data, etc.) make direct comparisons somewhat tenuous.

Regarding the impact of proximity to a right-of-way, the findings of Poon (1978) suggest that a property located 200 feet from an interurban railway would sell at a discount representing approximately 15% of the sales price of an otherwise similar property that is located 800 feet from the right-of-way and thus experiences no impact. Landis finds that being within 300 meters (approximately 1,000 feet) of the CalTrain right-of-way results in a discount of about $51,000, which is about 15.3% of the mean sales price for San Mateo County of $334,195 in 1990. Armstrong finds that being with 400 feet of the MBTA Fitchburg commuter rail line results in a discount of 18.90%, higher than the estimate by Landis, however this is expected since the buffer zone of 400 feet that is used is less than the 1,000 foot buffer zone used by Landis. Despite the shortcomings of these studies as discussed earlier, and their differences in methodology, data and study area characteristics, they do suggest a negative impact upon residential property values which may be as much as 35% or 40% in very close proximity (e.g. 50 to 100 feet) of a typical right-of-way, to perhaps as little as 5% at distances over several hundred feet from a right-of-way.

Regarding the impact of commuter rail accessibility, Diamond finds that the marginal value of each additional mile of proximity to a commuter rail station, evaluated at the sample mean appraised lot value of $21,700 in 1970 dollars, is $460, which is an increase of approximately 2.1% for each additional mile. Voith (1991) finds a premium of $3,437 for tracts served by SEPTA commuter rail, which represents 3.8% of the 1980 median house value for the areas analyzed. Landis, et. al., (1995) find that accessibility to CalTrain commuter rail stations has no significant impact upon residential property values, a finding supported by evidence from Bernick and Carroll (1991) who found mixed results regarding the perceived impacts of CalTrain stations upon rents in multi-family housing developments located near two CalTrain stations. Armstrong (1995) finds a premium of 7.1% for homes located within communities that have MBTA commuter rail service.

Although these findings provide some insight into the impact of commuter rail, it is clear that further research is necessary. The empirical analysis presented in Chapters 6 and 7 of this thesis attempts to overcome many of the shortcomings evident in the previous research efforts, and provide further insights into the nature and extent of a broad array of commuter rail impacts.

4.2 Heavy Rail Rapid Transit

Of all rail transit modes, heavy rail rapid transit has by far been the focus of the most empirical research and examination, much more so than commuter rail or light rail transit (see Table 4.1). This focus on heavy rail transit seems to be due in part to the enormous capital investments that have been required for many of the newer heavy rail systems and service extensions (recall Table 1.5). The enormous expenditures that are required for these systems are often justified in part by the potential for transit to affect land use and increase development, and in turn increase property values. Also, value capture techniques aimed at re-capturing a portion of this value increase for use in financing the transit investment have been discussed for many years, and some of the research reviewed here has attempted to identify if such value increases have actually occurred in practice.

The Bay Area Rapid Transit (BART) system in the San Francisco Bay area has been the focus of much research concerning the impacts of heavy rail transit service upon land use and property values. The planning, construction, and operation of BART was subject to a comprehensive and extensive series of analyses as part of the BART Impact Program, conducted by the Metropolitan Transportation Authority (MTC) and supported by the U.S. Department of Transportation and the U.S. Department of Housing and Urban Development.

BART service was initiated in five stages beginning in September 1972, with full weekday service and service through the Transbay tube commencing in 1974.

Although many of the early studies of BART undertaken during the 1970's identified increases in residential and commercial property values and rents in BART station areas prior to the initiation of BART service, later studies revealed that many of these pre-service increases had either disappeared or were substantially reduced after initiation of BART service. Davis (1970), in an analysis of the pre-service impacts of BART, found a positive effect upon property values within six block of the Glen Park BART station.[109] In another analysis of the pre-service impacts of BART service, Lee (1973) performed both a cross-sectional and a longitudinal analysis on single-family housing and commercial property data in BART station areas in Contra Costa County and Alameda County.[110] Using cross-sectional data consisting of between 32 and 42 single-family home sales observations for the years 1969 and 1971, five station areas in Contra Costa County were analyzed. Multiple regression models are used, with both linear and exponential model specifications estimated using OLS methods. The results from this particular set of residential analyses indicate that having access to a nearby BART station had little effect on residential property values.

Using an analysis of longitudinal data consisting of 151 sales of single-family homes for the years 1950, 1954, 1958, and 1960-1971 near the Bayfair BART station in Alameda County, Lee's findings indicate that the rate of increase in housing values in the "post" BART period (defined as various years between 1960 and 1967) was almost twice that for the "pre" BART period. However, the lack of other controlling variables in these models, and the general increase in inflation after 1967 noted by Lee, make definitive judgments concerning these findings problematic. In a similar analysis of commercial property values near the Hayward BART station in Alameda County, a small increase in commercial property values was found after 1964, however Lee concludes that this had little to due with the influence of BART.

In somewhat later studies, Dornbusch (1975) was one of the first to identify a reduction in residential property values near some station areas, which he attributed to increased noise and automobile traffic at station locations and problems related to parking overflow from park-and-ride lots onto local streets near stations.[111] Falcke (1978) found only

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109 Davis, Fredrick W. "Proximity to a Rapid Transit Station As a Factor in Residential Property Values." *The Appraisal Journal* 38. October, 1970.

110 Lee, Douglass B., Jr., Principal Investigator. *BART Impact Studies. BART-II: Pre-BART Studies of Environment, Land Use, Retail Sales. Part III, Land Use and Investment. Volume I: Econometric Studies.* June 29, 1973.

111 Dornbusch, David M. "BART-Induced Changes in Property Values and Rents." *Land Use and Urban Development Projects, Phase I, BART.* Working Papers WP 21-5-76. Washington, D.C.: U.S. Department of Transportation and U.S. Department of Housing and Urban Development. 1975.

a small positive effect upon property values near some stations, and no direct relation with distance from the station was found.[112] BART may have had a positive effect upon the entire area within a 14,000 foot radius of the Walnut Creek station area, and a small positive impact upon office rents was found within 100 feet of stations in the San Francisco CBD. Small to moderate increases in office rents were also found within 1,000 feet of stations in the Oakland CBD and the Walnut Creek area. In their survey of homeowners near BART stations, Baldassare, et. al. (1979) found a reduced preference for single-family housing located near BART stations, which as with the earlier findings by Dornbusch was thought to be the result of station related traffic, overflow parking, and noise.[113]

Dyett, et. al. (1979) performed an analysis of single-family houses located within 200 to 2,000 feet of six BART stations. While BART was being built, Dyett et. al. found that prices of single-family homes near the Glen Park, 24th Street, and South Hayward BART stations rose by 8% to 25%.[114] After service began, these premiums were found to have disappeared however, and in neighborhoods where station related traffic and overflow parking became a problem, single-family housing prices were shown to be reduced by about 10%. There was, however, no measurable decline in property values for properties located close to elevated or at-grade BART tracks. Rents for commercial office and retail properties increased in San Francisco, Walnut Creek, and Oakland, however these initial increases also disappeared with the initiation of BART service when earlier expectations regarding BART service levels as well as its impact upon walk-in traffic for retailers did not fully materialize.

More recent studies of BART reveal that even after 15 to 20 years of operation, the impact of BART upon land use, property values, and rents have been mixed. Positive impacts upon single-family home prices have been identified near BART stations, however increases in rental prices for multi-unit residential developments detected near some BART stations have been modest. For commercial properties, BART appears to have had no significant impact upon office and retail commercial property values, and although land uses near many BART stations have changed during the last 30 years, proximity to BART station appears not to have been a significant factor in this change.

Bernick and Carroll (1991), in addition to their study of CalTrain commuter rail service as discussed earlier, also studied BART heavy rail service and its effect upon multi-unit

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[112] Falke, Caj O. *Study of BART's Effects on Property Prices and Rents*. BART Impact Program, Land Use and Urban Development Project. 1978.

[113] Baldassare, Mark, Robert Knight, and Sherrill Swan. "Urban Services and Environmental Stressor: The Impact of the Bay Area Rapid Transit System on Residential Mobility." *Environment and Behavior* 11.

[114] Dyett, Michael, et. al. *BART Impact Program, The Impact of BART on Land Use and Urban Development, Interpretive Summary of the Final Report*. John Blayney Associates/David M. Dornbusch & Co. Inc., September 1979. DOT-P-30-80-08.

housing developments of over 30 units and having densities of greater than 15 units per acre. Of the seven developers of projects located near BART stations that were surveyed, two responded that proximity to BART had no impact upon rental prices for their projects, while five other developers indicated that proximity to a BART station had increased rental prices for their projects.[115]

Bernick, Cervero and Menotti (1994) use a matched-pairs comparisons approach along with a hedonic price model in one of three markets analyzed to estimate the rental price effects associated with proximity to BART stations in the East Bay.[116] In the Pleasant Hill-Walnut Creek-Concord submarket in Contra Costa County, data for 23 major residential projects built between 1985 and 1992 were analyzed. For the matched-pairs comparison, rents for three projects located within ¼ mile of the Pleasant Hill BART station were compared to rents for developments located beyond ¼ mile of a station. Considerable variation in the rents per square foot were found among the projects that were examined. However, controlling for differences in amenities at each of the developments, the rental premiums associated with proximity to the Pleasant Hill BART station appear quite modest. The hedonic price model for this submarket shows that in 1990, rental units within ¼ mile of the Pleasant Hill BART stations rented for a $34 per month premium compared with other similar rental units that were located more than ¼ mile from a BART station. In the Union City-Fremont submarket in southern Alameda County, data on 9 multi-unit residential projects were examined, with the matched-pairs comparisons revealing a small rent premium for units located near BART. In the Albany-El Cerrito-Richmond submarket in Contra Costa County, data on 13 multi-unit residential projects were examined, with the matched-pairs comparisons revealing a negligible premium associated with proximity to BART.

Landis, et. al. (1995), in their analysis of five rail transit systems in California, examine the impact of BART upon residential properties, commercial properties, and land use change.[117] Both the impacts of rail transit access as well as the possible negative impacts of rail transit related externalities such as noise are examined. For the analysis of BART, a total of 2,359 sales of single-family homes in Alameda and Contra Costa counties during 1990 are used. To estimate the impact of BART upon housing values, Landis uses a hedonic house price model, estimated with OLS methods using linear additive and exponential model

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[115] Bernick, Michael, and Michael Carroll. *A Study of Housing Built Near Rail Transit Stations: Northern California*. Working Paper 546. University of California at Berkeley, Institute of Urban and Regional Development. October 1991.
[116] Bernick, Michael, Robert Cervero, and Val Menotti. *Comparison of Rents at Transit-Based Housing Projects in Northern California*. University of California at Berkeley, Institute of Urban and Regional Development. September 1994.
[117] Landis, John, and Subhraijit Guhathakurta, William Huang, and Ming Zhang. *Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems*. Monograph 48. University of California at Berkeley, Institute of Urban and Regional Development. July 1995.

specifications, in which the sales price of single-family homes is regressed upon a set of home or commercial building characteristics, neighborhood or site characteristics, and locational characteristics. As in his analysis of CalTrain commuter rail service, dummy variables are used to represent the different municipalities in which the observations are located in an attempt to control for variables at the municipal level such as tax rates, school quality, and other public service quality measures. Roadway distance from each home to the nearest BART station is used as the accessibility measure, while a dummy variable indicating whether a house is located within 300 meters (approximately 1,000 feet) of the BART right-of-way serves as the proximity impacts measure.

No statistically significant impact was found relating proximity to at-grade and elevated sections of the BART right-of-way to residential property values either in Alameda or Contra Costa counties. Regarding access to BART stations, homes in Alameda County exhibit a premium of $1.91 per every meter they were located closer to a BART station in 1990. In Contra Costa County, this premium was found to be $1.04 per meter. Evaluated at the mean home value and mean distance to a station in each of the two counties, estimates of the elasticity of home value with respect to distance to the nearest BART station are similar for both counties at about -0.05. Data for commercial properties in Contra Costa and Alameda counties for 1988 to 1994 reveal that proximity to BART had no significant impact upon commercial property values. Landis also models land use change for hectare sized land use grids in the vicinity of nine BART stations during the 1965 to 1994 using a discrete choice model. In all cases, distance to the nearest BART station did not appear to be a significant determinant of land use change near BART stations.

Although the BART system has received much attention, a number of other heavy rail transit systems in the U.S. and Canada have also been studied during the last 25 years. In Philadelphia, Boyce, et. al. (1972) examined the property value impacts of the PATCO Lindenwold heavy rail line.[118] Boyce utilizes single-family residential sales data for approximately 24,000 home sales observations spanning the years 1965 to 1971. Operation of the line began in February 1969, serving southern New Jersey residents in the Philadelphia metropolitan area. Analysis of variance (ANOVA) and multiple regression models using linear additive model specifications estimated with OLS methods are utilized. Sales price is regressed upon a set of structural, site, neighborhood, and transportation related variables, including an estimate of travel time savings for users of the line. Possible negative proximity

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[118] Boyce, David E. et. al. *Impact of Rapid Transit on Suburban Residential Property Values and Land Development Analysis of the Philadelphia-Lindenwold High-Speed Line*. University of Pennsylvania, Wharton School of Finance and Commerce. November 1972. DOT-OS-10043..

impact related to the right-of-way were not considered. An increase in sales price of $149 for each $1 of daily travel time savings was found after the line opened, however there was little evidence of pre-service property value impacts. This finding of a small but significant increase in residential property values resulting from the Lindenwold Line has generally been supported by the findings of later related studies by Platt (1972), Mudge (1974), Slater (1974), Yang (1975) and Tang (1976).[119] These later studies indicated somewhat larger property value impacts.

Allen, et. al, (1986), as part of an investigation into the use of value capture techniques for the Lindenwold Line, examined the impacts of the line upon single-family home values.[120] Using 1,341 home sales observations for the year 1980, Allen uses a hedonic price model estimated with OLS methods using a linear additive model specification. Sale price is regressed upon a variety of structural, site, community, and travel variables, including the estimated transit travel cost savings. Possible negative proximity impact related to the right-of-way were not considered. Allen finds that for every $1 of daily travel cost savings, $443 was added to the value of a single-family home. The average daily savings was $10.34, indicating a capitalized savings of $4,581, which is 7.34% the median sales price of $62,411 in 1980. Although different types of data and methods are used, these findings are generally consistent with the most recent study of the Lindenwold Line by Voith (1991), who found a substantial premium of $6,707 in median census tract housing values for 1980 in 107 tracts served by the Lindenwold Line.[121] This premium represented 10% of the 1980 median house value for Camden County. Noting that this 10% premium is substantially greater than the 3.8% premium that he found in his other analysis of SEPTA commuter rail service, Voith hypothesizes that rail transit service quality may also affect the extent to which rail accessibility is capitalized into housing values. Voith suggests that the substantial difference in housing premiums found for PATCO and SEPTA rail service reflects differences in service quality between the two services, with PATCO service being approximately five times are frequent as SEPTA service, and with the PATCO travel time advantages over auto travel time to the CBD approximately three times as great as the travel time advantage for SEPTA service.

Smith (1978), in his examination of the value of urban amenities in Chicago, estimates the value of access to rail transit.[122] Using 300 new home sales observations in Chicago for

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[119] Knight, Robert L., and Lisa L. Trygg. "Evidence of Land Use Impacts of Rapid Transit Systems." *Transportation* 6, No. 3, 1977. pp. 321-247.
[120] Allen, Bruce W., et. al. *Value Capture in Transit: The Case of the Lindenwold High Speed Line*. U.S. Department of Transportation, Urban Mass Transportation Administration. April 1986. Report No. PA-11-0031.
[121] Voith, Richard. "Transportation, Sorting and House Values." *Journal of the American Real Estate & Urban Economics Association*, Volume 19, No. 2, Summer 1991. pp. 117-137.
[122] Smith, Barton A. "Measuring the Value of Urban Amenities." *Journal of Urban Economics* 5, 1978. pp. 371-387.

1971, he estimates the value of various urban amenities including access to rail transit, which is measured by the distance to rail transit in ½ mile intervals. A multiple regression model using a linear additive specification and estimated with OLS methods is utilized, in which a set of land price differentials estimated from the data set are regressed upon the corresponding set of amenity differences, one of which is the distance to rail transit in ½ mile intervals. Possible negative proximity impacts related to the right-of-way were not considered. Smith finds that the value of each additional ½ mile of proximity to a rail transit station increases the value of residential land by approximately $300. The data were then divided into two separate groups based on household income, and separate regressions were run. The results show that lower income households received little increase in property value resulting from proximity to rail transit, where as for higher income households property values increased by about $450 for each additional ½ mile of proximity to rail transit, well in excess of the $300 estimated for the pooled sample of households, suggesting that higher income households benefit more so than lower income households in terms of property value increases resulting from proximity to rail transit.

In Canada, Dewees (1976) examined the impact of the Bloor-Danforth heavy rail line in Toronto. In estimating the rent gradient in the vicinity of the line base upon walking travel time to stations, he found that transit access increased property values by about $2,370 per hour of travel time (weighted by mode), with the effect disappearing beyond the equivalent of about 1/3 mile walk from the station.[123] In a later analysis of the Toronto heavy rail system, Bajic (1983) also used a weighted travel time measure to model the impact of the Spadina heavy rail line upon residential property values.[124] Using a multiple regression model, Bajic found that the value of the average house in the Spadina area increased by about $2,237 in 1978. Using estimates of the value of time he had estimated earlier in a modal choice model, Bajic also estimated the capitalized value of travel time savings resulting from the subway based on a reasonable discount rate and time frame, and finds that these travel time savings are indeed reflected in the property value premiums measured earlier using the hedonic price model. In both of these Toronto studies, possible negative proximity impacts related to the right-of-way were not considered.

In Washington, D.C., Lerman, et. al. (1978) examined the pre-service impacts of the Washington Metro upon single-family and multi-family residential and commercial retail property values, in part to explore the basis for the use of value capture policies in transit

[123] Dewees, Donald N. "The Effect of a Subway on Residential Property Value in Toronto." *Journal or Urban Economics* 3. 1976. pg. 357.
[124] Bajic, Vladimir. "The Effects of a New Subway Line on Housing Prices in Metropolitan Toronto." *Urban Studies* 20. 1983. pg. 147.

finance.[125] A set of multiple regression models, with a mix of linear additive, multiplicative, exponential, and Box-Cox model specifications were used, estimated with OLS methods. Sales price deflated to 1969 dollars were regressed upon a set of structural, site, and socioeconomic variables, including a measure of the distance to the nearest Metro station, as well as a dummy variable indicating a location within 0.1 mile of a station, intended to detect any negative property value effects associated with being very close to a station. Sample sizes were 286 for single-family properties, 771 for multi-family properties, and 353 for retail properties between the years 1969 to 1976.

Lerman found that no one functional form was clearly superior, but that in all cases proximity to a Metro station was a statistically significant determinant of the sales price, with the effect of distance declining rather rapidly. The station proximity dummy variable indicating a location with 0.1 mile of a station was statistically insignificant. The impacts upon retail properties were much greater than the impact upon residential properties, with the estimated elasticity of sales price with respect to distance from a Metro station at -0.68 for retail properties, -0.19 for multi-family residential properties, and ranging between -0.06 to -0.13 for the single-family residential models. A later 1981 study of the Metrorail in Washington, D.C., also found a positive impact upon property values, concluding that townhouses within 1,000 feet of the Pentagon City station sold for $12,300 more than comparable units farther from Metro service.[126] Another noteworthy finding of the Lerman study was that, when using assessed value rather than sales value as the dependent variable in the multi-family residential model, transit access was not a significant determinant of assessed value. Also, the assessed value models all had greater goodness of fit measures (R^2) than those models using sales price as the dependent variable. Lerman suggests that when evaluating properties, assessors use criteria that are generally easy to observe and quantify, and thus largely ignore a wide range of variables that influence market prices.

As part of an analysis of commercial office developments in both Washington, D.C., and Atlanta, Cervero and Landis (1993) examine the impact of heavy rail service upon office rents, vacancy rates, and building densities.[127] A quasi-experimental approach is used, whereby station area office market characteristics over a twelve year period are compared with the office market characteristics of similar commercial areas that are not near transit. Three

[125] Lerman, S.R., D. Damm, E. Lerner-Lamm, and J. Young. *The Effect of the Washington Metro on Urban Property Values. Final Report.* U.S. Department of Transportation, Urban Mass Transportation Administration. July, 1978. UMTA-MA-11-0004-79-1.
[126] U.S. House of Representatives, Committee on Banking, Finance, and Urban Affairs, Subcommittee on the City. *Metrorail Impacts on Washington Land Values.* Washington, D.C., 1981.
[127] Cervero, Robert, and John Landis. "Assessing the Impacts of Urban Rail Transit on Local Real Estate Markets Using Quasi-Experimental Comparisons." *Transportation Research A*, Vol. 27A, No. 1, 1993. pp. 13-22.

station areas and two control areas are examined in Washington, D.C., and two station areas and two control areas are examined in Atlanta for the years 1978 to 1989. Quasi-experimental comparisons between the study and control areas are made by calculating the mean annual differences in several indicators of office market performance including office rents, vacancy rates, and office development densities. Paired *t*-tests are then used to determine if the differences in these means are statistically significant. The findings are mixed, with only some of the transit oriented office developments commanding a rent premium and other indicators of office market performance such as vacancy rates and density showing similarly mixed results.

In a later analysis of the same stations in Washington D.C., and Atlanta, Cervero (1994) uses a data set consisting of 60 observations of commercial office developments, obtained from pooling data for the years 1978 to 1989 across the five station areas studied (three in Washington, D.C., and two in Atlanta).[128] Multiple regression models, using linear additive model specifications and estimated with OLS methods, are used to estimate the impacts upon office rents, vacancy rates, and office density. Independent variables in the models typically include system ridership, a dummy variable indicating whether the station was a terminal station, a dummy variable indicating whether the location was part of a joint development project, regional unemployment rate, and the average office size. Findings show that the presence of joint development projects at stations raised office rents by about $3 per square foot, or roughly an 11% to 15% increase based on office market characteristics for 1989 for the five station areas. Controlling for rents and building size, vacancy rates were about 11% lower in station areas, and office density also appeared to be higher near stations.

In an examination of the MARTA heavy rail system in Atlanta, Nelson and McCleskey (1990) estimated the property value impacts of elevated heavy rail transit stations located on MARTA's East Line.[129] A total of 286 single-family home sales observations for 1986 located in the vicinity of three elevated MARTA stations are analyzed. Nelson and McCleskey note the possibility that proximity to these stations could have a negative impact upon property values, especially given that they are elevated and located in relatively stable residential neighborhoods. Multiple regression models are used, estimated using OLS methods with a mixed linear additive, quadratic, and multiplicative model specification. Their findings suggest that single-family property values decline by a small amount as distance from the MARTA stations increases, indicating that accessibility advantages appear to outweigh any possible negative impacts of being located near a station resulting from traffic noise or visual intrusion.

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[128] Cervero, Robert. "Rail Transit and Joint Development: Land Market Impacts in Washington, D.C., and Atlanta." *Journal of the American Planning Association*, Vol. 60, No. 1, Winter 1994. pp. 83-94.
[129] Nelson, Arthur C., and Susan J. McCleskey. "Improving the Effects of Elevated Transit Stations on Neighborhoods." *Transportation Research Record* 1266. 1990. pp. 173-180.

In a follow-up study, Nelson (1992) used the same data set of 286 single-family home sales from 1986 that was used in his 1990 study of MARTA in Atlanta, this time focusing upon the effects upon property values with respect to neighborhood income.[130] Again, multiple regression models are used, with linear specifications except for distance to a MARTA station which has a quadratic specification. Two separate models are estimated, one for homes south of the rail line that are in a predominantly lower-income neighborhood, and one for homes north of the rail line that are in a predominantly higher-income neighborhood. Contrary to findings by Diamond (1980) discussed earlier and findings by Gatzlaff and Smith (1993) discussed later, Nelson finds that in lower-income neighborhoods, proximity to a station increases property values, where as in the higher-income area, proximity to a station decreases property values. Nelson notes, however, that some of this negative effect upon property values in the higher-income area might be the result of proximity to the lower-income neighborhoods to the north of the line, and not proximity to the station. Also, his empirical findings suggest that in the lower-income area, a home located 300 feet from a station would sell at a premium of about $14,500 more than a comparable home located 3,000 feet from a station in a lower-income neighborhood. Based on 1980 census tract median values of owner-occupied housing units presented by Nelson for the lower-income area of $17,866, inflated at even 8% annually to $28,475, this represents about 50% of the inflated 1980 census tract value. An impact of this magnitude does not seem likely, nor is the magnitude of this impact generally consistent with the findings of his earlier 1990 study that uses the same data, or other empirical findings regarding the impact of heavy rail transit upon property values.

In a recent study, Gatzlaff and Smith (1993) examined the effect of the Miami Metrorail heavy rail system upon single-family detached residential property values [131] This study is notable for its use of both a repeat sales index methodology in conjunction with the more widely used hedonic price model approach. In developing the repeat sales indices, 912 owner-occupied single-family homes that were located within a one-square mile area surrounding each of eight different Metrorail stations and had sold at least twice between 1971 and 1990 were used to estimate the appreciation rates for home near Metrorail stations. An additional 63,555 home sales observations were used to construct to overall repeat sales index for the Miami metropolitan area. When these two indices were compared, the data showed that for the 18 years analyzed, the station area index was within the 95% confidence interval of the overall metropolitan area index. Therefore, Gatzlaff and Smith conclude that the indices

[130] Nelson, Arthur C. "Effects of Elevated Heavy-Rail Transit Stations on House Prices with Respect to Income." *Transportation Research Record* 1359. 1992. pg. 127-132.
[131] Gatzlaff, Dean H., and Marc T. Smith. "The Impact of the Miami Metrorail on the Value of Residences Near Station Locations." *Land Economics* 69 (1). February 1993. pp. 54-66.

are not significantly different, suggesting that Metrorail had no significant impact upon residential property values.

A hedonic model approach was also used on the same data set in an attempt to provide additional support for the findings of the repeat sales index approach. The first set of hedonic models were estimated using one panel of data from the station areas in the north, consisting of 481 home sales observations, and a second panel of data from the station areas in the south, consisting of 431 home sales observations. Models were estimated using linear, semi-log, exponential, and multiplicative model specifications, with the exponential model chosen as best and later used in estimating separate station area models for all eight stations. Sales price was regressed upon a set of structural, site, and transit related variables, including a dummy variable indicating that a sale occurred after 1980, which was after the announcement of the Metrorail system, and a distance variable measuring the distance of the property to the nearest Metrorail station in tenths of a mile. Gatzlaff and Smith also note the possibility that proximity to these stations could have a negative impact upon property values. The results of these initial models suggest that Metrorail impacts upon residential property values were insignificant in the areas around the southern stations, but did have a statistically significant positive impact in the northern station areas. Hedonic price models were then estimated separately for eight different station locations, revealing substantial variations in results between stations, which Gatzlaff and Smith hypothesize may be the result of differing neighborhood characteristics that are not included in the individual models. The effect of both the announcement of the Metrorail system and the effect of distance to the nearest station are weak for all of the locations examined. Gatzlaff and Smith note, however, that the estimated coefficient upon the Metrorail announcement dummy variable is positively correlated with mean neighborhood property values. In higher income areas, single-family homes experience small increases in value resulting from Metrorail, while less affluent areas experienced small decreases in value. According to Gatzlaff and Smith, this suggests that to the extent that Metrorail has improved accessibility, the capitalization of these benefits into house values has been of greater benefit to higher income households.

In an extensive study of transit service in New York City, Anas and Armstrong (1993) examine the impact of rail transit upon land values, in part as a precursor for recommendations regarding the use of value capture policies in transit finance.[132] In a station area model, Armstrong estimates the effect of walking distance from stations upon property values using

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[132] Anas, Alex, and Regina Armstrong. *Land Value and Transit Access: Modeling the Relationship in the New York Metropolitan Area*. Washington, D.C.: Urban Mass Transit Administration, U.S. Department of Transportation, September 1993. FTA-NY-06-0152-93-1.

separate hedonic price models for each of several land use types including one and two family residential, multi-family residential, office, retail, and vacant land. Linear model specifications are used, estimated with OLS methods. Over 98,000 real estate transaction records for the years 1982 to 1988 are used, with land value per square foot regressed upon parcel, neighborhood, station access, and transit characteristics. The findings reveal that for all but retail land uses and elevator apartments, negative rent gradients that decline with increasing distance from a station are present. Office uses exhibit the largest rent gradient, with vacant land, walk-up apartments, and single-family land uses following in descending order. For instance, one and two family properties located within 200 meters (1/8 mile) from a station sell for about $40 more per square foot than properties located 800 meters (1/2 mile) from a station. Overall, transit level of service variables including the percent of trains on-time at a station, whether that station has express or transfer service, and use of new or rehabilitated transit equipment on a line, affect the magnitude of the observed rent gradients, generally yielding steeper gradients for better service, as would be expected.

The preponderance of property value impact studies of heavy rail transit, as opposed to land use studies, most likely is the result of data availability issues. The ease of data acquisition appears to have largely dictated the focus upon single-family residential properties, with few studies having focused on multi-family housing, commercial properties or vacant parcels of land, or analyses of land use or land use change.

The heavy rail transit impact studies reviewed above have produced widely varying estimates of the impact of heavy rail transit upon property values. Some studies detected no impact, such as Gatzlaff and Smith (1993) in Miami and Landis, et. al, (1995) in San Mateo County for CalTrain service, or even negative property value impacts related to station proximity, such as Dornbusch (1975) and Baldassare (1979) in the San Francisco Bay Area, and Nelson (1992) in Atlanta. Others identified positive price effects as great as 10%, such as Al-Mosaind, et. al., in Portland, OR, and Voith (1991) in southern New Jersey. Despite these differences, most of the studies do find that heavy rail transit does have a significant impact upon property values however.

4.3 Light Rail Transit

Considerably less research has been performed related to the impacts of light rail transit systems (see Table 4.1). This may be partly because until about 1987, there were generally fewer light rail transit systems in the U.S. than there were heavy rail systems and commuter rail systems. Since 1987, ten new light rail systems have commenced service. Given that it typically takes several years for land and real estate markets to fully respond to investments in new transportation facilities, until very recently it would have likely been considered premature to study the impact of these systems upon land values.

Ferguson, et. al, (1988) examined the pre-service impacts of the Advanced Light Rapid Transit (ALRT) system in Vancouver, BC upon single-family home values.[133] Multiple regression analysis was used on observations obtained from the transit corridor as well a control corridor. Findings showed that the light rail line had an impact upon properties beginning about three years prior to operation of the line, and that homes near stations sold at a premium compared to those further from stations. No negative impacts from proximity to the line were detected.

Al-Mosaind, et. al., (1993) examined the impact of the MAX light rail system in Portland, OR upon single-family residential property values. Using 235 single-family home sales observations in 1988, multiple regression models using a linear additive specification and estimated with OLS methods are utilized. A limited number of structural and site related independent variables are included. Transit station access is represented as a dummy variable indicating a location within 500 meters (about 1/3 mile) in one model, and a continuous variable measuring meters of actual walking distance in a second model. In the first model, the dummy variable indicates an increase of $4,324 for homes within a 500 meter walking distance of a station, representing a premium of 10.6% of the mean property value of $40,554 for home sales observations that were located within a 500 meter walking distance of a station. In the second model, the coefficient of the distance variable indicates a negative, but statistically insignificant, price gradient of $21.75 per meter for homes located within 500 meters of a station. The study appears to have several shortcomings, however, including the use of a linear model specification, a relatively limited sample size, and the omission of variables such as school quality that have been identified in previous studies as a significant determinant of housing value, all of which likely result in a biased estimated of the impact of light rail access upon property values.

Landis, et. al. (1995) examine the impact of the light rail systems in Sacramento and San Diego upon residential property, and the impact of the light rail system in San Jose upon both residential and commercial property.[134] Both the impacts of light rail transit access as well as the possible negative impacts of light rail transit related externalities such as noise are examined. A total of 2,591 sales of single-family homes in Sacramento, San Diego, and San

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[133] Ferguson, Bruce G., Michael A. Goldberg, and Jonathan Mark. "The Pre-Service Impacts of the Vancouver Advanced Light Rail Transit System on Single-Family Property Values." In *Real Estate Market Analysis: Methods and Applications*, John M. Clapp and Stephen D. Messner, eds., New York City: Praeger. 1988.

[134] Landis, John, and Subhraijit Guhathakurta, William Huang, and Ming Zhang. *Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems*. Monograph 48. University of California at Berkeley, Institute of Urban and Regional Development. July 1995.

Jose during 1990 are used, with separate hedonic price models having linear additive model specifications estimated for each of these three study areas. Sales price is regressed upon a set of home or commercial building characteristics, neighborhood or site characteristics, and locational characteristics. Proximity to the light rail rights-of-way has no statistically significant effect in any of the three cases. In San Diego, homes exhibit a premium of $2.72 per every meter they were located closer to a light rail station in 1990. Commercial property values in San Diego, however, were not significantly affected by proximity to light rail transit. Homes in San Jose exhibit a similar premium of $2.61. In Sacramento, accessibility to light rail had no statistically significant effect upon property values.

The few existing analyses of light rail reviewed above suggest that light rail does appear to have a positive influence upon residential property values. In the case of Portland, the effect appears to be substantial, perhaps because of the relatively widespread implementation of transit supportive land use policies. However, many of the conclusions reached by these studies are based upon simple linear model specifications, even though much of the theoretical and empirical literature regarding property value impacts and their measurement using hedonic methods suggests the use of non-linear model specifications. Also, if correlated with the presence of rail, the influence of omitted variables such as neighborhood quality and school quality measures, may in part be reflected in the observed rail transit access premiums, thus resulting in biased estimates.

4.4 Transitway and Bus Priority Treatments

Although rail transit modes have been the focus of the vast majority of the existing literature, there have been a limited number of attempts to explore the land use impact of transitways, high-occupancy vehicle (HOV) lanes, and other bus priority treatments. Knight and Trygg (1977), in a review of busway facilities in Washington, D.C., California, Seattle, and Florida conclude that exclusive bus lanes incorporated into highways appear to have no land use impacts upon either residential or commercial development. They note that even busway facilities having ridership levels comparable to many commuter rail lines had no discernible land use impacts, and hypothesize that the general lack of fixed facilities associated with these systems is at least partially responsible for this finding.

Mullins, et. al., (1990) reviewed several operational transitways in the U.S. and Canada.[135] Their findings are similar to those of Knight and Trygg, and suggest that although in many cases transitways have provided significant improvements in corridor capacity, the

[135] Mullins, James A., Earl J. Washington, and Robert W. Stokes. "Land Use Impacts of the Houston Transitway System." *Transportation Research Record* 1237. 1990. pp. 29-38.

land use impacts of these facilities have been negligible. Although the extensive bus-only system in Ottawa, Canada, did appear to have some effect upon land use and development in areas surrounding stations, Mullins notes that this system has the highest ridership levels of any bus-only system in North America, and is atypical of busway systems in the U.S.. Thus, although highly patronized transitway systems incorporating a substantial amount of permanent fixed facilities may influence land use, the more limited facilities found in the U.S. are likely to have little if any effect.

4.5 Highways and Local Roadways

Many of the highway related studies are of a less recent vintage than much of the transit related work reviewed earlier, perhaps in part a reflection of the timing of the development of much of the interstate highway system in the U.S. (see Table 4.2). Some of the earlier highway studies use mostly longitudinal data and descriptive statistics in an attempt to measure the influence of highway accessibility and proximity impacts upon property values, while later studies typically utilize or are at least consistent with the hedonic price model approach. Regardless of their particular analytical approach, almost all the studies that were reviewed relied upon individual sales of single-family homes for their data, with sample sizes ranging between a mere handful of properties to much more extensive multi-year longitudinal data sets.

Most of the earlier empirical studies found sizable positive effects upon property values related to proximity to highway interchanges. More recent highway analyses generally find the accessibility effects upon property values to be more modest than those found in earlier studies, and also seem to focus somewhat more upon the negative impacts related to noise and air quality. This may be in part because as highways were expanded during the 1950's and into the 1970's, the relative accessibility advantage provided by them was likely diminished somewhat as highway access became more ubiquitous in many metropolitan areas, thus reducing the impact upon property values. At the same time, highway noise and other nuisance effects began to affect an increasing number of households as highways expanded and population increased, increasing both the amount of travel by highway as well as the number of persons exposed to nuisance effects by this travel. Overall, the findings regarding the impact of noise upon property values are fairly consistent, with estimates of property value reductions ranging from between about 0.16% per decibel of highway noise, up to about 0.63% per decibel. Thus, assuming that a home that is exposed to significant highway noise experiences noise levels of perhaps 75 dBA, or about 20 decibels greater than a home in a quiet area, these homes will experience a discount in value of perhaps 5% to 10%.

Table 4.2: Review of Selected Highway and Traffic Impact Studies

Author(s)	Study Area (Highway)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Adkins (1958)	Dallas, TX, and San Antonio, TX	descriptive statistics	sales price and assessed value	n/a	assessed value and sales price of vacant land increased, extent of impact up to 4 block beyond expressway frontage roads
Cribbins, Hill, & Seagraves (1962)	Cumberland County (I-95), Guilford County (I-84/I-40), and Rowan County (I-85), NC	longitudinal data analysis, and multiple regression models	land sales price per unit	size of parcel, year of sale, vacant/non-vacant, rural/urban, subdivision dummy, Interstate roadside location dummy, alternative roadway location dummy, straight line distance to CBD and to right-of-way, straight line distance to highway access	no pattern is found that could attribute vacant land value increases to highway construction
Buffington & Meuth (1964)	Austin, TX (I-35)	experimental controls and descriptive statistics	land sales price adjusted by CPI	n/a	premium of 163% for vacant land, with very strong effects found on abutting land; discount of about 13% found for subdivided land, with effect on abutting versus non-abutting land unclear
Buffington & Meuth (1964)	Temple, TX (I-35)	experimental controls and descriptive statistics	land sales price adjusted by CPI	n/a	enormous premium of 2,562% found for vacant land, abutting land values increased more than non-abutting land values
Brown & Michael (1973)	Indianapolis, IN	longitudinal data analysis using descriptive statistics	sales price	n/a	interchanges found to have a positive effect on the value of vacant land that decreases with distance, impacts found up to 1 mile from the interchange
Gamble, Langley & Pashek (1973)	Bogota, NJ (I-80), North Springfield, VA (I-495), Rosedale, MD (I-95), and Towson, MD (I-83 & I-695)	multiple regression model	sales price	noise, vibration, air pollution, schools/churches/ work/shopping/central city proximity, owner-occupied, age, lot size, corner lot, siding, central a/c, garage, no. of rooms, no. of stories, style, household age, socio-economic score, study area dummy	single-family discounted 4.5% to 15.5%, with noise dominates other impacts; hwy access benefits are far greater than highway environmental imacts, with access premium of 9% in Springfield
Vaughn & Huckins (1975)	Chicago urban and suburban areas	hedonic price model	sales price	living area, garage, lot size, age, exterior construction, interior design, distance to CBD, distance to Lake Michigan, no. of lots on block (density measure), no. of visible broken windows (blight measure), air pollution, availability of recreation land	NDI is 0.65% per decibel for detached single-family homes
Langley (1976)	North Springfield, VA (I-495)	repeat sales price index model	sales price	price index for each year and zone is commputed by regressing the log of price relatives for repeat sales on a transitional matrix indicating initial sale and resale	NDI is 0.32% per decibel for single-family homes
Anderson & Wise (1977)	Bogota, NJ (I-80), Towson, MD (I-83 & I-695), Rosedale, MD (I-95), and North Springfield, VA (I-495)	hedonic price model	sales price	number of rooms, number of bathrooms, age of house, dummy for design, dummy is highway is visible from house, and number of years respondent had lived in the house in 1972, NPL index or its logarithm are used in regressions for measuring noise impacts	NDI of 0.14%, 0.43%, & 0.25% per decible for N. Springfield, Towson, & pooled sample, respectively; thus N. Springfield &Towson discounts are $42 & $129 per decibel, respectively, for a $30,000 single-family home; no impacts upon time on market found
Bailey (1977)	North Springfield, VA (I-495)	hedonic price model	sales price	distance from highway up to 1,000 feet, house design/style, dummy for sale data after 1973 (reflecting a sewer extension moratorium), financing instrument, monthly time trend	a detached single-family home located 1,000 feet or more from the highway sold for 7.5% more than did the same house abutting on the highway, which implies an NDI iof 0.3% per decibel
Hall, Breston & Taylor (1978)	Mississauga, Burlington, and Ancaster, Ontario (Queen Elizabeth Highway)	hedonic price model	sales price	Leq index is computer for noise. Number of rooms, number of bathrooms, garage size, a dummy for swimming pool, and an annual time trend	the implied NDI is 1.05% per decibel for single-family homes

n/a: not applicable

NDI: noise depreciation index, representing the percentage rate of depreciation in home values for a per unit of noise exposure

Table 4.2: Review of Selected Highway and Traffic Impact Studies (continued)

Author(s)	Study Area (Highway)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Li & Brown (1978)	15 suburban towns located of Boston, MA	hedonic price model	sales price	no. of rooms, no. of baths, age, garage, fireplace, lot size, median HH income, pop. density, per pupil $, property tax rate, noise, air pollution, distance to CBD, ocean, rivers, hwy interchange, schools, commercial/industrial areas, major thruway	distance to highway interchange is significantly capitalized into single-family home prices
Nelson (1978)	Washington, D.C. urban and suburban areas	hedonic price model	median census tract property value owner estimates	census tract Ldn measure based on pop. density, no. of rooms, lot size, age, plumbing facilities, central a/c, racial composition, riverside location, accessibility index, industrial/commercial land uses, air pollution	NDI is 0.65% per decibel for Ldn >39, and 0.87% per decibel for greater than Ldn ≥ 50 for residential properties
Bagby (1980)	Burton Heights and Dickinson neighborhoods in Grand Rapids, MI (local street traffic)	ANOVA, and longitudinal data analysis using descriptive statistics	assessed values, sales price, census median home value estimates, and census median rents	n/a	single-family residential assessed values in Dickinson increased 9.35% from 1952-65, and only by 4.1% in Burton Heights; repeat sales data reveal $635 increase for Dickinson and only $16 for Burton Heights; sales data shows similar premiums for Dickinson
Allen (1981)	Northern Virgina near North Springfield (I-495), Newport News, VA, and Virginia Beach	hedonic price model	sales price deflated to constant 1978 dollars using price indexes for the urban areas	square feet of floor space, square feet of lot, number of baths, number of fireplaces, age of the house, dummy variables for style, type of basement, and type of construction; dummy variables are used for different noise contours	detached single-family property values discounted by $88 to $101 per decibel; homes within 70 dBA contour were on the market 11 days longer; NDI of 0.15% for Northern Virginia; NDI of 0.14% for Tidewater
Langley (1981)	North Springfield, VA (I-495)	repeat sales price index model	sales price	n/a	$3,000 to $3,500 discount for single-family homes within 1,000 feet of the highway, which implies an NDI of about 0.40% per decibel using noise levels from Gamble (1973)
Palmquist (1982)	Kingsgate (I-405) and North King County (I-5) near Seattle, WA, and an urban area just inside Spokane, WA (I-90)	repeat sales price index model, and hedonic price model	sales price	living area, lot area, attic area, basement area, garage, no. of bathrooms, no. of appliances, age, fireplaces, trees, membership in recreational associations, underground utilities, type of heating, floor type, quality rating, distance to nearest park	price index and hedonic approaches yield similar results; NDI are 0.48%, 0.30%, & 0.08% per decible for single-family homes, with differences possibliy caused by income differences among the three areas; no impact upon days on market
Tomasik (1987)	Phoenix, AZ	appreciation in sales prices in control and experimental areas are compared using descriptive statistics	sales price	n/a	no discernible negative property value effects; single-family homes within 1/2 mile of highway appreciated more than distant homes, however within this 1/2 miles there was no correlation measured between value and distance
Hughes & Sirmans (1992)	two neighborhoods in the Baton Rouge, LA, metropolitan area (local street traffic)	hedonic price model	sales price or sales price per square foot	living area, other area (car ports, storage, porches, etc.), lot size, age, favorable financing, days on the market, non-owner occupied, year sold dummy, high traffic dummy, no. of cars using street	traffic has a negative impact upon residential property value, with an 8.8% price reduction in the pooled sample for high traffic areas; property discounts are greater for city properties (9.2%) than for suburban properties (4.6%)
Palmquist (1992)	Kingsgate, WA (I-405), North King County, WA (I-5), and Spokane, WA (I-90)	hedonic price model	sales price	39 independent variables used, including age, living area, quality rating, exterior, baths, garages, heat type, fireplaces, porch/deck, lot size, underground utilities, location with many trees, distance to nearest park, busy street, highway noise level	single-family property values reduced by 0.48% for each decibel of highway noise in upper middle class areas; in lower middle class areas this value was 0.3% per decibel; in the poorest areas the effect was 0.08% per decibel
Hughes & Sirmans (1993)	two neighborhoods in the Baton Rouge, LA, metropolitan area (local street traffic)	hedonic price model	sales price	living area, other area (car ports, storage, porches, etc.), lot size, air conditioning, age, days on market, owner-occupied, year sold , high traffic dummy, no. of cars using street	11.49% discount for high traffic streets, with about a 0.847% discount for each additional 1,000 cars; owner occupied homes sell at a premium when compared to rented or vacant homes, perhaps reflecting maintenance levels

n/a: not applicable

NDI: noise depreciation index, representing the percentage rate of depreciation in home values for a per unit of noise exposure

In many ways related to the study of highway impacts are those studies that have analyzed the impact of local road traffic upon property values. Although one might expect the negative impacts from traffic on nearby local streets to generally be of a far lesser magnitude than the impact of highway noise, the potential impacts upon property values are still significant. In an analysis of single-family residential homes in Baton Rouge, LA, Hughes and Sirmans (1992) found that suburban properties located on high traffic streets sold at a discount of about 4.2%, while properties in urban areas that were located on high traffic streets sold at an even greater discount of 9.2%.[136] In a follow-up analysis of the properties in the same metropolitan area, Hughes and Sirmans (1992) found an even larger discount of about 11.5% for homes located on high traffic streets.[137]

4.6 Airports

A significant body of literature exists concerning the property value impacts of airport related noise (see Table 4.3). For the most part, interest in this subject has increased as a result of the often substantial expenditures for mitigation and abatement of airport noise in residential areas surrounding major airports. Abatement measures can include re-routing of aircraft approach and departure patterns, as well as the application of sound insulating materials in homes which are impacted. In either case, costs are incurred, in which case the economic benefits of such abatements measures, if known, help to justify these costs.

Results from twelve such studies were summarized and reviewed by Nelson in 1980, along with his separate study of airports in six U.S. cities.[138] In the six city study by Nelson, the mean census block property value is used as the dependent variable. Sample sizes range between 113 blocks to 185 blocks for each of the six cities. Variables in the model include the Noise Exposure Forecast (NEF) level in decibels, and other housing unit data at the block level. An attempt is also made to control for other variables such as access to the airport and the CBD, the quality of local services, and proximity to other facilities such as highways or parks in the sampling procedure itself by excluding such properties from the analysis. A

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[136] Hughes, William T., Jr., and C. F. Sirmans. "Traffic Externalities and Single-Family House Prices." *Journal of Regional Science*, Vol. 32 No. 4. November 1992. pp. 487-500.
[137] Hughes, William T., Jr., and C. F. Sirmans. "Adjusting House Prices for Intra-Neighborhood Traffic Differences." *The Appraisal Journal*. October 1993. pp. 533-538.
[138] Nelson, Jon P. "Airports and Property Values: A Survey of Recent Evidence." *Journal of Transport Economics and Policy*, Vol. XIV, No. 1. January 1980. pp. 37-52.

Table 4.3: Review of Selected Airport Impact Studies

Author(s)	Study Area (Airport)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Emerson (1972)	Minneapolis, MN	hedonic price model	sales price	house sq ft, lot size, age, garages, no. of baths. no. of stories, exterior construction, no. of ranges, fireplaces, distance to school, location within two lots of freeway, parks/open space nearby, % non-white in elementary schools, airport noise level	noise depreciation index (NDI) of about 0.58% per NEF is found for single-family residential properties
Paik (1972)	New York, Los Angeles (Los Angeles International), Dallas (Love Field)	hedonic price model	median census block property value owner estimates	mean no. of people per household, absolute no. of single-family homes, % of deteriorated houses, absolute no. of nonwhite homes, median no. of rooms per house	NDI of about 2.2% per NEF is found for owner-occupied single-family residential properties
Dygert (1973)	San Francisco, CA, and San Jose, CA	hedonic price model	mean assessed land value per square foot	accessibility to shopping, industrial, airport, schools, and CBD; no. of people per unit, % non-white units, terrain characteristics, dwelling unit per acre, property tax rate, airport noise	suggested NDI for residential land are 0.5% for San Francisco, and 0.7% for San Jose, but could be greater
Price (1974)	Boston, MA (Logan Airport)	hedonic price model	percentage change in median contract rent from 1960 to 1970	change in % nonwhite population, % nonwhites in 1960, % people over 65 years of age in 1960, distance to Boston CBD, % increase in property tax rate, % unit built before 1930, % units built since 1960, % units that are public housing units	implied NDI is 0.83% per NEF for multi-family residential rental units
Gautrin (1975)	London (Heathrow)	a "modified Mohring model" of land rents	sales price		NDI of 0.56% to 0.68% per NEF is found for single-family residential properties
De Vany (1976)	Dallas, TX	hedonic price model	mean census block property value owner estimates	no. of rooms, % of homes owner-occupied, age of housing, length of occupancy, % homes with air conditioning, distance to the CBD, airport noise	for a owner-occupied property bordering on the airport, the noise discount is $5,300, or $177 per NEF; using the mean value of housing of $22,000 yields a NDI of about 0.8% per NEF
McDougall (1976)	Los Angeles (Los Angeles International Airport)	hedonic price model	median census tract property value owner estimates	mean no. of rooms per unit, accessibility to bus service, neighborhood quality and land use, and school quality	a residential property of average value will decline in value by $24 if the weighted area subjected to 90 decibels or more increases by 1%
Maser, Riker, & Rosett (1977)	Rochester, NY (Greater Rochester International Airport)	hedonic price model	parcel sales price per acre of land plus structure	no. of rooms, % nonwhite population, property crime rate, condition of property, adjacent or visible land use characteristics such as apartments, industrial, public buildings, type of street, access to CBD, access to parks and/or bodies of water	the city NDI is about 0.82% to 0.95%, and the suburban NDI is about 0.55% to 0.68% per NEF for single-family residential properties
McMillan, Reid, & Gillen (1978)	Edmonton, Canada	hedonic price model	sales price	sq. ft. living area, construction date, no. of bathrooms, no. of bedrooms, sq. ft. lot size, no. of stories, duplex dummy varible, finished basement, brick exterior, garages, property tax rate, distance to CBD	NDI of about 0.5% per NEF is found for single-family residential properties
Mieszkowski & Saper (1978)	Toronto, Canada	hedonic price model	sales price	lot size, average room size, square of both room size and lot size, no. of bedrooms, no. of utility rooms, no. of bathrooms, dummy variables for 25 additional characteristics such as no. of stories, garage size, fireplaces, type of siding, etc.	noise depreciation rates of about 1.3%, 0.5%, and 0.5% are found for single-family residential properties

n/a: not applicable

NDI: noise depreciation index, representing the percentage rate of depreciation in home values for a per unit of noise exposure

NEF: noise exposure forecast level

Table 4.3: Review of Selected Airport Impact Studies (continued)

Author(s)	Study Area (Airport)	Methods Utilized	Measure of Value	Independent Variables	Nature and Magnitude of Findings
Nelson (1978)	Washington, D.C. (Washington National Airport)	hedonic price model	median census tract property value owner estimates	no. of rooms, lot size, housing age, central a.c., dummy for riverside locations, and accessibility to employment; tests are conducted for 18 other variables that proved to be insignificant, including property tax rate and school expenditure	NDI of 1.1% per NEF is found for owner-occupied single family residential properites
Abelson (1979)	Sydney, Australia	hedonic price model	sales price	no. of rooms, lot size, contract date, construction type, style, age, roof type, no. of stories, condition, garage, airport noise, access to shops, public transport quality, proximity to ocean, road width/blight/traffic, zoning, railway proximity, views	NDI of 0.4% per NEF for Marrickville; for higher-priced homes in Rockdale, the price difference between very noisy and quit houses was 10%, or a NDI of about 0.5% per NEF for single-family residential properties
Nelson (1980)	San Francisco, St. Louis, Cleveland, New Orleans, San Diego, and Buffalo	hedonic price model	mean census block property value owner estimates	mean number of rooms per unit, % of total housing units that are owner-occupied, % of population which is black, % of owner-occupied houses with substandard plumbing, % housing units that have central a/c	empirical results from six U.S. cities, on both individual and pooled bases, suggest an average NDI of about 0.50% to 0.55% per decibel for residential properties
O'Byrne, Nelson, & Seneca (1985)	Atlanta, GA (Hartsfield Airport)	hedonic price model	sales price and census block mean property value owner estimates	sale model: sale date, living area, no. of baths, ext. type, basement, no. of rooms, no. of bedrooms, central ac and heat, airport niose; census block model: no. of rooms, % owner-occupied, % black, % substandard plumbing, % built before 1933, central ac	for the sales price model, a discount of 0.67% per decibel is found for single-family residential properties; for the census tract model, a reduction in mean owner-occupied residential property value of 0.52% and 0.66% per decibel is found
Pennington, Topham, & Ward (1990)	Stockport, England (Manchester International Airport)	hedonic price model	sales price	age, number of garages, central heating, garden, detached house, terraced house, flat, bungalow, bedrooms dummies, bathroom dummies, living room dummies, month of sale, noise variable	preliminary analysis revales a discount of 6% in the most affected areas for single-family residential properties; use of neighborhood type variables reveals that this discount can be explained by factors other than aircraft noise however
Frankel (1991)	40 communities near Chicago (O'Hare Airport)	descriptive statistics	n/a	n/a	neighborhood quality, school proximity, & property taxes are ranked as highly important factors affecting residential property values; bid prices for noise affected properties are often too high because of a lack of information
Collins & Evans (1994)	Stockport, England (Manchester International Airport)	an artificial neural network (ANN)	sales price	age, type of house, format of house, no. of bedrooms and living rooms, garden, garages, central heating, aircraft noise impact, neighborhood classification	detached house values are more sensitive to aircraft noise than are those of semi-detached or terraced houses; detached houses suffer a discount of between 8.02% to 9.54%
Levesque (1994)	Winnipeg, Canada	hedonic price model	sales price	no. of stories, fireplace, recroom, family room, plot size, garage, no. of bedrooms, no. of bathrooms, distance to school, house age, time trend, number of noise events exceeding 75EPNL, average and std dev. EPNL of noise events	measures of loudness and event frequency correlate significantly with single-family residential housing prices

n/a: not applicable

NDI: noise depreciation index, representing the percentage rate of depreciation in home values for a per unit of noise exposure

NEF: noise exposure forecast level

hedonic price model using a multiplicative model specification is used, and is estimated with OLS methods. Results suggest a sensitivity of the mean census block property value to noise of about .50% to .55% per decibel of noise.

Twelve other airport noise property value impact studies were reviewed by Nelson. Findings of these studies, and the theoretical basis for each, were generally consistent, therefore they will not be discussed individually. The theoretical basis for these studies has been the hedonic price model, with the attempt being to measure the implicit marginal price of each additional unit of quiet, or the implicit marginal cost of each additional unit of noise. The dependent variable in six of these studies is the individual sales price of single family residential properties. In the other remaining studies, census block and census tract level median or mean housing prices are utilized as the dependent variable. For the studies utilizing individual sales data, sample sizes range from 67 to 990, with an average of about 500. Independent variables utilized in these six studies include a wide variety of structural attributes, site attributes, local service provision and cost variables, locational and accessibility variables, and environmental impact variables, with linear, exponential, and multiplication model specifications used in the different studies. Overall, the studies indicate decreases in residential property values resulting from airport noise of about .4% to 1.1% per decibel.

A more recent study of the noise impacts of Atlanta International Airport performed by O'Byrne and Nelson (1985) is notable in that is compares the use of aggregate census data and disaggregate housing sales data that are often widely, but independently, used in hedonic price studies. Two separate groups of hedonic models are estimated, using an exponential model specification estimated with OLS methods. Results from the individual property sales model indicate a decrease in property values of between -0.67% to -0.70% per decibel of noise. Results from the census block data model are generally consistent with those obtained from the individual sale model, and indicate a decrease in property values of between -0.52% to -0.66% per decibel of noise. As one would expect, the goodness-of-fit measure R^2 is somewhat greater for the regressions using the census block models using the grouped data rather than the individual sales models using disaggregate data. These findings are also consistent with the thirteen other studies of airport noise and property values presented by Nelson in 1980 and discussed earlier.

Chapter 5
A Case Study of MBTA Commuter Rail Service

The primary hypothesis of this thesis is that the provision of commuter rail service generates both beneficial and deleterious impacts that are reflected by variations in single-family residential property values. The chapter begins by providing the framework for an empirical analysis of the impacts of MBTA commuter rail service in Eastern Massachusetts. Eastern Massachusetts is considered not only for its proximity, thus facilitating the task of data collection, but also because of its well developed and fast growing commuter rail system. operated by the MBTA which, as discussed earlier in Chapter 2, has in recent years become embroiled in a serious debate regarding both the beneficial and deleterious impacts of its service upon communities and property owners. To provide for the selection of both study and control areas, a municipal data set containing key socio-economic and transportation related variables for almost two hundred communities in Eastern Massachusetts is developed.

5.1 Analytical Framework

For the purposes of this analysis, the commuter rail impacts to be analyzed are grouped into the two major categories of *proximity impacts* and *accessibility impacts*. Proximity impacts include noise, ground-borne vibration, and visual intrusion, the source of which is the operation of commuter rail equipment and facilities, and the receivers of which include those located within a given distance of these facilities. It is hypothesized that these types of physical impacts will result in various collateral economic impacts including property values that are lower than would otherwise be the case in the absence of these proximity impacts. Accessibility impacts include the superior access that the presence of commuter rail service may provide to areas of commercial activity and concentrations of employment. It is hypothesized that these impacts will result in higher property values than would otherwise be the case in the absence of commuter rail service.

5.1.1 Proximity Impacts

The evaluation of proximity impacts will focus upon the three types of commuter rail facilities most likely to generate proximity impacts: the *right-of-way* over which trains operate, the *grade crossings* through which trains pass, and the *stations* at which patron arrivals and departures occur. Because commuter rail service is often operated along rights-of-way that are shared with freight rail service or intercity passenger rail service, care must be taken not to attribute any impacts from these other services to commuter rail service. This could be accomplished in two ways. One method would be to identify a study area containing right-of-way along which both commuter rail and freight rail operate. After evaluating the property value impacts from these combined operations, one could attempt to apportion the combined impact among the two types of operations. This could be accomplished by using existing empirical noise models developed by the Federal Transit Administration, which require input data including the characteristics of the rail operations and equipment, and as output generate noise measures based upon these characteristics.[139] The relative noise impacts estimated from the noise model could then be used in differentiating between the impacts of commuter rail and freight rail service on the shared right-of-way. An alternative approach would be experimentally to control for the different impacts of commuter rail and freight rail operations by identifying study areas containing rights-of-way that have only one or the other type of service present. This latter approach is significantly more straightforward, robust, and easier to implement, and will therefore be used for this analysis. In addition, study areas with mixed commuter rail and freight rail traffic will also be analyzed, in order to provide a frame of reference for comparing the results of the two experimentally controlled analyses of commuter rail and freight rail impacts described above.

5.1.2 Accessibility Impacts

Accessibility, in the context of this analysis, refers to the relative advantage of one location over another in its ability to provide for ease of movement to and from centers of activity or interest. As it relates to commuter rail service, accessibility can be thought of as having both local and regional components, both of which are of interest to this analysis.

The regional component of commuter rail accessibility represents access from the station location to the central business district. Communities with commuter rail stations may have a considerable accessibility advantage over those communities that do not have a commuter rail station, and thus it is hypothesized that residential property values will be higher

[139] *General Transit Noise Assessment Model* , April 1995, sponsored by FTA contract #DTUM60-92-C-41008.

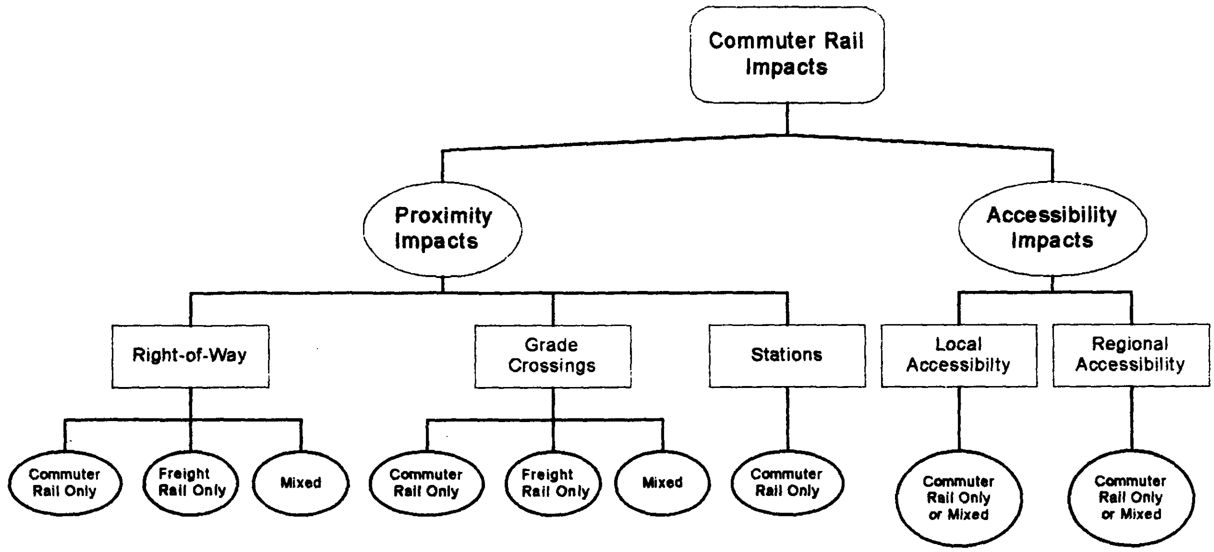
in communities with commuter rail access than would be the case in the absence of such access.

The local or sub-regional component of commuter rail accessibility represents the access to the station location from the residence. In a given community that has a commuter rail station, there will be some variation in access time required to reach the station from residences located throughout the community. This variation in access time may affect property values within the community. Considering both types of accessibility impact, the regional component will likely be stronger. The perceived effect of having a station in the same community as the residence, regardless of the actual travel time involved in accessing the station from particular locations within the community, should provide the primary impact upon property values. This is in many ways consistent with the manner in which residential properties are marketed by real estate firms. Often, the fact that the home is located within a community with commuter rail access may be extolled, and whether the property is a 3 minute drive to the station or an 8 minute drive to the station is not an issue. There is some evidence that locations within walking distance of a station, however, are considered to be particularly advantageous, since walking access to a station may allow a household to reduce automobile related capital and operating expenditures. However, it is still likely that the regional component of commuter accessibility may make itself more evident in any empirical analysis.

In order to evaluate the regional component of commuter rail accessibility, it will be necessary to compare similar properties in two or more communities, one having commuter rail access and the other without commuter rail access. Other confounding influences, in this case community specific attributes such as school quality, tax rate, and auto accessibility, must be held constant either experimentally or statistically in order to isolate the effect of commuter rail access. The presence or absence of commuter rail service in a given pair of study and control communities can be effectively represented in a hedonic price model as a binary dummy variable. However, appropriate consideration must also be given to varying levels of commuter rail service if data are pooled across many study and control communities. In this case, commuter rail travel time (including station access time, a transfer penalty time, and in-vehicle time) and level of service variables would need to be specified explicitly. The analysis of the regional component of commuter rail access will likely be the most complex empirical task of this thesis because there may be fewer opportunities for experimental control of independent variables, and the representation of some control variables such as regional auto accessibility may be difficult in practice.

To evaluate the local component of commuter rail accessibility, a single community having a commuter rail station can be selected, and similar properties within that community

Figure 5.1: Analytical Framework



having varying levels of access to the commuter rail station can be evaluated for changes in property value. The possible confounding effects of station related proximity impacts must be considered, and therefore properties immediately adjacent to a commuter rail station should not be selected in attempting to evaluate the local component of commuter rail accessibility.

The resulting analytical framework can be organized into nine discrete areas of analysis (see Figure 5.1). Seven areas are concerned with the evaluation of commuter rail and freight rail proximity impacts, five of them representing separate combinations of commuter rail facility types and rail traffic types. The eighth and ninth areas of analysis are concerned with the evaluation of commuter rail accessibility, one being the local component of commuter rail accessibility and the other being the regional component of commuter rail accessibility.

5.2 Rationale for Selection of Study Areas

Although it might seem at first glance that evaluating all nine areas would require a set of study areas comprised of at least as many communities, this may not be the case. Note first that both control and experimental sample observations for the analysis of right-of-way proximity impacts and the analysis of grade crossing proximity impacts can be drawn from within the same community for each type of rail traffic to be analyzed. The analysis of station impacts can also be drawn from within the same community for which observations are drawn for the analysis of "commuter rail only" right-of-way and "commuter rail only" grade crossing proximity impacts. In doing so, care must be taken in defining just which observations are close enough to these rail facilities to experience proximity impacts. There exists a significant amount of literature regarding the physical properties of noise and other impacts generated by these types of rail facilities, which will facilitate defining the appropriate spatial extent of impact areas surrounding these facilities. These observations become the experimental observations, while all other properties in the community not in close proximity to these rail facilities become the control observations. All seven proximity impact analyses and the analysis of local commuter rail access can proceed in this manner. Thus, comparisons of properties from different communities are not necessary to evaluate eight out of the nine areas of analysis. This reduces the amount of data necessary for analysis and limits the amount of bias that might be introduced from confounding variables such as the level of regional accessibility for a community by auto, as well as other community specific variables including tax rate and school quality, all of which are typically significant variables in most hedonic models of housing price.

To fully evaluate all nine areas of analysis will hopefully require data from as few as three separate communities. To see how this is so, again recall that three types of rail traffic are to be analyzed separately: commuter rail only, freight rail only, and mixed traffic. For each of these three types of traffic, a separate community must be selected in order to control experimentally for the presence or absence of each different kind of traffic. Each of these three communities, however, can serve for multiple analyses.

For the analysis of proximity impacts, one community can be utilized in evaluating the right-of-way, grade crossing, and station impacts for commuter rail only service. A second community can be utilized in evaluating the right-of-way and grade crossing impacts of freight rail only service. A third and final community can be utilized in evaluating the right-of-way and grade crossing impacts of mixed rail service.

For the analysis of local and regional commuter rail access, the same three communities can be used. In the evaluation of local commuter rail access, either the community selected earlier for the proximity impacts analysis of commuter rail only, or the community selected for the evaluation of the impact of mixed traffic can be used, again with both experimental and control observations selected from within the same community. In the evaluation of regional commuter rail access, there is a requirement for two communities, one from which to draw the experimental observations, and one from which to draw the control observations. Again, the experimental observations can be drawn from the commuter rail only community selected before. The control observations (those from a community with no commuter rail access) can be drawn from the freight rail only community selected before, which by design will have no commuter rail service. Therefore, data from perhaps as few as three communities will be required to evaluate all nine research areas.

Figure 5.2: Massachusetts Kind-of-Community Grouping Scheme

Classification	Description
(1) Urbanized Center	Manufacturing and commercial centers; densely populated; culturally diverse
(2) Economically Developed Suburbs	Suburbs with high levels of economic activity, social complexity and relatively high income levels
(3) Growth Communities	Rapidly expanding communities in transition
(4) Residential Suburbs	Affluent communities with low levels of economic activity
(5) Rural Economic Centers	Historic manufacturing and commercial communities; moderate levels of economic activity
(6) Small Rural Communities	Small towns; sparsely populated; economically undeveloped
(7) Resort/Retirement and Artisan	Communities with high property values; relatively low income levels, and enclaves of retirees, artists, vacationers and academicians

Source: *Municipal Financial Data. 22nd Edition*. Massachusetts Taxpayers Foundation, Inc. pg. 10.

Finally, if time and resources permit, it is possible that additional insights could be made concerning these impacts by duplicating the above analysis upon an additional set of three communities that have differing attributes than the original set of three communities. For instance, several state agencies in Massachusetts utilize a grouping scheme, presented in Figure 5.2, that groups cities and towns having common characteristics into one of seven different categories. Of the 186 towns within the eastern Massachusetts region under consideration, community types 2, 4, 1, and 3 are the most frequent, with 53, 40, 30 and 30 communities in each respective category. For this study, community types 2, 3, and 4 are of primary interest, since it is in these types of communities that the results of this thesis will be most applicable, with the debate concerning the impact of new commuter rail facilities often being the most contentious in these types of areas. The extent of the property value impacts associated with each type of proximity and accessibility impact may vary depending upon the type of community in which the impacts occur. Even if this does not prove to be true, empirical findings may be more defensible when presented to the general public if the findings are obtained from a community with similar characteristics to the community in which the debate is occurring.

5.3 Demographic and Socio-Economic Characteristics of Eastern Massachusetts

In order to facilitate the selection of an appropriate set of study areas and control areas for the analysis of commuter rail proximity and accessibility impacts, a municipal data set was compiled, containing the detailed characteristics of 186 cities and towns in the metropolitan Boston area. As a reference, Figure 5.3 presents an indexed base map of these 186 cities and towns. The development of this data set was accomplished by first obtaining various individual time series data sets available from a number of federal, state, local, and private organizations, including but not limited to:

- Massachusetts Executive Office of Environmental Affairs (EOEA), MassGIS
- Massachusetts Executive Office of Communities Development (EOCD)
- Massachusetts Department of Education
- Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau
- U.S. Dept. of Commerce, Bureau of the Census (STF 3A data, STF 1B data, 1994 TIGER data)
- Central Transportation Planning Staff (CTPS)
- Massachusetts Department of Public Utilities (MDPU)
- U.S. DOT, Federal Railroad Administration (FRA)
- Amtrak
- Springfield Terminal Railway Company
- Conrail
- Massachusetts Bay Transportation Authority (MBTA)

The raw data tables were then reconciled and checked for errors, and various refinements were made where necessary. The combined data set contains more than 170 separate data fields of contemporaneous information, including various geographic, demographic, social, economic development, housing, education,crime, fiscal and financial, transportation service and environmental impact data. The resulting data set was then used as the starting point from which the selection of the study areas proceeded. Major demographic and socio-economic characteristics and an overview of the transportation resources of Eastern Massachusetts follow, provided as context for the ensuing identification of study and control areas.

5.3.1 Demographic Characteristics

Massachusetts ranks as the third most densely populated state in the U.S., with an average of approximately 767 persons per square mile of land area in 1990, and with over 90% of the population living in metropolitan areas as defined by the U.S. Bureau of the Census. The distribution of population throughout the region is presented in Figure 5.4, which shows population density by community for 1992.[140] High population densities are found not only in Boston and immediately surrounding communities, but also in older industrial cities located

[140] Note that all population densities are calculated per square mile of land area only, not per square mile of total or gross area which includes water area as well as strictly land area.

Figure 5.3: Eastern Massachusetts Cities and Towns

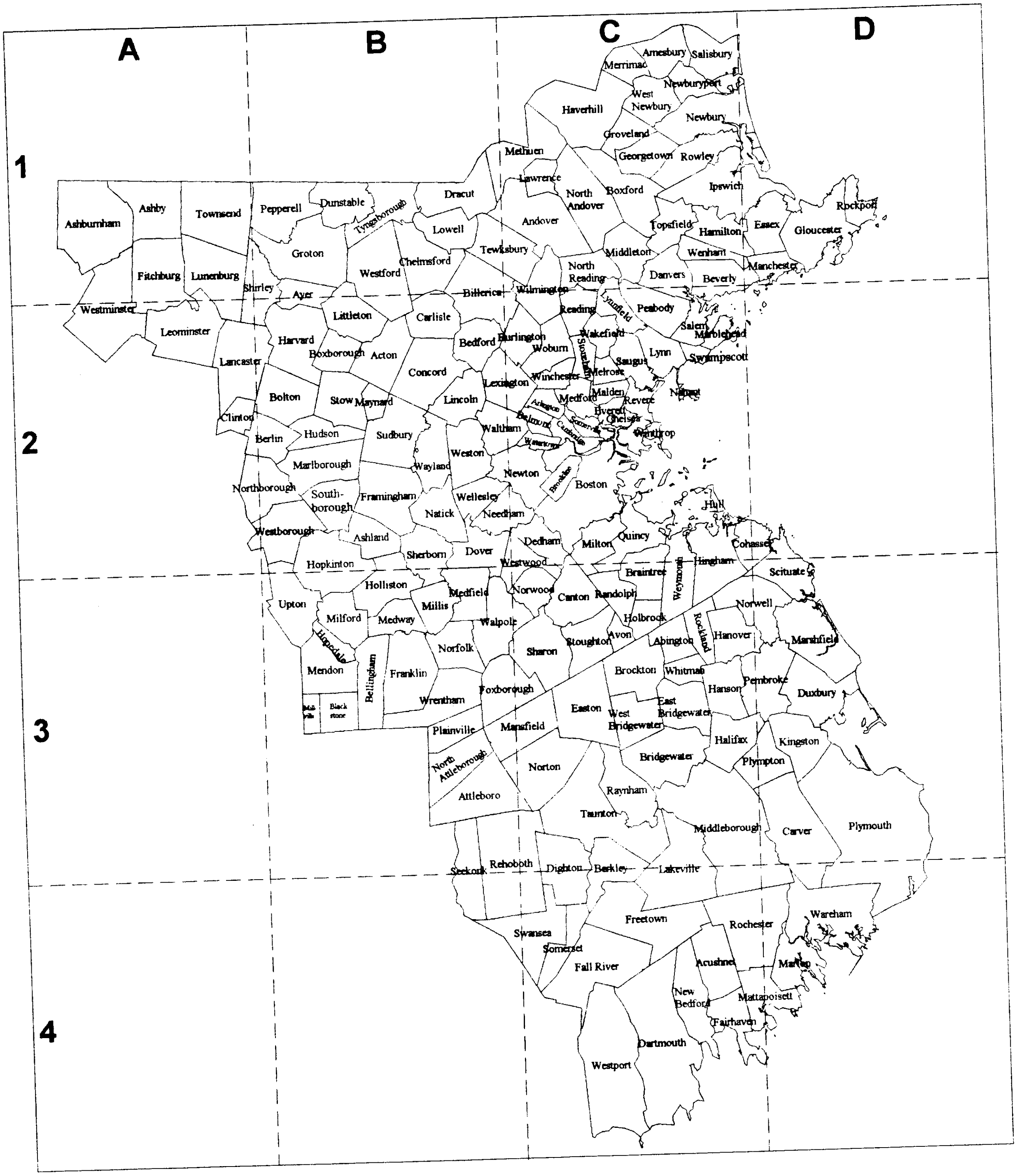


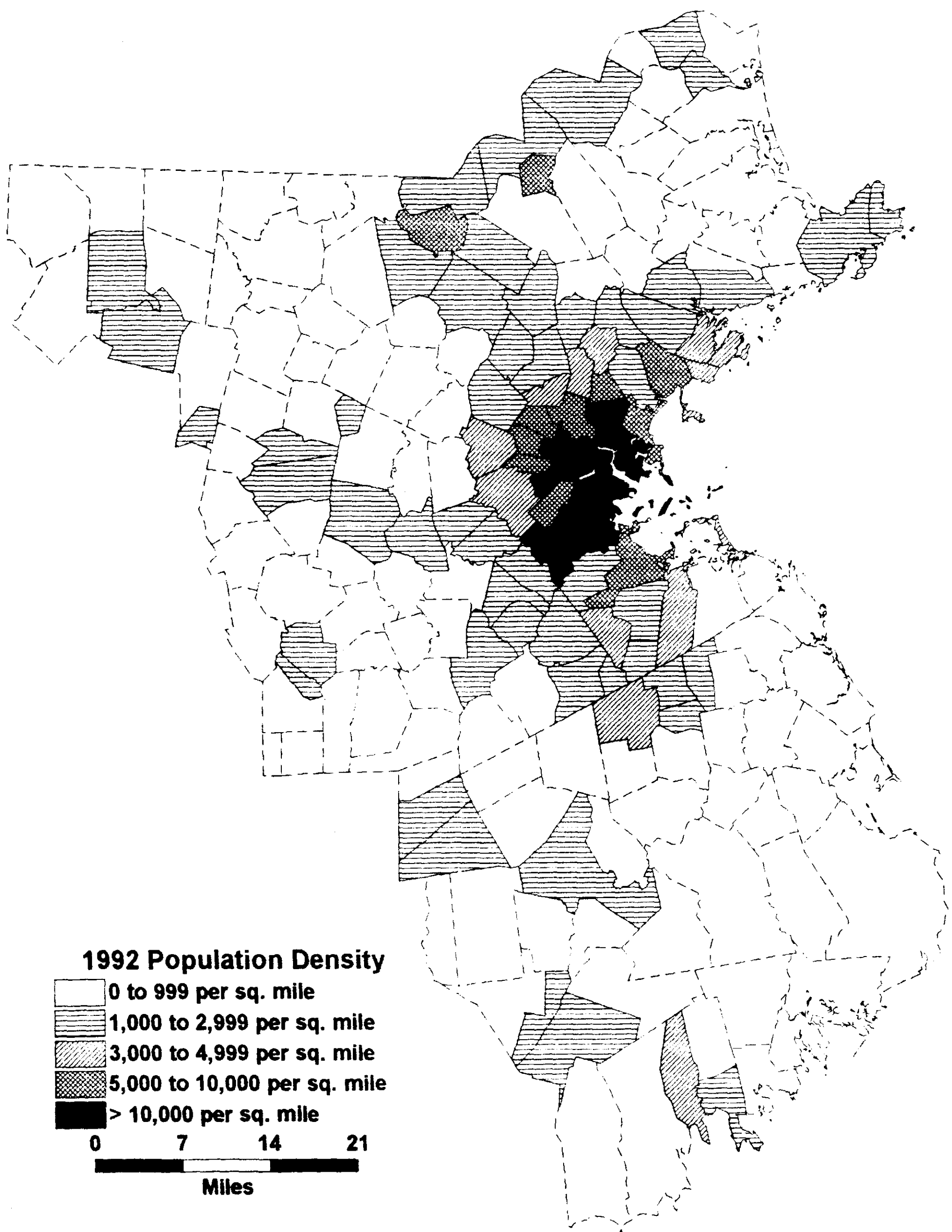
Figure 5.3: Eastern Massachusetts Cities and Towns (continued)

City/Town Name	Map Index
Abington	C 3
Acton	B 2
Acushnet	C 4
Amesbury	C 1
Andover	C 1
Arlington	C 2
Ashburnham	A 1
Ashby	A 1
Ashland	B 2
Attleboro	B 3
Avon	C 3
Ayer	B 1
Bedford	B 2
Bellingham	B 3
Belmont	C 2
Berkley	C 3
Berlin	B 2
Beverly	C 1
Billerica	B 1
Blackstone	B 3
Bolton	B 2
Boston	C 2
Boxborough	B 2
Boxford	C 1
Braintree	C 3
Bridgewater	C 3
Brockton	C 3
Brookline	C 2
Burlington	C 2
Cambridge	C 2
Canton	C 3
Carlisle	B 2
Carver	D 3
Chelmsford	B 1
Chelsea	C 2
Clinton	A 2
Cohasset	D 2
Concord	B 2
Danvers	C 1
Dartmouth	C 4
Dedham	C 2
Dighton	C 4
Dover	B 2
Dracut	B 1
Dunstable	B 1
Duxbury	D 3
East Bridgewater	C 3
Easton	C 3
Essex	D 1
Everett	C 2
Fairhaven	C 4
Fall River	C 4
Fitchburg	A 1
Foxborough	B 3
Framingham	B 2
Franklin	B 3
Freetown	C 4
Georgetown	C 1
Gloucester	D 1
Groton	B 1

City/Town Name	Map Index
Hamilton	C 1
Hanover	C 3
Hanson	C 3
Harvard	B 2
Haverhill	C 1
Hingham	C 2
Holbrook	C 3
Holliston	B 3
Hopedale	B 3
Hopkinton	B 2
Hudson	B 2
Hull	C 2
Ipswich	C 1
Kingston	D 3
Lakeville	C 4
Lancaster	A 2
Lawrence	C 1
Leominster	A 2
Lexington	C 2
Lincoln	B 2
Littleton	B 2
Lowell	B 1
Lunenburg	A 1
Lynn	C 2
Lynnfield	C 2
Malden	C 2
Manchester	D 1
Mansfield	C 3
Marblehead	C 2
Marion	D 4
Marlborough	B 2
Marshfield	D 3
Mattapoisett	D 4
Maynard	B 2
Medfield	B 3
Medford	C 2
Medway	B 3
Melrose	C 2
Mendon	B 3
Merrimac	C 1
Methuen	C 1
Middleborough	C 3
Middleton	C 1
Milford	B 3
Millis	B 3
Millville	B 3
Milton	C 2
Nahant	C 2
Natick	B 2
Needham	B 2
New Bedford	C 4
Newbury	C 1
Newburyport	C 1
Newton	C 2
Norfolk	B 3
North Andover	C 1
North Attleborough	B 3
North Reading	C 1
Northborough	B 2
Norton	C 3

City/Town Name	Map Index
Peabody	C 2
Pembroke	D 3
Pepperell	B 1
Plainville	B 3
Plymouth	D 3
Plympton	D 3
Quincy	C 2
Randolph	C 3
Raynham	C 3
Reading	C 2
Rehoboth	B 3
Revere	C 2
Rochester	C 4
Rockland	C 3
Rockport	D 1
Rowley	C 1
Salem	C 2
Salisbury	C 1
Saugus	C 2
Scituate	D 3
Seekonk	B 4
Sharon	C 3
Sherborn	B 2
Shirley	B 1
Somerset	C 4
Somerville	C 2
Southborough	B 2
Stoneham	C 2
Stoughton	C 3
Stow	B 2
Sudbury	B 2
Swampscott	C 2
Swansea	C 4
Taunton	C 3
Tewksbury	B 1
Topsfield	C 1
Townsend	A 1
Tyngsborough	B 1
Upton	B 3
Wakefield	C 2
Walpole	B 3
Waltham	B 2
Wareham	D 4
Watertown	C 2
Wayland	B 2
Wellesley	B 2
Wenham	C 1
West Bridgewater	C 3
West Newbury	C 1
Westborough	B 2
Westford	B 1
Westminster	A 2
Weston	B 2
Westport	C 4
Westwood	C 2
Weymouth	C 3
Whitman	C 3
Wilmington	C 1
Winchester	C 2
Winthrop	C 2

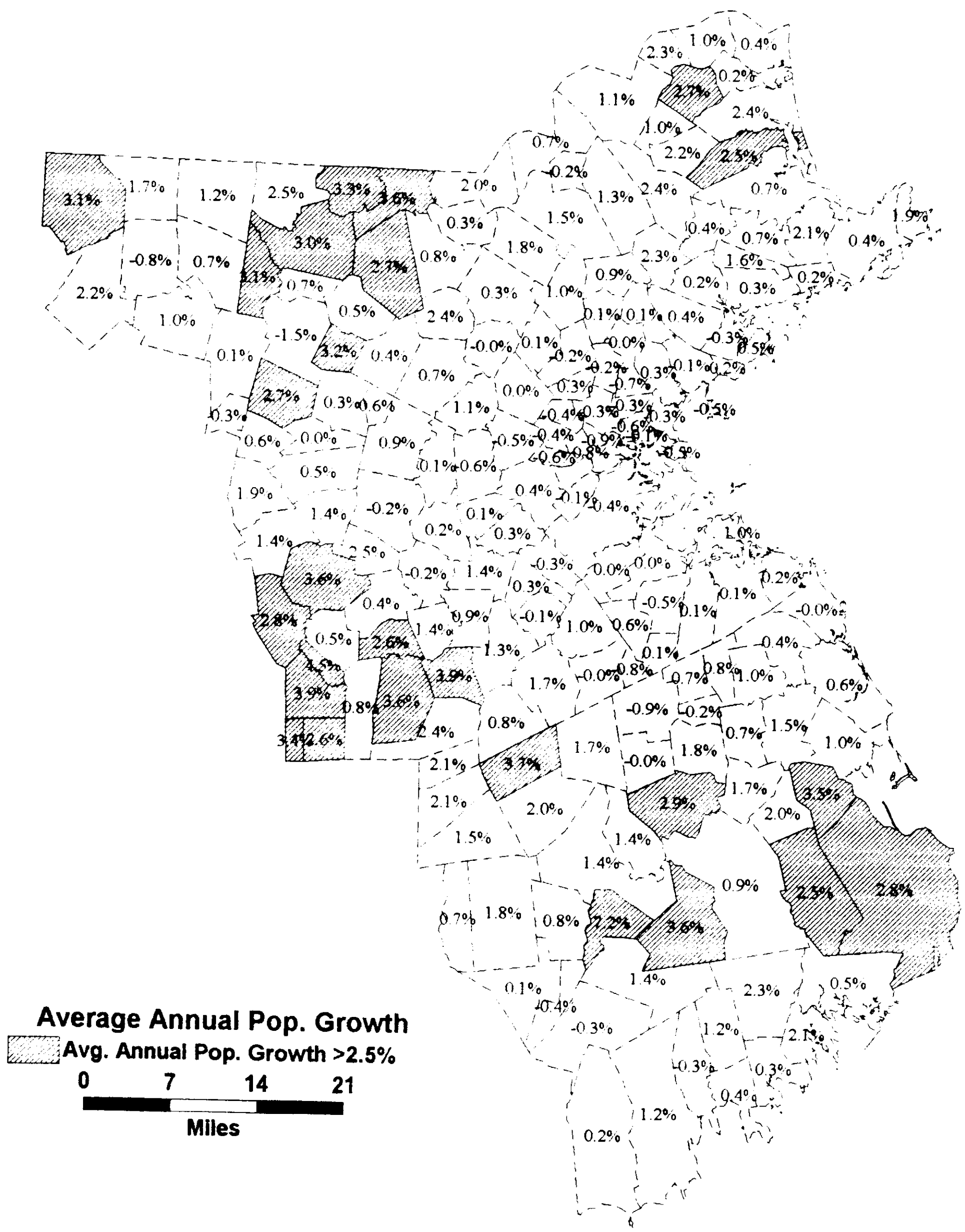
Figure 5.4: Population Density in Eastern Massachusetts



further from Boston such as Lowell, Lawrence, Brockton, and New Bedford.

For the recent period of 1984 to 1994, population growth rates in excess of 3% per year on average were limited primarily to areas far to the south, southwest, and northwest of Boston, as shown in Figure 5.5. Other growth and development measures reveal a similar pattern. For instance, the total number of single family residential building permits issued for the period 1990 to 1994, expressed as a percentage of total single family residential parcels

Figure 5.5: Population Growth In Eastern Massachusetts



existing in 1990, is generally highest in a circumferential band of communities some 30 miles from Boston, including many areas served by Interstate Route 495 (see Figure 5.8). Referring back to Figure 5.4, it can be seen that these high growth rates for the most part occurred in communities having low population densities of less than 1,000 persons per square mile. A scarcity of residential land parcels suitable for construction of new homes in denser inner suburbs has over time led to a "spill-over" of housing demand to communities even further from Boston, in the area of Interstate Route 495 and beyond. In many cases, existing and proposed commuter rail service in Eastern Massachusetts is capable of providing a high level of service to these fast growing outlying communities, thus these communities may benefit the most from commuter rail service.

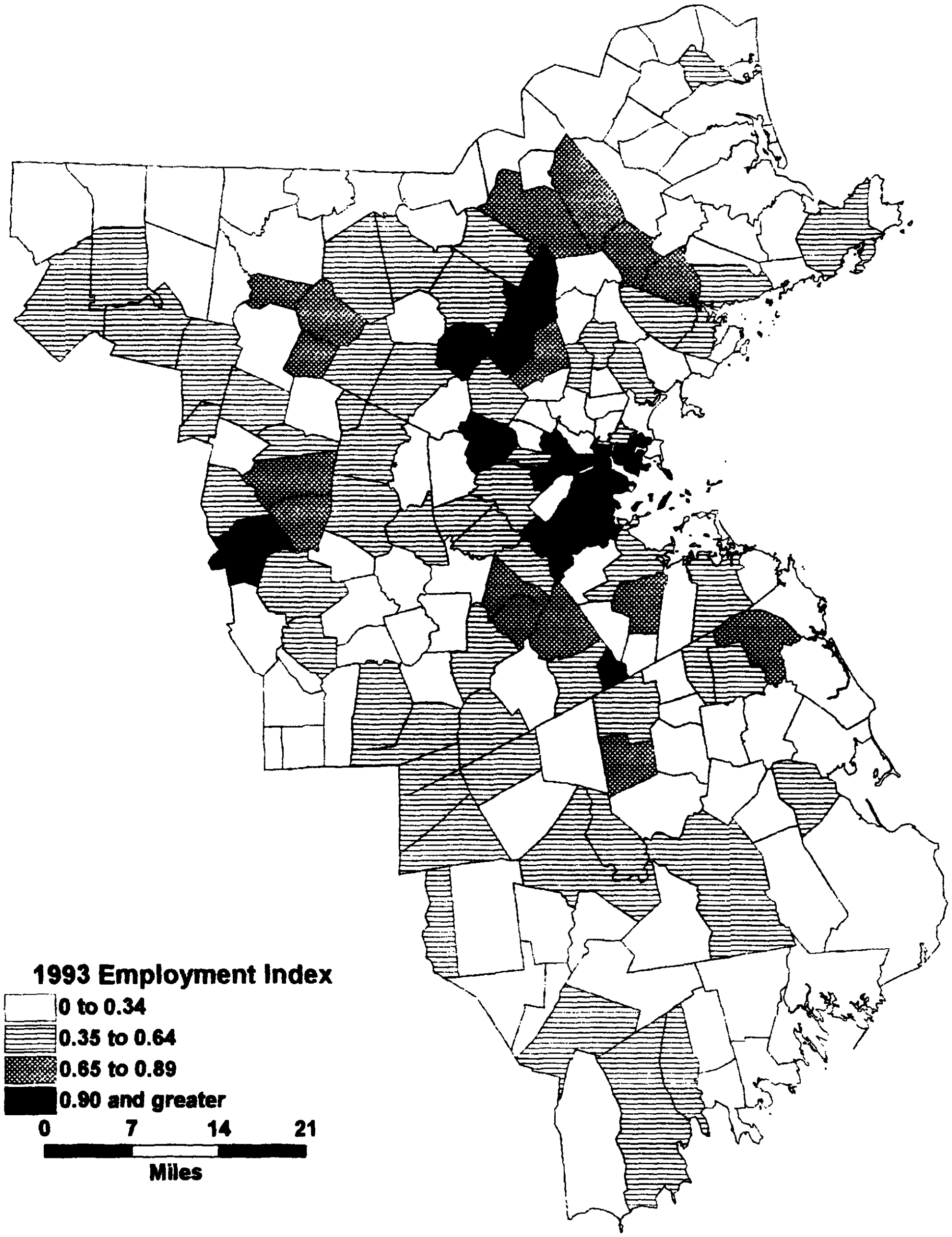
5.3.2 Employment Characteristics

Of all the New England states, Massachusetts has the largest number of jobs, along with a highly skilled workforce. Industries having a strong role in the Massachusetts economy include professional and financial services, health care, computer software, and information technology. The state is also a leader in many areas of research and the development of emerging technologies such as biotechnology. Nearly half of the three million people in Massachusetts who commute daily to work travel to jobs that are located in the state's 25 largest cities and towns.

In order to examine the spatial distribution of employment, employment by place of work data for 1993 were obtained from the Massachusetts Executive Office of Communities Development (EOCD) for communities throughout Eastern Massachusetts. Rather than examining only the absolute quantity of employment located in each community however, the level of employment in each community was related to its resident population. Doing so provides a more meaningful representation of the relative level of economic activity in each community, activity that could perhaps have a significant affect upon the empirical analysis of residential property values undertaken later. Therefore, 1993 population estimates were also obtained from EOCD, and an "employment index" was then developed for each community, calculated as the ratio of employment by place of work to resident population within each community. Figure 5.6 shows the resulting spatial distribution of employment in Eastern Massachusetts. In addition to the large concentration of employment in the metropolitan core area of Boston, Cambridge, and Somerville, employment levels in communities such as Wilmington, Burlington, and Bedford along the State Route 128 corridor to the northwest of Boston are also significant.

Figure 5.7 shows the spatial distribution of employment in major market areas of downtown Boston and the remainder of Boston and Cambridge, which when combined totaled approximately 640,000 jobs in 1990. Given the radially oriented nature of the MBTA commuter rail system, downtown Boston is the primary destination in the morning peak period, with passengers alighting at North Station, South Station, or Back Bay Station. Walking and transfers to rapid transit comprise the vast majority of egress mode trips from

Figure 5.6: Distribution of Employment in Eastern Massachusetts

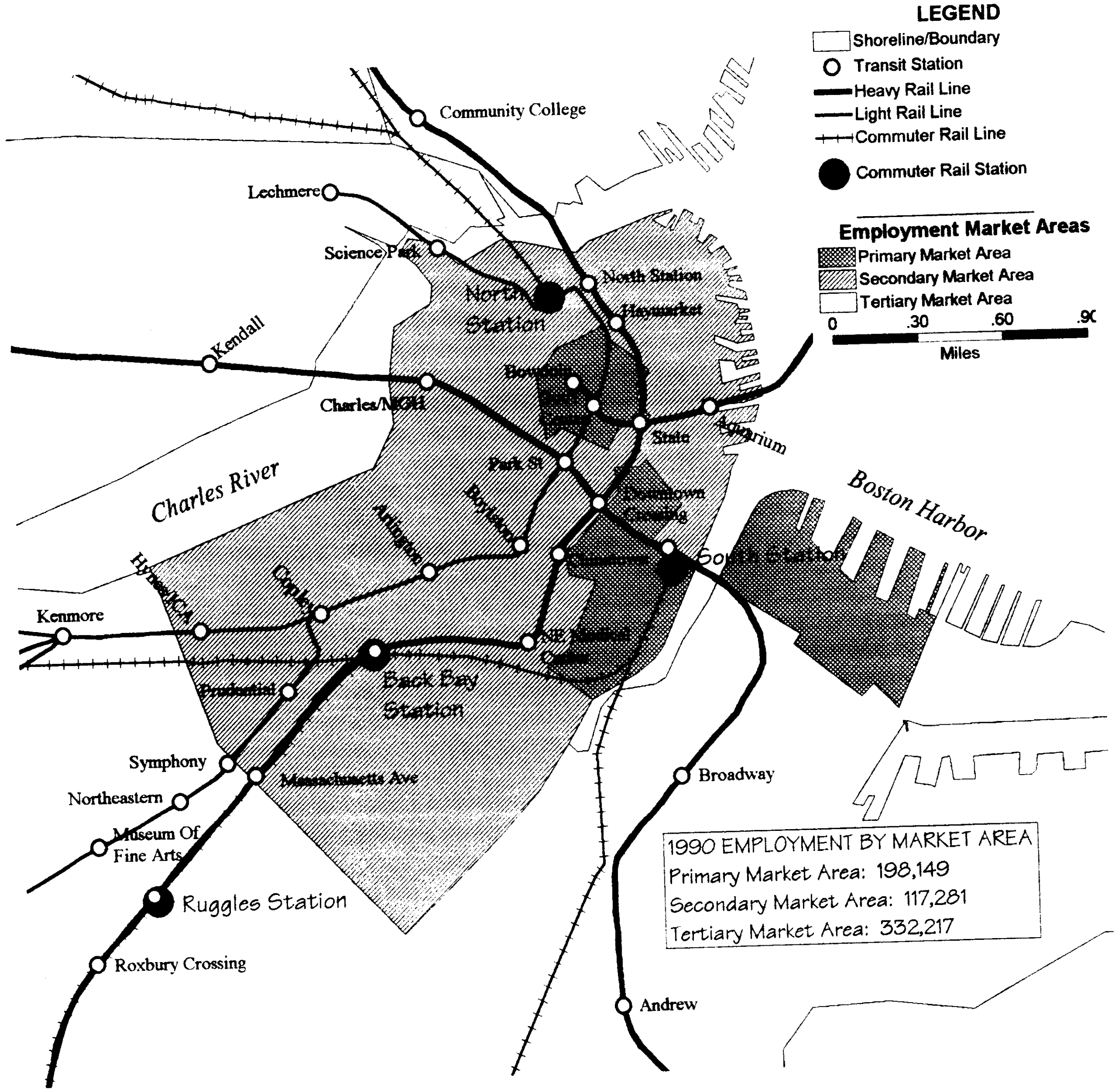


these stations during the morning peak period, with much of the employment located in the primary and secondary market areas accessible by either of these modes of egress.

5.3.3 Housing Market

Various characteristics of the Eastern Massachusetts real estate market and its submarkets must be considered when selecting both an appropriate study area and time frame for analysis. Generally, some of the primary influences affecting the efficient operation of the

Figure 5.7: Distribution of Employment in Boston



real estate market for single-family residential properties include seasonal variation in demand, local economic conditions, government regulatory practices, and the availability of financing.[141] In the case of Eastern Massachusetts, several specific market distortions must be addressed. Title V, a Massachusetts environmental law requiring the repair or replacement of

141 Bloom, George F., and Henry S. Harrison. *Appraising the Single Family Residence*. Chicago: American Institute of Real Estate Appraisers, 1978. pg. 69.

faulty septic systems prior to the sale of a property, took effect April 1, 1995. Real estate sales in the months following the implementation of this law slowed considerably, as homeowners, lawyers, and engineers worked their way through new and often complex regulations.[142] Therefore, sales after March 1995 should not be considered in this analysis.

In metropolitan Boston, 43 communities are provided water and sewer service by the Massachusetts Water Resources Authority (MWRA), which is currently in the later stages of implementing a $4.3 billion clean up of Boston Harbor. The tremendous cost of this project has put substantial upward pressure upon water and sewer rates in the MWRA district. In 1993, MWRA customers were paying on average $545 a year in water and sewer bills. If current projections are realized, however, customers could be paying $2,000 annually by the year 2003. MWRA rates are highest south of Boston, and as of May 1993, it was estimated that property values in the town of Weymouth had declined by approximately one-half to one percent because of increasing water and sewer rates.[143] The impacts on property values, if any, were just beginning to manifest themselves in some communities by late 1993. However, the effect of increasing water and sewer rates has impacted multifamily dwellings and income properties the most, and as such should not affect the analysis of single-family properties in this thesis.

In Massachusetts, all areas of the state saw an escalation in home values during the period of economic growth from 1982 to 1987 popularly known as the "Massachusetts Miracle." Property values peaked in most parts of metropolitan Boston between late 1987 and early 1989.[144] Declines in employment had begun during 1988, however, in large part coinciding with national macroeconomic conditions, and the period of 1988 to 1991 was one of negative economic growth.[145] Consequently, property values declined from this peak period, and by 1992 property values in metropolitan Boston had reached their low point. Decreases in property values during this period of economic recession were somewhat more severe in less affluent communities.

With the economy rebounding somewhat throughout 1992 and experiencing slow growth since then, the decline of the housing market in metropolitan Boston has stopped. Since the low point in early 1992, property values in the region have risen by about 10% during the following three years, or about 3.2% annually. Since 1992, the period between quarter 1, 1992, and quarter 4, 1994, has seen the slowest increases in values, with an increase

[142] Cassidy, Tina., "Mass. is tops in U.S. in home sales again," *Boston Globe*, 14 August 1996, sec. A, pg. 1.
[143] Bushnell, David, "MWRA bills make some houses harder to sell," *Boston Globe*, 29 May 1993, pg. 37.
[144] Case Shiller Weiss, Inc.. Case-Shiller Home Price Index for the Boston-Worcester-Lawrence-Lowell-Brockton, MA-NH CMSA.
[145] Coulson, N. Edward, and Steven F. Rushen, "Sources of Fluctuations in the Boston Economy," *Journal of Urban Economics.*, 38 (1995): pp. 74-93.

of about 4.5% during this two year period, and between the 2nd quarter of 1992 and the 2nd quarter of 1993, there was little if any change in housing prices in metropolitan Boston.[146] In order to avoid any significant changes in housing values due to overall market conditions from influencing the analysis of commuter rail impacts and possibly being misinterpreted as changes in value resulting from commuter rail impacts, these five quarters between early 1992 and early 1993 will serve as the primary time frame from which observations will be selected. Property data for all eight quarters of calendar years 1992 and 1993 have been collected, however, and are available for use if necessary.

5.4 Transportation Resources of Eastern Massachusetts

Unlike many cities in the south and west of the U.S., the patterns of development of many of the largest cities in Massachusetts were determined before the 20th Century. These factors in large degree determine the characteristics of Massachusetts travel patterns. In this section, only work trip related passenger transportation is reviewed, with information regarding other passenger and freight transportation modes and facilities such as airports and freight rail rights-of-way presented in Chapter 6 in relation to their environmental impacts.

5.4.1 Major Highways

The majority of both work and non-work related trips in Massachusetts are accomplished by means of automobile. Statewide, 1990 U.S. Census journey-to-work data reveal that drive alone, carpool, vanpool, and taxi modes combined to account for 83.1% of all trips to work.[147] In 1992, there were a total of 3,578,300 automobiles and light duty trucks (i.e. pickup trucks and vans) registered in Massachusetts.[148] Figure 5.8 shows the major highways serving Eastern Massachusetts. Although major interstate and state highways account for only 6.5% of the lane miles of the Massachusetts roadway network, travel on these major highways accounted for more than one third (36.7%) of all vehicles miles traveled in 1992.[149] Average daily traffic (ADT) levels on these major highways in 1990 ranged from 20,000 to 30,000 on the farther reaches of some radially oriented state highways and Interstate Route 495, to well over well over 100,000 on much of I-95/State Route 128 between Lynnfield and Braintree, and over 188,000 on Interstate 93 near Morrissey Boulevard in Boston.[150] Because of these heavy travel volumes, as well as the relative isolation of some

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146 Preer, Robert, "Housing market roller coaster slows down," *Boston Globe*, South Weekly section, 14 November, 1993, pg. 1.

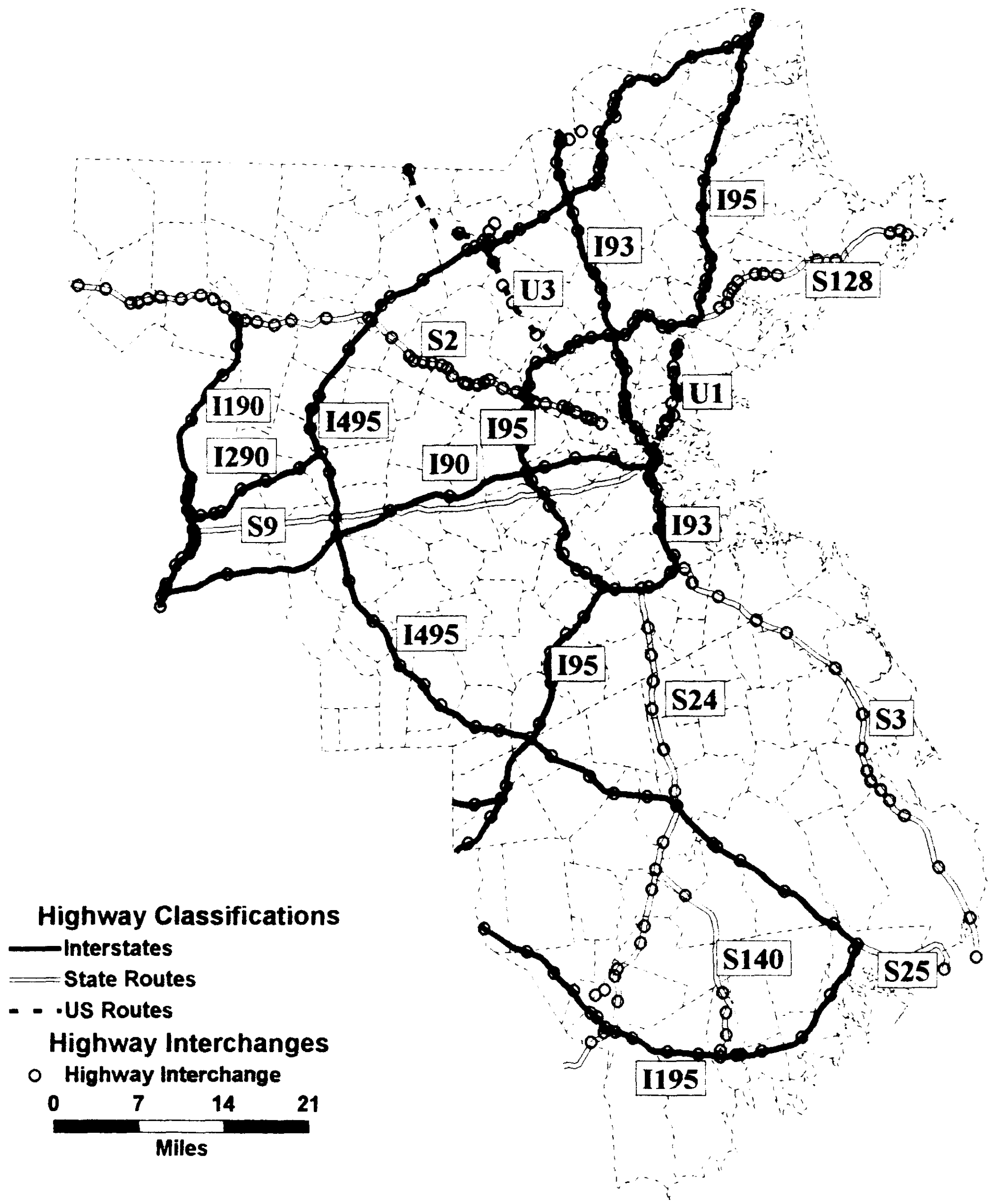
147 Central Transportation Planning Staff. *Transportation Facts for the Commonwealth of Massachusetts*. May 1994. pg. 6.

148 *Ibid*. pg. 7.

149 *Ibid*. pg. 10.

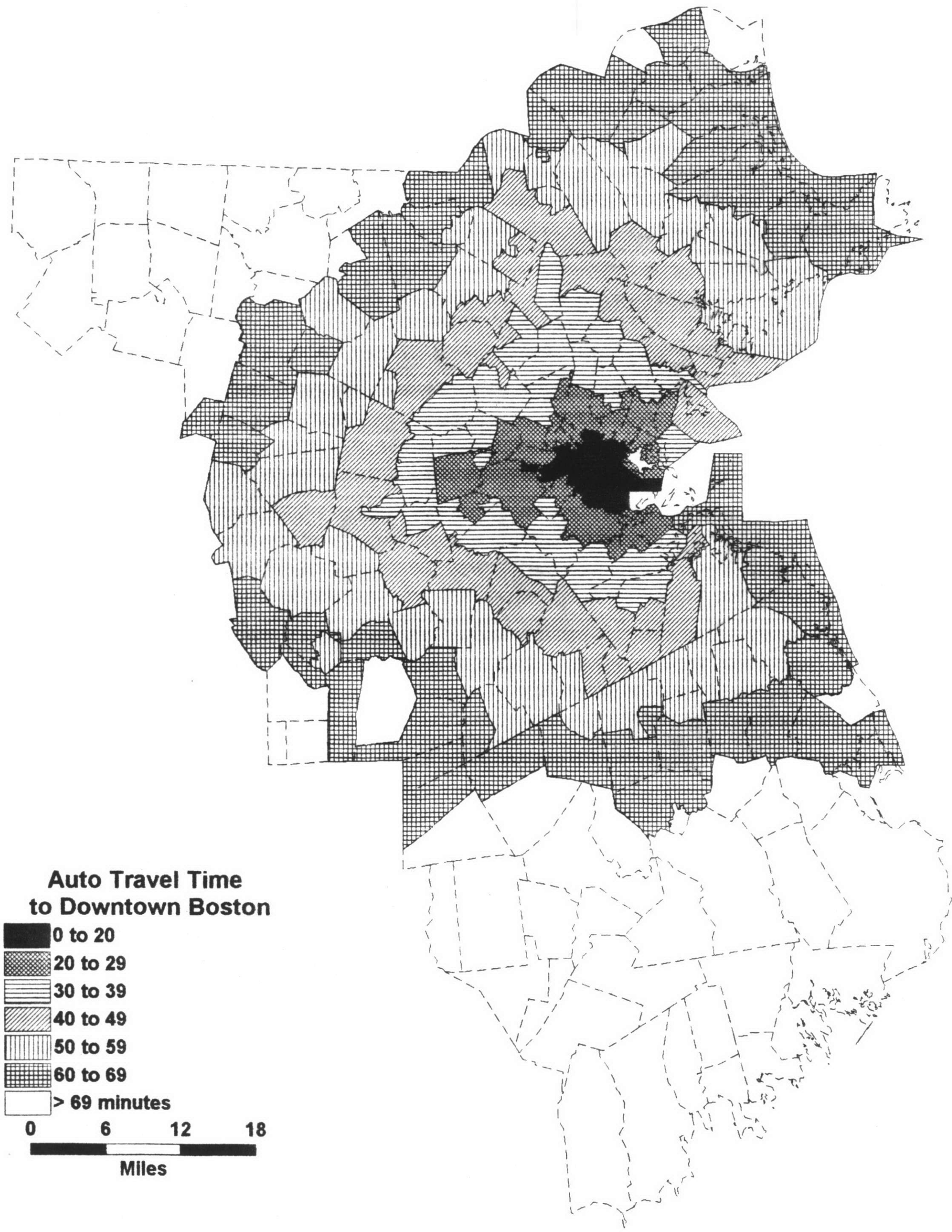
150 Department of Public Works, Bureau of Transportation Planning and Development. *1990 Traffic Volumes for the Commonwealth of Massachusetts*.

Figure 5.8: Major Highways in Eastern Massachusetts



communities from access to the highway network, peak period automobile travel times to Boston can be substantial, as Figure 5.9 shows.

Figure 5.9: AM Peak Auto Travel Time to Downtown Boston (1992)



5.4.2 Commuter Rail Service

The MBTA was established in 1964, and its district currently includes 78 cities and towns in the metropolitan Boston area, with service also provided to approximately 50 communities outside the district. After providing subsidies for several years to local railroads operating commuter rail service, in 1972 the MBTA acquired Penn Central commuter rail properties extending to the west and south of Boston. The MBTA then completed acquisition of the remainder of the commuter rail system in 1976, with the purchase of the Boston & Maine Railroad's commuter rail system to the north of Boston. After the MBTA assumed ownership of these various commuter rail properties, it was decided to utilize a contract operator, which until 1987 was the Boston & Maine Railroad. Since then, Amtrak has provided commuter rail service in eastern and central Massachusetts, under contract to the MBTA. As of 1995, service is operated on 11 lines consisting of 265 routes miles serving North and South Stations (see Figure 5.10). Most of the rights-of-way are shared with freight service operated primarily by Conrail or Guilford Industries, as will be discussed in Chapter 6. Diesel locomotives with push-pull passenger coaches, including newer bi-level coaches, are utilized throughout the commuter rail system. Limited off-peak and weekend service is offered, and monthly pass holders are also allowed free transfers to MBTA heavy rail and light rail service. The MBTA utilizes a distance based zone fare structure, and offers a variety of possible payment instruments. In 1993, approximately 66% of riders were monthly adult pass holders, by far the most common method of fare payment.[151] After a fare increase in 1991 which averaged approximately 16%, MBTA one-way commuter rail fares range between $0.85 and $4.75 (see Table 5.1).

Since the mid-to-late 1980's, the MBTA commuter rail system has experienced dramatic growth in ridership, but for the recessionary period of the late 1980's and early 1990's. In recent years, however, the MBTA commuter rail system has once again become one of the fastest growing commuter rail operations in the U.S. (see Figure 5.11). As of 1995, weekday ridership had surpassed 90,000, continuing dramatic growth that has averaged more than 8.5% annually since 1993. This strong growth in ridership may suggest that MBTA commuter rail service enhances accessibility for a sizable and growing number of commuters. Ridership is poised for continued growth, with the introduction of many new and expanded commuter rail services planned for the near future, including extensions to Newburyport, Worcester, North Easton, New Bedford, Fall River, Middleborough, Plymouth, and Scituate (see Figure 5.12).

[151] Humphrey, Thomas J. *MBTA Systemwide Passenger Survey, Commuter Rail 1993*. Produced by the Central Transportation Planning Staff (CTPS) for the Massachusetts Bay Transportation Authority (MBTA).

Figure 5.10: MBTA Commuter Rail System (1995)

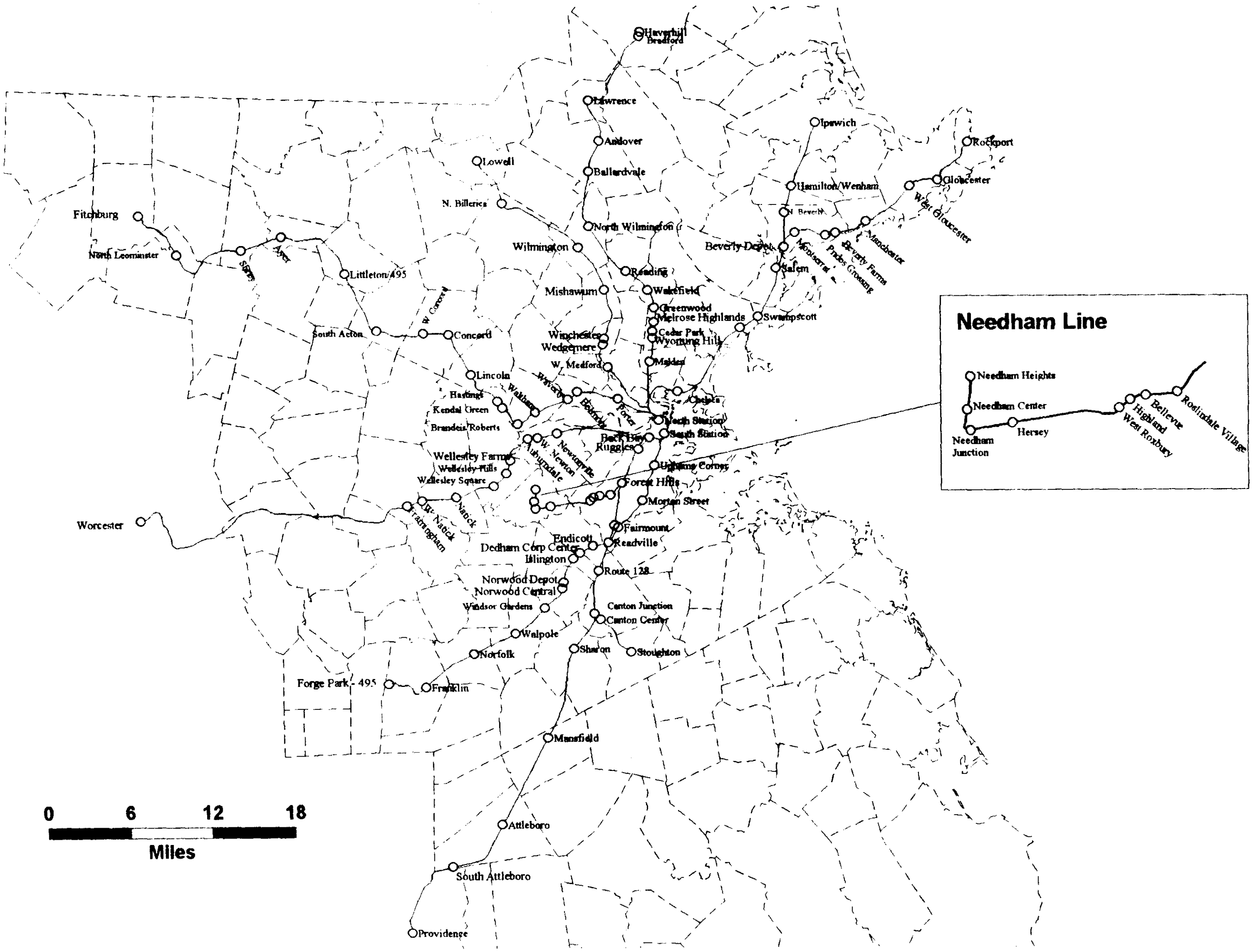


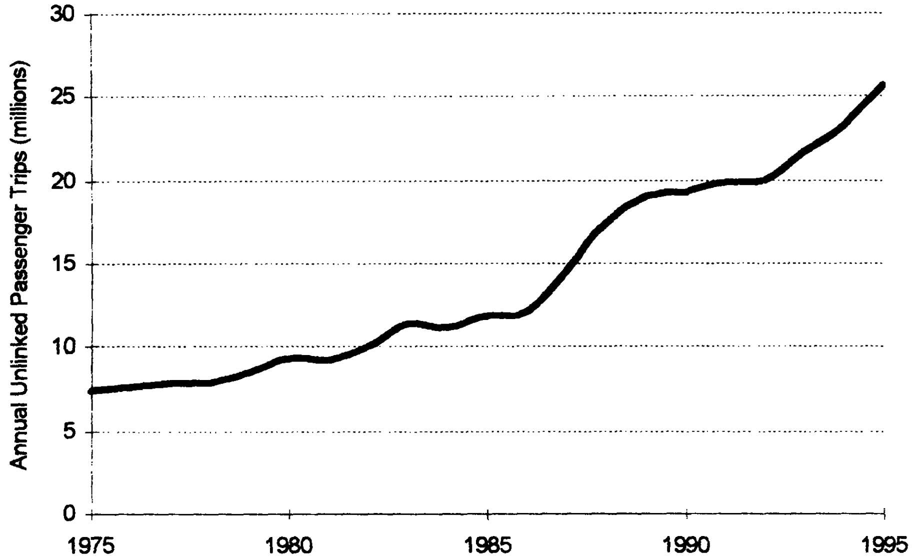
Table 5.1: MBTA Commuter Rail Station Characteristics (1993 - North Side Lines)

Station	City/Town	Line(s) Served	Fare Zone	One-Way Fare	Monthly Pass	Parking Capacity	Minutes to N. or S. Station in the AM Peak	Total Daily Inbound Boardings	Trains During the AM Peak
Porter	Cambridge	Fitchburg	1B	$1.25	$27.00	0	10	60	5
Belmont Center	Belmont	Fitchburg	1	$2.00	$64.00	0	15	81	4
Waverly	Belmont	Fitchburg	1	$2.00	$64.00	0	17	73	4
Waltham	Waltham	Fitchburg	2	$2.25	$72.00	50	21	256	5
Brandeis/Roberts	Waltham	Fitchburg	2	$2.25	$72.00	70	25	332	4
Kendal Green	Weston	Fitchburg	3	$2.50	$82.00	100	29	98	4
Hastings	Weston	Fitchburg	3	$2.50	$82.00	6	31	11	4
Lincoln	Lincoln	Fitchburg	4	$3.00	$94.00	149	34	222	5
Concord	Concord	Fitchburg	5	$3.25	$104.00	40	40	305	5
West Concord	Concord	Fitchburg	5	$3.25	$104.00	204	44	352	5
South Acton	Acton	Fitchburg	6	$3.50	$112.00	287	49	449	5
Littleton/495	Littleton	Fitchburg	7	$3.75	$120.00	15	60	93	4
Ayer	Ayer	Fitchburg	8	$4.00	$128.00	15	71	143	4
Shirley	Shirley	Fitchburg	8	$4.00	$128.00	25	76	46	4
North Leominster	Leominster	Fitchburg	9	$4.75	$136.00	49	84	104	4
Fitchburg	Fitchburg	Fitchburg	9	$4.75	$136.00	20	91	115	4
North Station	Boston	multiple	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Malden Center	Malden	Haverhill/Reading	1B	$1.25	$27.00	165	10	5	7
Wyoming Hill	Melrose	Haverhill/Reading	1	$2.00	$64.00	28	14	75	6
Melrose/Cedar Park	Melrose	Haverhill/Reading	1	$2.00	$64.00	68	16	152	7
Melrose Highlands	Melrose	Haverhill/Reading	1	$2.00	$64.00	28	18	340	7
Greenwood	Wakefield	Haverhill/Reading	2	$2.25	$72.00	6	20	69	6
Wakefield	Wakefield	Haverhill/Reading	2	$2.25	$72.00	117	23	727	7
Reading	Reading	Haverhill/Reading	2	$2.25	$72.00	420	29	898	7
North Wilmington	Wilmington	Haverhill/Reading	3	$2.50	$82.00	20	38	100	5
Ballardvale	Andover	Haverhill/Reading	4	$3.00	$94.00	105	45	111	6
Andover	Andover	Haverhill/Reading	5	$3.25	$104.00	135	49	283	6
Lawrence	Lawrence	Haverhill/Reading	6	$3.50	$112.00	164	54	189	6
Bradford	Haverhill	Haverhill/Reading	7	$3.75	$120.00	304	63	207	6
Haverhill	Haverhill	Haverhill/Reading	7	$3.75	$120.00	0	65	95	6
West Medford	Medford	Lowell	1B	$1.25	$27.00	30	11	285	5
Wedgemere	Winchester	Lowell	1	$2.00	$64.00	103	15	286	5
Winchester Center	Winchester	Lowell	1	$2.00	$64.00	237	18	394	5
Mishawum	Woburn	Lowell	2	$2.25	$72.00	195	25	478	5
Wilmington	Wilmington	Lowell	3	$2.50	$82.00	6	31	376	5
North Billerica	Billerica	Lowell	5	$3.25	$104.00	333	39	529	5
Lowell	Lowell	Lowell	6	$3.50	$112.00	680	47	1,093	5
Chelsea	Chelsea	Rockport/Ipswich	1B	$1.25	$27.00	425	12	38	5
Lynn	Lynn	Rockport/Ipswich	2	$2.25	$72.00	965	21	168	8
Swampscott	Swampscott	Rockport/Ipswich	3	$2.50	$82.00	131	24	498	8
Salem	Salem	Rockport/Ipswich	3	$2.50	$82.00	340	30	1,192	10
Beverly Depot	Beverly	Rockport/Ipswich	4	$3.00	$94.00	200	34	988	10
North Beverly	Beverly	Rockport/Ipswich	5	$3.25	$104.00	82	41	101	6
Hamilton/Wenham	Hamilton	Rockport/Ipswich	5	$3.25	$104.00	85	46	296	6
Ipswich	Ipswich	Rockport/Ipswich	6	$3.50	$112.00	170	53	357	5
Montserrat	Beverly	Rockport/Ipswich	4	$3.00	$94.00	101	36	234	3
Prides Crossing	Beverly	Rockport/Ipswich	5	$3.25	$104.00	6	41	21	3
Beverly Farms	Beverly	Rockport/Ipswich	5	$3.25	$104.00	25	43	92	3
Manchester	Manchester	Rockport/Ipswich	6	$3.50	$112.00	71	48	262	3
West Gloucester	Gloucester	Rockport/Ipswich	7	$3.75	$120.00	44	55	44	3
Gloucester	Gloucester	Rockport/Ipswich	7	$3.75	$120.00	34	60	334	3
Rockport	Rockport	Rockport/Ipswich	8	$4.00	$128.00	88	68	211	3

Table 5.1: MBTA Commuter Rail Station Characteristics (continued) (1993 - South Side Lines)

Station	City/Town	Line(s) Served	Fare Zone	One-Way Fare	Monthly Pass	Parking Capacity	Minutes to N. or S. Station in the AM Peak	Total Daily Inbound Boardings	Trains During the AM Peak
Route 128	Westwood	Attleboro/Stoughton	2	$2.25	$72.00	803	20	1,255	9
Canton Junction	Canton	Attleboro/Stoughton	3	$2.50	$82.00	781	26	1,264	7
Canton Center	Canton	Attleboro/Stoughton	3	$2.50	$82.00	209	29	378	4
Stoughton	Stoughton	Attleboro/Stoughton	4	$3.00	$94.00	500	38	975	4
Sharon	Sharon	Attleboro/Stoughton	4	$3.00	$94.00	518	30	810	5
Mansfield	Mansfield	Attleboro/Stoughton	6	$3.50	$112.00	775	38	1,643	6
Attleboro	Attleboro	Attleboro/Stoughton	7	$3.75	$120.00	781	48	1,213	6
South Attleboro	Attleboro	Attleboro/Stoughton	7	$3.75	$120.00	562	57	849	6
Providence	Providence	Attleboro/Stoughton	9	$4.75	$136.00	150	65	523	4
Hyde Park	Boston	multiple	1	$2.00	$64.00	121	16	417	7
Uphams Corner	Boston	Fairmount	1A	$0.85	$27.00	0	11	47	6
Morton Street	Boston	Fairmount	1B	$1.25	$27.00	50	16	184	6
Fairmount	Boston	Fairmount	1	$2.00	$64.00	33	20	324	6
Newtonville	Newton	Framingham/Worcester	1	$2.00	$64.00	0	16	392	4
West Newton	Newton	Framingham/Worcester	2	$2.25	$72.00	45	20	125	4
Auburndale	Newton	Framingham/Worcester	2	$2.25	$72.00	35	23	208	4
Wellesley Farms	Wellesley	Framingham/Worcester	3	$2.50	$82.00	135	27	395	4
Wellesley Hills	Wellesley	Framingham/Worcester	3	$2.50	$82.00	50	31	296	4
Wellesley Square	Wellesley	Framingham/Worcester	3	$2.50	$82.00	260	34	694	4
Natick	Natick	Framingham/Worcester	4	$3.00	$94.00	71	39	560	4
West Natick	Natick	Framingham/Worcester	4	$3.00	$94.00	163	39	646	6
Framingham	Framingham	Framingham/Worcester	5	$3.25	$104.00	121	44	973	6
Worcester	Worcester	Framingham/Worcester	9	$4.75	$136.00	n/a	60	n/a	3
Back Bay	Boston	multiple	1A	$0.85	$27.00	0	5	6	26
South Station	Boston	multiple	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Endicott	Dedham	Franklin	2	$2.25	$72.00	15	24	199	5
Dedham Corp Center	Dedham	Franklin	2	$2.25	$72.00	497	26	506	7
Islington	Westwood	Franklin	3	$2.50	$82.00	60	30	77	5
Norwood Depot	Norwood	Franklin	3	$2.50	$82.00	223	33	290	5
Norwood Central	Norwood	Franklin	3	$2.50	$82.00	393	33	876	7
Windsor Gardens	Norwood	Franklin	4	$3.00	$94.00	0	36	316	5
Walpole	Walpole	Franklin	4	$3.00	$94.00	377	41	661	5
Norfolk	Norfolk	Franklin	5	$3.25	$104.00	491	47	740	5
Franklin	Franklin	Franklin	6	$3.50	$112.00	185	54	600	5
Forge Park - 495	Franklin	Franklin	7	$3.75	$120.00	722	61	666	5
Readville	Boston	Franklin; Fairmount	2	$2.25	$72.00	0	20	412	11
Forest Hills	Boston	Needham	1B	$1.25	$27.00	195	13	55	5
Roslindale Village	Boston	Needham	1	$2.00	$64.00	143	16	326	5
Bellevue	Boston	Needham	1	$2.00	$64.00	37	20	213	5
Highland	Boston	Needham	1	$2.00	$64.00	178	22	405	5
West Roxbury	Boston	Needham	1	$2.00	$64.00	61	25	347	5
Hersey	Needham	Needham	2	$2.25	$72.00	322	30	547	5
Needham Junction	Needham	Needham	2	$2.25	$72.00	170	33	401	5
Needham Center	Needham	Needham	2	$2.25	$72.00	36	38	178	3
Needham Heights	Needham	Needham	2	$2.25	$72.00	14	42	150	3
Ruggles	Boston	multiple	1A	$0.85	$27.00	0	9	15	12

Figure 5.11: MBTA Commuter Rail Ridership 1975-1995

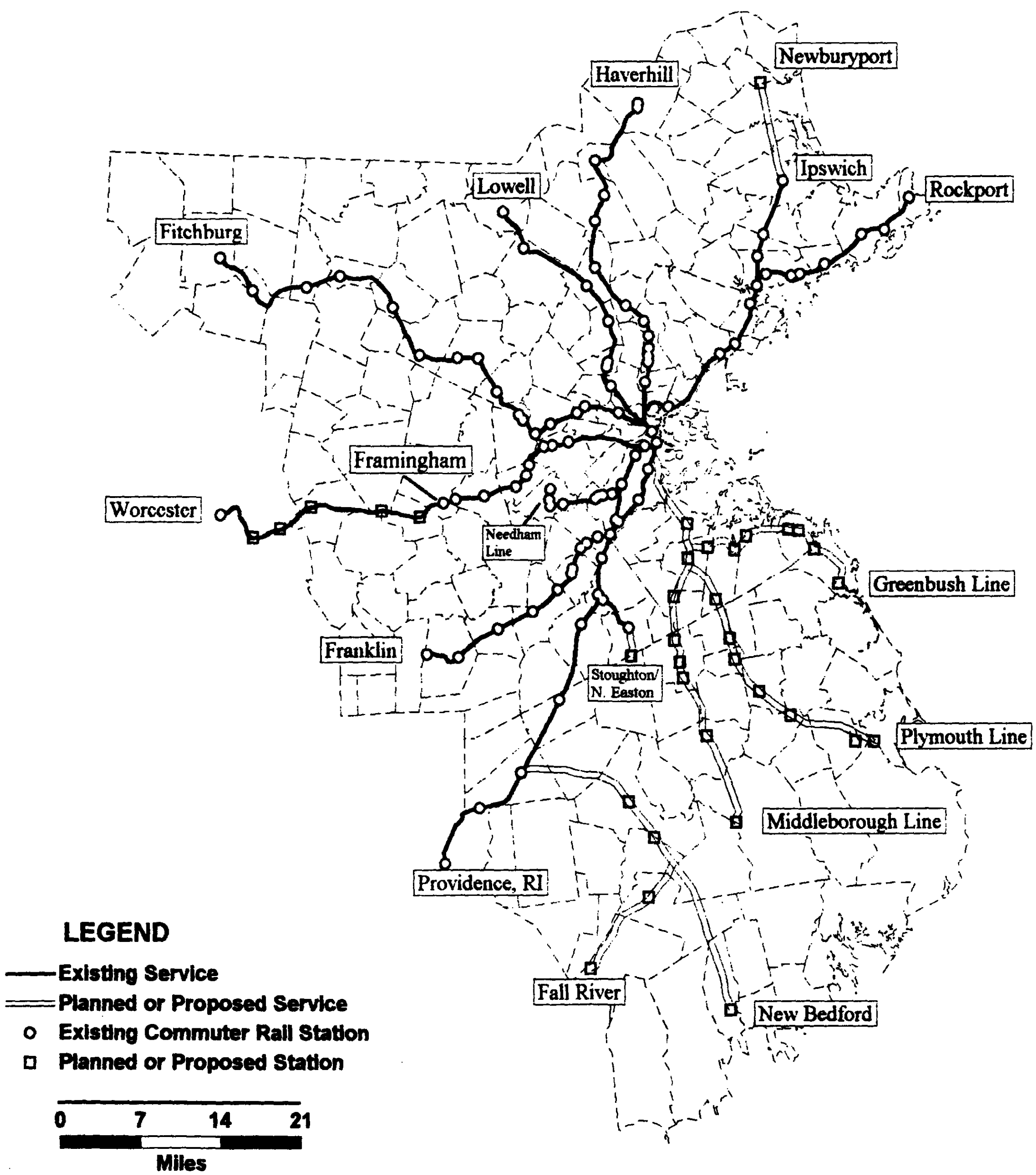


Source: MBTA Annual Reports and MBTA Budget Books, various years.

In determining the level of commuter rail access in communities throughout Eastern Massachusetts, data from the MBTA Systemwide Passenger Survey of 1993 was used.[152] Undertaken in October and November of 1993, this survey contained 19 questions pertaining to travel characteristics (including origin, destination, trip purpose) and service quality, and was the first such comprehensive systemwide data obtained from MBTA commuter rail passengers since 1975. Surveys were distributed on all weekday inbound trains on all lines, from the beginning of service with the first inbound train of the day to at least 9:00 PM. Over 16,000 surveys were completed, approximately 45% of average inbound weekday ridership of 37,000 at the time. Of particular interest were the individual station "Outer Town-Inner Town Matrix Tables," showing how many riders from each town of origin were traveling to each destination town or neighborhood for each individual commuter rail station. From the expanded survey data presented in these matrix tables, it was possible to calculate the total number of commuter rail riders originating in each town, and the different stations at which they boarded. This detailed ridership data, combined with 1993 average annual labor force data obtained from Massachusetts Department of Revenue, allowed the estimation of a commuter rail market capture index, calculated as the number of commuter rail riders originating from within a community as a percentage of the labor force in that community.

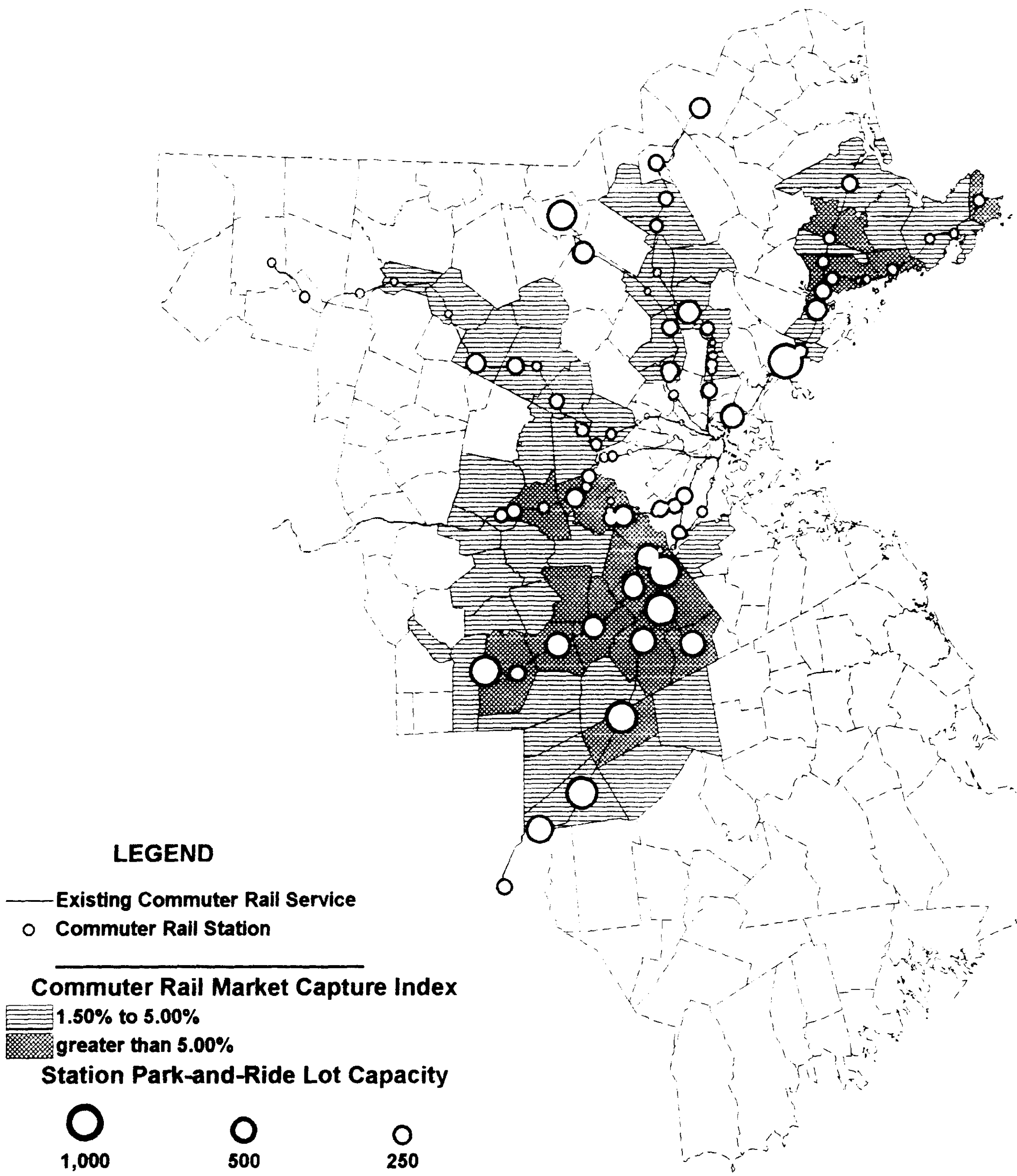
[152] *Ibid.*

Figure 5.12: Planned or Proposed MBTA Commuter Rail Service



This measure was used to represent the extent of commuter rail accessibility in each town, and is presented in Figure 5.13. The figure reveals that communities served by lines extending from South Station appear to capture a significantly higher portion of their labor force than lines to the north of Boston. This may in part be a reflection of having two major alighting

Figure 5.13: Commuter Rail Market Capture (1993)



stations, South Station and Back Bay Station, serving four of the five lines on the south side, and only one, North Station, serving the north side of the system. There are also fewer trip attractions within walking distance of North Station than there are within walking distance of either Back Bay or South Stations. Finally, as Figure 5.13 also shows, stations serving the south side generally have more park-and-ride lot capacity than those on the north side, allowing them to draw a large number of commuters both from the immediate community and from neighboring communities as well.

The extent of the area from which a given station draws boarding passengers varies considerably among stations and lines in the MBTA commuter rail system. Park & ride and walking are the most frequently used modes of station access, and the availability of parking at stations as well as ease of highway access to stations has a significant influence upon the extent of the trip attraction area of each station. Although park & ride is the most widely used mode of station access on all but the Fairmount Line, in the 1993 survey more than half of those surveyed had trip origins that were within towns served directly by the lines and stations that they used. The Attleboro/Stoughton line, having many stations with large park & ride facilities and convenient highway access, had the lowest rate of on-line origins at 57 percent. The Needham Line, with limited parking at stations and more closely spaced stations, had the highest on-line origin rate at 85%. The Framingham, Franklin, Rockport/Ipswich, and Haverhill/Reading Lines all had on-line origin rates of between 70 and 80 percent, and the Lowell, Fitchburg, and Fairmount Lines had on-line origin rates of between 58 and 62 percent. On all MBTA commuter rail lines, downtown Boston was the destination for the great majority of passengers, with passengers alighting at either North Station, Porter Square (with transfers to the Red Line), South Station, or Back Bay Station.

5.4.3 Commuter Boat Service

Regular commuter boat service is provided between the South Shore and Boston. Between the Shipyard in Hingham and Rowes Wharf in downtown Boston, a contract operator for the MBTA provides service weekdays from 6:00 AM to 10:30 AM, and 2:30 PM to 7:30 PM, with 15 minute headways during the peak hours. The one-way fare is $4.00, and the scheduled trip time is 35 minutes. Over 1,000 free parking spaces are provided to commuters at the Hingham Shipyard by the MBTA, the Department of Environmental Management, and the Massachusetts Highway Department. Although ridership varies seasonally, for fiscal year 1993 it averaged over 1,000 riders per weekday in each direction, with approximately half of the ridership originating from within Hingham. Most of the remaining riders originate in the towns of Scituate, Weymouth, Cohasset, and Hull.[153] Thus approximately 500 riders originate from within Hingham, or about 4.85% of the 1993 average annual labor force for the town of Hingham. This is quite substantial, and approximates the percentage of the labor force using

[153] U.S. Department of Transportation, Federal Transit Administration, and Massachusetts Bay Transportation Authority. *Old Colony Railroad Rehabilitation Project, Supplemental Draft Environmental Impact Statement/Report and Section 4(f) Evaluation for Transportation Improvements in the Greenbush Line Corridor*. March, 1995. pg. III-9.

commuter rail from other towns that are directly served by commuter rail stations (which ranges from about .5% for Fitchburg, to about 10% for Canton). Figure 5.14 presents commuter boat mode shares by block group derived from the 1990 U.S. Census journey-to-work data, revealing mode shares of greater than 5% even in areas several miles to the south of the Hingham Shipyard along State Route 3A. Additional commuter boat service is also provided from Pemberton Point in Hull to Boston, although this service provides only one trip per day, with a daily ridership of only about 100 drawn mostly from Hull itself.

5.4.4 MBTA and Local Transit Service

In addition to commuter rail and commuter boat service, the MBTA serves over 560,000 weekday riders on heavy rail, light rail, bus, and trackless trolley. Figure 5.15 shows MBTA heavy rail and light rail service in the metropolitan Boston area. As mentioned previously, commuter rail monthly pass holders are allowed free transfers to MBTA heavy rail or light rail service. Fourteen other regional transit authorities also provide bus and paratransit service throughout Massachusetts to over 100,000 weekday riders.[154]

5.5 Identification of Study Areas

A total of 186 cities and towns in Eastern Massachusetts were included in the initial municipal data set. In selecting the study areas for both the commuter rail only and mixed rail traffic types from the final data set of 81 cities and towns, various criteria were applied in a progressively restrictive process, typically resulting in the final selection of only one or two communities for the analysis of each rail traffic type. In the end, a total of seven study areas are selected, yielding a total of 4,967 possible sales observations during the 1992-1993 period with which to carry out the analysis of property value impacts.

As well as the temporal considerations discussed earlier related to the housing market in Eastern Massachusetts, there are also various spatial issues to be considered in selecting the study areas. The availability of Banker & Tradesman COMPReports is a key consideration in determining the viability of using certain locations as study areas. Although data contained in the COMPReports can be obtained directly from local and county level agencies, this is an extremely labor intensive process, making the availability of this data in a readily available machine-readable format a principal determinant in the selection of potential study areas. Therefore, the availability of COMPReports data reduced the selection subset to 137 communities from the initial 186.

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154 Central Transportation Planning Staff. *Transportation Facts for the Commonwealth of Massachusetts* May 1994. pg. 13.

Figure 5.14: South Shore Commuter Boat Mode Share

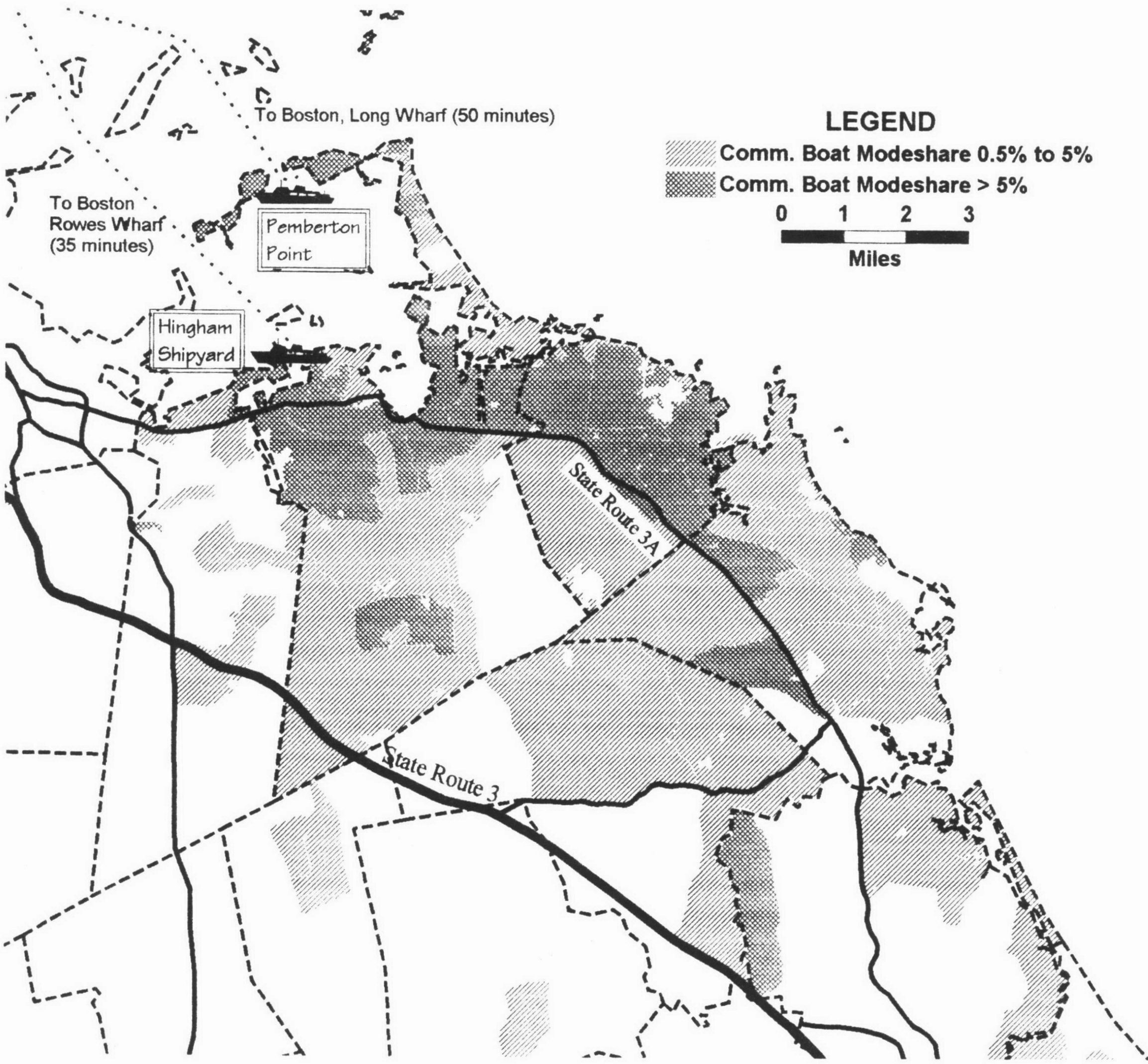
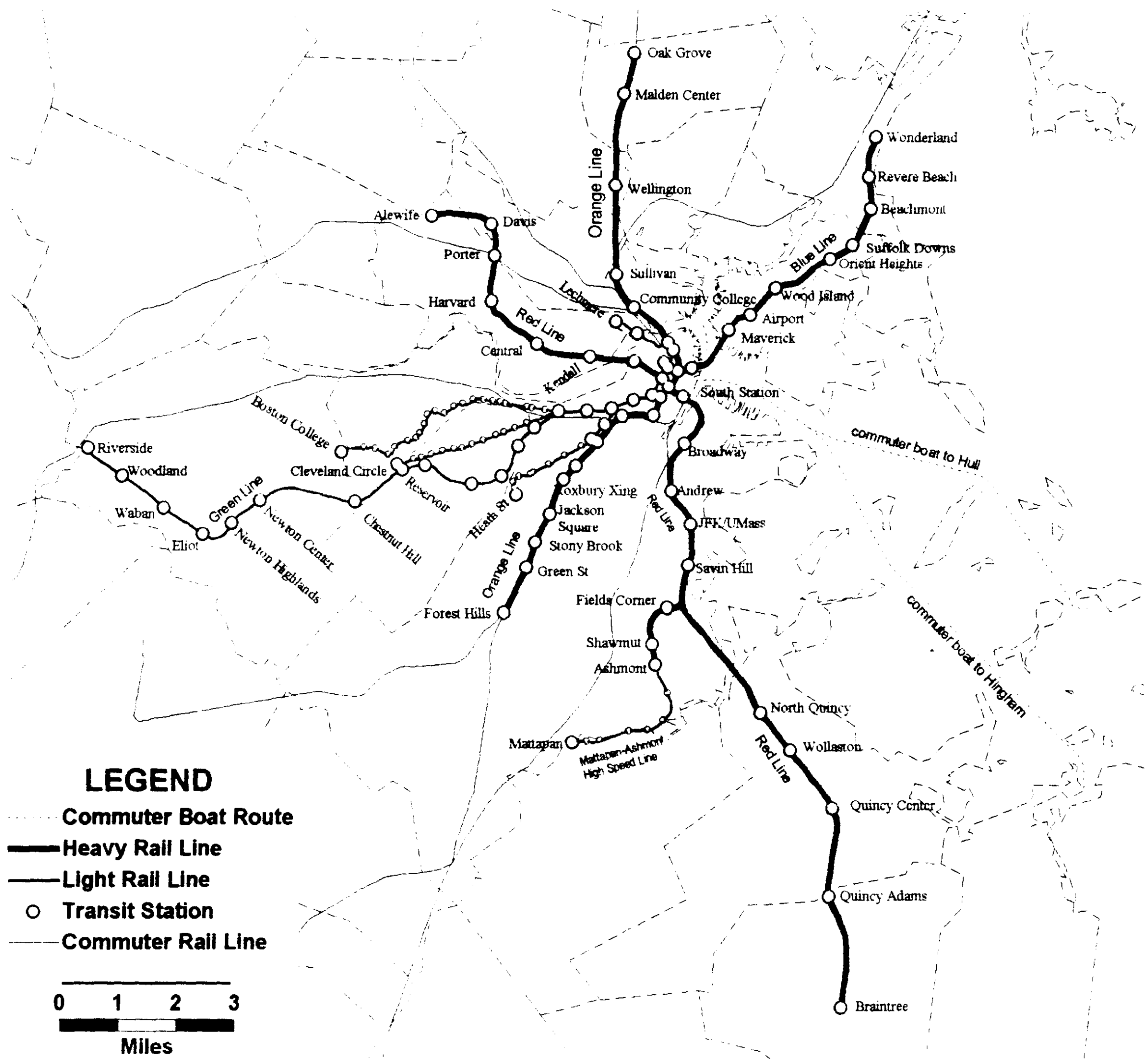


Figure 5.15: MBTA Heavy Rail and Light Rail Service



An additional consideration is the progress of the Old Colony Railroad commuter rail project to the south of Boston. Since 1959, no commuter rail service has been available to a large region to the south of Boston, other than that provided to the small area served by the Stoughton Branch. Currently, construction of the Old Colony Main Line from South Station to Braintree, and the Middleborough and Plymouth Lines from Braintree to Middleborough and Plymouth, respectively, is proceeding, with operation planned for the Fall of 1997. The Greenbush Line, although in the final stages of a supplemental environmental impact review, still faces possible legal hurdles as some communities through which it will pass continue to oppose its reconstruction as described earlier in Chapter 2. Although the vast majority of communities to the south of Boston do not currently have even indirect access to commuter rail service, recent anecdotal evidence suggests that property value impacts have occurred in some communities in anticipation of service to be provided by the Middleborough and Plymouth lines.[155] Therefore, communities to be served by the Old Colony commuter rail project, as described in the March 1992 *Old Colony Railroad Rehabilitation Project Final Environmental Impact Statement/Report*, were removed from consideration as study areas, resulting in a total of 115 communities remaining.

Urban areas, including Boston proper and its surrounding cities, and areas such as Lowell and Brockton, were removed from consideration for two primary reasons. First, ambient noise levels are typically much higher in these communities, and therefore the relative impact of any commuter rail generated proximity impacts would be more difficult to discern. Secondly, there exists the confounding influence of having other transit modes including heavy rail, light rail, and bus more readily available than in other less densely developed communities. This step resulted in 100 communities remaining for consideration. Of these 100, seven had less then 200 total sales records for homes and condos during calendar years 1992 and 1993 combined, and were therefore excluded because of the limited number of potential observations. This resulted in 93 remaining communities. Finally, the employment (by place of work) index estimated for each of these remaining communities as discussed earlier, was used in determining which communities are substantially economically developed, as indicated by an employment index value greater than .70. These communities were excluded from further consideration as study areas, resulting in a data set containing 81 cities and towns.

Rights-of-way having only light or sporadic freight rail service are considered to have only a negligible portion of their proximity impacts generated by this limited freight rail service, with the preponderance of proximity impacts generated by the far more frequent commuter rail

[155] Howley, Kathleen. "South: 'T factor' turns it around." *Boston Globe*, 28 March 1993, pg. 6.

service. Thus, in some cases, these types of right-of-way are included in the analysis of commuter rail only service, as in the case of Norfolk and Melrose. This should increase the possible number of commuter rail study areas, while at the same time reducing or eliminating any significant bias that might otherwise result from attempting to estimate commuter rail only proximity impacts from rail operations on a right-of-way shared with greater levels of freight traffic. The determination of the level of freight traffic during the 1992-1993 time frame was made based on a variety of sources.[156]

For the analysis of mixed commuter rail and freight rail service, rights-of-way having a medium amount of freight rail service, rather than heavy freight rail service, will be focused on. Many of the seven possible study areas for the commuter rail/heavy freight rail mix have other confounding influences including limited access highways. More importantly, as mentioned in Chapter 2, in some areas of the U.S., freight operators that lease trackage rights to commuter rail operators are finding that on their heavy freight routes, growing commuter rail operations are beginning to impede the growth of their core freight business. Therefore, it seems increasingly likely that rights-of-way with moderate amounts of freight rail service or no freight rail service will enjoy better prospects for success as new commuter rail routes, making the analysis of these types of facilities more broadly applicable to current and future practice in the industry. Furthermore, many fewer opportunities for the analysis of grade crossing impacts exist on routes having heavy freight traffic because of the higher degree of grade separation on many of these rights-of-way in the Boston area.

Communities along the Attleboro/Providence commuter rail line are excluded from the analysis. This is one of the two major Amtrak passenger routes in the Boston area, complicating the analysis somewhat with the addition of substantial intercity passenger train movements. More importantly, Amtrak routes in many major metropolitan areas of the U.S. already have commuter rail service, and therefore it is not likely that analysis of such a line would be applicable to many new or expanded commuter rail services. Finally, as in the case of heavy rail routes, many fewer opportunities for the analysis of grade crossing impacts exist on this route because of the higher degree of grade separation.

One final issue concerns the analysis of grade crossing impacts. Data from the Federal Railroad Administration (FRA) , Amtrak, Conrail, Springfield Terminal Railway Company, and the Massachusetts Department Public Utilities (DPU) were used in identifying all eligible at-

[156] Information concerning abandonments and freight rail operations was obtained from Karr, Ronald Dale, *The Rail Lines of Southern New England: A Handbook of Railroad History*. Pepperell, Massachusetts: Branch Lines Press, 1995. Various other sources, including petition documents to the Massachusetts Department of Public Utilities for whistle blowing waivers, and data from the FRA Grade Crossing Inventory were also used to ascertain the level of freight rail traffic on lines in eastern Massachusetts.

grade crossings in metropolitan Boston, and the status of any whistle blowing bans at these crossings. Among other refinements to the data that were necessary, grade crossing data were updated to reflect the time during which whistle blowing bans were implemented at some grade crossings in Acton, Andover, Franklin, and Wilmington, all of which had petitioned the DPU for whistle blowing bans in recent years. Grade crossings at which full or partial whistle blowing bans were implemented *after* quarter 4, 1993, are considered to have *no* whistle blowing ban for the purposes of this study, since property value records are selected for calendar years 1992 and 1993 only, when these bans were not yet in effect.

5.5.1 Commuter Rail Only Study Areas

For the commuter rail only traffic type, twelve communities satisfied the initial criteria of having at least one commuter rail station, and having commuter rail right-of-way with no heavy or medium freight traffic. As discussed above, right-of-way over which light or sporadic freight service operated was not excluded. As can be seen in Table 5.2, no one community provides an ideal study area, however four communities, highlighted in the first part of the table, do exhibit characteristics that make them superior as possible study areas for the commuter rail only analysis. These four communities are Ipswich, Norfolk, Needham, and Melrose.

Ipswich has one commuter rail station, and serves as the outer terminus for the Ipswich branch of the Rockport/Ipswich line. It has a relatively low population density, and also has a low employment to population ratio of .28. It is not located adjacent to any communities having a high employment to population ratio. Rail service in the town is commuter rail only, and the one at-grade crossing in the town has a whistle ban, thus avoiding any confounding influences. There are four AM peak commuter trains. Being the terminal station for this branch of the Rockport/Ipswich line, Ipswich may provide somewhat fewer confounding right-of-way impacts because the track between Ipswich and Newburyport was removed in 1994, having been unused since 1984. There are no other locally undesirable land uses present such as major highways, airports, military bases, or other significant sources of possible environmental impact. The town has 80% orthophoto coverage. There are a total of approximately 493 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Ipswich will provide for the analysis of the impact of local commuter rail access, and station proximity impacts.

Table 5.2: Values of Key Selection Criteria for Possible Study Area Communities

Community	Extent of Digital Ortho-photo Coverage	1991 Pop. Density (persons per sq. mi)	1993 Employ-ment by Place of Work Index	Adjoining Community has High Employment Index	Kind of Community Designation	Number of Commuter Rail Stations in Town	Total Commuter Rail Parking Available(1)	Commuter Rail Trains During the AM Peak Period	Average AM Peak Commuter Rail Schedule Time to Boston(2)	Cost of Commuter Rail Monthly Pass	1992 AM Peak Auto Travel Time to Downtown Boston (minutes)(3)	At-Grade Crossings (without whistle bans)	Limited Access Highway Right-of-Way in the Community	Airport Located in or Nearby Community
COMMUTER RAIL ONLY RAIL TRAFFIC AND COMMUTER RAIL/LIGHT FREIGHT TRAFFIC														
Beverly	0%	2,481	0.37	Yes	5	5	414	8	39.6	$100	54.3	0	Yes	Yes
Gloucester	0%	1,107	0.35	No	4	2	78	3	57.5	$120	66.1	4	Yes	No
Hamilton	0%	503	0.16	No	9	1	85	4	47.0	$104	59.0	0	No	No
Ipswich *	80%	367	0.28	No	9	1	170	4	54.0	$112	63.0	0	No	No
Needham *	100%	2,167	0.55	No	6	4	542	5	36.3	$72	34.6	5	Yes	No
Rockport	0%	1,066	0.17	No	5	1	88	3	68.0	$128	71.0	0	No	No
Stoughton	75%	1,678	0.49	Yes	7	1	500	4	38.0	$94	49.1	5	Yes	No
Melrose *	100%	5,935	0.21	No	5	3	124	7	16.0	$64	32.8	0	No	No
Norfolk *	5%	652	0.25	No	11	1	491	4	47.0	$104	61.0	2	No	Yes
Reading	100%	2,274	0.24	Yes	5	1	420	7	28.0	$72	37.1	0	Yes	No
Swampscott	50%	4,488	0.21	No	5	1	131	6	26.0	$82	43.4	0	No	No
Wakefield	100%	3,344	0.44	No	7	2	123	7	21.5	$72	36.6	0	Yes	No
MIXED COMMUTER RAIL AND MEDIUM FREIGHT RAIL TRAFFIC														
Acton *	0%	885	0.51	No	6	1	287	5	48.0	$112	53.4	4	Yes	No
Belmont	100%	5,225	0.25	Yes	5	2	0	4	16.0	$64	25.3	0	Yes	No
Concord *	55%	697	0.55	Yes	6	2	244	5	41.0	$104	45.2	0	No	Yes
Fitchburg	0%	1,430	0.42	No	4	1	20	4	89.0	$136	87.8	0	Yes	Yes
Leominster	60%	1,313	0.42	No	4	1	49	4	82.0	$136	80.0	0	Yes	Yes
Lincoln	100%	535	0.16	Yes	8	1	149	5	33.0	$94	35.4	0	Yes	Yes
MIXED COMMUTER RAIL AND HEAVY FREIGHT RAIL TRAFFIC														
Billerica	0%	1,462	0.54	Yes	7	1	333	5	39.0	$104.00	51.4	0	Yes	No
Haverhill	0%	1,557	0.32	No	4	2	304	5	65.0	$120.00	67.2	2	Yes	No
Medford	100%	7,037	0.06	No	5	1	30	5	11.0	$27.00	24.9	0	Yes	No
Natick	25%	2,013	0.58	No	7	2	234	5	41.5	$94.00	38.7	0	Yes	No
Newton	100%	4,601	0.49	Yes	5	3	80	5	19.7	$69.33	23.6	0	Yes	No
Wellesley	100%	2,598	0.63	No	6	3	445	5	30.7	$82.00	32.8	0	Yes	No
Winchester*	100%	3,356	0.31	Yes	5	2	340	5	16.5	$64.00	30.0	0	No	No

* Community selected as a study area

(1) Total parking for all commuter rail stations within a community.

(2) Scheduled commuter rail travel time to North Station or South Station. In towns with multiple stations, this time represents a weighted average to reflect stations serviced by different lines or skip stop service on some trains.

(3) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

Norfolk has one commuter rail station, and is located on the outer portion of the Franklin line. It has a relatively low population density, and also has a low employment to population ratio of .25. It is not located adjacent to any communities having a high employment to population ratio. Of the 186 towns in the original data set, Norfolk has the second highest population growth rate between 1984 and 1994 of 39%. Analysis of Norfolk may yield insights into the impacts of commuter rail service in fast growing suburban communities. Rail service in the town is a mix of commuter rail and some light freight service. There are four AM peak commuter trains, and two grade crossings, neither with whistle bans, providing the opportunity to assess grade crossing impacts. There is a small airport in the northern portion of the town, however it is a small general aviation facility, and thus should not prove to be a problem. There are no other locally undesirable land uses present such as highway rights-of-way or any nearby military bases. The town does not have any digital orthophoto coverage currently available, however the area was flown during both 1995 and 1996 and this coverage is awaiting processing. Digitized USGS quads available from MassGIS should provide an adequate basemap for the analysis of right-of-way, grade crossing, and station proximity impacts. There are a total of 457 sales of home and condos during 1992 and 1993 combined. Given its characteristics, Norfolk will provide for the analysis of local commuter rail access, and station, grade crossing, and right-of-way related proximity impacts.

Melrose has three commuter rail stations on the inner portion of the Haverhill line. It has a relatively high population density, but also has a low employment to population ratio of .21. Rail service in the town is a mix of commuter rail and light freight, and there are four at-grade crossings, all four of which have whistle blowing bans, thus providing for the analysis of right-of-way impacts without the possible confounding influence of grade crossing impacts. There are seven AM peak commuter trains. There are no other locally undesirable land uses present such as major highways, airports, military bases, or other significant sources of possible environmental impact. The town has 100% orthophoto coverage, and there are a total of approximately 672 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Melrose will provide for the analysis of local commuter rail access, right-of-way impacts, and to some extent station impacts, although there is little parking available at the three commuter rail stations within the town.

Needham has four commuter rail stations on the outer portion of the Needham line. It has a moderately high population density, and a relatively low employment to population ratio of .55, although this is higher than for Ipswich and Norfolk. Rail service in the town is commuter rail only, and there are five at-grade crossings, none of which have whistle blowing bans. There are five AM peak commuter trains. Route 128 does pass through the eastern portion of the town, however any observations that are close to this highway right-of-way can be identified and eliminated from the analysis. There are no other locally undesirable land uses present such as airports, military bases, or other significant sources of possible environmental impact. The town has 100% orthophoto coverage, and there are a total of 1,049 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Needham will provide for the analysis of local commuter rail access, station impacts, right-of-way impacts, and grade crossing impacts.

The other seven commuter rail only towns were not selected as study areas for various reasons, most often being the presence of locally undesirable land uses such as highway rights-of-way or busy airports, the existence of economic development patterns that might be unfavorable to the analysis of residential property values (e.g., a high employment to population ratio in the town or in nearby towns), or a lack of orthophoto coverage.

5.5.2 Commuter Rail and Medium Freight Rail Study Areas

Acton has one commuter rail station on the middle portion of the Fitchburg line. It has a low population density, and a relatively low employment to population ratio of .51, although this is again somewhat higher than for Ipswich and Norfolk. Rail service in the town is a mix of commuter rail and medium freight traffic, and there are six at-grade crossings, four of which did not have whistle blowing bans prior to the first quarter of 1994. It is the only town having a mix of commuter rail and medium freight traffic that has grade crossings that do not have whistle blowing bans. Of particular interest is the fact that these four grade crossings resulted in enough public concern regarding noise impacts that they were subsequently granted whistle blowing bans effective December 1994 through an act of the state legislature, and against the recommendation of the Massachusetts Department of Public Utilities, the agency that oversees the issuance of whistle blowing bans at at-grade crossings. Therefore, this town may provide particular insights into the impact of grade crossing whistle blowing. Route 2 does pass through the middle of the town, however any observations that are in close proximity to this highway right-of-way can be identified and eliminated from the analysis. There are no airports, military bases, or other significant sources of possible environmental impact. There are five AM peak commuter trains. The town does not have any digital orthophoto coverage available, although the area was flown during 1995 and this is currently awaiting processing. Digitized USGS quads available from MassGIS should provide an adequate basemap for the analysis of right-of-way, grade crossing, and station proximity impacts. There are a total of 998 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Acton will provide for an analysis of local commuter rail access, station impacts, right-of-way impacts, and in particular grade crossing impacts.

Concord has two commuter rail stations on the middle portion of the Fitchburg line. It has a low population density, and a relatively low employment to population ratio of .55, although this is again somewhat higher than for Ipswich and Norfolk. Rail service in the town is a mix of commuter rail and medium freight traffic, and there are five at-grade crossings, all five of which have whistle blowing bans. As with Acton, Route 2 passes through the middle of Concord, however any observations that are in close proximity to this highway right-of-way can be identified and eliminated from the analysis. There are no airports, military bases, or other significant sources of possible environmental impact. Although Hanscom Field is nearby in Bedford, L_{dn} noise contour maps show that impacts of 60 L_{dn} and greater do not affect any significant portions of Concord. There are five AM peak commuter trains. The town has 55% digital orthophoto coverage currently available, with the remaining area flown during 1995 and currently awaiting processing. Digitized USGS quads available from MassGIS should provide an adequate basemap for the portions of the town that do not have orthophoto coverage. There are a total of 598 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Concord will provide for an analysis of local commuter rail access, station impacts, and right-of-way impacts.

5.5.3 Commuter Rail/Heavy Freight Rail Study Areas

Winchester has two commuter rail stations, and serves the inner portion of the Lowell line. It has a moderately high population density, but a relatively low employment to population ratio of .31. Rail service in the town is a mix of commuter rail and medium to heavy freight traffic, and there are no at-grade crossings. There are no highways, airports, military bases, or other significant sources of possible environmental impact. There are five AM peak commuter trains. The town has 100% digital orthophoto coverage currently available. There are a total of 700 sales of homes and condos during 1992 and 1993 combined. Given its characteristics, Winchester will provide for an analysis of local commuter rail access, station impacts, and right-of-way impacts.

5.6 Identification of Control Areas

In order to perform the analysis of the regional component of commuter rail access, it was necessary to identify a set of control areas not served by commuter rail service. Because direct experimental comparisons between study and control town property pairs are not utilized in this thesis, the control areas are not strictly required to directly correspond with a study community. However, in the aggregate, control areas were selected to represent generally similar communities as those selected as study areas, which, although not strictly necessary because of the use of multiple regression analysis in analyzing the effect of regional commuter rail accessibility upon property values, may make the findings more defensible if presented to the general public. The use of town to town comparisons in the selection of the control areas is used here simply as the basis for selecting a group of control areas that in the aggregate were generally similar in many respects to the study areas.

Recall that the regional component of commuter rail accessibility represents access from the station location to the central business district. Communities with commuter rail stations may have an accessibility advantage over those communities that do not have a commuter rail station, or that do not have reasonable access to a station in an adjacent community. Thus, it is hypothesized that residential property values may be higher in communities with commuter rail access than would otherwise be the case. For this portion of the analysis, the regional component of commuter rail accessibility is of primary interest, and thus is considered the primary attribute. Other factors affecting property values are of secondary interest, in as much as these factors must be controlled for while attempting to isolate the separate influence of regional commuter rail accessibility upon property values. The set of control areas was chosen such that they do not have commuter rail access of any consequence to Boston, but are similar in other key characteristics to their associated study areas. This was done to minimize the potential effect of secondary attributes and other confounding influences, thereby facilitating the isolation of the effect of the primary attribute, commuter rail access, upon property values.

In addition to the absence of commuter rail access, the remaining principal characteristics upon which the control areas were selected include:

- AM peak auto travel time to downtown Boston (1992)
- Per pupil expenditure (1993)
- Residential property tax rate (1991)
- Median household income (1989)
- Employment (by place of work) index (1993, ratio of employment by place of work to population)
- Median home sales price (1992)
- Total home and condo sales transactions (1992-1993)
- Journey-to-work public transport mode share (1990)

A number of other characteristics, including population density, population growth rate, crime rate, and percentage of owner occupied housing, although not explicitly appearing in the comparison tables presented later in this chapter, are implicitly considered since control community candidates were chosen only from those communities having been previously assigned the same "kind-of-community" codes as the study community. The derivation of these codes is discussed in more detail later in this chapter. Coastal proximity, and the presence or absence of facilities including airports and military facilities that could be the source of possible confounding proximity impacts, were also considered. The same comprehensive municipal data set used in selecting the study areas was used as the basis for selecting the control areas. Again, a total of 186 cities in towns in Eastern Massachusetts were included initially. The same process of elimination used in selecting the study areas was also used in selecting the control areas, with one exception.

Although all communities designated as being within the Old Colony Railroad Project planning area (as described in the March 1992 *Old Colony Railroad Rehabilitation Project Final Environmental Impact Statement/Report*) were removed from consideration during the selection of the seven study areas, several of these Old Colony planning area communities included in the set of possible control areas. Although anecdotal evidence suggests that some property value impacts may have already occurred as a result of this project, indications are that these impacts have so far been limited to communities to be served directly by the Middleborough and Plymouth lines, currently under construction with initial operation planned for September 1997. Therefore, several communities within the Old Colony planning area but not directly served by the Middleborough and Plymouth Lines were included in the set of possible control areas.

Also, progress on the Greenbush Line of the Old Colony Railroad rehabilitation project has lagged far behind that of the Middleborough and Plymouth Lines, as discussed in Chapter 2. Although a Supplemental Draft Environmental Impact Statement/Report was completed for the Greenbush Line in March 1995 and the go-ahead for selection of a preferred alternative and completion of a Supplemental Final Environmental Impact Statement/Report was announced on November 29, 1995, a fair amount of uncertainty still surrounds the progress of the Greenbush Line. There remains the possibility of legal challenges by opponents of the project, as well as potential funding problems. Also, there are possible operational problems related to the proposed routing of New Bedford/Fall River commuter rail trains via the Middleborough Line and Old Colony Main Line to South Station, as required in a January 1996 state bond funding provision providing $136 million for the Fall River/New Bedford commuter rail service.[157] These additional trains could pose capacity problems on the Old Colony Main Line through Quincy and Dorchester, making it difficult to add further traffic to

[157] Chiasson, George, editor. *CNE Interchange*. Central New England Railway Association. February 1996.

the Main Line from the Greenbush Line in 1999 or 2000, when Greenbush service is anticipated.

Because of these continuing uncertainties surrounding the project, and because final design and construction have not yet begun, the likelihood of any possible property value impacts in towns to be served by the proposed Greenbush Line would seem to be minimal or nonexistent as of the 1992-1993 time frame of this analysis. Therefore, towns to be served by the proposed Greenbush service were included in the set of possible control areas.

After following this elimination process, as well as eliminating the seven towns selected previously as study areas, a total of eighty-three cities and towns remained as candidates for control areas. Fifty-six of these communities satisfied the initial criterion of not having a commuter rail station within their municipal boundaries. It was from this final set of fifty-six communities that the control towns were chosen.

As an aid in grouping communities with like characteristics together for analysis, each community was assigned to one of twelve "kind of community" categories based upon characteristics including population density, population growth rate, household income, unemployment rate, and ratio of employment (by place of work) to population (used as a proxy for the relative level of economic development in a community). Although the Massachusetts Department of Education had previously developed a formal community classification scheme in the mid-1980's as shown previously in Figure 5.2, it was felt that this scheme, using only seven categories of community type, did not provide an adequate level of detail, and as a result grouped communities with substantially disparate characteristics together.[158] For instance, the Massachusetts Department of Education classification system groups such different communities as Boxborough and Weston together under the somewhat broad class of "Residential Suburbs," which are described as "affluent communities with low levels of economic activity." Although broadly speaking these two communities could be described as above, there are marked differences between them. Population growth between 1984 and 1994 was 31.7% for Boxborough, one of the highest in Eastern Massachusetts, whereas Weston actually lost population during the same time period, experiencing a decline in population of 5.6%. Although both communities can be characterized as low density, the population density in Weston (591 persons per sq. mi.) is almost twice that of Boxborough (328 persons per sq. mi.). The ratio of employment (by place of work) to population is only .31 in Weston, but is more than twice as high in Boxborough at .78. Most striking, in addition to the difference in population growth rates, is the difference in household income, with

[158] Massachusetts Taxpayers Foundation. *Municipal Financial Data*, 22nd edition, pg. 10.

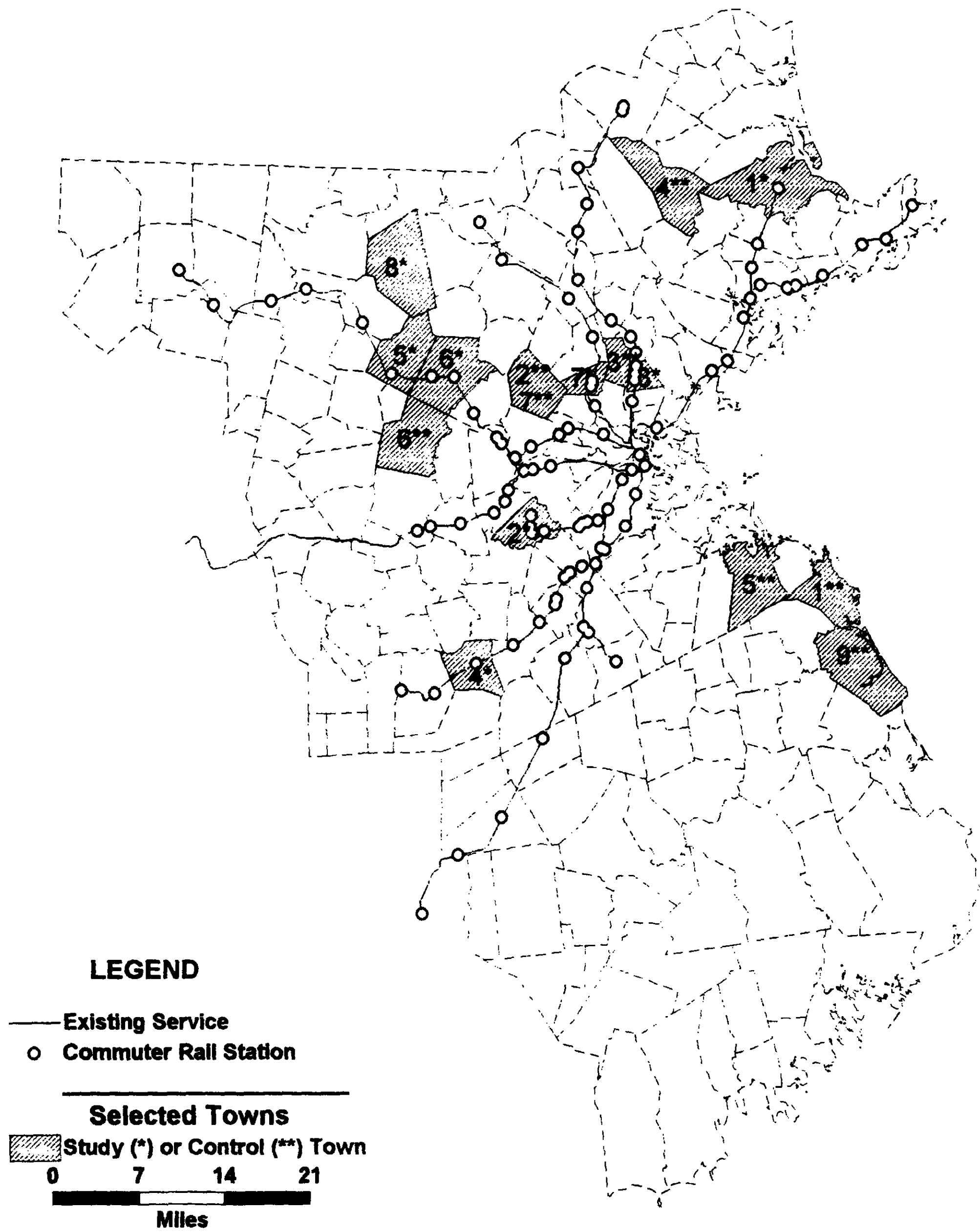
Weston ($95,134) almost twice that of Boxborough ($51,330). Finally, median housing values are 80% higher in Weston ($477,100) than in Boxborough ($266,100). Because of this type of shortcoming exhibited by the existing grouping scheme, the more detailed twelve type scheme was developed and used for this analysis.

The kind-of-community designations, combined with the detailed data available from the municipal data set that was developed, greatly facilitated the selection of comparable control communities for each of the seven study communities. Table 5.3 through Table 5.9 show detailed data for the principal characteristics discussed earlier for the top five control town candidates, presented in rank order of decreasing preference from left to right in each table for each study town. In addition to the six control towns that are chosen, three additional communities including Marshfield, Arlington and Westford were selected as alternates. Figure 5.16 presents all selected study and control communities. These three communities ranked highly as control towns, but were not selected as first choices for a variety of reasons. However, because the control town candidates that were chosen may themselves prove not to be ideal candidates in practice (for instance, the median sales price for Scituate is somewhat higher than that of Ipswich, which may result in fewer comparable sales), these additional communities were selected as alternates, and transaction records and other data were also collected for them. Also, Westford may prove useful for the analysis of heavy freight rail impacts upon property values, with one the heaviest traveled freight lines in New England passing through it.

Control Town for Ipswich

For the study town of Ipswich, the town of Scituate proves to be the best candidate as a control town (see Table 5.3). Scituate compares well on most key characteristics, however the 25% higher median sales price in Scituate may make it more difficult to identify comparable properties, although the 670 total 1992-1993 home and condo sales should provide a more than adequate number of observations from which to do so. Also, Scituate has a somewhat higher median household income. Scituate, like Ipswich, is a coastal community, which may have implications for the measurement of property values. Studies of the impact of proximity to beaches and their attendant recreational opportunities have shown that proximity

Figure 5.16: Study and Control Communities Selected



Note: Westford (8*) is the freight rail only study town, and has no specific corresponding control town. Marshfield (9**) is an alternate control town, and has no specific corresponding study town.

Table 5.3: Principal Characteristics of the Control Town Candidates for Ipswich

Town Name [Rank Order]	Ipswich	Scituate [1]	Marshfield [2]	Foxborough [3]	Easton [4]	Harvard [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	63.0	65.6	69.2	59.0	59.2	66.0
absolute difference from Ipswich -->	-----	2.6	6.2	-4.0	-3.8	3.0
relative difference from Ipswich -->	-----	4.1%	9.8%	-6.3%	-6.0%	4.8%
1993 Commuter Rail Market Capture Index (2)	3.97%	0.00%	0.00%	3.59%	3.00%	1.20%
absolute difference from Ipswich -->	-----	-3.97%	-3.97%	-0.38%	-0.97%	-2.77%
relative difference from Ipswich -->	-----	-100.0%	-100.0%	-9.5%	-24.4%	-69.7%
1990-1991 Integrated Per Pupil Cost (3)	$5,287	$4,778	$4,342	$4,800	$4,238	$6,112
absolute difference from Ipswich -->	-----	-$509	-$945	-$487	-$1,049	$825
relative difference from Ipswich -->	-----	-9.6%	-17.9%	-9.2%	-19.8%	15.6%
Residential Property Tax Rate (per $1,000) (4)	$10.05	$11.09	$10.72	$11.71	$12.63	$8.90
absolute difference from Ipswich -->	-----	$1.04	$0.67	$1.66	$2.58	-$1.15
relative difference from Ipswich -->	-----	10.3%	6.7%	16.5%	25.7%	-11.4%
1989 Median Household Income (5)	$42,386	$52,044	$48,986	$45,405	$50,647	$47,299
absolute difference from Ipswich -->	-----	$9,658	$6,600	$3,019	$8,261	$4,913
relative difference from Ipswich -->	-----	22.8%	15.6%	7.1%	19.5%	11.6%
1993 Employment (by place of work) Index (6)	0.28	0.16	0.18	0.52	0.29	0.11
absolute difference from Ipswich -->	-----	-0.12	-0.10	0.24	0.01	-0.17
relative difference from Ipswich -->	-----	-42.9%	-35.7%	85.7%	3.6%	-60.7%
1992 Median Sales Price (7)	$130,000	$162,500	$130,000	$151,700	$120,000	$205,000
absolute difference from Ipswich -->	-----	$32,500	$0	$21,700	-$10,000	$75,000
relative difference from Ipswich -->	-----	25.0%	0.0%	16.7%	-7.7%	57.7%
Total 1992-1993 Home and Condo Sales (7)	493	670	1,110	657	857	240
1990 Journey-to-Work Public Transport Mode Share(8)	4.31%	5.15%	2.29%	4.55%	3.17%	12.75%
Highway Accessibility Notes	Indirect access to Rt 95, Rt 1	No direct highway access	Rt 3	Rt 95, Rt 495	Rt 24	Rt 2, Rt 495
Other Notes	Coastal community	Higher population density; within Old Colony Project planning area, coastal community; 2.77% ferry boat journey-to-work mode share	Higher population density; within Old Colony Project planning area; coastal community	Possible impacts from Northeast Corridor; medium freight traffic on Framingham Branch; 8 grade crossings with no whistle bans	Higher population density; median year built is 16 years more recent	Possible impacts from operations at former Fort Devens military facility and Moore Airfield; 11.87% bus journey-to-work mode share

Notes: Items having significantly unfavorable deviations from the study town are shaded.

(1) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

to beaches results in increased property values.[159,160] Therefore, selection of a control town such as Scituate that is also a coastal community may help to control for some of the qualitative differences that may exist between coastal and non-coastal communities. Care should be taken in analyzing properties in both Ipswich and Scituate to control for proximity to beaches, and thus avoid any confounding influence that this could have upon the measurement of the impact of commuter rail access upon property values. One final note concerning Scituate is that under current proposals for the Greenbush Line project, estimated commuter rail trip times from Scituate to South Station would average about 54 minutes (58 minutes from the proposed Greenbush station, and 51 minutes from the proposed North Scituate station), with four inbound trains in the AM peak. In 1991, Ipswich was also served by four inbound trains in the AM peak, with an average trip time to North Station of 54 minutes. With the service levels proposed for the Greenbush Line in Scituate so closely matched to those that currently exist in Ipswich, any findings from the analysis of property values in Ipswich should provide particularly relevant insights into the potential effect of Greenbush Line service upon property values in the town of Scituate.

The other four control town candidates do not fare as well when comparing characteristics. In particular, Marshfield fares well on all but one important characteristic, having a per pupil expenditure that is 18% less than that of Ipswich.

Foxborough has a relatively high percentage of its labor force (3.59%) using commuter rail from stations located in adjacent towns, with a total of 301 boardings of passengers originating in Foxborough recorded in the 1993 survey data. These Foxborough commuter rail boardings occurred primarily at Mansfield (151) and Sharon (94) stations, with 56 other boardings at Canton Junction, Dedham Corporate Center, Walpole, and Norfolk stations. Foxborough also has a somewhat higher ratio of employment to population than does Ipswich. Freight traffic on the Framingham Branch, with eight grade crossings having no whistle blowing bans, and commuter rail, AMTRAK, and freight traffic on the Northeast Corridor would also pose potential problems related to proximity impacts generated by these facilities and difficulty in adequately controlling for these impacts.

Easton has a relatively high percentage of its labor force (3.00%) using commuter rail from stations located in adjacent towns, with a total of 338 boardings of passengers originating in Easton recorded in the 1993 survey data. These Easton commuter rail boardings occurred primarily at Stoughton (161), Canton Junction (82), and Mansfield (66) stations, with 29 other

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[159] Rinehart, James R., and Jeffrey J. Pompe. "Adjusting the Market Value of Coastal Property for Beach Quality." *The Appraisal Journal*, October 1994. pp. 604-608.
[160] Edwards, Steven F., and F. J. Gable. "Estimating the Value of Beach Recreation from Property Values: An Exploration with Comparisons to Nourishment Costs." *Ocean and Shoreline Management* (1991): pp. 37-55.

boardings at Sharon and Canton Center stations. Also, Easton has a significantly lower per pupil expenditure, and higher residential property tax rate than that of Ipswich.

Harvard has a 58% higher median sales price, which when combined with a total of only 240 sales of homes and condos during 1992-1993, would likely make it extremely difficult to identify an adequate number of comparable properties.

Control Town for Needham

For the study town of Needham, the town of Lexington proves to be the best candidate as a control town (see Table 5.4). Lexington compares well on all key characteristics, however noise contours from Hanscom Airfield in nearby Bedford do extend into the western part of Lexington near the highway interchange of Route 128 and Route 225. Although only a few residential properties are affected by the outermost 55 L_{dn} noise contour, some care should be taken to avoid using observations that are located within this impact zone. Also, the former Lexington Branch right-of-way, now the Minuteman Bikeway, extends for the entire length of the town from the southeast to the northwest. Passenger service on this line was discontinued permanently in January 1977, and although not formally abandoned until 1991, no traffic operated over the line after January 1981. After official abandonment in 1991, the line from North Cambridge near the MBTA Alewife Redline station to Bedford was converted into the Minuteman Bikeway, a recreational facility that has proven to be quite popular with bicyclists, joggers, and in-line skaters. Experience with other rail trails along abandoned railroad rights-of-way in the United States suggests that trail opponents often argue that rail trails will increase crime, trash, and other nuisances, and thereby decrease property values of abutting properties. The few empirical studies related to rail trails, however, suggest that the opposite is true, with a 1987 study of the Burke-Gilman Trail in Seattle revealing no increase in crime and a favorable impact on property values.[161] Therefore, properties located in close proximity to the Minuteman Bikeway should be avoided when attempting to identify comparable properties.

The other four control town candidates do not fare as well when comparing characteristics. In particular, Arlington has a somewhat lower median sales price, which would make it more difficult to identify comparable properties, although this would be lessened by the large number of potential observations. Also, Arlington has a higher residential property tax rate and lower median household income. As in the town of Lexington, the Minuteman

[161] Montange, Charles H. *Preserving Abandoned Railroad Rights-of-Way for Public Use: A Legal Manual*. January, 1989. pp. 139-140.

Table 5.4: Principal Characteristics of the Control Town Candidates for Needham

Town Name [Rank Order]	Needham	Lexington [1]	Arlington [2]	Lynnfield [3]	Milton [4]	Marblehead [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	34.6	36.3	30.8	44.0	30.6	49.8
absolute difference from Needham -->	-----	1.7	-3.8	9.4	-4.0	15.2
relative difference from Needham -->	-----	5.0%	-11.0%	27.2%	-11.6%	43.9%
1993 Commuter Rail Market Capture Index (2)	7.28%	0.22%	0.22%	0.76%	1.51%	1.23%
absolute difference from Needham -->	-----	-7.06%	-7.06%	-6.52%	-5.77%	-6.05%
relative difference from Needham -->	-----	-97.0%	-97.0%	-89.6%	-79.3%	-83.1%
1990-1991 Integrated Per Pupil Cost (3)	$6,359	$7,041	$6,483	$5,836	$5,250	$6,207
absolute difference from Needham -->	-----	$682	$124	-$523	-$1,109	-$152
relative difference from Needham -->	-----	10.7%	1.9%	-8.2%	-17.4%	-2.4%
Residential Property Tax Rate (per $1,000) (4)	$10.37	$11.16	$12.47	$11.00	$12.33	$9.77
absolute difference from Needham -->	-----	$0.79	$2.10	$0.63	$1.96	-$0.60
relative difference from Needham -->	-----	7.6%	20.3%	6.1%	18.9%	-5.8%
1989 Median Household Income (5)	$60,357	$67,389	$43,309	$58,561	$53,130	$53,333
absolute difference from Needham -->	-----	$7,032	-$17,048	-$1,796	-$7,227	-$7,024
relative difference from Needham -->	-----	11.7%	-28.2%	-3.0%	-12.0%	-11.6%
1993 Employment (by place of work) Index (6)	0.55	0.56	0.21	0.32	0.18	0.21
absolute difference from Needham -->	-----	0.01	-0.34	-0.23	-0.37	-0.34
relative difference from Needham -->	-----	1.8%	-61.8%	-41.8%	-67.3%	-61.8%
1992 Median Sales Price (7)	$219,590	$249,000	$175,000	$183,000	$170,000	$191,000
absolute difference from Needham -->	-----	$29,410	-$44,590	-$36,590	-$49,590	-$28,590
relative difference from Needham -->	-----	13.4%	-20.3%	-16.7%	-22.6%	-13.0%
Total 1992-1993 Home and Condo Sales (7)	1,049	953	1,135	347	674	768
1990 Journey-to-Work Public Transport Mode Share(8)	10.02%	4.66%	16.24%	2.89%	10.16%	6.47%
Highway Accessibility Notes	Rt 128, indirect access to Mass. Turnpike	Rt 128, Rt 2	Rt 2	Rt 128, Rt 1	Rt 93	No direct highway access
Other Notes	Sporadic freight service on Dover Secondary	Possible noise impacts from Hanscom Field; former Lexington Branch right-of-way (Minuteman Bikeway)	Higher population density; lower % of owner occupied housing; median year built is 10 years older; 15.73% bus and subway journey-to-work mode share	Lower population density; sporadic freight service on Newburyport Branch	MBTA Red Line (Mattapan-Ashmont High Speed Line) access; 6.6% subway journey-to-work mode share, median year built is 10 years older	Higher population density; coastal community; median year built is 10 years older

Notes: Items having significantly unfavorable deviations from the study town are shaded.

(1) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

Bikeway runs along the former Lexington Branch right-of-way through Arlington, and as discussed earlier, existing empirical evidence suggests possible property value impacts from these types of facilities. Finally, Arlington has a relatively high work trip mode share for public transport modes including bus and MBTA Red Line heavy rail service, which may make Arlington a less than ideal candidate to serve as a control community since it receives a substantial amount of public transportation service itself.

Lynnfield has a significantly longer AM peak auto travel time to downtown Boston, and has sporadic freight service on the Newburyport Branch, but otherwise compares favorably.

Milton has a substantially lower median sales price, again making it more difficult to identify comparable properties, although this too would be lessened somewhat by the large number of sales from which observations could be drawn. Also, Milton has a significantly lower per pupil expenditure and lower ratio of employment to population, as well as a higher residential property tax rate. Milton also has a significant percentage of its labor force (1.51%) using commuter rail from stations located in Boston, with a total of 198 passenger boardings originating in Milton and using stations at Fairmount (89), and Readville (78), with 31 others boarding at Hyde Park and Morton Street stations. Finally, Milton also has access to the MBTA Red Line Mattapan-Ashmont High Speed Line, which could result in a confounding influence upon property values.

Marblehead has a significantly longer AM peak auto travel time to downtown Boston. Also, Marblehead is a coastal community, which unlike the case of selecting Scituate as a control town for Ipswich, is not a desirable attribute in selecting a control town for Needham, a non-coastal community.

Control Town for Melrose

For the study town of Melrose, the town of Stoneham proves to be the best candidate as a control town, comparing favorably on all key characteristics (see Table 5.5). Stoneham does, however, have a moderate percentage of it labor force (1.13%) using commuter rail from stations located in adjacent towns, with a total of 134 passenger boardings originating in Stoneham. Most of these riders board at Melrose Highlands (51) and Wakefield (51) stations, with the remainder spread among several other stations including Melrose/Cedar Park, Greenwood, West Medford, Winchester Center, and Mishawum. The Stoneham Branch rail line was abandoned in 1982 but for its first half mile to a point near Route 93 and the Stoneham town line. Therefore, this line will not pose a problem as far as proximity impacts are concerned.

Table 5.5: Principal Characteristics of the Control Town Candidates for Melrose

Town Name [Rank Order]	Melrose	Stoneham [1]	Arlington [2]	Milton [3]	Peabody [4]	Saugus [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	32.8	31.7	30.8	30.6	44.7	33.9
absolute difference from Melrose -->	-----	-1.1	-2.0	-2.2	11.9	1.1
relative difference from Melrose -->	-----	-3.4%	-6.1%	-6.7%	36.3%	3.4%
1993 Commuter Rail Market Capture Index (2)	2.85%	1.13%	0.22%	1.51%	0.74%	0.14%
absolute difference from Melrose -->	-----	-1.72%	-2.63%	-1.34%	-2.10%	-2.71%
relative difference from Melrose -->	-----	-60.4%	-92.3%	-47.0%	-73.9%	-95.2%
1990-1991 Integrated Per Pupil Cost (3)	$5,085	$4,919	$6,483	$5,250	$4,974	$5,466
absolute difference from Melrose -->	-----	-$166	$1,398	$165	-$111	$381
relative difference from Melrose -->	-----	-3.3%	27.5%	3.2%	-2.2%	7.5%
Residential Property Tax Rate (per $1,000) (4)	$10.45	$11.92	$12.47	$12.33	$8.71	$8.36
absolute difference from Melrose -->	-----	$1.47	$2.02	$1.88	-$1.74	-$2.09
relative difference from Melrose -->	-----	14.1%	19.3%	18.0%	-16.7%	-20.0%
1989 Median Household Income (5)	$44,109	$43,343	$43,309	$53,130	$39,800	$41,919
absolute difference from Melrose -->	-----	-$766	-$800	$9,021	-$4,309	-$2,190
relative difference from Melrose -->	-----	-1.7%	-1.8%	20.5%	-9.8%	-5.0%
1993 Employment (by place of work) Index (6)	0.21	0.35	0.21	0.18	0.45	0.35
absolute difference from Melrose -->	-----	0.14	0.00	-0.03	0.24	0.14
relative difference from Melrose -->	-----	66.7%	0.0%	-14.3%	114.3%	66.7%
1992 Median Sales Price (7)	$162,500	$149,000	$175,000	$170,000	$140,000	$129,000
absolute difference from Melrose -->	-----	-$13,500	$12,500	$7,500	-$22,500	-$33,500
relative difference from Melrose -->	-----	-8.3%	7.7%	4.6%	-13.8%	-20.6%
Total 1992-1993 Home and Condo Sales (7)	672	585	1,135	674	1,112	775
1990 Journey-to-Work Public Transport Mode Share(8)	15.64%	4.65%	16.24%	10.16%	1.63%	6.14%
Highway Accessibility Notes	Indirect access to Rt 93 and Rt 1	Rt 93	Rt 2	Rt 93	Rt 95, Rt 128, Rt 1	Rt 1
Other Notes		Median year built is 19 years more recent	Higher population density; former Lexington Branch right-of-way (Minuteman Bikeway); 15.73% bus and subway journey-to-work mode share	Lower population density; MBTA Red Line (Mattapan-Ashmont High Speed Line) access: 6.6% subway journey-to-work mode share	Sporadic freight service on the Newburyport Branch; median year built is 20 years more recent	Lower population density; light freight service on Saugus Branch; possible impacts from Rockport/Ipswich line; median year built is 16 years more recent

Notes: Items having significantly unfavorable deviations from the study town are shaded.

(1) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

The other four control town candidates do not fare as well when comparing characteristics. In particular, Arlington has a much higher per pupil expenditure, as well as a higher residential property tax rate and a relatively high work trip mode share for bus and MBTA Red Line heavy rail.

Milton has a significantly higher median household income. As before, Milton also has a significant percentage of its labor force (1.51%) using commuter rail from stations located in Boston, as well as access to the MBTA Red Line Mattapan-Ashmont High Speed Line, which could result in a confounding influence upon property values.

Peabody has a significantly longer AM peak auto travel time to downtown Boston and a lower residential property tax rate, as well as sporadic freight service on the Newburyport Branch that could result in potentially confounding proximity impacts.

Saugus has a lower residential property tax rate, and a significantly lower median home sales price which could make it more difficult to identify comparable properties. Sporadic freight service on the Saugus Branch could also result in confounding proximity impacts.

Control Town for Norfolk

For the study town of Norfolk, the town of Boxford proves to be the best candidate as a control town, comparing favorably on all but one characteristic, that being a significantly higher median household income than that of Norfolk (see Table 5.6). Although the total of 428 home and condo sales for the period of 1992-1993 is somewhat lower than in other towns, the almost identical median sales price for 1992 to that in Norfolk suggests that finding comparable properties should not be overly difficult, even given this somewhat small number of observations from which to choose. Note that all five of the potential control candidates are classified as having experienced high levels of population growth between 1984 and 1994, as did Norfolk.

The other four control town candidates do not fare as well when comparing characteristics. In particular, although Westford compares favorably on all of the principal characteristics, one of the most heavily traveled freight lines in New England passes through Westford along the Stony Brook Branch, with four grade crossings having no whistle blowing bans and generating possible proximity impacts that could have a confounding influence upon property values.

West Newbury compares favorably on many characteristics, however median sales price is significantly lower in West Newbury, which when combined with a total of only 210 sales of homes and condos during 1992-1993, would likely make it extremely difficult to identify an adequate number of comparable properties.

Table 5.6: Principal Characteristics of the Control Town Candidates for Norfolk

Town Name [Rank Order]	Norfolk	Boxford [1]	Westford [2]	West Newbury [3]	Hopkinton [4]	Wrentham [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	61.0	55.0	67.3	65.0	53.0	63.0
absolute difference from Norfolk -->	-----	-6.0	6.3	4.0	-8.0	2.0
relative difference from Norfolk -->	-----	-9.8%	10.3%	6.6%	-13.1%	3.3%
1993 Commuter Rail Market Capture Index (2)	8.95%	0.11%	0.76%	0.00%	1.26%	2.83%
absolute difference from Norfolk -->	-----	-8.84%	-8.19%	-8.95%	-7.69%	-6.12%
relative difference from Norfolk -->	-----	-98.8%	-91.5%	-100.0%	-85.9%	-68.4%
1990-1991 Integrated Per Pupil Cost (3)	$4,393	$4,748	$4,730	$4,506	$4,736	$4,457
absolute difference from Norfolk -->	-----	$355	$337	$113	$343	$64
relative difference from Norfolk -->	-----	8.1%	7.7%	2.6%	7.8%	1.5%
Residential Property Tax Rate (per $1,000) (4)	$10.39	$10.75	$9.70	$11.28	$9.71	$11.39
absolute difference from Norfolk -->	-----	$0.36	-$0.69	$0.89	-$0.68	$1.00
relative difference from Norfolk -->	-----	3.5%	-6.6%	8.6%	-6.5%	9.6%
1989 Median Household Income (5)	$63,763	$78,562	$60,566	$56,591	$54,356	$46,331
absolute difference from Norfolk -->	-----	$14,799	-$3,197	-$7,172	-$9,407	-$17,432
relative difference from Norfolk -->	-----	23.2%	-5.0%	-11.2%	-14.8%	-27.3%
1993 Employment (by place of work) Index (6)	0.25	0.10	0.37	0.13	0.40	0.41
absolute difference from Norfolk -->	-----	-0.15	0.12	-0.12	0.15	0.16
relative difference from Norfolk -->	-----	-60.0%	48.0%	-48.0%	60.0%	64.0%
1992 Median Sales Price (7)	$188,500	$190,000	$186,000	$155,000	$158,900	$151,500
absolute difference from Norfolk -->	-----	$1,500	-$2,500	-$33,500	-$29,600	-$37,000
relative difference from Norfolk -->	-----	0.8%	-1.3%	-17.8%	-15.7%	-19.6%
Total 1992-1993 Home and Condo Sales (7)	457	428	1,035	210	759	535
1990 Journey-to-Work Public Transport Mode Share (8)	6.43%	1.06%	0.62%	1.00%	0.92%	3.04%
Highway Accessibility Notes	No direct highway access	Rt 95	Rt 495	Rt 95, Rt 495	Rt 495, Mass. Turnpike	Rt 95, Rt 495
Other Notes	High population growth; possible noise impacts from small general aviation airport	High population growth; lower population density	High population growth; heavy freight service on Stony Brook Branch; 4 grade crossings with no whistle bans	High population growth; lower population density; median year built 11 years older	High population growth; Conrail Boston Line located at northern border of town ; lower population density	High population growth

Notes: Items having significantly unfavorable deviations from the study town are shaded.

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(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. ***1990-1991 Per Pupil Expenditures by Program***. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

Hopkinton has a significantly shorter AM peak auto travel time to downtown Boston. Also, the Conrail Boston Line located at the northern edge of town, with frequent AMTRAK and heavy Conrail freight traffic (and as of 1994 commuter rail movements servicing Worcester) would also pose potential problems related to proximity impacts generated by this facility and difficulty in adequately controlling for these impacts.

Wrentham compares favorably on only about half of the principal characteristics, having a significantly lower median household income, as well as a significantly lower median sales price. Wrentham also has a relatively high percentage of its labor force (2.83%) using commuter rail from stations located in adjacent towns, with a total of 137 passenger boardings originating in Wrentham. Wrentham commuter rail passengers boarded at Norfolk (52), Franklin (34), and Walpole (31) stations, with the remaining 20 passenger boardings at Mansfield and Canton Center stations.

Control Town for Acton

For the study town of Acton, the town of Hingham proves to be the best candidate as a control town, comparing favorably on all key characteristics (see Table 5.7). Hingham is, however, a coastal community, which may potentially have an effect upon property values in the town, as discussed previously in the case of Scituate. Also, Hingham has one of the most highly patronized commuter boat services in the metropolitan Boston area, running between the Hingham Shipyard and Rowes Wharf in Boston as described earlier. Commuter boat work trip mode share in Hingham for 1990 was approximately 5%. Therefore, any results obtained from comparing Hingham to Acton will certainly be conservative, in that any premium in property values that might be measured for the town Acton using comparable properties from Hingham would likely be even greater if Hingham did not have such a highly patronized commuter boat operation.

The other four control town candidates do not fare as well when comparing characteristics. In particular, Norwell compares favorably on all but one characteristic, and would likely have been selected as the control town but for the fact that only 407 homes and condos were sold during the 1992-1993 period, thus reducing the possibility of identifying an adequate number of comparable sales.

Stow has a relatively high percentage of its labor force (1.43%) using commuter rail from stations located in adjacent towns, with a total of 45 boardings of passengers originating in Stow recorded in the 1993 MBTA survey data, all of which boarded at the South Acton station. Also, only 242 homes and condos were sold in Stow during the 1992-1993 period,

Table 5.7: Principal Characteristics of the Control Town Candidates for Acton

Town Name [Rank Order]	Acton	Hingham [1]	Norwell [2]	Stow [3]	Medfield [4]	Hanover [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	53.4	50.5	54.0	57.0	50.0	56.0
absolute difference from Acton -->	-----	-2.9	0.6	3.6	-3.4	2.6
relative difference from Acton -->	-----	-5.4%	1.1%	6.7%	-6.4%	4.9%
1993 Commuter Rail Market Capture Index (2)	2.65%	0.00%	0.00%	1.43%	5.39%	0.00%
absolute difference from Acton -->	-----	-2.65%	-2.65%	-1.22%	2.74%	-2.65%
relative difference from Acton -->	-----	-100.0%	-100.0%	-46.1%	103.6%	-100.0%
1990-1991 Integrated Per Pupil Cost (3)	$5,686	$5,197	$5,658	$6,236	$4,929	$4,801
absolute difference from Acton -->	-----	-$489	-$28	$550	-$757	-$885
relative difference from Acton -->	-----	-8.6%	-0.5%	9.7%	-13.3%	-15.6%
Residential Property Tax Rate (per $1,000) (4)	$12.32	$12.53	$11.36	$12.53	$12.08	$11.44
absolute difference from Acton -->	-----	$0.21	-$0.96	$0.21	-$0.24	-$0.88
relative difference from Acton -->	-----	1.7%	-7.8%	1.7%	-1.9%	-7.1%
1989 Median Household Income (5)	$61,394	$60,274	$60,462	$66,292	$66,084	$54,759
absolute difference from Acton -->	-----	-$1,120	-$932	$4,898	$4,690	-$6,635
relative difference from Acton -->	-----	-1.8%	-1.5%	8.0%	7.6%	-10.8%
1993 Employment (by place of work) Index (6)	0.51	0.51	0.65	0.34	0.32	0.46
absolute difference from Acton -->	-----	0.00	0.14	-0.17	-0.19	-0.05
relative difference from Acton -->	-----	0.0%	27.5%	-33.3%	-37.3%	-9.8%
1992 Median Sales Price (7)	$191,500	$200,000	$185,000	$175,000	$203,000	$152,000
absolute difference from Acton -->	-----	$8,500	-$6,500	-$16,500	$11,500	-$39,500
relative difference from Acton -->	-----	4.4%	-3.4%	-8.6%	6.0%	-20.6%
Total 1992-1993 Home and Condo Sales (7)	998	775	407	242	564	457
1990 Journey-to-Work Public Transport Mode Share(8)	3.55%	8.96%	2.96%	2.82%	5.01%	3.92%
Highway Accessibility Notes	Rt 2	No direct highway access	Rt 3	Rt 495, near Rt 2	No direct highway access	Rt 3
Other Notes		Within Old Colony Project planning area; coastal community; similar population density; median year built 14 years older; 5.09% ferry boat journey-to-work mode share	Within Old Colony Project planning area; lower population density	Lower population density; possible noise impacts from small general aviation airport	Medium freight traffic on Framingham Branch; 7 grade crossings with no whistle bans	Within Old Colony Project planning area

Notes: Items having significantly unfavorable deviations from the study town are shaded.

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(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

thus significantly reducing the possibility of identifying an adequate number of comparable sales.

Medfield has a relatively high percentage of its labor force (5.39%) using commuter rail from stations located in adjacent towns, with a total of 315 boardings originating in Medfield. Medfield commuter rail passengers boarded at Walpole (188), Needham Junction (46), Dedham Corporate Center (39), and Norwood Central (18) stations, with the remaining 24 passengers boardings at Hersey, Norwood Depot, Windsor Gardens, Norfolk, Islington, and Norfolk stations. Also, Medfield has a significantly lower per pupil expenditure, and the Framingham Branch through Medfield sees significant amounts of freight traffic and has seven grade crossings with no whistle blowing bans, thereby posing a variety of potential problems related to proximity impacts generated by these rail facilities.

Hanover has a significantly lower per pupil expenditure, as well as a significantly lower median sales price. Hanover also has just over 400 home and condo sales for the 1992-1993 period, which when combined with the significantly lower median sales price would make the identification of comparable properties difficult.

Control Town for Concord

For the study town of Concord, the town of Sudbury proves to be the best candidate as a control town, comparing favorably on all but one key characteristic, having a significantly lower per pupil expenditure than Concord (see Table 5.8). This may require the explicit consideration of this school quality proxy variable when comparing properties located in each of the towns, especially since the magnitude and direction of the difference in per pupil expenditure would have a positive bias upon property values in Concord, which might otherwise be misinterpreted as being the result of commuter rail access. There is also sporadic Conrail freight service on the South Sudbury industrial track, however the remainder of the Framingham & Lowell line from South Sudbury to West Concord was abandoned in 1982, and the Central Massachusetts Line was abandoned in 1980.

The other four control town candidates do not fare as well when comparing characteristics. In particular, Southborough compares favorably on all but two characteristics, having a significantly lower per pupil expenditure, and having a median sales price that is 40% less than that of Concord, making an adequate number of comparable properties unlikely.

Wayland has a significantly lower AM peak period auto travel time to downtown Boston, a lower per pupil expenditure, and a much higher residential property tax rate.

Table 5.8: Principal Characteristics of theControl Town Candidates for Concord

Town Name [Rank Order]	Concord	Sudbury [1]	Southborough [2]	Wayland [3]	Norwell [4]	Medfield [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	45.2	46.0	45.0	37.5	54.0	50.0
absolute difference from Concord -->	-----	0.8	-0.2	-7.7	8.8	4.8
relative difference from Concord -->	-----	1.8%	-0.4%	-17.0%	19.5%	10.6%
1993 Commuter Rail Market Capture Index (2)	4.76%	0.95%	0.60%	1.50%	0.00%	5.39%
absolute difference from Concord -->	-----	-3.80%	-4.16%	-3.26%	-4.76%	0.64%
relative difference from Concord -->	-----	-80.0%	-87.3%	-68.5%	-100.0%	13.4%
1990-1991 Integrated Per Pupil Cost (3)	$7,796	$6,402	$5,886	$6,480	$5,658	$4,929
absolute difference from Concord -->	-----	-$1,394	-$1,910	-$1,316	-$2,138	-$2,867
relative difference from Concord -->	-----	-17.9%	-24.5%	-16.9%	-27.4%	-36.8%
Residential Property Tax Rate (per $1,000) (4)	$10.21	$11.63	$10.48	$14.06	$11.36	$12.08
absolute difference from Concord -->	-----	$1.42	$0.27	$3.85	$1.15	$1.87
relative difference from Concord -->	-----	13.9%	2.6%	37.7%	11.3%	18.3%
1989 Median Household Income (5)	$69,917	$79,092	$61,743	$72,057	$60,462	$66,084
absolute difference from Concord -->	-----	$9,175	-$8,174	$2,140	-$9,455	-$3,833
relative difference from Concord -->	-----	13.1%	-11.7%	3.1%	-13.5%	-5.5%
1993 Employment (by place of work) Index (6)	0.55	0.39	0.66	0.34	0.65	0.32
absolute difference from Concord -->	-----	-0.16	0.11	-0.21	0.10	-0.23
relative difference from Concord -->	-----	-29.1%	20.0%	-38.2%	18.2%	-41.8%
1992 Median Sales Price (7)	$260,000	$238,000	$156,500	$239,705	$185,000	$203,000
absolute difference from Concord -->	-----	-$22,000	-$103,500	-$20,295	-$75,000	-$57,000
relative difference from Concord -->	-----	-8.5%	-39.8%	-7.8%	-28.8%	-21.9%
Total 1992-1993 Home and Condo Sales (7)	598	854	440	484	407	564
1990 Journey-to-Work Public Transport Mode Share(8)	5.49%	2.02%	0.98%	3.60%	2.96%	5.01%
Highway Accessibility Notes	Rt 2	No direct highway access	Rt 495, Mass. Pike	Massachusetts Turnpike	Rt 3	No direct highway access
Other Notes	Possible noise impacts from Hanscom field	Sporadic freight service on South Sudbury Industrial Track; median year built 9 years more recent	Conrail Boston Line at southern border of town; light freight on Fitchburg Secondary		Within Old Colony Project planning area; median year built 8 years more recent	Medium freight traffic on Framingham Branch; 7 grade crossings with no whistle bans; median year built 10 years more recent; 4.53% railroad journey-to-work mode share

Notes: Items having significantly unfavorable deviations from the study town are shaded.

(1) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

Norwell has a much higher AM peak period auto travel time to downtown Boston, and a lower per pupil expenditure. Norwell also has a 29% lower median sales price, which when combined with a total of only 407 sales of homes and condos during 1992-1993, would likely make it difficult to identify an adequate number of comparable properties.

Medfield compares favorably on fewer than half of the key characteristics, having a relatively high percentage of its labor force (5.39%) using commuter rail from stations located in adjacent towns, with a total of 315 boardings originating in Medfield as discussed earlier. Also, Medfield has a significantly lower per pupil expenditure, and a significantly higher residential property tax rate. The lower median sales price for Medfield may also make it difficult to identify an adequate sample of comparable properties. Finally, the Framingham Branch through Medfield sees significant amounts of freight traffic and has seven grade crossings with no whistle blowing bans, thereby posing a variety of potential problems related to proximity impacts generated by these rail facilities.

Control Town for Winchester

For the study town of Winchester, the town of Lexington also proves to be the best candidate as a control town, although not ideal (see Table 5.9). Lexington compares well on many but not all key characteristics, and as mentioned earlier noise contours from Hanscom Airfield in nearby Bedford do extend into the westernmost part of Lexington near Route 128 and Route 225, necessitating some care in avoiding the use of observations that are located within this impact zone. Also, the Minuteman Bikeway may have an impact upon the property values of adjacent properties, and therefore sales observations that are in close proximity to the bikeway should not be selected as comparable properties.

Although Lexington is not an ideal control community, the other four control town candidates do not fare as well when comparing characteristics. In particular, Milton has a substantially lower median sales price, again making it more difficult to identify comparable properties, although this would be lessened somewhat by the large number of sales from which observations could be drawn. Also, Milton has a significantly lower median household income. As before, Milton also has a significant percentage of its labor force (1.51%) using commuter rail from stations located in Boston, with a total of 198 passenger boardings originating in Milton and using stations at Fairmount (89), and Readville (78), with 31 others boarding at Hyde Park and Morton Street stations. Finally, Milton also has access to the MBTA Red Line Mattapan-Ashmont High Speed Line, which could result in a confounding influence upon property values.

Table 5.9: Principal Characteristics of the Control Town Candidates for Winchester

Town Name [Rank Order]	Winchester	Lexington [1]	Milton [2]	Arlington [3]	Stoneham [4]	Saugus [5]
1992 AM Peak Auto Time to Boston (minutes) (1)	30.0	36.3	30.6	30.8	31.7	33.9
absolute difference from Winchester -->	-----	6.3	0.6	0.8	1.7	3.9
relative difference from Winchester -->	-----	21.1%	2.0%	2.7%	5.7%	13.0%
1993 Commuter Rail Market Capture Index (2)	4.99%	0.22%	1.51%	0.22%	1.13%	0.14%
absolute difference from Winchester -->	-----	-4.77%	-3.49%	-4.77%	-3.87%	-4.86%
relative difference from Winchester -->	-----	-95.6%	-69.8%	-95.6%	-77.4%	-97.3%
1990-1991 Integrated Per Pupil Cost (3)	$5,772	$7,041	$5,250	$6,483	$4,919	$5,466
absolute difference from Winchester -->	-----	$1,269	-$522	$711	-$853	-$306
relative difference from Winchester -->	-----	22.0%	-9.0%	12.3%	-14.8%	-5.3%
Residential Property Tax Rate (per $1,000) (4)	$11.39	$11.16	$12.33	$12.47	$11.92	$8.36
absolute difference from Winchester -->	-----	-$0.23	$0.94	$1.08	$0.53	-$3.03
relative difference from Winchester -->	-----	-2.0%	8.3%	9.5%	4.7%	-26.6%
1989 Median Household Income (5)	$65,994	$67,389	$53,130	$43,309	$43,343	$41,919
absolute difference from Winchester -->	-----	$1,395	-$12,864	-$22,685	-$22,651	-$24,075
relative difference from Winchester -->	-----	2.1%	-19.5%	-34.4%	-34.3%	-36.5%
1993 Employment (by place of work) Index (6)	0.31	0.56	0.18	0.21	0.35	0.35
absolute difference from Winchester -->	-----	0.25	-0.13	-0.10	0.04	0.04
relative difference from Winchester -->	-----	80.6%	-41.9%	-32.3%	12.9%	12.9%
1992 Median Sales Price (7)	$257,500	$249,000	$170,000	$175,000	$149,000	$129,000
absolute difference from Winchester -->	-----	-$8,500	-$87,500	-$82,500	-$108,500	-$128,500
relative difference from Winchester -->	-----	-3.3%	-34.0%	-32.0%	-42.1%	-49.9%
Total 1992-1993 Home and Condo Sales (7)	700	953	674	1,135	585	775
1990 Journey-to-Work Public Transport Mode Share(8)	8.45%	4.66%	10.16%	16.24%	4.65%	6.14%
Highway Accessibility Notes	Indirect access to I 93	Rt 128, Rt 2	Rt 93	Rt 2	Rt 93, Rt 128	Rt 1
Other Notes		Lower population density; former Lexington Branch right-of-way (Minuteman Bikeway); median year built 11 years more recent	Lower population density; MBTA Red Line (Mattapan-Ashmont High Speed Line) service; 6.6% subway journey-to-work mode share	Higher population density; somewhat lower percentage of owner occupied housing; Minuteman Bikeway; 15.73% bus and subway journey-to-work mode share	lower percentage of owner occupied housing; median year built 13 years more recent	Light freight service on Saugus Branch; possible impacts from Rockport/Ipswich line; higher crime rate; median year built 10 years more recent

Notes: Items having significantly unfavorable deviations from the study town are shaded.

(1) Central Transportation Planning Staff (CTPS). Travel times are for 1992 to Traffic Zone 5 (downtown Boston financial district). Town averages calculated as population weighted averages of individual traffic zones.

(2) Calculated as commuter rail riders as a percentage of labor force in 1993. 1993 ridership by origin "inner" town from MBTA Systemwide Passenger Survey, Commuter Rail 1993, North Side Station-by-Station Tables, and South Side Station-by-Station Tables. Outer Town-Inner Town Matrix Tables. 1993 average annual labor force, Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau.

(3) Represents that average cost of education for all children residing in a community, regardless of the school district where they attend school. In addition to a local district's current operating cost, a portion of a member regional school district's costs are included in the local district's total expenditures. Source: Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July, 1992. Publication # 17159.

(4) Massachusetts Department of Revenue, Municipal Data Management and Technical Assistance Bureau. FY 1991 residential property tax rate per $1,000 of assessed valuation.

(5) 1990 Census of Population and Housing, Summary Tape File 3 (STF3A) on CD-ROM, Massachusetts (data field P080A001) [machine-readable data files]. Prepared by the Bureau of the Census. Washington, D.C., 1992.

(6) Calculated as the ratio of employment by place of work to population for 1993. 1993 employment by place of work data and 1993 population estimates obtained from the Massachusetts Executive Office of Communities Development (EOCD).

(7) Secondary source, Massachusetts Executive Office of Communities Development (EOCD). Primary source, Banker & Tradesman.

(8) 1990 U.S. Census journey-to-work data. Includes bus or trolley bus, street car or trolley, subway or elevated, railroad, and ferry boat modes.

Arlington also has a substantially lower median sales price, again making it more difficult to identify comparable properties, although this too would be lessened somewhat by the large number of sales from which observations could be drawn. Also, Arlington has a significantly lower median household income and a somewhat higher per pupil expenditure. As in the town of Lexington, the Minuteman Bikeway runs along the former Lexington Branch right-of-way through Arlington, and as discussed earlier, existing empirical evidence suggests possible property value impacts from these types of facilities. Finally, Arlington has a relatively high mode share for public transportation modes such as bus and MBTA Red Line heavy rail service.

Stoneham has a significantly lower per pupil expenditure, as well as a lower median household income and a median home sales price that is 42% less than that of Winchester.

Saugus has a longer AM peak auto travel time to downtown Boston, a lower residential property tax rate, lower median income and a median home sales price half that of Winchester. Sporadic freight service on the Saugus Branch could also result in confounding proximity impacts.

Chapter 6
Development of the Parcel-Level Data Set

Having established the aggregate basis for the case study of MBTA commuter rail service in Chapter 5, the development of the disaggregate parcel-level data set is reviewed here. Using the municipal and zonal level data collected earlier as a starting point, data for individual single-family detached residential properties in each of the eight study communities and their related control communities were collected for the 1992 to 1993 time frame designated earlier. A wide variety of data is required to provide for adequate experimental and statistical control of all confounding influences upon residential property values, and the isolation of any variation in property values resulting from the proximity impacts and accessibility impacts of commuter rail service. An extensive amount of data was obtained from a wide array of public and private agencies and organizations, with additional development and refinements made where necessary in order to achieve the level of accuracy required for later empirical analyses in Chapter 7. Recent developments in the availability and quality of real estate data, the continued development of software tools including geographic information systems (GIS) and the availability of associated geographic data sources, and increased access to machine-readable sources of demographic and socioeconomic data available on CD-ROM as well as via the internet combine to make this enormous data collection and analysis task manageable.

6.1 Dependent Variable and Measures of Value

The impact of commuter rail service upon residential properties most often elicits the greatest public response, in large part because residential land uses are generally more susceptible to proximity impacts such as noise than are commercial and industrial land uses. Existing empirical findings are mixed regarding the extent to which accessibility to rail transit is incorporated into property values, and although conventional wisdom often seems to suggest that commercial properties benefit to a larger extent from rail transit accessibility than do residential properties, empirical evidence does not necessarily support this assertion, and in some cases suggests the contrary. As indicated in Chapter 4, data availability issues have also to some extent prescribed the use of more readily available residential property data rather than commercial property data in attempts to measure the impact of rail transit upon property values, development and land use. For these reasons, residential land uses are the focus of the empirical analysis presented herein.

Although multi-family residences and condominiums fall under the category of residential properties, these markets differ in many respects from the market for single-family detached residential housing. Also, existing empirical evidence suggests that multi-family properties are discounted to a lesser extent due to noise impacts than are single-family properties..[162,163] A likely explanation for this is that renters, making up the bulk of multi-family housing and apartment dwellers, are generally mobile and short-term occupants, and as such exhibit less concern over environmental impacts than homeowners who have a longer term commitment to a property. Because existing empirical evidence suggests that the impacts of commuter rail service, if any, are relatively modest, the use of single-family residential properties should thus provide the greatest opportunity for distinguishing the impacts of commuter rail from among the myriad other attributes that affect property values. However, even though the vast majority of single-family detached residential properties in the study and control areas are owner-occupied, it is impossible to know from the available data if the specific properties chosen for the parcel-level data set are indeed owner-occupied. Therefore, any environmental impact cost estimates obtained from the data set may be modestly biased downwards, since not all of the single-family detached residential properties in the parcel-level data set are necessarily owner-occupied.

Having determined that single-family detached residential properties are most suitable for the case study analysis, the specific measure of housing value to be utilized as the dependent variable in subsequent analyses was considered next. It is the aim of this thesis to estimate the impacts of commuter rail service, as they are reflected in the value of single family residential properties. It is hoped that these impacts can be interpreted in terms of real dollar impacts for the given time period over which the observations are collected. Hence, a measure of value as close to that of the true market value of the property would be preferred. A variety of value measures were considered including asking price, assessed value and selling or transaction price.

Asking price was deemed inadequate as an accurate measure of the fair market value of a single family residence for the primary reason that asking price, under a variety of market conditions, often tends to overestimate the true value of the property. This could be the result of either a legitimate overestimation of the fair value of the home on the part of the seller, or

[162] Frankel, Marvin. "Aircraft Noise and Residential Property Values: Results of a Survey Study." *Appraisal Journal*. January 1991. pp. 96-110.
[163] Collins, Alan, and Alec Evans. "Aircraft Noise and Residential Property Values: An Artificial Neural Network Approach." *Journal of Transport Economics and Policy*, Vol. XXVII, No. 2. May 1994. pp. 175-197.

more likely, a tendency to start with an asking price which overstates the true value of the property, in the hope that negotiations will still result in a selling price which is satisfactory to the seller, or at least equivalent to their true expectations of the value of property. Recent empirical studies confirm this. A 1992 study showed that homeowners in the U.S. who are not selling their home overestimate the true value of their house (as represented by sales price) by approximately 5 to 6% on average, and homeowners who are selling their home tend to overestimate the value of their home by an even greater margin of about 8%.[164] Although findings have been somewhat mixed, some researchers have also found that these errors are generally unrelated to characteristics of the owner, the house, or the local market such that when these homeowner estimates are used as the dependent variable in a hedonic price equation, the estimated parameters, excluding the constant term, will be unbiased and consistent.[165] However, given that these findings are far from certain, it would seem wise to avoid the use of asking price as the dependent variable in this thesis.

Assessed value, as estimated by the local Board of Assessors in each community, was also not considered to be an accurate measure of the fair market value of a single family residential property. First, assessed values are in many cases not adequately responsive to changes in the market conditions, since revaluations of assessed values typically occur only periodically, in many cases with up to three years between revaluations, which is the maximum time period mandated by Massachusetts state law.[166] The local nature of assessed values also make them subject to a variety of practices that are specific to various local jurisdictions, thereby making inter-jurisdictional comparisons of assessed values difficult or impossible. Within a given municipal jurisdiction, however, assessment practices are typically consistent and uniform. Also, a survey of town assessors in the study communities suggests that proximity to commuter rail stations and rights-of-way are generally not considered in the estimation of assessed values by these communities. This finding is generally supported by the empirical literature.

Damm et. al, in their study of the Washington Metro heavy rail system, found that when assessed value was used as the dependent variable in models of multi-family housing prices, measures of proximity to transit stations that were statistically significant in models using sales price as the dependent variable became statistically insignificant and were also a factor of nine less than those estimates obtained when using sales price as the dependent variable. Models using assessed value also exhibited substantially greater R^2 goodness-of-fit

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164 Goodman, John L., Jr., and John B. Ittner. "The Accuracy of Home Owners' Estimates of House Value." *Journal of Housing Economics* 2, 1992. pp. 350.
165 *Ibid.*
166 *Municipal Financial Data*. 21st edition. Massachusetts Taxpayers Foundation. pg. 13.

measures than similar models using sales price as the dependent variable.[167] Damm et. al, conclude that assessors significantly understate or ignore the influence of transit access on multi-family residential properties, and mostly rely upon more easily measured factors such as the number of dwelling units in a multi-family property when developing estimates of value. Therefore, in attempting to estimate the difference in value between properties within the same community resulting from variations in a given primary attribute, such as the relative level of commuter rail service for a property, it may be feasible to use assessed values to control for heterogeneous secondary attributes of single-family parcels. Viewing the assessed value as being representative of the sum total of all secondary attributes allows this single value to be used to control for all secondary attributes. The specific magnitude of individual secondary attributes is unimportant, as long as the sum total of these attributes yields the same measure of value between two properties that have different combinations of attributes, but combinations that in total provide the same level of utility to the consumer.

Selling price, although a more accurate measure of fair market value than the two indictors described above, is not a perfect measure by any means. To be a perfect indicator of the true market value, transactions would have to be carried out under almost ideal market conditions. However, the market for single family residential properties, like most markets, is subject to various influences affecting its efficient operation. As mentioned in Chapter 5, some of the primary influences affecting the efficient operation of the real estate market for single-family residential properties include seasonal variation in demand, local economic conditions, government regulatory practices, and the availability of financing. Even with the various market distortions, however, sales price is still by far the preferred measure of market value, and will be utilized for the empirical analyses presented in Chapter 7. The great majority of the literature reviewed in Chapter 4 also utilizes sales price as the independent variable. With proper consideration and the judicious selection of the final sample of properties, the impact of some of the more substantial distortions can be minimized.

6.2 Real Estate Data

Only in recent years have real estate transaction and assessment data become more readily accessible, with improvements in both the completeness of the data available, and in the ease of use of the data as machine-readable data formats have become more prevalent. For many regions of the U.S., these types of data are available for purchase from a variety of data

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[167] Damm, David, et. al. "Response of Urban Real Estate Values in Anticipation of the Washington Metro." *Journal of Transport Economics and Policy*, Vol. XIV, No. 3, September 1980. pp. 328.

Figure 6.1: Banker & Tradesman COMPReports Data Fields

- Street Address
- Purchase Price
- Mortgage Amount
- Lender
- Names of the Buyer and Seller
- Filing Date at the Registry of Deeds
- Purchase Price at Last Sale of Property
- Date of Last Sale of Property
- Tax Identification Number
- Map Identification Number
- State Land Use Code
- Style of Building
- Year Built
- Total Number of Rooms
- Number of Bedrooms
- Number of Bathrooms
- Lot Size
- Interior Square Footage
- Fiscal Year
- Assessed Value of Land
- Assessed Value of Building
- Total Assessed Value

vendors such as TRW-Redi and Transamerica Information Management Services.[168] Although this data can be obtained directly from public agencies including county Registry of Deeds and Town Assessors, this is a labor intensive and tedious task requiring matching of transactions data obtained from the Registry of Deeds with assessment data obtained from Town Assessors. Also, few counties and towns have this data available in a machine-readable format. Therefore, in most cases the only practical alternative is to purchase this data from a private vendor.

In Massachusetts, *Banker & Tradesman*, a real estate data publishing company, provides real estate transactions data for the entire state, obtained from county Registry of Deeds.[169] Data are based on sales from $25,000 to $1,000,000, and property transactions data are differentiated into condominium sales, and sales of other single family and multifamily residential property. This transactions data, which contains only basic information such as the address, purchase price, mortgage amount, lender, names of buyer and seller, and filing data at the registry, is then enhanced with property details obtained from Town Assessors for more then 150 towns in eastern Massachusetts, which includes most of the metropolitan Boston area. The resulting data product, called *COMPReports*, is available in machine-readable format for a cost of approximately $0.06 to $0.10 per transaction record, depending on the quantity of data purchased. Property details included in the COMPReports typically include the data fields presented in Figure 6.1.

The COMPReports data do exhibit some shortcomings, however. Not all towns and cities collect data for certain items, such as a separate count of the number of bedrooms. Also, there are no statewide standard definitions for some items such as interior square footage. For instance, in some towns this includes the amount of living area, be it heated or unheated, and

[168] Clauretie, Terrence M. "Property Data from Tax Assessors." *Journal of Real Estate Literature*, 3:205-210, 1995. American Real Estate Society.
[169] Banker & Tradesman, Data Products Group, Real Estate Data Publishing. Boston, MA.

thus may include a finished but unheated basement, whereas in other jurisdictions it is considered to be primarily the heated areas of the home. Such discrepancies are discussed later, and some guidance might be obtained by speaking directly with the local assessors in the towns that are selected for analysis.

Data files were obtained from Banker & Tradesman for all single-family detached residential property transactions occurring during calendar years 1992 and 1993 in the sixteen study and control communities identified earlier. In total, this represented over 7,000 property records. These raw data were subjected to a series of quality control procedures to identify and discard records that for various reasons were inadequate for inclusion in the final data set. First, the data were checked for internal consistency, for example cross referencing town names with zip codes to ensure that these fields were correct. Other logical tests were applied to certain data fields, for instance to ensure that the year built data field did not contain values that exceeded the year 1993. Units of measurement were also inspected and adjusted to ensure that they were consistent, for example, lot sizes were sometimes reported in acres and other times in square feet. Next, although the original data set was not to have contained records with a sale price less than \$25,000 or greater than \$1,000,000, approximately 20 of these records were identified and discarded. Likewise, the record type and property type fields were inspected to ensure that refinanced properties ("refi's"), condominiums, multi-family properties, vacant land or commercial properties were excluded from the final data set.

Further criteria were applied to the data set in order to ensure that sales records were bona fide in nature, involving an "arms-length" transaction between a buyer and seller, each with sufficient knowledge, for self-interest and without distress, thus yielding the most accurate representation of the true market value as possible. Using information from the buyer and seller last names fields, approximately 141 possible intra-family transactions were identified and discarded. Thirty records involving foreclosure deeds, noted in the deed type field, were discarded, since such deeds identify distressed properties sold at foreclosure, often at a significant discount compared with the true market value. Transactions having mortgage amounts which exceeded the selling price of the property were also discarded, since financing is usually not granted for more than 95% of the sales price of the home except under extreme circumstances of a very active market and a buyer with extraordinarily good credit, or in some cases, if improvements to the property are to be made with the excess of the mortgage amount. In this situation, it was felt that at the time of the transaction, the property did not yet embody the value from such future improvements, however, and therefore approximately 100 such transactions were discarded. Repeat sales of the same property that appeared to be highly unusual, for instance the sale of the same property within a very short time period of a few days or weeks, led to both the initial and all subsequent sales records for such properties being discarded, since it was thought that such transactions were likely distressed or otherwise peculiar in a way so as to affect the market value as represented by the sales price. Finally, because some towns did not collect data for certain items, or because of errors in subsequent data processing by Banker & Tradesman, records lacking key data fields such as sales price or number of bedrooms were discarded. This eliminated about 2,000 records including most or all records in the study towns of Concord and Melrose, and the control town of Stoneham. Therefore, it was decided to eliminate the few remaining records for these towns altogether, as well as those for the control town of Sudbury. Doing so should not significantly impact the analysis, however, since the five remaining study towns adequately represent all of the rail traffic scenarios discussed earlier in Chapter 5, and multiple study areas were selected initially in order to prepare for just such a contingency. The remaining data set used for the analysis in Chapter 7 consists of 4,093 transaction records of single-family detached residential properties sold during 1992 and 1993 in the remaining eleven study and control communities.

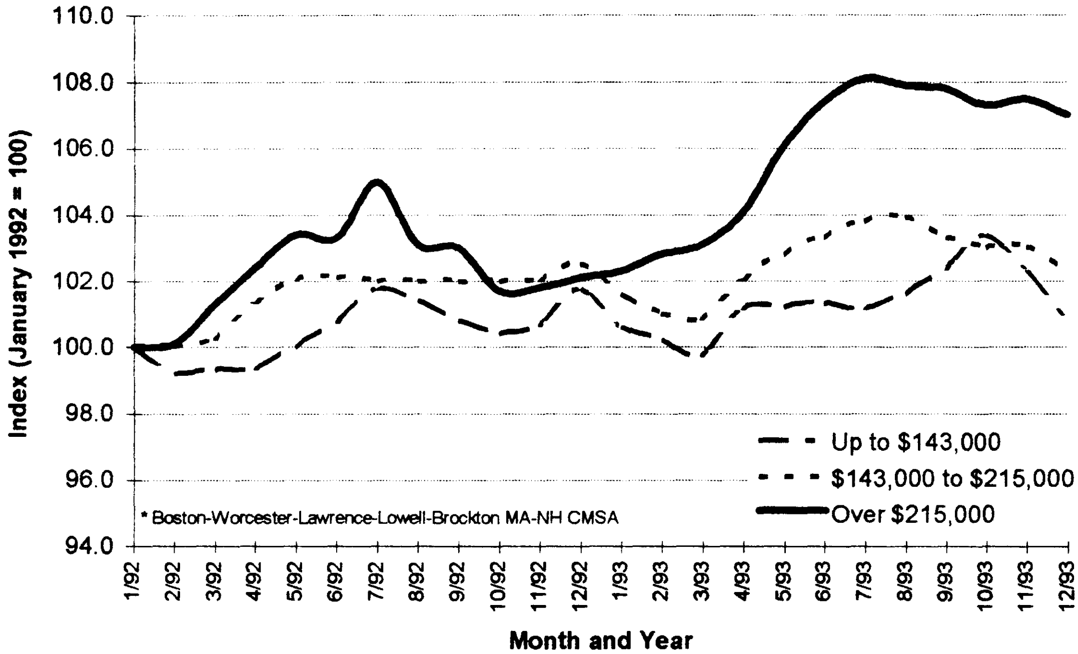
Although a new commuter rail facility will probably have varied property value impacts over time during its planning, construction, and operation, this thesis focuses on the spatial, rather than the temporal, element of these property value impacts for a well-established commuter rail facility. The fact that commuter rail service in the Boston area, as in many other areas around the United States, is well established and has operated over existing rights-of-way for a significant number of years largely dictates this cross-sectional analytical approach, as does the limited availability of appropriate study areas with newly implemented services and facilities, which would be required for a more involved time series analysis using longitudinal or pooled data sets. Although it is possible for the same property to appear at more than one point in time in the data set used here, no attempt was made to obtain such matched observations, and no use was made of this fact if it occurred. Seventy-four records in the final data set include one or more repeat sales of the same property during the two year study time frame.

Although a cross-sectional analytical approach is used, the real estate sales data utilized are of necessity collected from a two year time period, during which overall real estate market forces are likely to have had an impact on sales prices. Therefore, prior to using this data, variations in sales prices over this time frame resulting strictly from market forces must be eliminated so as to avoid introducing bias into the parameter estimates of both the primary and secondary attributes of each property. If such an adjustment procedure were not performed, then variations in sales price related solely to the point in time at which the sale of a particular property occurred might very well be misinterpreted as being associated with proximity to a commuter rail facility, if all other variables are held constant. Thus, a property might be valued higher than an otherwise similar property not because it is located within walking distance of a commuter rail station, but because it was sold months later during a more active market period in which a higher price could be obtained.

By design, the 1992 to 1993 time frame selected for analysis was chosen to minimize just such temporal market variations as much as possible, however because of the two year time frame, a number of moderate real estate market fluctuations remain in the data. Therefore, housing price indices developed by the real estate analysis firm of Case-Shiller Weiss, Inc., and based on repeat property sales data were used to control for time series changes in property values resulting from overall market forces. The "nominal" sales prices reported in the Banker & Tradesman data were deflated to January 1992 dollars using the Case-Shiller home price index for metropolitan Boston. Although the spatial extent of housing sub-markets are arguably more limited than the metropolitan Boston region as a whole, obtaining more detailed housing price indices available at county, town, or zip code level would have been cost prohibitive. Fortunately, however, the publicly available metropolitan-level indices are differentiated into three separate price class submarkets. Figure 6.2 presents the Case-Shiller home price index for metropolitan Boston for the 1992 to 1993 time frame.

It should be noted here that the use of median sales prices during a given time period to develop a price index to control for changes in a given real estate market, as is done in much of the existing empirical literature, may be significantly affected by compositional shifts in the housing actually being sold during a period. For instance, if market conditions are such that more properties in the lower end of the market (less than $143,000) are being sold in a given area during a certain time period, the median sales price based on the sub-sample of sales data for this period will be lower than if a random sub-sample of all single-family properties across all price classes had been sold during this period. However, this compositional shift of sales to properties in the lower end of the market does not necessarily mean that market prices have decreased. Any reduction in the median sales value may solely be an artifact of the particular sub-sample of the market offered for sale and/or sold during the time period in question, since the median is simple the middle value of a set of house prices that happen to sell in an area during a given time period. Therefore, such compositional shifts impart a sample selection bias that likely distort analyses that attempt to draw inferences about the entire population of properties in a given market area. This could result in incorrect and misleading deflator adjustments being applied to the nominal sales price data, since even if the value of individual properties may not have changed over a given time period, the value of the median sales price may have changed because of shifts in the composition of sales.

Figure 6.2: Case-Shiller Home Price Index by Sales Price Class for the Metropolitan Boston Region



In much of the empirical literature presented in Chapter 4, dummy variables representing given time periods are often used in hedonic price models in an attempt to control for time series market variations. However, this method likely suffers from the same problem as using median sales prices as a price index. In this case, however, compositional shifts in the housing actually sold during a period may affect the parameter estimates for these time period dummy variables, since the dependent variable of the model is typically the selling prices for the particular sub-sample of sales occurring during the period. If any shifts have occurred in the composition of properties sold between periods, these dummy variable parameter estimates may indicate a reduction in sales price for a given period, when in fact the prices of individual properties may not have changed. Therefore, in practice, the estimated dummy variable parameters may be more an indicator of the particular compositional shift in sales for a given period, rather than an indicator of market price movements in the overall market.

Since the impact of the primary attributes that much of this research is attempting to measure is often marginal and limited in nature (e.g. often much less than a 10% impact upon home prices), it is likely that even subtle variations introduced by the improper deflation of housing prices contained within a time series could introduce significant bias in attempting to estimate the capitalization effects resulting from any number of sources of interest. The use of the Case-Shiller home price index based upon repeat sales data will eliminate these types of biases in this thesis.

6.3 Structural Attributes

In total, the properties considered here are a combination of the parcel of land, and the improvements or structures built on that land. The attributes of the structure or home itself and related measurement issues are briefly described here. Not all of the data fields discussed here are necessarily utilized for each of the analyses in Chapter 7.

Usable Living Area

Usable living area, for the purposes of this study, includes the total square footage measurements of all living areas in the home. Although there is no uniform standard definition of usable living area among tax assessment jurisdictions, usable living area is typically designated as all areas of the home other than patios, open porches, garages, unfinished basement areas, utility closets, unfinished attic areas, front entry ways, and other areas which are deemed not to be directly utilized as living space on a daily basis. All records in the final data set contain information for usable living area.

Bedrooms

More than 90% of the records in the final data set contain data for the number of bedrooms. For the town of Scituate, however, only the total number of rooms and the number of bathrooms was indicated. Therefore, for this town only, an estimate of the number of bedrooms is made based upon the relationship in the remainder of the data set between the number of total rooms, bedrooms, and bathrooms.

Bathrooms

Both whole baths, typically having three or more fixtures, and half-baths, typically having two fixtures, are considered. The total number of bathrooms is considered to be the sum total of the these two values, therefore there may be non-integer values for this data field. Although it may be prudent to estimate the value of whole baths and half-baths separately since a half-bath may not necessarily be valued at half that of a whole bath, the manner in which the data is reported does not allow one to distinguish between the two. Therefore, only the total bathrooms figure, as reported, is used. All records in the final data set contain this information.

Total Rooms

The total number of rooms, including living areas, dining rooms, and kitchens as well as the number of bedrooms and bathrooms, is reported for approximately 80% of the final data set. This data is used primarily as an aid in estimating the number of bedrooms for records that do not report this data.

Heating System type and fuel

Heating system type was reported for approximately 25% of the records in the final data set. The most prevalent heating system types reported in the data set are forced hot water and forced hot air, with oil and natural gas the most prevalent heating fuels. Previous empirical research suggests that in most cases, heating system type and fuel are statistically insignificant determinants of sales price, however this hypothesis could be explored by using this data for the few towns for which it is reported when performing town specific analyses in Chapter 7.

Age

The age of the home at the year of sale, determined from the year built data field, is used as a proxy for structural quality. Although age is not a perfect indicator of structural quality because of the varying levels of maintenance at each property (including the possibility of complete remodeling having taken place), even with proper maintenance, structures tend to wear out with age or become obsolete, reducing the property's marketability. All records in the final data set contain year built information.

Style

In appraisal practice, it is known that the architectural style of the structure can significantly impact the marketability of the property. The variation in demand for a particular style of home at any given point in time can therefore affect the sales price. Housing styles that are predominant in the final data set include Colonial, Cape, and Ranch. Approximately 90% of the records in the final data set contain style information.

Garages

Garage capacity was measured in terms of the number of vehicles which could be accommodated in any garages on the property, including attached and detached garages as well as basement garages. The Banker & Tradesman data set, however, contained virtually no data records for this data type. To remedy this situation, an attempt was made to obtain multiple listing service (MLS) real estate sales data for the years 1992 and 1993 from the Greater Boston Real Estate Board (GBREB) in the hopes of matching this data to the Banker & Tradesman data set, thus improving the quality and level of detail of the final data set significantly. Although superficially the MLS data appeared to contain far more detail than the Banker & Tradesman data, the GBREB data vendor, Quest Technologies, unfortunately discards data that is more than three years old. Therefore, no garage data was available for the properties in the final data set from any available source.

Assessed Value

Assessed values are estimated by the local Board of Assessors in each property tax jurisdiction, which in Massachusetts is typically at the municipal level. Revaluations of assessed values typically occur on a periodic basis with as many as three years between revaluations in Massachusetts. Also, the methodology used in developing assessments may vary between each jurisdiction, thereby making inter-jurisdictional comparisons of assessed values difficult. Within a given municipal jurisdiction, however, assessment practices are typically uniform. All records in the final data set contain assessed value information.

6.4 Site and Locational Attributes

The next group of data developed for the final data set were those characteristics specific to the parcel of land itself and its surrounding neighborhood. Once again, not all of the data fields discussed here are necessarily utilized for each of the analyses in Chapter 7.

Lot Size

The land area of the parcel on which the house is located was recorded directly from the Banker & Tradesman data, with lot sizes originally recorded in acres converted to square feet. All records in the final data set contain lot size information.

Pool

The presence of an above-ground or in-ground swimming pool was considered as an amenity which typically has a positive impact upon the value of a residential property.[170] The literature review suggests that the presence of a swimming pool is seldom used as a controlling variable in house price analyses. Pools are less ubiquitous in Massachusetts than in warmer climates, and are only useful for a few months of the year. Because of substantially maintenance requirements, pools are even viewed as a liability by some. Previous property value analyses in Massachusetts that have including pool data have found it to be an insignificant contributor to housing value.[171] Therefore, although the Banker & Tradesman data does not contain pool data, the absence of this data should not significantly or systematically bias the analyses in Chapter 7.

Town Sewer

The presence of a connection to a municipal sewer system, rather than an individual septic system, has been found to contribute to the value of residential properties in previous empirical studies. Such a connection can help to reduce the cost of wastewater disposal, and

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[170] Bloom, George F., and Henry S. Harrison. *Appraising the Single Family Residence*. Chicago: American Institute of Real Estate Appraisers, 1978. pg. 99.

[171] Armstrong, Robert J., Jr. "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values." *Transportation Research Record* 1466. 1995. pp. 88-98.

may also make additional development of a residential parcel, such as additions or in-law apartments with bathroom fixtures and kitchens, possible without over taxing an existing septic system. Finally, a municipal sewer connection can reduce the financial risks related to environmental regulations and other possible regulatory entanglements such as Title V in Massachusetts, requiring repair or replacement of faulty septic systems prior to the sale of property. Therefore, even when considered in light of user fees charged for sewer service, the contribution to property value of sewer connections is likely to be positive. However, as in the case of the garage data, the Banker & Tradesman data provided no sewer data, and attempts to obtain supplemental MLS data were unsuccessful. Aggregate information regarding sewer service at the town level was obtained from a real estate firm statistical abstract of community profiles. This information may be useful in conducting a post mortem examination of the Chapter 7 analyses to ensure that towns with commuter rail service do not also have widespread sewer service that may be confounding the findings with respect to commuter rail accessibility.

Zoning

Zoning inhibits the use of land by means of legal regulation carried out by local government. In the process, the ability of land to be put to more intensive uses is prohibited in order to protect the health, safety, and general welfare of the public. As a result, zoning prevents property from increasing in value by limiting the uses to which that land can be put, primarily by limiting the intensity to which the land can be developed. In addition, this is a noncompensatory process, in which municipalities are not required by law to compensate for this loss in value. For the purpose of this analysis, an attempt was made to identifiy single family residential properties which were located in commercially or industrially zoned areas, and would therefore provide the potential for more intensive use of the property and hence a property value greater than that which would exist in the presence of residential zoning controls. Although the Banker & Tradesman data does not contain this information, a review of local zoning maps suggests that very few of the sample properties are located in commercially or industrially zoned areas. Therefore, the lack of parcel specific zoning data should not significantly or systematically bias the analyses in Chapter 7.

Population Density

It is widely recognized in the literature that externalities at the neighborhood level can have a significant impact upon property values.[172] Although more compact land use patterns combined with transit oriented development may achieve reductions in auto travel and

[172] Li, Mingche M., and H. James Brown. *Micro-Neighborhood Externalities and Hedonic Housing Prices*. February 1978.

roadway congestion and thus promote broader environmental goals as discussed in Chapter 1, neighborhood density externalities may occur as a result of the negative aspects of dense neighborhoods. Deleterious impacts of dense housing may include increased noise, congestion of public areas such as streets, sidewalks, and parks, litter, and in some cases selfishness and negative social behavior fostered by crowding.[173] Population density, measured at the census block group and census block levels, is used as a proxy for these impacts.

Proximity to Recreational Amenities

Just as externalities at the neighborhood level can have a deleterious impact upon property values, local amenities such as parks, recreational areas, and beaches can have a positive impact upon property values by improving the quality of a neighborhood relative to others in the community or region. Empirical findings regarding access to parks and conservation lands have been mixed. Although some studies have found positive house price effects, the magnitude of these effects appears to vary based upon the specific characteristics of each park. Detailed data regarding the specific characteristics of parks is often difficult to obtain or unreliable. If parks draw large numbers of visitors, negative house price effects have also been found because of noise and other nuisance effects upon neighboring properties. For these reasons, proximity to parks is not considered in this study. Because a number of the study and control communities are coastal, however, proximity to the ocean is considered, and measured as the straight line distance to the coastline of the Atlantic Ocean.

Income

The basis for including neighborhood socio-economic characteristics such as income in a housing price model, as well as the interpretation of such variables, is sometimes ambiguous. For instance, if higher income neighborhoods can also be considered higher quality, a neighborhood income variable could suggest that all households prefer to live in higher income neighborhoods. However, there is evidence that households prefer not to live in higher income neighborhoods, but prefer to live in neighborhoods dominated by households similar to themselves, in this case, neighborhoods dominated by households of similar incomes.[174] If this were true, then only high income households would prefer high income neighborhoods, in which case the only reason higher median income areas would have higher values is because they are in short supply.

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[173] Strange, William. "Overlapping Neighborhoods and Housing Externalities." *Journal of Urban Economics*, 32, 1992. pp. 17-39.

[174] Li, Mingche M., and H. James Brown. *Micro-Neighborhood Externalities and Hedonic Housing Prices*. February 1978. pg. 4.

In much of the previous empirical work related to housing price models, neighborhood median income appears to act as a proxy for other neighborhood characteristics which, if measured directly and properly specified, would make neighborhood median income an insignificant determinant of housing price. Also, as Voith notes, it may be inappropriate to include income in a hedonic price model as an explanatory variable for housing value, since doing so may be misleading in some instances. For example, if workers choose to live in a neighborhood because of its accessibility to the CBD, and if employment in the CBD is also higher wage than other employment, then a hedonic housing price model might suggest that accessibility is not a significant determinant of housing value, but that neighborhood income is. However, the true causal factor for the value premium is the accessibility, which happens to be correlated with having a high income job in the CBD."[175]

Empirical evidence reviewed in Chapter 4 does provide some guidance regarding income levels and the valuation of transit accessibility and proximity impacts. In most of the research, income is not included explicitly as an independent variable in a hedonic price model. Instead, different models are estimated for different samples stratified by income. In this way, the value of accessibility to transit and commuter rail has been found to vary with income levels by a number of researchers including Nelson (1992), Diamond (1980), and Gatzlaff & Smith (1993), as discussed in Chapter 4. Results suggest that the value of rail transit access is greater in higher income areas. Likewise, studies of localized externalities and proximity impacts, such as Palmquist (1992), that have reviewed the differential impact of noise upon property values with respect to income have found that higher income groups have a greater willingness to pay for quiet. Given these findings, census block group level median income is utilized as a control variable which, at the very least, should be utilized to stratify samples by income class prior to conducting analyses in Chapter 7.

6.5 Provision and Cost of Local Services

School Quality

The quality of education provided by the public school system in a community is often regarded as being a significant factor in the locational decisions of homeowners, particularly those with school aged children, although even home buyers with no children often still consider the quality of the school system when purchasing a home, since this is a marketable attribute in case of a future sale of the property. Although empirical analyses have generally shown that there is no statistically significant relationship between per pupil expenditures and

[175] Voith, Richard. "Transportation, Sorting, and House Values." *Journal of the American Real Estate & Urban Economics Association*, Volume 19, No. 2, Summer 1991. pg. 130.

school quality as measured by student achievement, it is hypothesized that per pupil expenditures represent a measure of *perceived* school quality to many home purchasers.[176] Therefore, the primary measure of educational quality used in this thesis is per pupil expenditure. Performance on standardized assessment tests is also used in the final set of study and control communities as an alternative measure of *actual* school quality, however the limited empirical literature that uses such a measure of school quality suggests that this measure will likely be found to be statistically insignificant.

Per pupil expenditure data were obtained for the school year 1990-1991, which was the most recent information available from the Massachusetts Department of Education at the time most of the properties in the final data set were sold. Many suburban communities share school districts with other communities, making the proper representation of per pupil expenditure for a given community somewhat complicated. To account for such inter-jurisdictional issues while adequately representing the overall expenditure of resources for all students residing in a community, the specific measure used is defined as an "integrated per pupil cost," which represents the average cost of education for all children residing in a community, regardless of the school district where they attend school. This cost includes not only the operating costs of the local school district, but also a portion of any member regional school district's costs.[177]

The alternative measure of school quality used is a weighted index developed for each community from assessment test data provided by the Massachusetts Educational Assessment Program (MEAP), which tests students at three grade levels on a biennial basis. The most recent test score information available at the time during which properties in the final data set were sold was from the 1990 test administration at the 4th, 8th, and 12th grade levels. Unlike the use of SAT scores, which are not taken by a representative population of students, the MEAP assessment test is required of all students at these grade levels, and thus should provide an adequate measure of overall actual school quality.

Test score data are reported for each of four subject areas including reading, mathematics, science, and social studies, in each of the three grade levels. To provide for a comparable single-number measure of school quality across school districts, a comparable index measure was calculated for each community. The possible range of scores in each subject area is between 1,000 and 1,600, therefore each individual score by grade and subject area was

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176 Hanushek, Eric A. "The Impact of Differential Expenditures on School Performance," *Educational Researcher*, Vol. 18, May 1989. pp. 45-51.

177 Massachusetts Department of Education, Office of School Finance. *1990-1991 Per Pupil Expenditures by Program*. July 1992. Publication # 17159.

first scaled downward by 1,000. Next, scores were averaged across subject areas to obtain one composite score for each grade level in each community. Finally, these composite scores were then weighted by the student population taking the test at each grade level, and then averaged to arrive at a final composite score index value for each community. For communities with students attending regional school districts, the test score results for the regional school district were used where applicable.

Crime

Crime rates are used a proxy representing the quality of local police services and the overall level of safety and personal security experienced in the community. Both violent and non-violent crime data were obtained for each of the study and control communities. Where possible, calendar year 1991 data is used, however because reporting of crime data by communities is voluntary, in some cases 1992 or 1993 data are used. Crimes reported by communities to the Massachusetts Department of Safety are classified according to 29 types of offenses, consistent with those used in the Federal Bureau of Investigation's Uniform Crime Reports (UCR). For this thesis, crimes are classified as violent or non-violent. Violent crimes are defined as criminal homicide, rape, robbery and aggravated assault. Non-violent, or property, crimes are defined as burglary, larceny, motor vehicle theft, and arson. Both types of crimes are reported in the final data set as crimes per 1,000 population.

Property Tax Rate

When considering the quality of public services which are provided, one must also take into consideration the costs involved with the provision of such services. In the United States, local property taxes, or *ad valorem* taxes, are the primary source of revenue for local governments.[178] These revenues are then used for the provision of public services such as police and fire protection and public education. Given a choice between two communities that are equivalent with respect to both the quantity and quality of public services and other municipal characteristics, prospective homeowners will, assuming rational economic behavior, express a preference to live in the community with the lower property tax rate. For each of the study and control communities, the residential property tax rate in effect for the fiscal year 1992, as reported by the Massachusetts Department of Revenue and expressed in dollars per $1,000 of assessed valuation, is reported in the final data set.

It should be noted briefly that Massachusetts law includes a property tax limitation regulation known as Proposition 2½ which limits both the total levy, or amount, of revenue that can be raised by a municipality via property taxes, as well as the extent to which this

[178] Platt, Rutherford H. *Land Use Control: Geography, Law, and Public Policy*. Englewood Cliffs, New Jersey: Prentice Hall, 1991. pg. 159.

amount can be increased on an annual basis.[179] Although this law does not directly regulate the property tax rate, it may still have an indirect effect upon this rate to some extent. However, any such effect resulting in a revenue shortfall would in all likelihood be reflected in the provision of local services, and therefore any property value impacts resulting from a lower tax rate caused by Proposition 2½ would essentially be counteracted by the impact of reduced public services. In addition, Proposition 2½ has provisions for overrides, allowing communities to increase assessments by more than the 2.5% limited set by the regulation, contingent upon a majority vote of approval.

6.6 Use of Geographic Information Systems (GIS)

Geographic Information Systems (GIS) software and data are utilized extensively in the development and analysis of all spatially related variables used in this thesis. Transportation analysis, proximity impacts analysis, and real estate analysis are by their nature spatially oriented, and recent advances in both GIS software and the data available with which to conduct spatially related analyses allow these data and techniques to be used extensively here. Spatial data including both vector and raster data and associated attribute data have been obtained from Massachusetts Executive Office of Environmental Affairs (EOEA), the Massachusetts Executive Office of Community Development (EOCD), the U.S. Department of Commerce, the U.S. Bureau of the Census, the U.S. Department of Transportation, and the Central Transportation Planning Staff (CTPS) among others. These data include a wide variety of political boundaries, census geography, and transportation facilities and associated attribute data.

A major source of raw vector and polygon GIS data is the U.S. Bureau of the Census TIGER/Line 1994 data. As mentioned in Chapter 4, these GIS data files and commercial derivatives of these publicly available geographic files are based upon source data that for most part consists of USGS 1:100,000 scale Digital Line Graph (DLG) data for coverage of rural, small city, and suburban areas, and the Census Bureau's GBF/DIME-Files and to a lesser extent USGS 1:24,000 scale quadrangles for other areas.[180] For this reason, the Census Bureau specifically notes that its data products are designed only to show the relative position of features, and thus do not require positional accuracy. The positional accuracy of the information based on DLG data is no greater than the established National Map Accuracy standards for 1:100,000 scale maps from the USGS, which is approximately +/- 167 feet,

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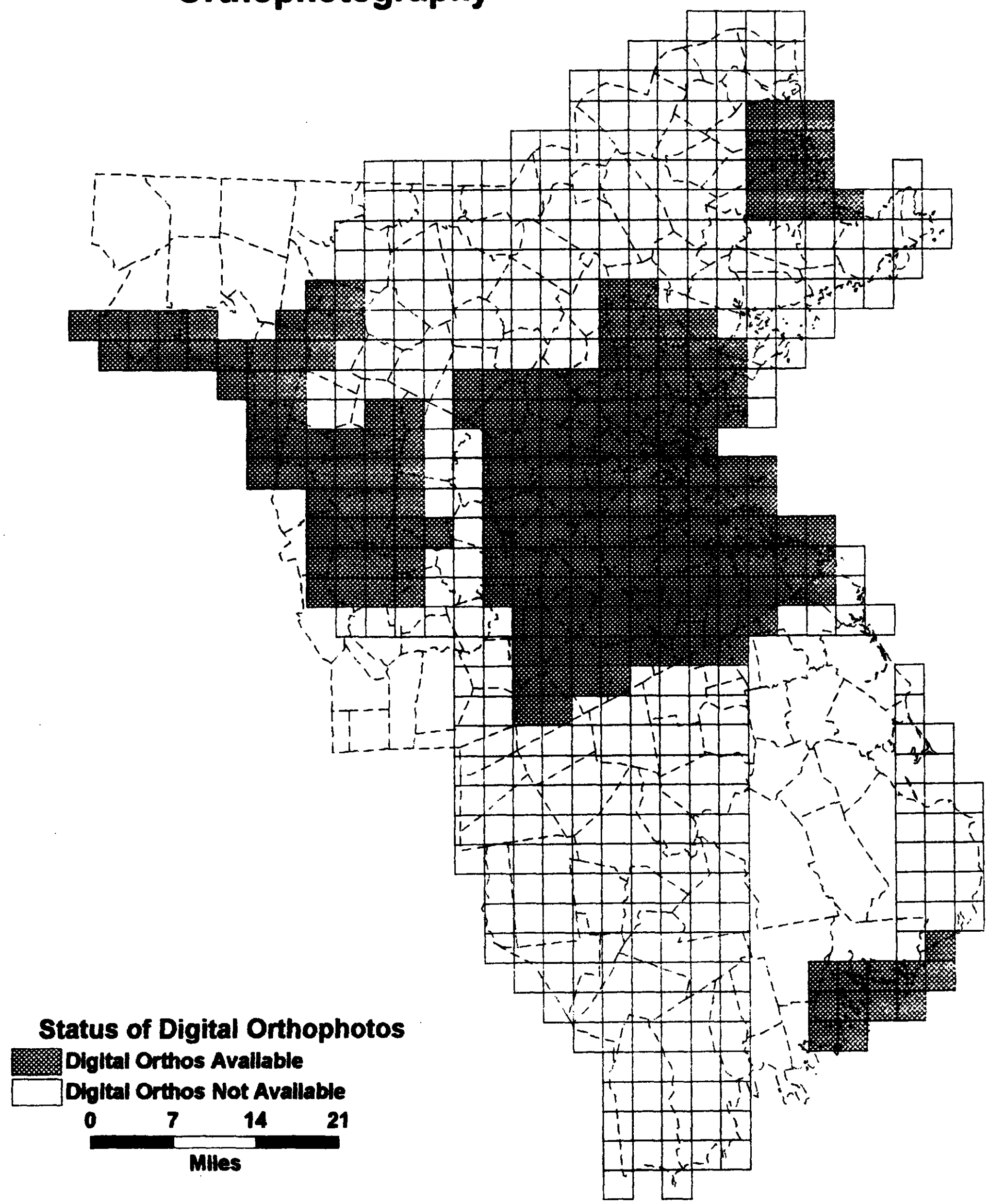
[179] Commonwealth of Massachusetts, Department of Revenue, Division of Local Services. *Everything You Always Wanted to Know About Levy Limits ...But Were Afraid to Ask: A Primer on Proposition 2½*. pg. 1.
[180] *TIGER/Line® Files, 1994 Technical Documentation*. Prepared by the Bureau of the Census. Washington, D.C.: The Bureau. pg. 5-1.

suggesting that even at best, the positions of features are likely to contain errors of 167 feet.[181] In addition to the positional accuracy of the GIS data, the Census Bureau notes that the accuracy of the address ranges assigned to road features in TIGER/Line files is also limited, and may contain address range overlaps, gaps, odd/even reversals and other errors.[182] Therefore, the interpolation routines used by GIS software packages for so-called "roof-top" geocoding are likely to assign locational coordinates to a given street address that may contain substantial errors, further compounding the positional inaccuracies, and making relative distance measures used for the analysis of proximity impacts highly suspect. Given the highly localized nature of noise and other externality effects of rail transit facilities, and their non-linear relationship with distance from the facility, positional accuracy is a key element that has in the past been overlooked.

Despite these problems, the TIGER/Line 1994 data are used here, however only as an initial base which is later substantially augmented and corrected with the aid of much higher accuracy raster data including 1:5,000 scale digital-orthophotos and 1:24,000 scale digital USGS topographic quadrangles. In Massachusetts, 1:5,000 scale black and white digital orthophoto images are made available by EOEA.[183] The images used for this thesis were collected during spring "leaves off" period at a flying height of 15,000 feet, with the majority flown in 1995, although some areas used for analysis were flown during 1992 and 1994. MassGIS scanned the resulting photography at 15 microns, and the images were then differentially rectified. Figure 6.3 shows areas of Eastern Massachusetts for which aerial photography has been flown and/or processed into digital orthophotos. These images are distributed on CD-ROM as 4,000 x 4,000 meter quadrangles at a nominal cost, with approximately 40 quadrangle images, at 1 meter resolution, per CD-ROM. The images meet or exceed the National Map Accuracy Standards to the extent that 90% of the well defined features fall within 2.5 meters of their true position on the ground. The original images have been resampled at 1 meter resolutions, where each pixel on the digitized image represents 1 meter on the ground.[184] Both the 1:5,000 scale and 1 meter resolutions are more than adequate to identify individual residential structures and other features including transportation facilities, as can be seen in Figure 6.4 which depicts a sample portion of one of the aerial photos for the town of Needham. In areas for which digital orthophotography is not available,

[181] *Ibid.* pg. 5-3.
[182] *Ibid.* pg. 5-5.
[183] Massachusetts Executive Office of Environmental Affairs. MassGIS. 1:5,000 scale black and white digital orthophoto images.
[184] Massachusetts Executive Office of Environmental Affairs. MassGIS. *MassGIS Datalayer Descriptions and Guide to User Services*. January, 1996. pg. 17.

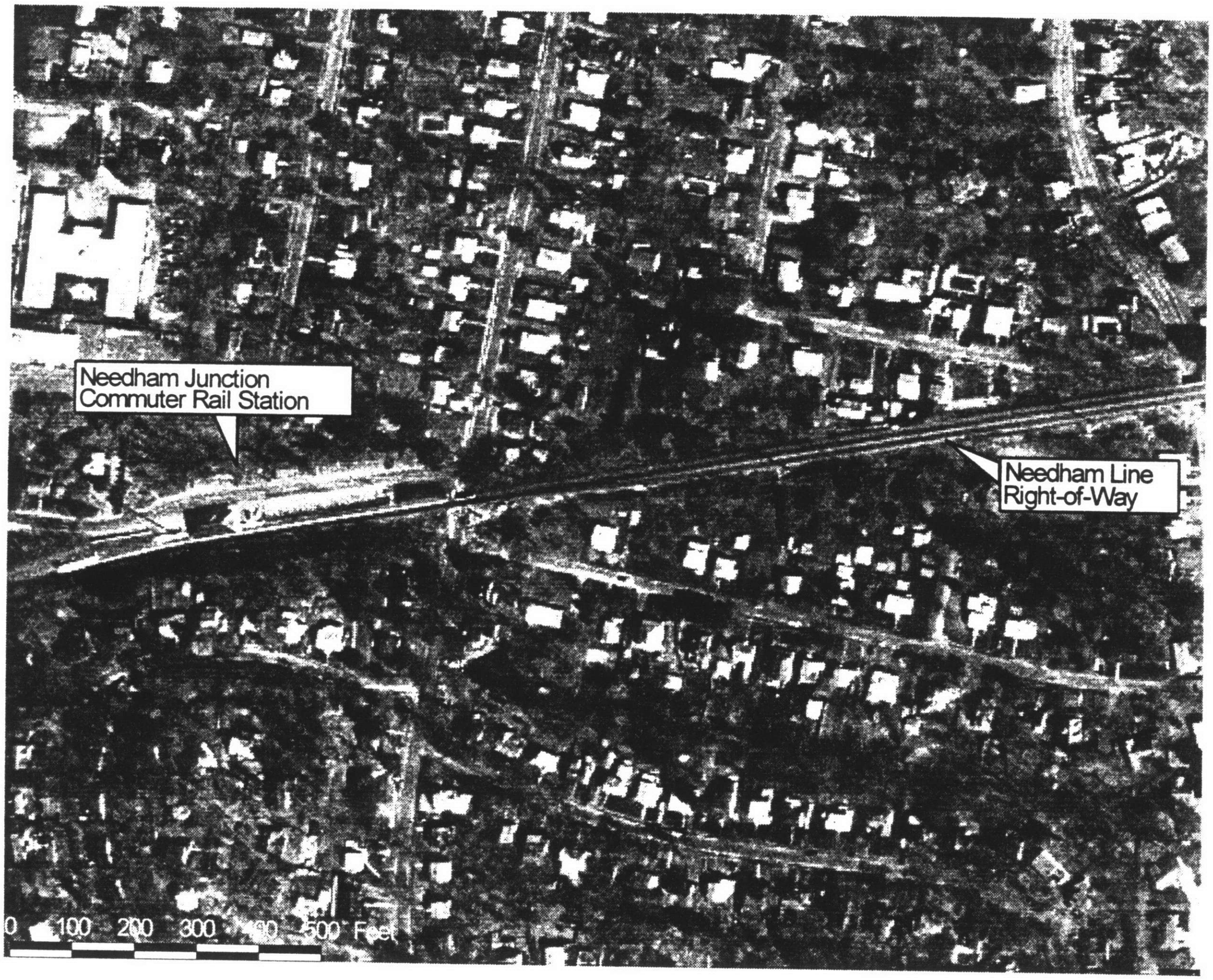
Figure 6.3: Status of Eastern Massachusetts Digital Orthophotography



scanned 1:24,000 scale USGS topographic quadrangles, identifying manmade structures such as homes and transportation facilities, were used as a substitute (see Figure 6.5).

All proximity variables used in this thesis are developed based upon the digital orthophotography or USGS quadrangles, ensuring that all proximity measurements are of the highest possible accuracy. GIS software including TransCAD, Maptitude, and ArcView are

Figure 6.4: Digital Orthophotography



used extensively in the manipulation of this geographic data and the development of the final accessibility and proximity variables.

Because of the limited accuracy inherent in the TIGER/Line 1994 data, all major transportation facilities such as highways, commuter rail and freight rail lines, grade crossings, and stations were repositioned using the digital aerial photography and digital USGS quads as a base reference, thus dramatically improving their positional accuracy. With this accomplished, the address indexed TIGER/Line 1994 road layer was then used as the basis for determining the locational coordinates of each of the 4,093 properties in the final data set. Although there do exist commercially available geocoding services, these services were deemed too expensive for the quality of work provided, since they still primarily rely on 1:100,000 scale base maps, especially in non-urban areas, and standard geocoding interpolation routines in order to produce geocodes. As an alternative, geocoding was performed using TransCAD GIS software.

Using a combination of the zip code, street name, and street address the interpolation routines used by TransCAD for geocoding attempt to match street addresses in the data set to address range information in the TIGER/Line road layer. In order to improve this process, the original address information contained in the Banker & Tradesman data were first processed using a 1996 U.S. Postal Service CASS-certified postal database in conjunction with address standardization software. The address standardization procedure corrects many common errors that often reduce matching rates, such as phonetic mis-spellings (e.g. Wyndmire vs. Windmere), incorrect street type suffixes (e.g. Rd instead of Ln) and improperly concatenated street names (e.g. Meadow View Rd vs. Meadowview Rd). When using the strictest and most accurate geocoding match criteria, this address standardization procedure dramatically improved the initial match rates. Based on the initial geocoding trials, the TIGER/Line 1994 data were also updated extensively with newly constructed roads, subdivisions, and address ranges using the aerial photography, USGS quadrangles, and site visits as guidance. After all records in the final data set were assigned initial geocodes, properties located within noise screening distances of major transportation facilities, as prescribed by the Federal Transit Administration (FTA) and discussed later, were identified.[185] These locations were then manually repositioned to match the precise location of the actual address, again using the aerial photography, USGS quadrangles, and site visits. In combination with the earlier repositioning of major transportation facilities based on the aerial photography, the repositioning of these geocoded addresses provides for proximity measures having accuracies that substantially exceed those obtained in previous research efforts.

6.7 Regional Accessibility

Accessibility on a regional scale is measured in terms of the journey-to-work travel time for highway, commuter rail, and commuter boat modes for each property location in the final data set. Travel times developed in this section represent line haul, in-vehicle travel on these modes. Additional travel times and wait times representing the local or sub-regional

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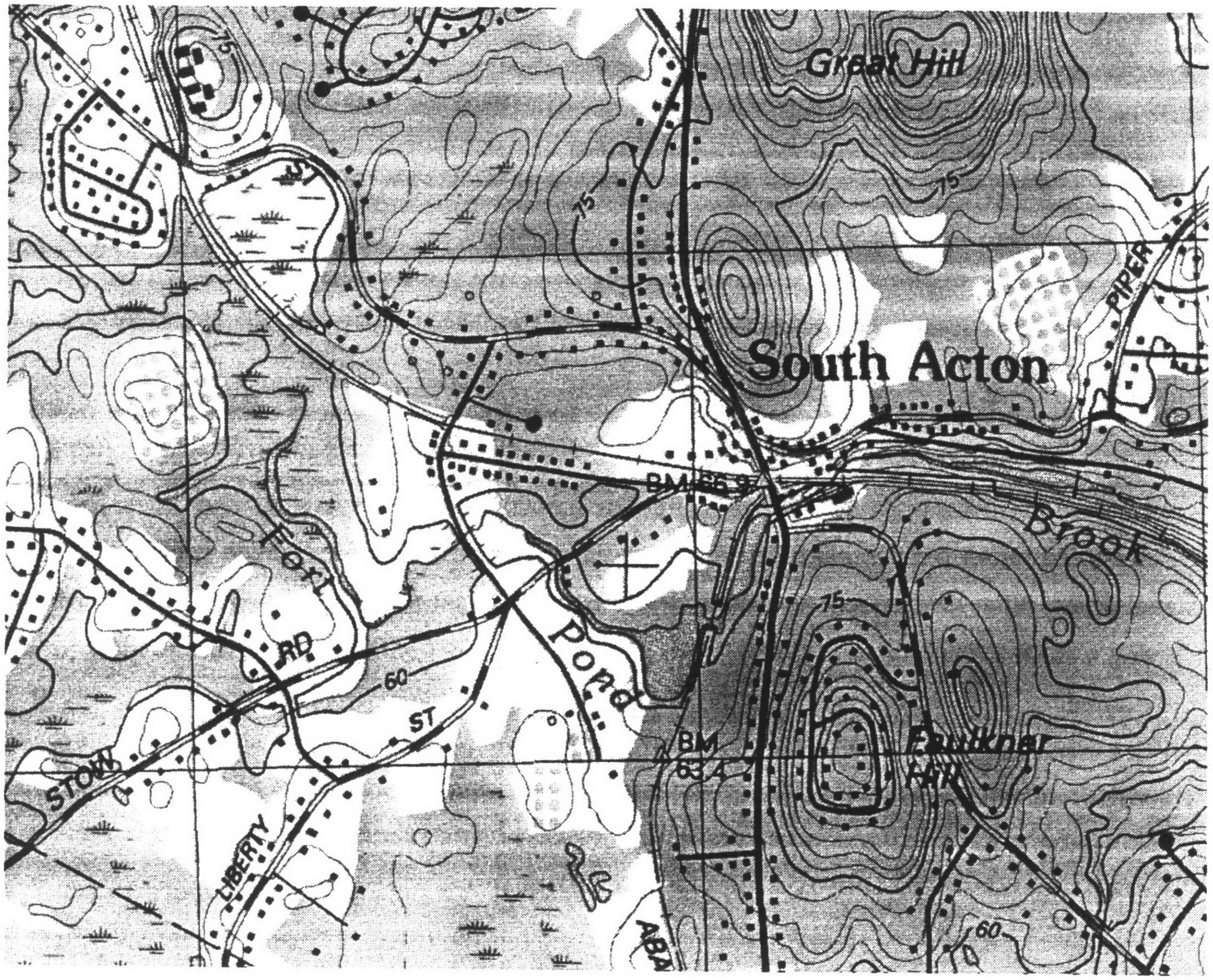
[185] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment.* April 1995. pp. 4-3 and 5-16.

Figure 6.5: 1:24,000 Scale USGS Quadrangle



component of accessibility consisting of travel to highway interchanges, commuter rail stations, and commuter boat terminals are developed in later sections. It is expected that the marginal implicit price of regional highway accessibility is greater than that of regional rail accessibility or regional commuter boat accessibility. Although MBTA heavy rail, light rail, and express bus transit do provide some level of regional accessibility throughout metropolitan Boston, earlier controls used in selecting both study and control towns have by design minimized these impacts.

Auto

For auto travel, AM peak auto travel times by traffic zone for 1992, provided by the Central Transportation Planning Staff (CTPS) and presented earlier in Chapter 5, Figure 5.9, are used to represent regional auto accessibility to downtown Boston. Non-CBD oriented accessibility is also an important consideration, particularly in light of the increasingly decentralized employment patterns evident in many U.S. metropolitan areas including Boston. After controlling for access to the CBD with the use of the CTPS traffic zone auto times, it is hypothesized that higher average journey-to-work times should serve as an effective proxy for accessibility to other employment centers. Therefore, 1990 journey-to-work average travel times at the block group level are used for this purpose.

Commuter Rail

Line haul commuter rail travel times from each station to either North Station or South Station were obtained directly from the operating schedules in effect for 1993. Since MBTA commuter rail operations typically maintain their scheduled departure and arrival times, the use of scheduled rather than actual times is acceptable. In addition to variations in commuter rail travel times, other key level of service indicators, in particular the number peak of period trains serving a station, must be considered. As Table 5.1 presented earlier shows, with respect to the number of daily AM peak trains, the five study communities received comparable levels of service consisting of five AM peak period trains per day, the only difference being Needham, where two of the five peak period trains short turn at Needham Junction, providing Needham Center and Needham Heights with only three AM peak period trains daily. Because these service levels are comparable, inclusion of the number of AM peak trains as an independent variable should not be necessary. In separate analyses of the town of Needham, however, it may still be wise to include this variable as an independent variable. Property value effects resulting from the higher frequency of service at Needham Junction and Hersey stations might otherwise be misinterpreted as being the result of the differences in travel time among the stations, since travel time and frequency of service are in this case negatively correlated.

Commuter Boat

Regularly scheduled commuter boat operations serving suburban Boston are unique to the South Shore, and for this thesis are relevant only to the control communities of Hingham, Scituate, and portions of Marshfield as shown earlier in Chapter 5, Figure 5.14. As with the commuter rail travel times, the commuter boat travel time of 35 minutes from the Hingham Shipyard to Rowes Wharf in Boston is taken directly from the operating schedule.

6.8 Local Accessibility

The local or sub-regional component of accessibility is measured in terms of the travel time from each of the address records in the final data set to the nearest highway interchange, commuter rail station, or commuter boat terminal. For commuter rail and commuter boat, a terminal wait time is also added. TransCAD, a popular transportation planning and GIS software package, is used extensively in developing the local access travel time measures for each property.

Highway

For highway travel, shortest path network procedures are used to calculate auto travel times over the local road network to the nearest major highway interchange for each property. The updated TIGER/Line 1994 road network developed earlier during the geocoding process was used as a base layer. Functional classifications for each road type are reported in the original TIGER/Line data, and include primary roads such as interstate and state limited access roadways, secondary roads including U.S. highways and other two lane and four lane state highways and arterials, connecting and collector roads, and local neighborhood roads and city streets. Some connecting roads and collector roads in the TIGER/Line data were incorrectly coded as local neighborhood roads, and were therefore updated using the correct roadway classifications depicted on USGS quadrangle topographic maps. Having updated the link classifications, link speed attributes were developed based on site visits and sample travel time runs. Even during peak periods, auto travel over local roadways in the study and control communities is generally uncongested, and therefore link speeds were generally near the posted speeds limits and free flow conditions. These link speed characteristics were then assigned to each roadway functional classification. TransCAD shortest path network procedures were then used to calculate the shortest path based on travel time from each property in the data set to each limited access highway interchange. In the final data set, the travel time in minutes to the nearest limited access highway interchange is reported for each property.

Commuter Rail

Procedures similar to the above procedures used in estimating travel time to highway interchanges were used for estimating auto travel time to the nearest commuter rail station. A five minute station wait time, representing the time spent in parking, waiting at the platform, and boarding the train, is also added to the auto access time. This wait time is consistent with the findings of the 1993 MBTA commuter rail passenger survey, in which the median waiting time was reported as being between 4 and 6 minutes on every commuter rail line.[186] In the

[186] Humphrey, Thomas J. *MBTA Systemwide Passenger Survey: Commuter Rail 1993.* March 1995. pg. 2-3.

final data set, the auto travel time to the nearest commuter rail station including the wait time is reported for each property.

In addition to station access time by auto, walking time was also estimated, since as Table 6.1 shows, in addition to park & ride and kiss & ride modes, walking represents a substantial share of station access trips for many of the stations that serve the study communities. As with the auto station access times, walking times are also estimated using TransCAD shortest path procedures. However, the TIGER/Line 1994 road network required updating to include additional node connection points in the network, such that the geocoded address data could be connected to the existing road network in a way that resulted in more logical and realistic walking paths and distance. Otherwise, the manner in which addresses were connected to nodes on the network resulted in awkward walking paths that significantly overestimated the walking distances, particularly for properties within a modest distance of the stations, which in this case are the locations of most interest.

Rather than reporting station proximity by walking in terms of distance, walking time in minutes is utilized instead, primarily to provide for interpretation of the findings relative to the auto station access mode times. As with the auto access times, a five minute station wait time is added to the estimated walk time. Traffic engineering and transit planning practice suggest that walking speeds of approximately 3 mph are representative of most pedestrians, therefore this value is used here.[187,188] Because various analyses in Chapter 7 utilize dummy variables to represent whether a property is located within walking distance of a commuter rail station, it is necessary to specify the walkshed of a typical commuter rail station. In practice, most planning agencies suggest a walkshed area extending approximately 1/3 to 1/2 mile from stations. Findings from the 1993 MBTA commuter rail survey suggest a walkshed of similar magnitude, since of passengers reporting walking as their mode of commuter rail station access, less than 4% walked more than 20 minutes, which is equivalent to one mile at an average walking speed of 3 miles per hour. Because this suggests a walkshed of considerably less than one mile for MBTA commuter rail stations, 1/2 mile, or a 10 minute walk, is used as an appropriate value.

Regarding station choice behavior for passengers originating in the study communities, survey data presented in Table 6.1 clearly show that the vast majority of passengers choose to board at stations that are located within the same town as their trip origins. For all study

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[187] Garber, Nicholas J., and Lester A. Hoel. *Traffic and Highway Engineering*. St. Paul, MN: West Publishing Company, 1988. pg. 44.
[188] Beimborn, Edward, et. al. *Guidelines for Transit Sensitive Suburban Land Use Design*. Final Report. July 1991. U.S. Department of Transportation, Urban Mass Transit Administration. DOT-T-91-13. pg. 86.

Table 6.1: Commuter Rail Station Access Characteristics

Origin Town	Boarding Station	1993 Daily Boardings	% Rider from Origin Town Using Station	Station Parking Capacity	Access Mode: Park & Ride	Access Mode: Kiss & Ride	Access Mode: Walk	Access Mode: Other	Access Time (minutes): 0 to 5	Access Time (minutes): 6 to 10	Access Time (minutes): 11 to 15	Access Time (minutes): 16 to 20	Access Time (minutes): greater than 20	Wait Time (minutes): 1 to 6	Wait Time (minutes): 7 to 10	Wait Time (minutes): greater than 10
Ipswich	Ipswich	249	95.8%	170	58.2%	14.0%	26.9%	0.9%	39.9%	35.2%	12.6%	5.9%	6.5%	70.3%	22.8%	6.9%
	Hamilton/Wenham	11	4.2%	85	67.0%	10.2%	16.0%	6.8%	45.4%	37.8%	12.0%	1.4%	3.4%	72.5%	21.6%	5.8%
TOTALS		*260*	*100.0%*	*255*	*58.5%*	*13.9%*	*26.5%*	*1.1%*	*40.1%*	*35.3%*	*12.6%*	*5.7%*	*6.3%*	*70.4%*	*22.7%*	*6.9%*
Winchester	Winchester Center	314	57.7%	237	35.8%	18.4%	44.9%	0.8%	45.2%	37.7%	11.5%	3.7%	1.9%	69.6%	24.6%	5.8%
	Wedgemere	214	39.3%	103	68.8%	6.0%	25.3%	0.0%	46.6%	36.7%	10.0%	5.0%	1.8%	87.1%	12.9%	0.0%
	West Medford	16	2.9%	30	35.8%	7.8%	56.4%	0.0%	40.8%	43.0%	15.1%	1.1%	0.0%	70.0%	28.2%	1.8%
TOTALS		*544*	*100.0%*	*370*	*48.8%*	*13.2%*	*37.5%*	*0.4%*	*45.6%*	*37.4%*	*11.0%*	*4.2%*	*1.8%*	*76.5%*	*20.1%*	*3.4%*
Acton	South Acton	212	76.3%	287	70.1%	21.2%	7.6%	1.1%	31.5%	30.4%	19.4%	9.9%	8.8%	66.4%	28.1%	5.5%
	West Concord	56	20.1%	204	59.0%	15.4%	25.6%	0.0%	37.3%	31.2%	14.7%	6.1%	10.7%	60.2%	31.0%	8.8%
	Concord	10	3.6%	40	44.4%	14.9%	40.7%	0.0%	30.2%	39.9%	20.8%	5.4%	3.7%	70.1%	27.2%	2.7%
TOTALS		*278*	*100.0%*	*531*	*66.9%*	*19.8%*	*12.4%*	*0.9%*	*32.6%*	*30.9%*	*18.5%*	*9.0%*	*9.0%*	*65.3%*	*28.7%*	*6.1%*
Needham	Hersey	472	45.3%	322	55.1%	8.4%	35.7%	0.7%	52.8%	30.4%	7.7%	5.4%	3.7%	85.1%	12.8%	2.1%
	Needham Junction	244	23.4%	170	48.1%	17.5%	33.7%	0.8%	38.3%	35.3%	16.4%	6.8%	3.3%	71.0%	20.8%	8.2%
	Needham Center	167	16.0%	36	35.0%	9.6%	52.5%	2.8%	67.0%	27.3%	5.1%	0.0%	0.6%	86.7%	11.6%	1.7%
	Needham Heights	149	14.3%	14	20.1%	13.4%	66.4%	0.0%	50.0%	35.6%	8.2%	2.7%	3.4%	82.8%	15.6%	1.6%
	Wellesley Square	9	0.9%	260	49.1%	12.2%	38.1%	0.6%	36.6%	34.6%	15.6%	4.4%	8.9%	70.6%	20.9%	8.5%
	West Roxbury	2	0.2%	61	24.2%	5.8%	66.8%	3.2%	54.5%	31.6%	10.1%	3.5%	0.3%	79.1%	19.1%	1.8%
TOTALS		*1,043*	*100.0%*	*863*	*45.2%*	*11.5%*	*42.4%*	*1.0%*	*51.1%*	*31.8%*	*9.5%*	*4.4%*	*3.1%*	*81.6%*	*15.0%*	*3.4%*
Norfolk	Norfolk	353	93.1%	491	80.0%	16.1%	3.7%	0.3%	35.5%	42.7%	18.5%	3.0%	0.4%	63.6%	22.4%	14.0%
	Walpole	20	5.3%	377	71.6%	14.2%	13.3%	0.9%	38.1%	41.1%	12.1%	6.4%	2.3%	60.5%	31.2%	8.3%
	Norwood Central	6	1.6%	393	54.1%	19.0%	24.4%	2.4%	46.3%	38.8%	12.3%	0.2%	2.4%	58.8%	34.3%	6.9%
TOTALS		*379*	*100.0%*	*1,261*	*79.1%*	*16.0%*	*4.5%*	*0.3%*	*35.8%*	*42.5%*	*18.0%*	*3.1%*	*0.5%*	*63.3%*	*23.1%*	*13.6%*

Source: Humphrey, Thomas J. *MBTA Systemwide Passenger Survey. Commuter Rail 1993*. March 1995.

Notes: Row and column entries may not total because of lack of survey responses to some categories of information

Station access data are for all origin towns to each station communities but the town of Acton, greater than 90% of the commuter rail trip origins were from within the same town as the boarding station. Correspondingly, progressively fewer numbers of passengers choose to board at stations that are located in towns further inbound along the same line. This behavior is generally consistent with commuter rail station choice behavior that has been observed for other commuter rail systems. Station choice models estimated in the New York metropolitan area for NJTransit suggest that station choice is most influenced first by the presence of a station in the same town from which the passenger is originating, next by station access time, and then frequency of service at the station. In the New Jersey model, parking availability and parking fees have less influence upon station choice than these other factors.[189] Because of the recent strong growth in MBTA commuter rail ridership, parking availability may exert more of an influence in the Boston area because of recurring and systematic parking shortages now being experienced at many commuter rail stations.

As well as utilizing explicit travel times to station sites as an indicator of accessibility, a dummy variable representing the presence of a commuter rail station in a community is used as an alternative measure. This is to explore whether there is a more generally perceived accessibility advantage in having a station located within a community, regardless of the actual travel time from each individual property to the station. As mentioned in Chapter 5, this is in many ways consistent with the manner in which residential properties are marketed by real estate firms, with the simple presence of a commuter rail station in the community typically being the focus of attention, and the small variations in driving time to the station from locations throughout the community being of secondary importance.

Commuter Boat

Auto travel times to the Hingham Shipyard from properties located in the three control communities located on the South Shore were estimated in a manner identical to that for estimating the commuter rail station auto access times. Lacking any empirical data regarding terminal wait time for commuter boat service, a 5 five minute wait time, consistent with commuter rail service, is also used. Because of the location of the Hingham Shipyard commuter boat terminal relative to residential areas in Hingham, walk access for commuter boat service from Hingham is negligible, and therefore is not considered for the analysis in Chapter 7.

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[189] Kastrenakes, Cheryl Rosen. "Development of a Rail Station Choice Model for NJ TRANSIT." *Transportation Research Records* 1162. pp. 16-21.

6.9 Proximity Related Externalities

As discussed earlier in Chapter 2, the environmental impacts associated with the proximity of residential land uses to commuter rail facilities are often of particular concern when considering new commuter rail services. Typical impacts generated by commuter rail service include noise, ground-borne vibration, and to a lesser extent airborne pollution and visual intrusion, the source of which is the operation of commuter rail equipment and facilities, and the receivers of which include those located within a given distance of these facilities. Impacts generated by the operation of freight rail lines, highways, airports, and other transportation facilities are in many ways similar. The major impact types are considered in turn below, followed by discussion of the development of detailed commuter rail noise assessments for each property. Much of the commuter rail noise and vibration material presented herein is taken from a recent guidance document sponsored by the Federal Transit Administration (FTA), entitled *Transit Noise and Vibration Impact Assessment,* April 1995, which presents an overview of the state of the art and practice in noise and vibration impact assessment for many transit modes including commuter rail.[190]

Noise can be defined as unwanted sound.[191] The three primary components of noise are loudness, pitch, and fluctuation with time. Loudness is typically measured in decibels (dB), which refer to the general strength of noise. The decibel unit denotes the ratio between two quantities that are proportional to power, and when used to describe sound, the number of decibels is 10 times the logarithm to the base 10 of the ratio (p^2/p_{ref}^2), where p is the sound pressure measured in micro-pascals and p_{ref} is a reference pressure of 20 micro-pascals.[192] On average, a sound level increase of 10 dB corresponds with an approximate doubling of subjective loudness. Pitch is incorporated into the noise measure by weighting decibel measures to account for human sensitivity to various pitches, such as high frequency sounds that have been shown in surveys to be particularly annoying to most populations. The resulting measure is called an A-weighted decibel (dBA). For reference, some typical sources of both indoor and outdoor noise and their magnitudes as measured in dBA are presented in Figure 6.6.

A series of noise events, such as a series of train passbys, result in fluctuations in noise levels over time. These fluctuations in noise over time can be incorporated into single-number noise descriptors that facilitate manageable measurements and impact assessment. In transit

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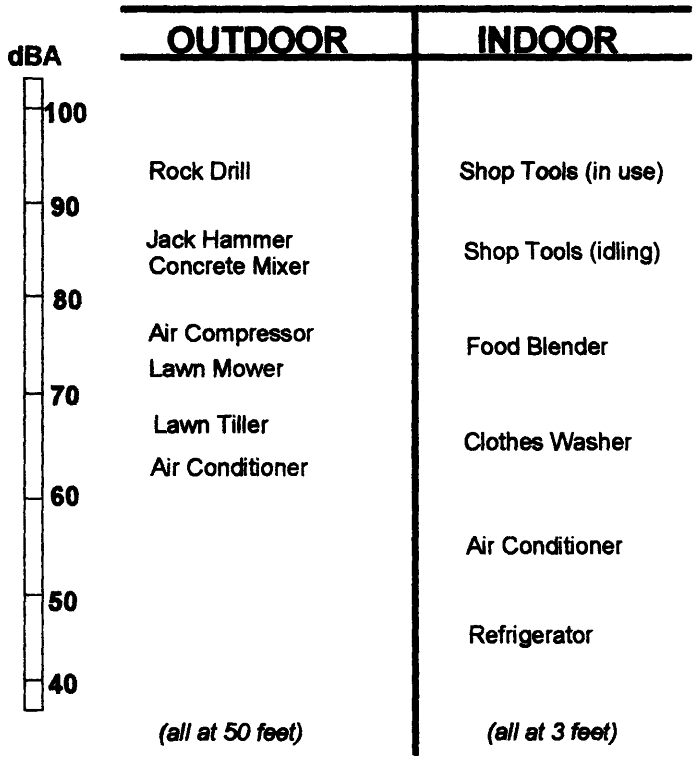
[190] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment.* Final Report. April 1995. DOT-T-95-16.

[191] Harris, Cyril M. , Ph.D., ed. *Handbook of Noise Control.* New York: McGraw-Hill Book Company, 1979. pg. 1-1.

[192] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment.* Final Report. April 1995. DOT-T-95-16. pg. 2-10.

Figure 6.6: Typical A-Weighted Sound Levels



noise assessment, there are four single-number descriptors typically used to describe noise depending upon the particular application in question.

The *Maximum Level (L_{max})* represents that maximum noise level reached during a single noise event, for instance the loudest noise level reached during a single train passby. Transit vehicle noise specifications are often expressed in L_{max}, as are noise guidelines set forth by the American Public Transit Association (APTA). However, L_{max} is typically not used as a descriptor for transit environmental noise impact assessment because it ignores both the number of noise events and their duration, which are important components in determining people's reaction to noise.

The *Sound Exposure Level (SEL)* describes the cumulative noise exposure from a single noise event, or the "noise dose", and represents the total amount of sound energy that enters a receiver's ears during a noise event such as a train passby. Because SEL incorporates the duration of events, louder events have greater SELs than do quieter ones, and events that have a longer duration have greater SELs than do shorter ones. In this manner, it is possible for the SEL of a loud event of short duration to equal that of a quieter event that is of longer duration. However, like L_{max}, SEL does not take into consideration the number of noise events occurring during a given period of time. SEL can, however, be used in combination with other data to calculate one-hour and 24-hour cumulative noise descriptors.

The *Hourly Equivalent Sound Level $L_{eq}(h)$* describes the cumulative one hour exposure to noise. Just as SEL incorporates the duration of a single noise event into a single-number descriptor, $L_{eq}(h)$ incorporates not only the duration of single events, but also the number of single events occurring in a one hour time period. SEL measures for a series of noise events occurring during a given hour can be summed and used to calculate $L_{eq}(h)$ according to the following equation:

$$L_{eq}(h)=10\ \log_{10}\left[\sum_{i=1}^{N} SEL\right] - 35.6$$

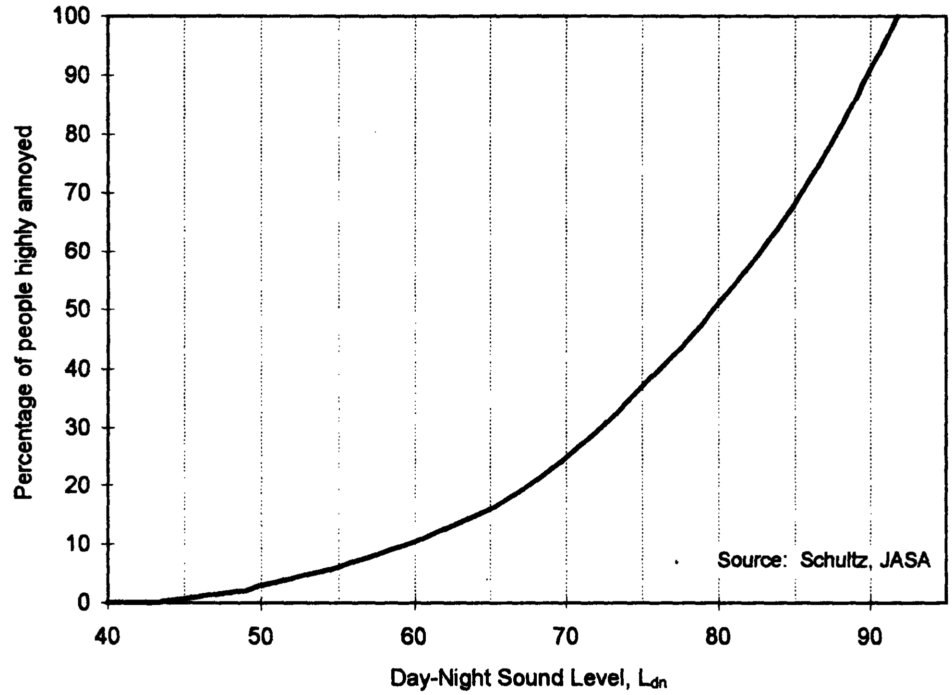
for all noise events *i* occurring in hour *h*. $L_{eq}(h)$ is often utilized as the measure of cumulative noise impact for non-residential land uses that do not involve sleeping activities, and is used by the Federal Highway Administration (FHWA) in assessing highway and traffic noise impacts.

The preferred noise descriptor when assessing noise impact upon residential land uses, however, is the *Day-Night Sound Level L_{dn}* . L_{dn} represents a cumulative 24-hour exposure, rather than just one hour as does L_{eq}. Also, in calculating L_{dn} from SEL measures, a 10 dBA penalty is applied to each SEL for noise events occurring between 10 PM and 7 AM, when residential land uses are most sensitive because of sleeping activities and when background or ambient noise levels are also less, making transit noise more noticeable. As shown before, $L_{eq}(h)$ can be derived from a series of SEL measures for noise events during a given hour. In a similar manner, 24 hourly L_{eq} measures can be summed and used to calculate L_{dn} according to the following equation:

$$L_{dn}=10\ \log_{10}\left[\sum_{i=1}^{24} L_{eq}\right] - 13.8$$

for all $L_{eq}(h)$ from hour 1 to 24, where nighttime L_{eq}'s are increased by 10 dBA before summing.

Figure 6.7: Community Annoyance Due to Noise



Large numbers of independently administered community attitudinal surveys have consistently confirmed the relationship between L_{dn} sound levels and levels of community annoyance. Typical L_{dn} values for a residential areas are approximately 50 L_{dn} for rural residential areas, 55 L_{dn} for suburban residential areas, 60 L_{dn} for "quiet" urban residential areas, and 70 L_{dn} for a "very noisy" urban residential area.[193] Figure 6.7 presents the Schultz curve, named after the author who compiled a synthesis of a large number of these community attitudinal surveys, and estimated the relationship shown in the figure. Variation between the different communities surveyed, and differences in the survey instruments that are utilized and the manner in which questions are worded accounts for most deviations from this relationship. Figure 6.8 presents the varying levels of community reaction that typically result from the introduction of a new noise source into a residential setting, relative to the ambient or existing noise level typical of an urban residential environment. As can be seen, widespread community reaction often occurs when noise levels are increased even just a few L_{dn} above the pre-existing ambient noise levels.

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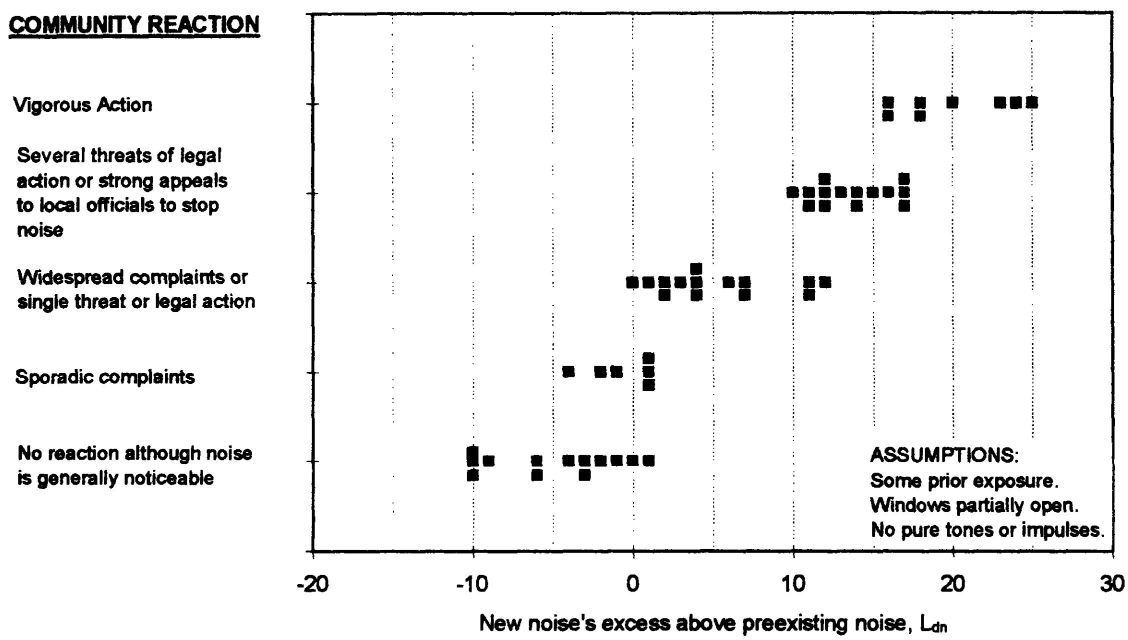
[193] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment.* Final Report. April 1995. DOT-T-95-16. pg. 2-18.

Figure 6.8: Community Reaction to New Noise Relative to Existing Noise in a Residential Urban Environment



Both commuter rail and freight rail operations generate ground-borne vibration resulting from rolling contact between the train wheels and the track. This vibration energy is conducted through the track support system, into the adjacent ground and through the soil into the foundations of nearby buildings, causing the building to move or vibrate. The descriptor typically used for vibration measurement is VdB, or decibels, which like many noise descriptors is based on a logarithmic scale. In most residential areas, background vibration levels are typically 50 VdB or lower. The threshold of perception for vibration in humans is approximately 65 VdB, however in most cases no significant response is observed unless the vibration levels exceed 70 VdB. For commuter rail, locomotives are the primary source of vibration. At 50 feet from the right-of-way, vibration levels for commuter rail typically average about 75 VdB, although levels as high as 85 VdB are sometimes observed. These levels depend upon many factors, including the geologic conditions specific to a site, the physical characteristics of the guideway, and the characteristics of the receiving building.

The suggested screening distance for the identification of vibration impacted receivers is 200 feet for commuter rail, far less than the suggested screening distance for noise impacts discussed later. Also, for noise events classified as "infrequent" by having fewer than 70 events per day as does MBTA commuter rail service, ground-borne vibration levels of up to 80

VdB are generally considered acceptable for residential buildings. Generalized vibration curves for commuter rail suggest that levels of 80 VdB or higher are typically only found within 80 to 100 feet of the right-of-way. These facts suggests that noise is typically the dominant type of impact, particularly in areas beyond 200 feet from the right-of-way. There are also many factors that influence the level of vibration experienced by a receiver, many of which are themselves difficult to measure accurately, and in practice it is often difficult to develop accurate estimates of ground-borne vibration levels.

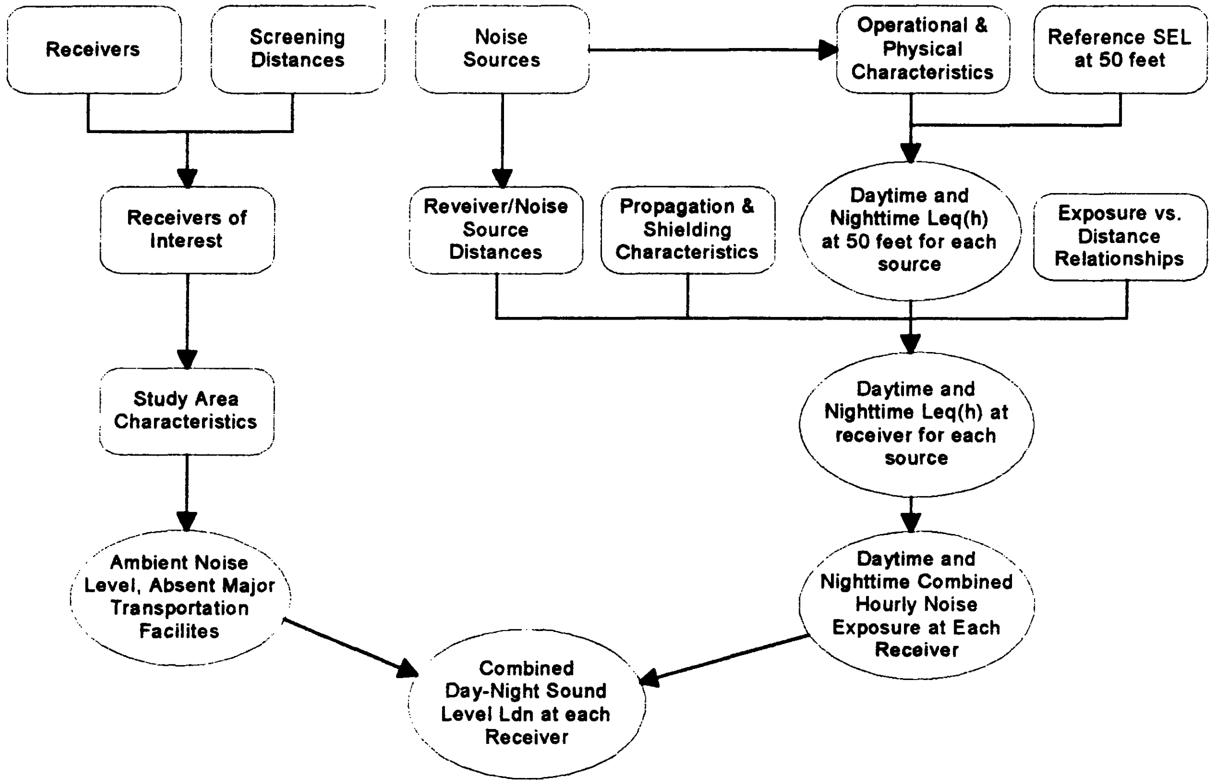
For these reasons, noise impacts are the primary focus of this thesis, with vibration impacts given secondary consideration, in so much as the observed property value impacts resulting from estimated commuter rail noise levels may somewhat overestimate the true impact of this noise, since they will likely also represent a portion of the influence from unobserved and unmeasured vibration impacts, particularly in very close proximity to the right-of-way (e.g. up to 100 feet).

Proximity impacts related to visual intrusion and air quality, as discussed in Chapter 2, are also given only secondary consideration for many of the same reasons, including the lack of research concerning these impacts and difficulty in developing accurate estimates concerning their impact upon receivers. Again, particularly in close proximity to commuter rail rights-of-way and stations, visual and air quality impacts may inflate estimates of the property value impacts resulting from commuter rail related noise, which must be considered in interpreting results of the analyses in Chapter 7.

Commuter Rail and Freight Rail Proximity Impacts

Procedures set forth by the FTA were used in performing a detailed noise assessment for each property in the final data set. Figure 6.9 presents an overview of these procedures as they were applied in this thesis. For commuter rail and freight rail modes, specific noise sources are considered individually at first, and then combined later into a single estimate of L_{dn} at each receiver or property. The first step in this process was the identification of commuter rail and freight rail related noise sources, including all rights-of-way, grade crossings, stations, and layover yards. Data from the MBTA were used to identify commuter rail rights-of-way, stations, and layover yards. Detailed data concerning the physical parameters and operating characteristics of these facilities were also obtained from the MBTA, AMTRAK, and the Massachusetts Department of Public of Utilities (DPU) which regulates operating conditions on intra-state rail lines. Attribute data collected included the number of operations by time of day and direction, operating speeds, and the number of locomotives and passenger coaches in each train consist. Also, where possible, information concerning the characteristics of the guideway including whether track is jointed or welded, aerial/at-

Figure 6.9: Overview of Detailed Noise Analysis Procedure

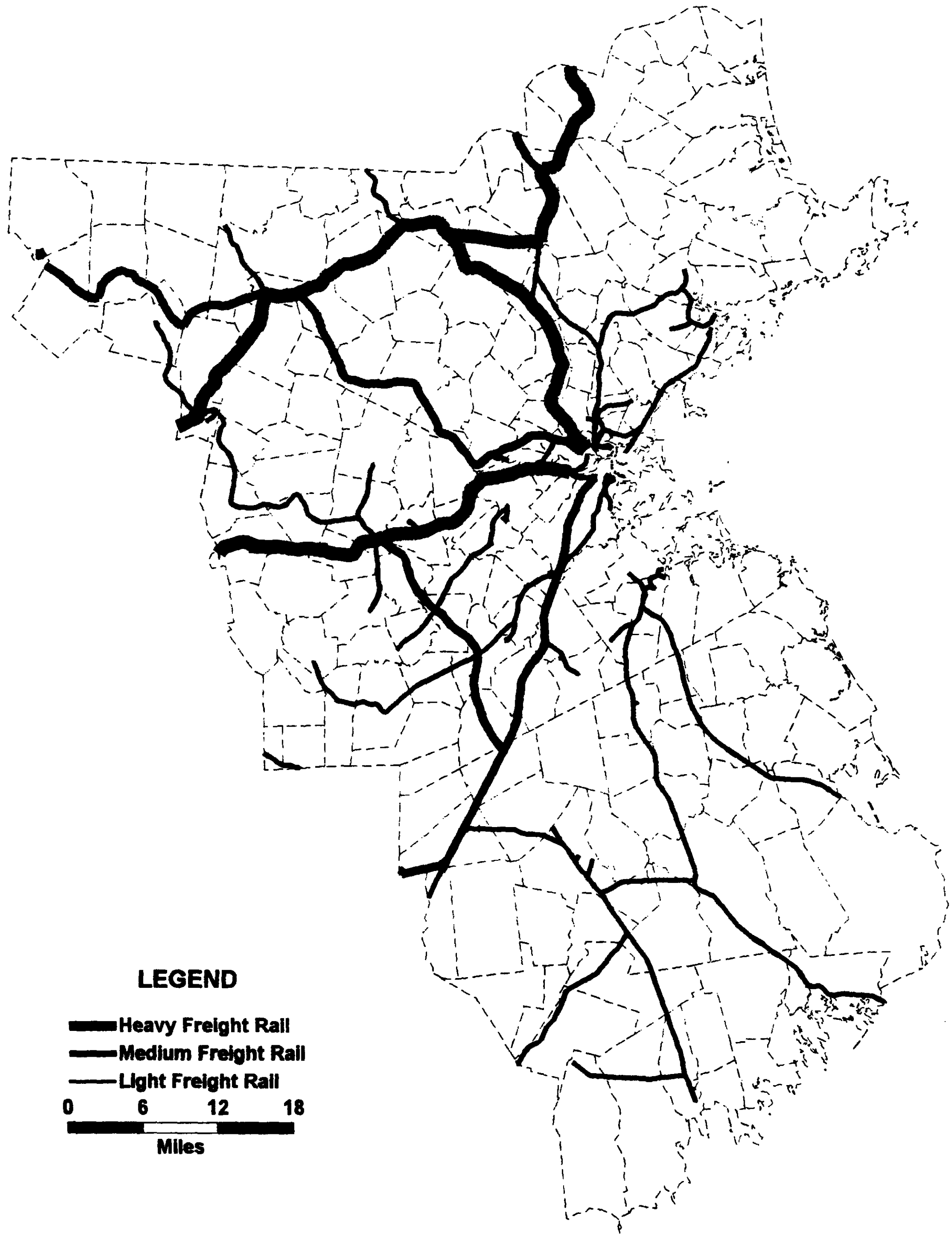


grade/tunnel, and whether ties are made of wood or concrete was also collected. In all cases, efforts were made to collect data representative of the years 1992 and 1993 in order to be consistent with the property sales data set. For freight rail lines, the railroad layer information obtained from the 1994 U.S. Census TIGER files was updated by identifying rail lines that had been abandoned as of 1990. Information regarding the type, frequency, and operating characteristics such as speed and consist size of freight rail operations conducted over all rail lines in Eastern Massachusetts during 1990-1994 was obtained from various sources, again for the years 1992 and 1993 where possible.[194] Freight rail lines operating in Eastern Massachusetts are presented in Figure 6.10.

For the commuter rail and freight rail lines identified above, information regarding the location and characteristics of both commuter rail and freight rail grade crossings was then obtained. This was a far more difficult task than originally anticipated, requiring the collection, reconciliation, and updating of multiple data sources. Data fields in the Federal Railroad Administration grade crossing inventory were first used to identify only those public and

[194] Abandonments and freight rail operations data obtained from Karr, Ronald Dale. *The Rail Lines of Southern New England: A Handbook of Railroad History*. Pepperell, Massachusetts: Branch Lines Press, 1995. Other sources include whistle ban petition documents to the Massachusetts DPU, and FRA Grade Crossing Inventory attribute data.

Figure 6.10: Freight Rail Lines in Eastern Massachusetts



private grade crossings that were at-grade with auto traffic, excluding pedestrian crossings and under or over passes.[195] Next, preliminary latitude and longitude data from FRA was used initially to identify the locations of these at-grade crossings. However, many errors were found in this preliminary locational data, requiring substantially editing and updating of this information to ensure accuracy. Next, because many grade crossings in Eastern Massachusetts have been granted whistle blowing bans as discussed earlier in Chapter 2, Section 2.2.2, information regarding whistle blowing waivers at specific grade crossings was obtained from the Massachusetts Department of Public Utilities (DPU)[196], Amtrak[197], Springfield Terminal Railway Company[198], and Conrail.[199] Figure 6.11 shows that location and whistle blowing ban status of all at-grade crossings on commuter rail and major freight lines in Eastern Massachusetts.

Having identified all relevant commuter rail and freight rail noise sources, these facilities were repositioned in all affected study and control communities using the digital orthophotography as a base reference as described earlier. Next, using noise screening distances suggested by FTA, all possible noise impact properties were identified and similarly repositioned using the aerial photography as baseline, supplemented by site visits in many cases. Based on FTA and DPU guidance, the noise screening distances utilized for unobstructed noise paths are 750 feet for commuter rail rights-of-way, 450 feet for commuter rail stations, 1,000 feet for layover yards, and 750 feet for grade crossings without whistle blowing bans.[200] This ensured the highest accuracy in the proximity distance measures between these various facilities and each property that were calculated using TransCAD. To confirm that distances depicted in the aerial photography were being accurately measured by the GIS software, MBTA commuter rail coaches shown in the aerial photography were used as identifiable reference features whose true measurements (85 feet in length) were known previously and could be independently verified. In addition to aiding in the development of these distance measurements, GIS techniques also facilitated the association of the attribute information for each closest noise source with each property, which was necessary as input

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195 U.S. Department of Transportation, Federal Railroad Administration, Grade Crossing Inventory, May 1994 update.

196 Massachusetts Department of Public Utilities. *Town of Acton*, DPU 89-160, October 3, 1991. *Town of Andover*, D.P.U. 93-121, March 28, 1994. *Town of Wilmington*, D.P.U. 90-49, July 6, 1993. *Town of* Franklin, D.P.U. 89-92, November 6, 1990.

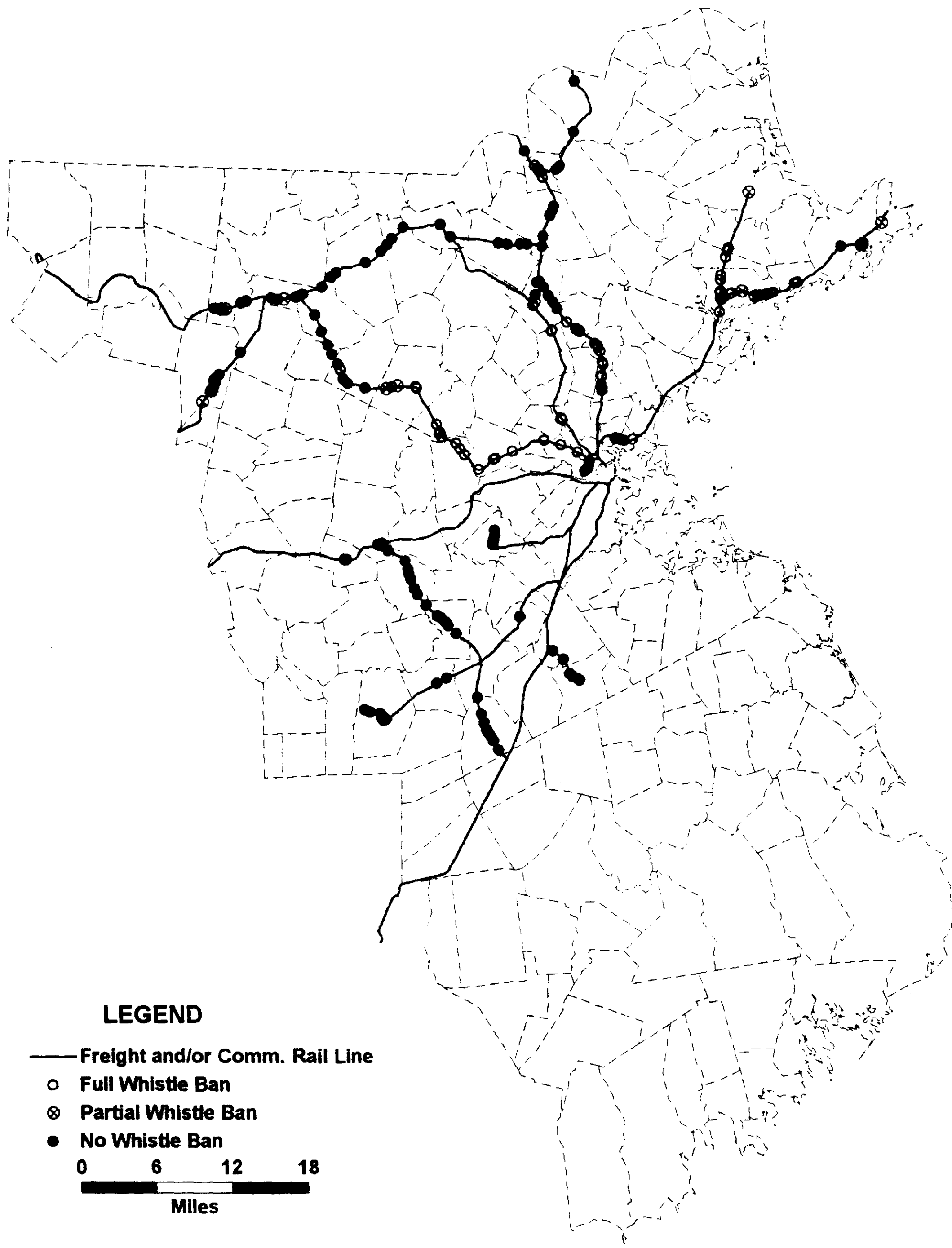
197 National Railroad Passenger Corporation. Amtrak. New England Division Commuter Lines. *Employee Timetable No. 6, Special Instructions*. Effective February 26, 1996.

198 Springfield Terminal Railway Company. *Timetable No. 1*. Effective January 2, 1995.

199 Michael Cross, Consolidated Rail Corporation, Northeastern Division. Telephone interview.

200 U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment*. Final Report. April 1995. DOT-T-95-16. pg. 4-3. The obstructed noise path distance of 1,000 feet for "yards and shops" was used for layover yard screening distances. DPU whistle blowing ban waiver applications were used as guidance for determining grade crossing screening distances.

Figure 6.11: At-Grade Crossings and Whistle Ban Status in Eastern Massachusetts



data for the detailed noise assessments.

In many cases, the noise impacts from these commuter rail and freight rail facilities overlap and interact in complex ways. For instance, commuter rail and freight rail operations on a shared right-of-way have noise impacts along the right-of-way and at grade crossings that overlap, but are each a function of the separate operating parameters of each rail traffic type. Especially when attempting to make comparison among study areas having different commuter rail characteristics (for instance, one with commuter rail traffic only and one with combined freight and commuter rail operations), it is important to account fully and accurately for these many differences and interactions. Therefore, rather than simply using the distance measures as a proxy for noise impact, detailed noise assessments allowing the development of a single-number noise descriptor based on the combined noise impact from each source are utilized. Later, once the value of each decibel of L_{dn} impact is determined from the analysis in Chapter 7, estimates of how residential property values vary with respect to proximity to each separate noise source may be estimated by decomposing the marginal contribution of each specific noise source type to the overall noise at a property.

Utilizing the highly accurate measurements of the proximity of each noise source to each receiver or property, and the detailed noise source operating and physical characteristics, L_{dn} noise exposure estimates were estimated for each property according to current FTA noise assessment guidelines. First, ambient noise conditions for each property are estimated based upon population density per square mile (p), based on procedures promulgated by FTA and the Environmental Protection Agency (EPA), according to the following formula:

$$\mathbf{L_{dn} = 22 + 10\log(\mathit{p}) \qquad (in\ dBA)}$$

In areas away from major transportation facilities, this formula provides an appropriate although somewhat low estimate of L_{dn} noise levels. It is used as an initial noise level baseline for all properties, including those closer to commuter rail and freight rail lines, to ensure that noise levels for properties near the screening distance for these facilities are not underestimated.

After estimating the ambient noise level in the absence of any transportation facility impacts, the daytime $L_{eq}(h)$ at 50 feet and the nighttime $L_{eq}(h)$ at 50 feet are calculated separately for each noise source based on the reference SELs and the operating characteristics and physical parameters of each individual noise source and time of day. Calculations used in determining these $L_{eq}(h)$ noise levels resulting from commuter rail and freight rail operations are presented in Table 6.2. Although the formulae presented were not developed specifically

Table 6.2: Computation of $L_{eq}(h)$ at 50 feet

Diesel-Electric Locomotives

$$L_{eqL}(h) = SEL_{ref} + 10\log(N_{locos}) + C_T - 10\log\left(\frac{S_{train}}{50}\right) + 10\log(V_{train}) - 35.6$$

$$\text{where} \quad C_T = \begin{cases} 0 & for \quad T<6 \\ 2(T-5) & for \quad T\geq 6 \end{cases}$$

assuming a diesel locomotive power rating of approximately 3,000 hp

Rail Vehicles

$$L_{eqC}(h) = SEL_{ref} + 10\log(N_{cars}) + 20\log\left(\frac{S_{train}}{50}\right) + 10\log(V_{train}) - 35.6$$

with the following adjustments made as applicable:
+5 dBA for jointed track
+4 dBA for an aerial structure with slab track

Locomotive Horns/Whistles

$$L_{eqH}(h) = SEL_{ref} - 10\log\left(\frac{S_{train}}{50}\right) + 10\log(V_{train}) - 35.6$$

Crossing Signals

$$L_{eqX}(h) = SEL_{ref} + 10\log(N) + 10\log\left(\frac{E}{3600}\right) - 35.6$$

Locomotive Idling

$$L_{eqY}(h) = SEL_{ref} + 10\log(N) + 10\log\left(\frac{E}{3600}\right) - 35.6$$

Automobiles

$$L_{eqA}(h) = SEL_{ref} + 10\log(V_{auto}) + \left[38.1 \times \log\left(\frac{S_{auto}}{50}\right)\right] - 10\log\left(\frac{S_{auto}}{50}\right) - 35.6$$

Source: U.S. Department of Transportation, Federal Transit Adminsitration. *Transit Noise and Vibration Assessment*. April 1995. DOT-T-95-16.

N_{locos} = average number of locomotives per train
N_{cars} = average number of passenger cars per trains
T = average throttle setting of diesel-electric locomotive
S_{train} = train speed, in miles per hour
S_{auto} = automobile speed in miles per hour, excluding stop time at red lights
V_{train} = average hourly volume of train traffic, in trains per hour. For calculation of daytime Leq(h), use the average hourly daytime volume of traffic in trains per hour, calculated as (number of trains 7 AM to 10 PM) /15. For calculation of nighttime Leq(h) use the average hourly nighttime volume of traffic in trains per hour, calculated as (number of trains 10 PM to AM to 7 AM) /9
V_{auto} = average hourly volume of automobile traffic, in vehicles per hour. For calculation of daytime Leq(h), use the average hourly daytime volume of automobile traffic in vehicles per hour, calculated as (number of vehicles 7 AM to 10 PM) /15. For calculation of nighttime Leq(h) use the average hourly nighttime volume of automobile traffic in vehicles per hour, calculated as (number of vehicles 10 PM to AM to 7 AM) /9.
E = duration of one event, in seconds
N = number of events of this type that occur during one hour. For calculation of daytime Leq(h), use the average hourly daytime number of events of this type calculated as (number of events 7 AM to 10 PM) /15. For calculation of nighttime Leq(h) use the average hourly nighttime number of events of this type calculated as (number of events 10 PM to AM to 7 AM) /9

Table 6.3: Source Reference SELs at 50 feet

Noise Source	Source Type	Reference SEL (dBA)	Approximate Lmax (dBA)
Rail Cars	Fixed-Guideway	82	80
Locomotives - Diesel	Fixed-Guideway	92	88
Locomotives Horns or Whistles	Fixed-Guideway	108	105
Crossing Signals	Stationary	109	73
Automobiles	Highway/Transit	73	70
Locomotive Idling	Stationary	116	80

Source: U.S. Department of Transportation. Federal Transit Administration. *Transit Noise and Vibration Impact Asses.* April 1995. DOT-T-95-16. pp. 6-10, 6-14, 6-17.

for freight rail operations, no readily available and superior methods of freight rail noise assessment could be located. Therefore, these methods are utilized here in conjunction with appropriate adjustments related to the operating and physical condition characteristics of freight rail operations in the study and control areas. Note that the duration of crossing signal events are dependent upon the number and length of locomotives and rail vehicles in each train consist. Rail vehicle lengths used in the computations are 65 feet for locomotives, 85 feet for passenger coaches, and 65 feet for rail freight cars. Reference source noise levels used in these computations are presented in Table 6.3 and are expressed in terms of SEL at a reference distance of 50 feet and a reference speed. Both commuter rail and freight locomotive whistles are assumed to be used only at at-grade crossings where there are no whistle blowing bans in effect, or only partial bans (e.g. whistles in one direction only) in effect, as identified earlier.

With estimates of hourly noise exposure at 50 feet from each source now available, propagation characteristics are then considered in computing the actual noise exposure at the receivers of interest for each noise source. This is achieved by using the relationships between noise exposure and distance for each type of noise source, as presented in Table 6.4. The "ground factor" G adjustment is included to account for the relative heights of both the noise source and the receiver, the height of any noise barrier located between the two, and whether ground conditions between the source and receiver are "hard" (i.e. non-absorptive) or soft. For hard ground, G = 0. For soft ground, which is assumed for this thesis, G is calculated as:

$$G = \begin{cases} 0.66 & H_{eff} < 5 \\ 0.75\left(1 - \dfrac{H_{eff}}{42}\right) & 5 < H_{eff} < 42 \\ 0 & H_{eff} > 42 \end{cases}$$

Table 6.4: Noise Exposure vs. Distance Relationships

Stationary Sources

$$L_{eq}(h) = L_{eq}(h)\Big|_{at\ 50\ feet} - 20\log\left(\frac{D}{50}\right) - 10G\log\left(\frac{D}{50}\right)$$

Fixed-Guideway Rail Car Passbys

$$L_{eq}(h) = L_{eq}(h)\Big|_{at\ 50\ feet} - 10\log\left(\frac{D}{50}\right) - 10G\log\left(\frac{D}{42}\right)$$

Fixed-Guideway Locomotive and Rubber-Tired Passbys, Highway Vehicle Passbys and Horns

$$L_{eq}(h) = L_{eq}(h)\Big|_{at\ 50\ feet} - 10\log\left(\frac{D}{50}\right) - 10G\log\left(\frac{D}{29}\right)$$

Source: U.S. Department of Transportation, Federal Transit Adminsitration. *Transit Noise and Vibration Assessment*. April 1995. DOT-T-95-16.

D = distance in feet from source to receiver
G = "ground factor"

where H_{eff} is equal to:

$$H_{eff} = \frac{H_s + 2H_b + H_r}{2}$$

and where H_s is the height of the noise source (8 feet for trains with diesel-electric locomotives), H_b is the height of any noise barriers present, and H_r is the height of the noise receiver (assumed at 5.5 feet). For all estimates, topography is assumed to be flat.

Prior to combining these propagation adjusted daytime and nighttime noise exposure estimates for each noise source, a pure tone penalty of 5 dBA is applied to noise sources including crossing bells and train horns and whistles that can be particularly annoying to people. After accounting for any pure tone penalties, an estimate of shielding attenuation is subtracted from these propagation adjusted daytime and nighttime noise exposure estimates for each source based on distance from source to receiver. Although inspection of the aerial photography would have allowed the determination of the number of intervening buildings between each noise source and each receiver, this was not possible given resource constraints. As an alternative, estimates of shielding attenuation are made based on general rules suggested by FTA, namely that one row of intervening buildings is assumed every 100 feet, with a -4.5 dBA attenuation for the first row, and an additional -1.5 dBA for each additional row up to a maximum of -10 dBA attenuation.[201]

Finally, these adjusted daytime noise exposure estimates are combined into composite estimates of both hourly daytime and hourly nighttime noise exposure. The formula for combining hourly noise exposure estimates for each time of day into a measure of the total hourly L_{eq} from all sources for that time of day is:

$$L_{eq}(total) = 10\log\left(\sum_{all\ noise\ sources} 10^{\left(\frac{L_{eq}}{10}\right)}\right)$$

These combined daytime and nighttime hourly noise exposure estimates are then combined into a single-number noise exposure estimate of L_{dn}, with nighttime noise being increased by a 10 dBA penalty. The formula for L_{dn} is:

$$L_{dn} = 10\log\left[(15)\times 10^{\left(\frac{L_{eq}(day)}{10}\right)} + (9)\times 10^{\left(\frac{L_{eq}(night)+10}{10}\right)}\right] - 13.8$$

Other Transportation Facility Related Proximity Impacts

Unlike freight rail operations on rights-of-way shared with commuter rail, the noise impacts of many other types of transportation facilities such as highways and airports are for the most part independent of commuter rail operations, and were therefore controlled for experimentally by identifying impacted properties and eliminating them from further analysis. For the major highways shown earlier in Chapter 5, Figure 5.8, a screening distance of 1,000 feet was utilized for identifying potentially noise affected properties. This screening distance is based on suggested FTA guidelines for noise from Interstate Highways, as well as the findings of earlier empirical studies of highway noise impact reviewed in Chapter 4.

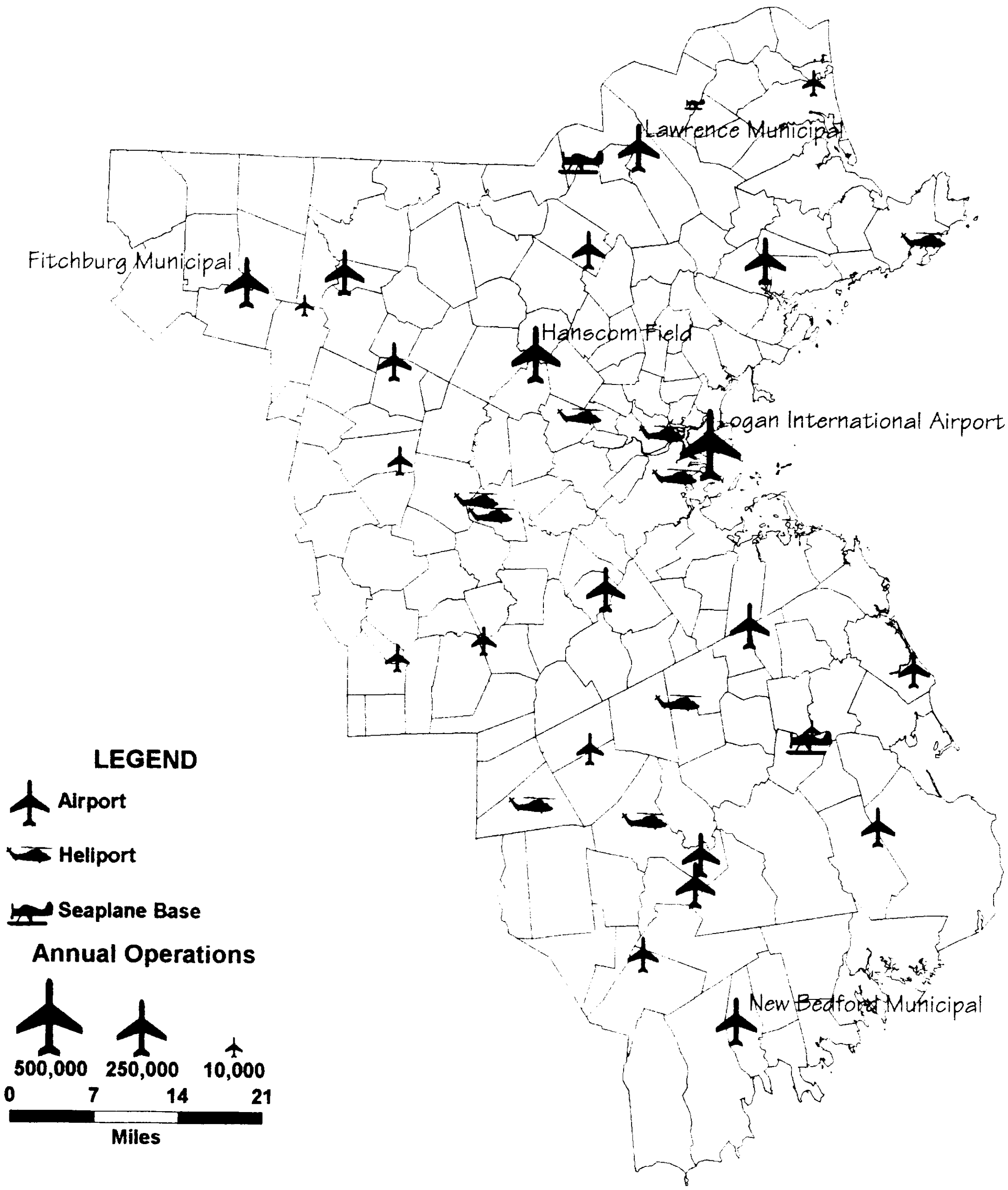
Variations in traffic levels and the speed of traffic on local roadways were estimated in accordance with the road classifications used earlier in estimating local auto travel times. The

[201] U.S. Department of Transportation, Federal Transit Administration. *Transit Noise and Vibration Impact Assessment.* Final Report. April 1995. DOT-T-95-16. Table 5-7, footnote 1, pg. 5-16.

road class on which each property had frontage was identified using the address data and GIS procedures, and served as a proxy variable for traffic and operating conditions. Each property was then assigned to one of three qualitative local road traffic impact classes. Generally, arterial roads, collector roads, and local roads were considered to be high, medium, and low impact, respectively.

Commercial, military, and general aviation airports in Eastern Massachusetts were identified using Federal Aviation Administration (FAA) and Massachusetts Aeronautical Commission (MAC) data. Figure 6.12 shows the location, type, and level of activity at each facility. Discussions with FAA and MAC personnel suggest that for most general aviation facilities, significant noise impacts do not typically extent beyond the boundary of the airport. For the study and control communities, only Hanscom Field in Bedford might have a possible impact. Noise contour information for Hanscom obtained from the Massachusetts Port Authority reveals that no sample properties are impacted by 60 L_{dn}, or higher noise levels. There are 23 sample properties between the 55 L_{dn} and the 60 L_{dn} noise level contours, however because these levels are not significantly greater than the ambient noise levels throughout much of this community, they remain in the data set. Another possible source of impact relevant only to Lexington is the Minuteman Bikeway. Because existing research suggests that bikeway facilities may affect property values as discussed in Chapter 5, eight properties that are located within 150 feet of the bikeway are excluded from further analysis.

Figure 6.12: Airports and Heliports in Eastern Massachusetts



Chapter 7
Analysis and Interpretation

With the development of the disaggregate parcel-level data set described in Chapter 6 now complete, the methods presented in Chapter 3 are applied to this data in evaluating the possible impacts of commuter rail service upon single-family residential property values. The chapter begins with the analysis of first the local and then the regional components of commuter rail accessibility. Following this, proximity related externalities generated by both commuter rail and freight rail operations are examined. Where possible, the various analytical techniques such as hedonic models and paired data analysis described earlier in Chapter 3 are utilized, and the results from each method are compared for consistency and cross-validation.

7.1 Commuter Rail Local Accessibility

The main data set containing 4,093 records was used to obtain a pooled data set of 2,231 observations for the five study towns served by commuter rail. Variable definitions are presented in Table 7.1, followed by summary statistics for the main data set of 4,093 records presented in Table 7.2. Because only one half of the records in the pooled data set contained data for heating system type and fuel, these data fields were eliminated. Fifty-six records for which there was no housing style data were eliminated, leaving a total of 2,175 records in the pooled data set. Finally, 62 homes that were within 1,000 feet of a major highway (mostly in Needham and Acton) were eliminated from the final data set, leaving a total of 2,113 records in the final pooled data set to be used in evaluating local commuter rail accessibility. This pooled data set of study towns was then further stratified by town into five individual study town data sets.

The Acton data set was reduced to 469 records from 495 records because of 26 homes within 1,000 feet of a major highway. The Ipswich data set was reduced to 268 records from 270 records because of 2 records that had no style data. The Needham data set had no heating system or fuel data, so these fields were eliminated from the data set, and the data set was

Table 7.1: Variable Definitions

Variable Name	Description
Dependent Variable and Measures of Value	
SLPRIC	Sales price (fair market property value) in thousands of real January 1992 dollars, as adjusted with Case-Shiller repeat sales home price index
LPRICE	Dummy variable indicating whether house is classified as being in the lower price range (values of SLPRIC up to $143)
MPRICE	Dummy variable indicating whether house is classified as being in the moderate price range (values of SLPRIC from $143 to $215)
HPRICE	Dummy variable indicating whether house is classified as being in the higher price range (value of SLPRIC over $215)
ASDVAL	Total assessed value of building and lot in thousands of dollars
Structural Attributes	
ULAREA	Usable living area measured in square feet
BEDS	Number of bedrooms
BATHS	Total number of bathrooms, including whole and half baths
FCDWAT	Dummy variable indicating that the heating system type is forced hot water
FCDAIR	Dummy variable indicating that the heating system type is forced hot air
HTOTH	Dummy variable indicating that the heating system type is some other than forced hot water or forced hot air
OIL	Dummy variable indicating heating fuel type is oil
GAS	Dummy variable indicating heating fuel type is natural gas
OTFUEL	Dummy variable indicating heating fuel type is some other than oil or natural gas
AGE	Age of the house in years as of year of sale
AGE100	Dummy variable indicating that the house is 100 years of age or older, and therefore classified as antique by the local assessor
COLONL	Dummy variable indicating a colonial style house
CAPE	Dummy variable indicating a cape cod style house
RANCH	Dummy variable indicating ranch style house
CONTMP	Dummy variable indicating contemporary style house
STLOTH	Dummy variable indicating architectural style is some other than those listed above
Site and Location Attributes	
LTSQFT	Lot size measured in square feet
POPDEN	1990 population density per square mile for the block group within which house is
COAST	Distance from house to coastline of the Atlantic Ocean (feet)
HHINC	Block group median household income (1989 dollars)
Provision and Cost of Local Services	
PUPIL	Per pupil expenditure measured as an integrated student cost for fiscal year 1992
SCLTST	A weighted school quality index based upon 1990 state standardized MEAP test
VCRIME	Violent crime rate measures as crimes per 1,000 population (for 1991, 1992, or
NVCRIM	Non-violent property crime rate measures as crimes per 1,000 population (for 1991, 1992, or 1993)
TXRATE	Residential property tax rate per $1,000 of assessed valuation (fiscal year 1992)
Local and Regional Accessibility Measures	
AUTO1	Network estimated AM peak period auto access time to the nearest major highway interchange (minutes)
AUTO2	CTPS 1992 estimated AM peak period travel time from CTPS zones to downtown Boston financial district CTPS Zone 5 (minutes)
JTWTIM	Block group journey-to-work time from 1990 U.S. Census (minutes)
STATN	Home is located in a town that receives direct commuter rail service by virtue of having a commuter rail station located within its corporate boundary
RAIL1	Network estimated AM peak period auto access time to the nearest commuter rail station (minutes)
WLKTIM	Network estimated walking access time to the nearest commuter rail station
WLK12M	Dummy variable indicating house is located within 1/2 mile (10 minute walk time) of a commuter rail station
WLK14M	Dummy variable indicating house is located within 1/4 mile (5 minute walk time) of a commuter rail station
RAIL2	1991 average AM peak period commuter rail scheduled travel time from nearest commuter rail station to North or South station (minutes)
BOAT1	Network estimated AM peak period auto access time to the Hingham shipyard commuter boat terminal (minutes)

Table 7.1: Variable Definitions (continued)

Variable Name	Description
Proximity Impact Measures	
CROWFT	Distance from house to nearest commuter rail right-of-way (feet)
CROW1000	Dummy variable indicating house is located within 1,000 feet of commuter rail right-
FROWFT	Distance from house to nearest freight rail right-of-way (feet)
XINGFT	Distance from house to nearest commuter rail or freight rail at-grade crossing at which train whistles are blown for all or some train crossings (feet)
STNFT	Distance from house to nearest commuter rail station (feet)
LAYOFT	Distance from house to nearest commuter rail layover facility (feet)
HWYFT	Distance from house to nearest major highway right-of-way (feet)
HWY1000	Dummy variable indicating house is located within 1,000 feet of a major highway
TRFHVY	Dummy variable indicating house located on a street with heavy traffic volume
TRFMED	Dummy variable indicating house located on a street with moderate traffic volume
TFHVYMED	Dummy variable indicating house located on a street with heavy or moderate traffic
TRFLGT	Dummy variable indicating house located on a street with light traffic volume
BKWYFT	Distance from house to Minuteman Bikeway (feet)
BKWY150	Dummy variable indicating house is located within 150 feet of Minuteman Bikeway
LDN1	Estimated total combined noise exposure of house from all sources, measured in L_{dn} and assuming no shielding from intervening buildings
LDN1_IPT	Dummy variable indicating house is noise impacted above what the ambient noise level would be in the absence of any transportation facilities, under the assumptions
LDN2	Estimated total combined noise exposure of house from all sources, measured in L_{dn} and assuming shielding from intervening buildings
LDN2_IPT	Dummy variable indicating house is noise impacted above what the ambient noise level would be in the absence of any transportation facilities, under the assumptions

reduced to 667 records from 701 records because of 34 homes that were within 1,000 feet of a major highway. The Norfolk data set was reduced to 300 records from 305 records because 5 records had no style data. The Winchester data set had no heating system or fuel data, so these fields were eliminated, and the data set was reduced to 458 records from 460 records because of two homes that were within 1,000 feet of a major highway. The data set was further reduced to 409 records because of 49 records for which there was no style data.

Note that for all of the local accessibility models presented below, for the multi-category dummy variables representing housing style and local traffic level, colonial style is used as the benchmark for the housing style group of variables, and light traffic is the benchmark for the local road traffic variables. For the quasi-experimental hedonic models of both accessibility and proximity related externality effects upon property values, inspection of the correlation coefficients for initial model runs indicated very high collinearity between the RAIL1 and WLKTIM variables. This would be expected a priori given the use of similar networks and network procedures in estimating these variables. In the final model specifications as presented, this problem is addressed by treating walking access as a dummy variable indicating whether a property is located within a 10 minute (1/2 mile) walk of a commuter rail station, except for Acton where 15 minutes (3/4 mile) is used because of sample

Table 7.2: Summary Statistics

Variable Name	Mean	Std. Dev.	Min.	Max.	Number of Obs.	Spatial Level of Data
SLPRIC	$248.284	$117.047	$24.796	$1,032.424	4,093	parcel
LPRICE	0.148	-	-	-	4,093	parcel
MPRICE	0.334	-	-	-	4,093	parcel
HPRICE	0.518	-	-	-	4,093	parcel
ASDVAL	$233.981	$95.318	$31.200	$967.000	4,093	parcel
Structural Attributes						
ULAREA	2,159	987	456	10,624	4,093	parcel
BEDS	3.3	0.9	1.0	10.0	4,093	parcel
BATHS	1.9	0.7	0.5	6.5	4,093	parcel
FCDWAT	0.679	-	-	-	1,070	parcel
FCDAIR	0.237	-	-	-	1,070	parcel
HTOTH	0.083	-	-	-	1,070	parcel
OIL	0.728	-	-	-	1,070	parcel
GAS	0.227	-	-	-	1,070	parcel
OTFUEL	0.045	-	-	-	1,070	parcel
AGE	42.3	38.2	1.0	338.0	4,093	parcel
AGE100	0.062	-	-	-	4,093	parcel
COLONL	0.345	-	-	-	3,635	parcel
CAPE	0.157	-	-	-	3,635	parcel
RANCH	0.189	-	-	-	3,635	parcel
CONTMP	0.049	-	-	-	3,635	parcel
STLOTH	0.149	-	-	-	3,635	parcel
Site and Location Attributes						
LTSQFT	36,589	58,408	871	1,611,738	4,093	parcel
POPDEN	2,001	1,764	165	7,247	4,093	block group
COAST	56,790	40,666	56	150,924	4,093	parcel
HHINC	$64,751	$15,503	$29,667	$107,696	4,093	block group
Provision and Cost of Local Services						
PUPIL	$5,534	$854	$4,243	$7,102	4,093	town
SCLTST	437.8	41.0	365.8	491.9	4,093	town
VCRIME	0.895	0.611	0.310	2.525	4,093	town
NVCRIM	15.984	5.643	1.866	24.668	4,093	town
TXRATE	$13.87	$1.35	$12.00	$16.88	4,093	town
Local and Regional Accessibility Measures						
AUTO1	9.2	6.5	0.3	30.4	4,093	parcel
AUTO2	48.9	13.9	28.0	72.0	4,093	CTPS traffic zone
JTWTIM	25.8	4.3	15.7	39.7	4,093	block group
STATN	0.545	-	-	-	4,093	parcel
RAIL1	14.7	14.3	0.6	54.0	4,093	parcel
WLKTIM	132.1	157.4	1.0	591.0	4,093	parcel
WLK12M	0.063	-	-	-	4,093	parcel
WLK14M	0.009	-	-	-	4,093	parcel
RAIL2	34.3	15.5	11.0	66.0	4,093	parcel
BOAT1	55.3	19.4	5.1	93.8	4,093	parcel

Table 7.2: Summary Statistics (continued)

Variable Name	Mean	Std. Dev.	Min.	Max.	Number of Obs.	Spatial Level of Data
Proximity Impact Measures						
CROWFT	26,436	34,218	97	125,812	4,093	parcel
FROWFT	45,391	41,266	107	161,980	4,093	parcel
XINGFT	32,795	34,203	113	126,017	4,093	parcel
STNFT	20,215	22,143	258	98,199	4,093	parcel
LAYOFT	43,445	31,366	486	125,875	4,093	parcel
HWYFT	11,858	9,548	127	40,220	4,093	parcel
HWY1000	0.042	-	-	-	4,093	parcel
TRFHVY	0.055	-	-	-	4,093	parcel
TRFMED	0.129	-	-	-	4,093	parcel
TRFLGT	0.816	-	-	-	4,093	parcel
BKWYFT	67,894	49,958	78	178,516	4,093	parcel
BKWY150	0.002	-	-	-	4,093	parcel
LDN1	54.4	4.8	44.6	76.2	4,093	parcel
LDN1_IPT	0.268	-	-	-	4,093	parcel
LDN2	53.3	4.3	44.2	70.5	4,093	parcel
LDN2_IPT	0.027	-	-	-	4,093	parcel

size constraints. Also, variables for heating system type and fuel were often insignificant, and thus are not presented in the final model specifications.

7.1.1 Paired Data Analysis

For each of the five study towns served by commuter rail, property pairs were identified within each community on the basis of comparing assessed values. Each town data set was first differentiated into study properties designated as having superior local access to commuter rail stations. Specifically, for the towns of Acton and Ipswich, properties located within a 12.5 minute walk (5/8 mile) from a station, but greater than 500 feet from the commuter rail right-of-way, were included in the study group. For Needham and Winchester, properties located within a 10 minute walk (1/2 mile) from a station, but greater than 500 feet from the commuter rail right-of-way, were included in the study group. Finally, for Norfolk, properties located within a 15 minute walk (3/4 mile) from a station, but greater than 500 feet from the commuter rail right-of-way, were included in the study group. A total of 232 study properties were identified among the five study towns. Care was taken to avoid including properties in the study group that were both highly accessible to commuter rail stations but also within 500 feet of the right-of-way, since inclusion of these properties would likely introduce a downward in the sales price of such a study property.

Next, control properties not having significant local access to commuter rail stations were identified. For all of the five study towns, control properties were chosen so as to have a greater than 20 minute (1 mile) walk to the nearest station, and to be located at greater than 800 feet from the right-of-way. A total of 1,240 control properties were identified.

Matched property pairs from within each town were then identified from the study and control group of each town on the basis of assessed value. Because assessed value can be viewed as a continuous variable, one would expect few exactly matching properties, and in fact there were only 32 study and control property pairs that had exactly matching assessed values. To increase the number of pairs to which the nonparametric tests described earlier in Chapter 3 could be applied, both the study and control groups were rank ordered by assessed value, and the two properties having assessed values that bracketed the study property assessed value were also chosen. In this way, a total of 496 property pairs were identified based on both the 32 exact matches of assessed value, 232 matches of properties for which the control property was assessed slightly lower than the study property, and 232 matches for which the control property was assessed slight higher than the study property.

In the aggregate, these 492 property pairs are now viewed as representing 496 Bernoulli trials as discussed earlier in Chapter 3, and both a sign test and a Wilcoxon signed-rank test are applied to determine whether the primary attribute, in this case local accessibility to commuter rail stations, has a statistically significant effect upon sales prices. Thus, for each of the property pairs, the sign of the difference between the real adjusted sales price was evaluated, as well as its magnitude. For 281 (56.7%) of the 496 property pairs in this particular analysis of local commuter rail accessibility, the more accessible study property exhibited a greater sales price than the less accessible control property. Using a sign test at the 0.05 level of significance, the null hypothesis that the probability that for the *i*th pair of properties the more accessible properties will exhibit a greater sales price than the control properties is equal to 0.5, can be rejected. Therefore, as presented in Table 7.3 and evaluated using the sign test, local accessibility to commuter rail stations does appear to have a statistically significant impact upon property values. Evaluation with the Wilcoxon signed-rank test is consistent with the findings of the sign test, indicating that local accessibility to commuter rail stations does appear to have a statistically significant impact upon property values. Referring back to the 496 property pairs, the mean difference between the study and control properties is $14,900, which as a percentage of the mean control property sales price of $272,000 is approximately 5.5%. However, the standard deviation of the differences is $68,576, indicating a broad dispersion of the differences around this mean value, perhaps in part the result of varying degrees of local commuter rail accessibility among the different study properties included in the study group.

Table 7.3: Paired Data Analysis Results for Local Commuter Rail Accessibility

Sign Test	
n =	496
number of positive differences =	281
level of significance =	0.05
lower bound of the critical region =	266

Wilcoxon Signed-Rank Test	
n =	496
S_n =	76,604
$E(S_n)$ =	61,628
$Var(S_n)$ =	10,199,434
level of significance =	0.05
test statistic Z_n =	4.689
critical Z_n =	1.645

* statistically significant at the indicated level of significance (one-tailed test)

7.1.2 Quasi-Experimental Hedonic Models

Acton

Initial and intermediate runs of various quasi-experimental local commuter rail accessibility hedonic models for the town of Acton, not presented here, performed moderately well, with fourteen of twenty-two independent variables statistically significant, and only two of the fourteen statistically significant variables having signs opposite those anticipated. However, the station auto access time variable lnRAIL1 exhibited a sign that was both opposite that anticipated and statistically significant at the .01 level using a two-tailed test of significance. Variables for heating system type and heating fuel type were either statistically insignificant or exhibited statistically significant signs opposite to those anticipated.

The final quasi-experimental model specification for Acton, presented in Table 7.4, overcomes some of the shortcomings of the intermediate models. In this final model for Acton, thirteen of eighteen independent variables are statistically significant, with only one of these statistically significant variables exhibiting a sign opposite that anticipated. Once again, however, the station auto access time variable lnRAIL1 exhibited a sign that was both opposite

Table 7.4: Regression Results for Quasi-Experimental Hedonic Models of Local Commuter Rail Accessibility

	Acton			Ipswich			Needham			Norfolk			Winchester		
Variable	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio
lnULAREA	0.33347	0.06545	5.095 †††	0.37263	0.10261	3.632 †††	0.32536	0.03414	9.530 †††	0.13350	0.12763	1.046	0.40885	0.04721	8.660 †††
lnBEDS	0.02526	0.07144	0.354	0.03701	0.10478	0.353	0.14731	0.03383	4.355 †††	-0.00741	0.10313	-0.072	0.04302	0.04470	0.962
lnBATHS	0.31056	0.07461	4.163 †††	0.05702	0.09606	0.594	0.15288	0.02514	6.082 †††	0.89131	0.15727	5.667 †††	0.09759	0.04280	2.280 ††
lnAGE	-0.00903	0.01202	-0.751	0.10074	0.02486	4.052 ***	-0.03699	0.01397	-2.647 †††	0.13353	0.02023	6.601 ***	-0.06010	0.02029	-2.962 †††
AGE100	0.13749	0.08045	1.642 †	0.01046	0.11241	0.149	-0.08567	0.04136	-2.145 **	0.00860	0.17110	0.136	0.02924	0.03543	0.831
CAPE	-0.06137	0.04559	-1.366 †				-0.08496	0.01956	-4.529 †††	-0.15604	0.07176	-2.328 †††	-0.01806	0.03129	-0.567
RANCH	-0.08803	0.03737	-2.447 †††				-0.09857	0.01887	-5.491 †††	-0.19304	0.08275	-2.551 †††	-0.12007	0.04314	-2.944 †††
CONTMP	-0.13454	0.04515	-3.178 †††							-0.08244	0.09111	-0.899	0.15687	0.03412	4.287 ***
STLOTH	-0.14447	0.06132	-2.514 †††				-0.06677	0.02102	-3.277 †††	-0.25372	0.10037	-2.866 †††	-0.02632	0.02852	-0.921
lnLTSQFT	0.05402	0.01977	2.732 †††	0.02641	0.03001	0.88	0.13622	0.01774	7.679 †††	-0.02400	0.03446	-0.696	0.15213	0.02598	5.856 †††
lnPOPDEN	-0.04913	0.03634	-1.352 †	-0.04626	0.05464	-0.847	0.03742	0.01560	2.399 **	-0.22080	0.20481	-1.078			
lnHHINC	-0.03293	0.06922	-0.476	-0.26087	0.25031	-1.042	0.12193	0.03161	3.857 †††	0.43911	0.13079	3.357 †††	0.40730	0.05885	6.921 †††
lnAUTO1	0.01504	0.02917	0.516	-0.02727	0.10631	-0.256	0.05528	0.01786	3.094 ***	-0.05792	0.11693	-0.495	-0.01992	0.03649	-0.546
lnRAIL1	0.09460	0.03714	2.547 **	0.21904	0.13201	1.659 *	0.05905	0.03005	1.965 **	-0.07005	0.06975	-1.004	-0.07831	0.03629	-2.158 ††
WLK12M				-0.08753	0.17582	-0.433	0.03042	0.02346	1.289 †	0.01478	0.15467	0.172	-0.00757	0.03639	-0.191
WLK34M	0.09910	0.07015	1.382 †												
lnRAIL2							-0.18316	0.08097	-2.262 ††						
TRFHVY	-0.26585	0.05218	-5.897 †††	-0.02474	0.12324	-0.142	-0.15919	0.03356	-5.149 †††	-0.02399	0.10347	-0.183	-0.07406	0.05646	-1.335 †
TRFMED	-0.08309	0.03084	-2.797 †††	0.01314	0.06416	0.236	-0.10952	0.02381	-4.859 †††	-0.03552	0.08569	-0.379	-0.04092	0.04364	-0.935
LDN1	-0.00127	0.00524	-0.242	0.01113	0.01416	0.786	0.00431	0.00344	1.251	0.00837	0.01214	0.689	0.00451	0.01101	0.410
Constant	2.75877	0.96587	2.856 †††	3.71991	3.08906	1.204	0.41329	0.53695	0.770	0.06712	1.44939	0.046	-3.44744	1.23530	-2.791 ***

	Acton		Ipswich		Needham		Norfolk		Winchester	
	Dependent Variable =	lnSLPRIC	Dependent Variable =	lnSLPRIC	Dependent Variable =	lnSLPRIC	Dependent Variable =	lnSLPRIC	Dependent Variable =	lnSLPRIC
	Observations =	469	Observations =	268	Observations =	667	Observations =	300	Observations =	410
	R^2 =	0.570	R^2 =	0.204	R^2 =	0.689	R^2 =	0.455	R^2 =	0.746
	Adjusted R^2 =	0.553	Adjusted R^2 =	0.160	Adjusted R^2 =	0.680	Adjusted R^2 =	0.420	Adjusted R^2 =	0.735
	Std. Error =	0.245	Std. Error =	0.424	Std. Error =	0.165	Std. Error =	0.334	Std. Error =	0.199
	F-ratio =	33.158	F-ratio =	4.621	F-ratio =	79.656	F-ratio =	13.035	F-ratio =	67.496

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1982. pg. 801.

that anticipated and statistically significant, this time at the .05 level using a two-tailed test of significance. The WLK34M variable, however, is both statistically significant at the .10 level using a one-tailed test of significance, and exhibits the anticipated positive sign indicating a property value premium for properties located within 15 minute (3/4 mile) walk of the South Acton commuter rail station. The WLK34M coefficient, when properly adjusted to account for the dichotomous nature of the independent variable, indicates an increase in value of 9.9 percent for properties located within 3/4 mile of the South Acton commuter rail station.

Ipswich

Initial and intermediate runs of various quasi-experimental local commuter rail accessibility hedonic models for the town of Ipswich, not presented here, performed quite poorly, with only four of twenty-three independent variables statistically significant, and half of these four exhibiting signs opposite those anticipated. All accessibility related variables were statistically insignificant, and the explanatory power of the model is surprisingly low, as indicated by the adjusted R-squared of only .159. Distance to the coastline was included as a variable in intermediate models, but was consistently statistically insignificant.

The final quasi-experimental model specification for Ipswich, presented in Table 7.4, fails to overcome the shortcomings of the intermediate models. The model continues to perform poorly, with only three of fourteen independent variables statistically significant, two of which exhibit signs opposite that anticipated. Again, the explanatory power of the final Ipswich model remained surprisingly low. Although lnRAIL1 is statistically significant at the .10 level using a two-tailed test of significance in the final model, it exhibits a sign opposite that anticipated. The WLK12M variable remained statistically insignificant in the final model for Ipswich.

Needham

Because the CONTMP style category had only three observations out of the 667 total for Needham, this category was combined into the STLOTH style category. Unlike all but one of the other study towns, Needham is served by more than one commuter rail station. Served by a total of four stations, Needham has by far the largest number of stations of any of the study towns including Winchester, which is served by two stations. Because line haul commuter rail travel time to South Station for the Needham Heights station, at 42 minutes, is 40 percent greater than that for Hersey station, at 30 minutes, line haul commuter rail travel times were included in the local accessibility model for Needham. Also, because two of the five AM peak period trains serving Needham short turn at Needham Junction, providing

Needham Center and Needham Heights with only three AM peak period trains daily, the number of AM peak trains serving the nearest commuter rail station is also included in the first local accessibility model for Needham.

The first model for Needham, including the lnRAIL2 and lnTRAINS variables, performed rather well, with fifteen of nineteen independent variables all highly statistically significant, and only three of the statistically significant variables having signs opposite those anticipated. However, both the station auto access time variable lnRAIL1 and the station walk time access variable lnWLKTIM were statistically insignificant. The level of service variable lnTRAINS was also statistically insignificant. The commuter rail line haul time variable lnRAIL2, however, is statistically significant and has the correct sign. The coefficient of -.3317 for lnRAIL2 can be interpreted to imply that for every one percent increase in line haul commuter rail travel time within Needham, single-family residential property values decline, on average, by .33 percent.

Inspection of the correlation coefficients in the variance-covariance matrix reveals low levels of collinearity among almost all of the independent variables, however, as well as being statistically insignificant, the lnTRAINS level of service variable is also highly correlated with lnRAIL2 as revealed in the variance-covariance matrix.

Because the intermediate models for Needham performed so well, few changes were made to the final model presented in Table 7.4. In the final model, in which the lnTRAINS variable is excluded, seventeen of eighteen independent variables are highly statistically significant, and only four of these seventeen exhibit signs that are opposite to those anticipated. As in the final model for Acton, however, the lnRAIL1 variable exhibits a sign opposite to that anticipated. The WLK12M variable, however, is both statistically significant at the .10 level using a one-tailed test of significance, and exhibits the anticipated positive sign indicating a property value premium for properties located within a 10 minute (1/2 mile) walk of a commuter rail station in Needham. The WLK12M coefficient, when properly adjusted to account for the dichotomous nature of the independent variable, indicates an increase in value of 3.0 percent for properties located within a 10 minute (1/2 mile) walk of a commuter rail station in Needham. The commuter rail line haul time variable lnRAIL2 is again statistically significant, and has the correct sign. The coefficient of -.1831 for lnRAIL2 can be interpreted to imply that for every one percent increase in line haul commuter rail travel time within Needham, single-family residential property values decline, on average, by .18 percent.

Norfolk

Initial and intermediate runs of various quasi-experimental local commuter rail accessibility hedonic models for the town of Norfolk performed rather poorly, with only nine of twenty-two independent variables statistically significant, however only two of the nine statistically significant variables exhibited signs opposite those anticipated. Both the station auto access time variable lnRAIL1 and the station walk time access variable lnWLKTIM were statistically insignificant.

The final quasi-experimental model specification for Norfolk, presented in Table 7.4, performs as poorly as many of the intermediate specifications. Only six of eighteen independent variables are statistically significant, with one of these six exhibiting a sign opposite that anticipated. Both lnRAIL1 and WLK12M are statistically insignificant in the final model for Norfolk.

Winchester

The initial and intermediate runs of various quasi-experimental local commuter rail accessibility models for the town of Winchester performed moderately well, with ten of seventeen independent variables statistically significant, and only two of these statistically significant variables having signs opposite those anticipated. Although both the station auto access time variable lnRAIL1 and the station walk time access variable lnWLKTIM are statistically significant, lnRAIL1 exhibits a sign opposite to that which is anticipated. Inspection of the correlation coefficients in the variance-covariance matrix reveals low levels of collinearity among almost all of the independent variables, however, the variables LDN1 and lnPOPDEN were nearly perfectly collinear, causing problems during estimation of initial models that resulted in lnPOPDEN being excluded from further models.

Because the intermediate models for Winchester performed so well, few changes were made to the final model presented in Table 7.4. In the final model, nine of seventeen independent variables are statistically significant, with only one of these nine exhibiting a sign opposite to that anticipated. The variable lnRAIL1 is statistically significant, and exhibits the anticipated sign. The coefficient of -.0783 for lnRAIL1 can be interpreted to imply that for every one percent increase in station access time by the auto mode, single-family residential property values decline in Winchester, on average, by .078 percent, or just under one tenth of one percent. The WLK12M variable, however, is statistically insignificant.

7.1.3 Pooled Hedonic Models

After analyzing the characteristics of local commuter rail accessibility for each of the study towns individually, a series of pooled models combining data from all five study towns were specified. These pooled models incorporate many of the same variables as the local models, with additional variables used to control for variations in the cost and quality of municipal services, crime rates, and variations in regional accessibility by both auto and commuter rail also included. A dummy variable is included to indicate that a town is a coastal community, in this case representing Ipswich.

Initial model runs indicated major problems with multicollinearity among a number of the independent variables. The violent crime and non-violent variables, specified separately, were highly correlated, as would be expected, and were therefore combined into a single crime rate variable in subsequent models. The school quality variable lnSCLTST was highly correlated with lnPUPIL, lnCRIME, lnRAIL2, and lnAUTO2. Therefore, lnSCLTST was excluded from subsequent models, with lnPUPIL alone representing school quality. The lnTXRATE variable is highly correlated with lnPUPIL, lnAUTO2, lnVCRIME, and lnNVCRIM. The lnTXRATE variable also exhibits a sign opposite that anticipated, and is statistically insignificant at all but the .10 level using a two-tailed test of significance. Finally, because the quasi-experimental model for the town of Ipswich performed so poorly, it was decided to exclude these observations from the final pooled model. This reduced the final pooled data set by only 268 observations, or by about 12 percent from the original number of observations used in the intermediate pooled models, while improving the explanatory power and overall performance of the final pooled model somewhat.

The final pooled hedonic model for local commuter rail accessibility, presented in Table 7.5, performs rather well. Seventeen of twenty-three independent variables are highly statistically significant, only three of which exhibit signs opposite to those anticipated. The overall explanatory power of this model is reasonably good as indicated by the adjusted R^2 of .61. There remain some variables that are highly correlated, however, particularly lnCRIME and lnPUPIL, which unfortunately are highly correlated in this pooled four town data set. The lnRAIL1 and WLK12M variables are statistically insignificant, indicating that accessibility on a local scale to commuter rail stations is not a significantly contributing factor to the value of single-family residential properties. The lnRAIL2 variable is statistically significant, however, and exhibits the anticipated sign. The coefficient of -.16208 for lnRAIL2 can be interpreted to imply that for every one percent increase in commuter rail line haul travel time to Boston, single-family residential property values decline, on average, by .162 percent.

Table 7.5: Regression Results for Pooled Hedonic Model of Local Commuter Rail Accessibility

		Dependent Variable =	lnSLPRIC
		Observations =	1,846
		R^2 =	0.617
		Adjusted R^2 =	0.612
		Std. Error =	0.241
		F-ratio =	127.314
Variable	**Coefficient**	**Std. Error**	**t-ratio**
lnULAREA	0.39169	0.02859	13.698 †††
lnBEDS	0.10809	0.02836	3.811 †††
lnBATHS	0.23100	0.02590	8.918 †††
lnAGE	0.03040	0.00694	4.378 ***
AGE100	-0.03539	0.02873	-1.240
CAPE	-0.06807	0.01843	-3.816 †††
RANCH	-0.07799	0.01773	-4.570 †††
CONTMP	0.00985	0.02437	0.414
STLOTH	-0.09816	0.01997	-5.163 †††
lnLTSQFT	0.06579	0.01161	5.666 †††
lnPOPDEN	-0.01986	0.01567	-1.268
lnHHINC	0.13351	0.02738	4.877 †††
lnPUPIL	7.07283	1.01973	6.936 †††
lnCRIME	-0.86746	0.14579	-5.950 †††
lnAUTO1	0.06170	0.01591	3.877 ***
lnAUTO2	-0.40598	0.08602	-4.720 †††
lnJTWTIM	0.20294	0.06671	3.042 ***
lnRAIL1	0.02735	0.01848	1.480
WLK12M	0.02725	0.02203	1.231
lnRAIL2	-0.16208	0.05260	-3.081 †††
TRFHVY	-0.15392	0.02776	-6.007 †††
TRFMED	-0.07782	0.01917	-4.217 †††
LDN1	0.00198	0.00269	0.737
Constant	-57.45449	8.45821	-6.793 ***

(1) Includes data from Acton, Needham, Norfolk, and Winchester

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1982. pg. 801.

7.2 Commuter Rail Regional Accessibility

The pooled hedonic model presented below for the analysis of regional commuter rail accessibility focuses upon the possible impact that commuter rail may have upon properties by virtue of their being located within a community served by commuter rail, regardless of the impact that marginal variations in station access time to a station within that community may have upon property values.

7.2.1 Paired Data Analysis

As discussed earlier in Chapters 3 and 6, the local nature of assessed values make them subject to a variety of practices that are specific to local jurisdictions, thereby making acceptable inter-jurisdictional comparisons of assessed values impossible. Because of these differences, it was impossible to conduct the necessary paired data analysis for properties located in different towns that would have been necessary to implement this methodology for the analysis of commuter rail regional accessibility.

7.2.2 Quasi-Experimental Hedonic Models

Both the local commuter rail accessibility analysis for the town of Needham, and the pooled hedonic model of local commuter rail accessibility offer some insights into the influence of commuter rail line haul time upon single-family residential property values. In the local accessibility model for Needham, presented earlier in Table 7.4, the variable lnRAIL2 is statistically significantly different from zero at the .01 level. The estimated coefficient of -0.18316 indicates that for every one percent increase in commuter rail line haul travel time on the Needham Line, single-family residential property sales prices in Needham decline by about 0.18 percent. The regression results for the pooled hedonic model of local commuter rail accessibility, presented earlier in Table 7.5, are also statistically significant at the .01 level. The findings of this pooled model are surprisingly consistent with those of the Needham model, with the estimated coefficient of -0.16208 for the lnRAIL2 variable in the pooled model indicating that for every one percent increase in commuter rail line haul travel time, single-family residential property sales prices in the four study towns selected for the pooled model decline by about 0.16 percent. These findings are also consistent with previous research by Armstrong (1993) which indicated a .137 percent decline in single-family residential property values for every one percent increase in commuter rail line haul time.[202]

[202] Armstrong, Robert J., Jr. "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values." *Transportation Research Record* 1466. 1995. pp. 88-98.

7.2.3 Pooled Hedonic Models

For the pooled model of regional accessibility, a total of 3,268 observations from both study and control towns were combined. In many ways similar to the pooled local accessibility model presented earlier, this model also contained a dummy variable indicating whether a property was located in a town directly served by commuter rail. Of the original 4,093 records, those having no style data were eliminated, which included all of the Marshfield records, leaving 3,635 records. An additional 167 records located within 1,000 feet of a major highway were also eliminated, leaving 3,468 records. Finally, data for the town of Westford were eliminated because of impacts from heavy freight rail, resulting in the final 3,268 records. The dummy variable COASTTWN was introduced in order to control for the possible amenity effect of being located in coastal community with access to beaches. The dummy variable COMMBOAT was also added to control for the availability of direct commuter boat service to Boston from the town of Hingham. As with the local accessibility models presented earlier, for the multi-category dummy variables representing housing style and local traffic level, colonial style is used as the benchmark for the housing style group of variables, and light traffic is the benchmark for the local road traffic variables.

The final pooled hedonic model for regional commuter rail accessibility, presented in Table 7.6, performed rather well. Twenty-one of twenty-seven independent variables are statistically significant, only six of which exhibit signs opposite to those anticipated. The overall explanatory power of this model is reasonably good as indicated by the adjusted R^2 of .57. Inspection of the zero-order correlation coefficients in the variance-covariance matrix reveals relatively low levels of collinearity among all of the independent variables, however the condition index diagnostic for collinearity calculated for this final regional access model indicates the presence of substantial multicollinearity. The main variable of interest in this model, STATN, is just barely statistically significant at the .10 level using a one-tailed test, and indicates that single-family residential properties located in communities served by commuter rail sell for a premium of about 3.8% over otherwise comparable properties located in communities not served by commuter rail.

7.3 Summary of Commuter Rail Accessibility Findings

Regarding local commuter rail accessibility, the results of the paired data analysis using nonparametric inference procedures as presented in Table 7.3 suggest that local accessibility to commuter rail stations does have a statistically significant impact upon property values. The average difference in sales price between study properties located within 1/2 mile, or in some

Table 7.6: Regression Results for Pooled Hedonic Model of Regional Commuter Rail Accessibility

Dependent Variable =	lnSLPRIC
Observations =	3,268
R^2 =	0.575
Adiusted R^2 =	0.571
Std. Error =	0.293
F-ratio =	162.289

Variable	Coefficient	Std. Error	t-ratio
lnULAREA	0.44072	0.02487	17.723 †††
lnBEDS	0.07620	0.02514	3.031 †††
lnBATHS	0.22866	0.02181	10.487 †††
lnAGE	0.08589	0.00608	14.118 ***
AGE100	-0.04425	0.02413	-1.864 *
CAPE	-0.08946	0.01595	-5.868 †††
RANCH	-0.05138	0.01612	-3.264 †††
CONTMP	0.00320	0.02378	0.146
STLOTH	-0.10996	0.01769	-6.577 †††
lnLTSQFT	0.06044	0.00908	6.657 †††
lnPOPDEN	-0.01241	0.01288	-0.964
lnHHINC	0.13436	0.02770	4.850 †††
lnPUPIL	1.11309	0.08813	12.631 †††
lnCRIME	-0.03124	0.01760	-1.775 ††
lnTXRATE	0.11806	0.09028	1.308
lnAUTO1	0.04735	0.01317	3.595 ***
lnAUTO2	-0.55439	0.08386	-6.611 †††
lnJTWTIM	0.20814	0.05802	3.587 ***
lnRAIL1	0.03435	0.01737	1.978 **
lnRAIL2	0.08206	0.03014	2.723 ***
WLK12M	0.00920	0.02424	0.390
STATN	0.03830	0.02964	1.283 †
lnBOAT1	-0.14763	0.02076	-7.113 †††
COASTTWN	-0.04230	0.04320	-0.979
TRFHVY	-0.11783	0.02416	-5.176 †††
TRFMED	-0.07522	0.01628	-4.795 †††
LDN1	0.00005	0.00251	0.021
Constant	-8.61249	0.85441	-10.080 ***

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1982. pg. 801.

cases 5/8 mile or 3/4 mile, of a commuter rail station was about 5.5%, but varied widely among the various property pairs examined.

The findings of the quasi-experimental hedonic models of local commuter rail accessibility presented in Table 7.4, although mixed, provide some additional evidence, albeit meager, of a possible positive impact upon single-family property values arising from local accessibility to commuter rail stations. For the town of Acton, the WLK34M variable is statistically significant at the .10 level using a one-tailed test, and indicates an increase in value of 9.9 percent for properties located within a 15 minute (3/4 mile) walk of the South Acton commuter rail station. For Needham, the WLK12M variable is statistically significant at the .10 level using a one-tailed test, and indicates an increase in value of 3.0 percent for properties located within a 10 minute (1/2 mile) walk of one of the four commuter rail stations in Needham. Finally, for Winchester, the variable lnRAIL1 is statistically significant, and the coefficient of -.0783 for lnRAIL1 can be interpreted to imply that for every one percent increase in station access time by the auto mode, single-family residential property values decline in Winchester, on average, by .078 percent., or just under one tenth of one percent.

In light of these findings, the possible impacts of local commuter rail upon single-family property values appears somewhat tenuous, given that two of the three cases presented above are statistically significant at only the .10 level. Also, it is conceivable that unobserved attributes, such as local accessibility to town centers having significant retail activity, may be confounding the estimated impacts of local commuter rail accessibility. In part, the study town selection methodology, as presented in Chapter 5, was designed to avoid communities characterized as significant employment centers, thus helping to avoid these types of possible confounding influences. However, in some cases such as that of town centers, this was not the case. It is not entirely clear, however, in what direction the impact would bias the local commuter rail accessibility measure if a commuter rail station were located within a town center area. For instance, if nearby access to retail opportunities is viewed as a positive attribute, then the impact would tend to reinforce any local station accessibility impact, leading to a positive bias in the observed property value impacts of local commuter rail accessibility. However, if the town centers are viewed as higher activity areas generating nuisance effects such as increased traffic and noise, then the impact would tend to negate any local station accessibility impact, leading to a negative bias in the observed property value impacts of local commuter rail accessibility. For the five study towns analyzed here, the one station in Ipswich and three of four stations in Needham are located in areas that provided significant local retail and commercial opportunities. For the remaining three study towns, local retail opportunities near stations are far less prevalent, and in the case of South Acton, virtually non-existent.

Fortunately then, the findings of the local accessibility hedonic models described above are likely not significantly influenced by such confounding influences, except perhaps for the Needham model.

Regarding regional commuter rail accessibility, findings from the quasi-experimental hedonic models for the town of Needham, and the pooled hedonic model of local commuter rail accessibility suggest that commuter rail line haul time does indeed have a statistically significant impact upon single-family residential property values. In the local accessibility model for Needham, presented earlier in Table 7.4, the variable lnRAIL2 is highly statistically significantly different from zero at the .01 level, with the estimated coefficient of -0.18316 indicating that for every one percent increase in commuter rail line haul travel time on the Needham Line, single-family residential property sales prices in Needham decline by about 0.18 percent. The regression results for the pooled hedonic model of local commuter rail accessibility, presented earlier in Table 7.5, are also highly statistically significant at the .01 level. These findings are surprisingly similar to those of the Needham model, with the estimated coefficient of -0.16208 for the lnRAIL2 model indicating that for every one percent increase in commuter rail line haul travel time, single-family residential property sales prices in the four study towns selected for the pooled model decline by about 0.16 percent.

In addition to these relatively convincing findings regarding regional commuter rail accessibility, the pooled hedonic model of regional commuter rail accessibility, presented earlier in Table 7.6, also indicates that regional commuter rail accessibility serves as a positive influence upon single-family residential property values. The variable STATN, although just barely statistically significant at the .10 level using a one-tailed test, indicates that single-family residential properties located in communities that have a commuter rail station increase in value over otherwise comparable properties in other communities not served by commuter rail by about 3.8 percent. This finding is also generally consistent with the findings of Voith (1991) and Armstrong (1993), who as discussed earlier in Chapter 4, found similar impacts of 3.8 percent and 7.0 percent, respectively, for properties located in areas served by commuter rail.[203,204]

7.4 Proximity Related Externalities - Commuter Rail Only

The estimates of site specific noise impact developed in Chapter 6 for rights-of-way, grade crossings, layover yards, and stations revealed that rights-of-way and grade crossings

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[203] Voith, Richard. "Transportation, Sorting and Housing Values." *Journal of the American Real Estate & Urban Economics Association*, Volume 19, No. 2, Summer 1991. pp. 117-137.

[204] Armstrong, Robert J., Jr. "Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values." *Transportation Research Record* 1466. 1995. pp. 88-98.

tend to dominate the impacts upon properties in the main data set. Too few observations were in close proximity to layover facilities in Needham and Ipswich to allow for an acceptable analysis of the possible impact, and noise estimates for commuter rail stations were consistently well below the estimated ambient noise levels in the study towns, and were thus insignificant contributors to the composite L_{dn} noise estimates developed in Chapter 6. Therefore, rights-of-way and grade crossings are the focus of the proximity related externalities analysis that follows.

7.4.1 Paired Data Analysis

As was done previously in the analysis of local commuter rail accessibility, property pairs were identified within each of the commuter rail only communities on the basis of comparing assessed values. Each town data set was first differentiated into study properties designated as being affected by right-of-way and grade crossing generated noise, as determined by application of the screening distances presented earlier in Chapter 6. Specifically, for Ipswich, the right-of-way impact study group properties were selected such that they were located within 750 feet of the right-of-way, but greater than 500 feet from the one grade crossing in Ipswich. Because of the limited sample size and the previous findings related to local station accessibility, no consideration was given to proximity to stations. The grade crossing impact records were selected such that they were located within 750 feet of the one grade crossing in Ipswich. Again, because of the limited sample size and the previous findings related to local station accessibility, no consideration was given to proximity to stations.

For Needham, the right-of-way impact study group records were selected such that they were located within 750 feet of the right-of-way, greater than 750 feet from the grade crossings, and at least a 10 minute (1/2 mile) walk from any station. The grade crossing impact records were selected such that they were located within 750 feet of grade crossings, but at least a five minute (1/4 mile) walk from a station.

For Norfolk, the right-of-way impact study group records were selected such that they were located within 750 feet of the right-of-way, greater than 750 feet from the grade crossings, and at least a 15 minute (3/4 mile) walk from any station. There was only one record located with 1,000 feet of the one grade crossing in Norfolk, and it was only a 3 minute walk to the Norfolk station because of the relative location of the Norfolk station and the grade crossing. Therefore, Norfolk has no grade crossing study group.

Next, control properties not located in close proximity to either the right-of-way or grade crossings were identified. For both the right-of-way analyses and the grade crossing analyses, control properties were chosen such that they were located at greater than 1,000 feet from the right-of-way, and thus 1,000 feet from grade crossings as well. Also, although the findings of the local accessibility analyses presented earlier for the five commuter rail study towns were mixed, control groups for these towns are also chosen to be at least a 15 minute (3/4 mile) walk from stations. A total of 808 control properties, used for both the right-of-way and grade crossing analyses, were identified.

As before, matched property pairs from with each town were then identified from the study and control groups of each town on the basis of assessed value. For the right-of-way analysis, there were six study and control property pairs that had exactly matching assessed values, and for the grade crossing analysis, there were only two property pairs whose assessed value matched exactly. The two properties having assessed values that bracketed the study property assessed value when rank ordered were also chosen in order to increase the number of pairs to be used for the nonparametric tests. In this way, a total of 90 property pairs were identified for the right-of-way analysis, and a total of 34 property pairs were identified for the grade crossing analysis.

Viewed representing 90 and 34 Bernoulli trials as discussed earlier, both a sign test and a Wilcoxon signed-rank test were applied to determine whether the primary attribute, in this case proximity to either a right-of-way or grade crossing, has a statistically significant effect upon sales prices. For 62 (69%) of the 90 property pairs in the right-of-way analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.7 show that the null hypothesis can be rejected, and therefore proximity to commuter rail rights-of-way does appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically significant effect upon property values. Referring back to the 90 property pairs, the mean difference between the study and control properties is -$22,555, which as a percentage of the mean control property sales price of $216,438 is approximately -10.4%. The standard deviation of the differences is $53,839.

For 21 (62%) of the 34 property pairs in the grade crossing analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.7 show that the null hypothesis cannot be rejected, and therefore proximity to commuter rail grade crossings does not appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically insignificant effect upon property values.

Table 7.7: Paired Data Analysis Results for Proximity Related Externalities - Commuter Rail Only

Sign Test

Right-of-Way		*Grade Crossings*	
n =	90	n =	34
number of negative differences =	62 *	number of negative differences =	21
level of significance =	0.05	level of significance =	0.05
lower bound of the critical region =	53	lower bound of the critical region =	22

Wilcoxon Signed-Rank Test

Right-of-Way		*Grade Crossings*	
n =	90	n =	34
S_n =	1,063	S_n =	224
$E(S_n)$ =	2,048	$E(S_n)$ =	298
$Var(S_n)$ =	61,766	$Var(S_n)$ =	3,421
level of significance =	0.05	level of significance =	0.05
test statistic Z_n =	-3.961 *	test statistic Z_n =	-1.257
critical Z_n =	-1.645	critical Z_n =	-1.645

* statistically significant at the indicated level of significance (one-tailed test)

7.4.2 Quasi-Experimental Hedonic Models

For the quasi-experimental hedonic models for proximity impacts presented below, earlier models utilized for the local accessibility analyses were referred to for guidance in developing model specifications. Because the LDN1 variable, used as a control measure in the local accessibility models, was consistently statistically insignificant throughout all of the analyses, various alternatives were used for the proximity related externalities analyses presented below. First, distances to each of the major noise sources, rights-of-way and grade crossings, were included as proxy variables for noise impact. In many cases, these two variables may be highly collinear, in which case only the distance to the right-of-way was utilized as an independent variable. Dummy variables were used as another alternative measure of proximity impacts, indicating whether a property was located within the noise screening distances of rights-of-way and grade crossings, as presented in Chapter 6. Again, in some instances these variables may be highly collinear, in which case only the right-of-way dummy variable was utilized.

Ipswich

Quasi-experimental hedonic models for Ipswich incorporating the distance measures lnCROWFT and lnXINGFT performed poorly, with only four of fifteen variables statistically significant, with half of these four exhibiting signs opposite those anticipated. As with the local accessibility models for Ipswich presented earlier, the explanatory power of all the Ipswich models presented here was surprisingly low, and both lnCROWFT and lnXINGFT were statistically insignificant. Inspection of the correlation coefficients in the variance-covariance matrix revealed that lnCROWFT and lnXINGFT were also highly collinear, as anticipated. A similar model incorporating only lnCROWFT, although lacking some of the multicollinearity problems of the earlier model, still failed to overcome the poor performance of earlier models. The model incorporating the XING1000 and CROW1000 dummy variables was even worse, with these two variable being highly collinear. A similar model incorporating only the CROW1000 variable, presented in Table 7.8, although reducing the multicollinearity problems, again failed to overcome the shortcomings of the earlier models. In all of the models, proximity variables were statistically insignificant.

Needham

Quasi-experimental hedonic models for Needham incorporating the distance measures lnCROWFT and lnXINGFT performed well, with seventeen of nineteen variables statistically significant, and only three of these seventeen exhibiting signs opposite those anticipated. As presented in Table 7.8, both lnCROWFT and lnXINGFT were statistically significant, however lnXINGFT exhibits a sign opposite that anticipated. The estimated coefficient of .0423 for the right-of-way impact variable lnCROWFT indicates that for every one percent increase in distance from the right-of-way, single-family residential property values increase by .04 percent. Inspection of the correlation coefficients in the variance-covariance matrix revealed relatively low levels of multicollinearity.

A second model, not presented here, incorporating the XING850 and CROW750 dummy variables performed equally as well, with the CROW750 variable statistically significant at the 0.01 level and exhibiting the anticipated sign, and the XING850 variable statistically insignificant. The estimated coefficient for CROW750 of -0.06902 indicates that single-family residential properties located within 750 feet of the Needham Line right-of-way sell for about 6.9 percent less than otherwise comparable properties in Needham.

Needham - Subset of Noise Impacted Properties

For Needham, 80 properties were located within 750 feet of the right-of-way. This was the only study town having a sizable enough subset of properties located within close proximity of the right-of-way, allowing enough degrees of freedom for a hedonic model to be estimated for this subset. For this subset of impacted properties, a series of models similar to those run for the local accessibility analyses were run, in this case to see if the LDN1 variable

Table 7.8: Regression Results for Proximity Related Externalities - Commuter Rail Only

	Ipswich			Needham			Needham Subsample			Norfolk		
Variable	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio
lnULAREA	0.39665	0.10070	3.939 †††	0.31723	0.03399	9.333 †††	0.30340	0.08743	3.470 †††	0.13078	0.12788	1.023
lnBEDS	0.02333	0.10376	0.225	0.15013	0.03364	4.463 †††	0.18292	0.10727	1.705 ††	-0.00921	0.10321	-0.089
lnBATHS	0.05666	0.09611	0.589	0.14631	0.02503	5.846 †††	0.16258	0.07796	2.085 ††	0.89243	0.15713	5.679 †††
lnAGE	0.10030	0.02488	4.032 ***	-0.04309	0.01391	-3.098 †††	-0.06854	0.07226	-0.948	0.13612	0.02031	6.704 ***
AGE100	-0.00392	0.11137	0.020	-0.07437	0.04105	-1.862 *				0.01472	0.17119	0.171
CAPE				-0.08623	0.01943	-4.631 †††	-0.03516	0.05806	-0.588	-0.15714	0.07164	-2.351 †††
RANCH				-0.09621	0.01875	-5.386 †††	-0.09508	0.06036	-1.625 †	-0.19542	0.08247	-2.595 †††
CONTMP										-0.08516	0.09112	-0.931
STLOTH				-0.07161	0.02103	-3.522 †††	-0.00914	0.07379	-0.088	-0.25856	0.10032	-2.932 †††
lnLTSQFT	0.02390	0.02992	0.799	0.13917	0.01759	7.914 †††	0.06221	0.07665	0.812	-0.02418	0.03446	-0.702
lnPOPDEN	-0.04840	0.05474	-0.884	0.04173	0.01481	2.818 ***	0.01314	0.06846	0.192	-0.15588	0.21347	-0.730
lnHHINC	-0.21797	0.24269	-0.898	0.12674	0.03152	4.021 †††	0.22821	0.14155	1.612 †	0.40465	0.13719	2.949 †††
lnAUTO1	-0.01686	0.10484	-0.161	0.02937	0.02165	1.357	0.04387	0.07138	0.615	-0.04470	0.11821	-0.378
lnRAIL1	0.12394	0.06703	1.849 *	0.03703	0.03522	1.051	0.18698	0.07017	2.665 ***	-0.06969	0.06815	-1.023
WLK12M	0.01244	0.23370	0.170	0.04539	0.02363	1.890 ††	0.14117	0.05950	2.249 ††	0.03038	0.15017	0.274
lnRAIL2				-0.29836	0.08489	-3.515 †††						
TRFHVY	-0.02181	0.12308	-0.118	-0.15517	0.03333	-5.042 †††				-0.02681	0.10308	-0.212
TRFMED	0.01060	0.06409	0.197	-0.11599	0.02394	-5.137 †††				-0.04416	0.08565	-0.485
TFHVYMED							-0.06531	0.06468	-1.012			
lnCROWFT				0.04237	0.01358	3.119 †††	0.02128	0.04156	0.512	-0.02352	0.03115	-0.755
CROW1000	-0.22944	0.28773	-0.762									
lnXINGFT				-0.04413	0.02064	-2.139 **	-0.00399	0.02676	-0.149			
Constant	3.89958	3.08667	1.263	1.15174	0.64159	1.795 ††	-0.30536	2.02017	-0.151	0.63871	1.39094	0.459

	Ipswich	Needham	Needham Subsample	Norfolk
Dependent Variable =	lnSLPRIC	lnSLPRIC	lnSLPRIC	lnSLPRIC
Observations =	269	668	77	301
R^2 =	0.204	0.693	0.665	0.455
Adjusted R^2 =	0.159	0.684	0.575	0.420
Std. Error =	0.424	0.163	0.152	0.333
F-ratio =	4.618	77.039	7.432	13.045

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations. *The American Economic Review*, September 1982. pg. 801.

may be a statistically significant determinant of properties values over the range in which estimated noise levels are above what would be the ambient noise in the absence of commuter rail service. Three properties that were greater than 100 years old were removed from the data set, and properties located on heavily traveled streets (as indicated by the TRFHVY and TRFMED variables) were combined and represented by the one variable TFHVYMED.

The model incorporating the LDN1 variable performed moderately well, with ten of sixteen variables statistically significant, and only two of these exhibiting signs opposite that expected. However, in this subset, LDN1 is highly correlated with lnRAIL2. Estimating the same model without the lnRAIL2 variable reduces this collinearity, however the LND1 variable is statistically insignificant. In models using lnCROWFT and lnXINGFT, lnXINGFT is highly collinear with lnRAIL2. Estimating the same model without the lnRAIL2 variable, as presented in Table 7.8, again reduces this problem, however both lnCROWFT and lnXINGFT are statistically insignificant.

Norfolk

Quasi-experimental hedonic models for Norfolk incorporating the distance measure lnCROWFT performed rather poorly, with only six of nineteen variables statistically significant, with one of these exhibiting a sign opposite that anticipated as shown in Table 7.8. The variable lnCROWFT is statistically insignificant in this first model. Alternative models estimated with the dummy CROW850 indicating properties located within 850 feet of the right-of-way performed similarly, with CROW850 being statistically insignificant.

7.5 Proximity Related Externalities - Mixed Commuter Rail and Freight Rail

Again, as with the commuter rail only study towns, rights-of-way and grade crossings are the focus of the proximity related externalities analysis that follows. However, the study towns analyzed here are characterized as having commuter rail and freight rail operating on shared rights-of-way.

7.5.1 Paired Data Analysis

As before, property pairs were identified within each of the two study communities on the basis of comparing assessed values. Each town data set was first differentiated into study properties designated as being affected by right-of-way and grade crossing generated noise, as determined by application of the screening distances presented earlier in Chapter 6. Specifically, for Acton the right-of-way impact study group records were selected such that they were located within 750 feet of the right-of-way, greater than 750 feet from the grade crossings, and at least a 10 minute (1/2 mile) walk from any station. The grade crossing impact records were selected such that they were located within 750 feet of grade crossings, but at least a 10 minute (1/2 mile) walk from any station. For Winchester, the right-of-way impact study group records were selected such that they were located within 750 feet of the right-of-way and at least a 10 minute (1/2 mile) walk from any station. Because there are no grade crossings in Winchester, there is no grade crossing study group.

Control properties not located in close proximity to either the right-of-way or grade crossings were then identified. For both the right-of-way analyses and the grade crossing analyses, control properties were chosen such that they were located at greater than 1,000 feet from the right-of-way, and thus 1,000 feet from grade crossings as well. Also, although the findings of the local accessibility analyses presented earlier for the five commuter rail study towns were mixed, control groups for these towns were also chosen to be at least a 15 minute (3/4 mile) walk from stations. A total of 670 control properties, used for both the right-of-way and grade crossing analyses, were identified.

As before, matched property pairs from with each town were then identified from the study and control groups of each town on the basis of assessed value. For the right-of-way analysis, there were eight study and control property pairs that had exactly matching assessed values, and for the grade crossing analysis, there were no property pairs whose assessed value matched exactly. The two properties having assessed values that bracketed the study property assessed value when rank ordered were also chosen in order to increase the number of pairs to be used for the nonparametric tests. In this way, a total of 66 property pairs were identified for the right-of-way analysis, and a total of 18 property pairs were identified for the grade crossing analysis.

Viewed representing 66 and 18 Bernoulli trials as discussed earlier, both a sign test and a Wilcoxon signed-rank test were applied to determine whether the primary attribute, in this case proximity to either a right-of-way or grade crossing, has a statistically significant effect upon sales prices. For 36 (54.5%) of the 66 property pairs in the right-of-way analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.9 show that the null hypothesis cannot be rejected, and therefore proximity to commuter rail rights-of-way does not appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically insignificant effect upon property values.

For 10 (55.5%) of the 18 property pairs in the grade crossing analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.9 show that the null hypothesis cannot be rejected, and therefore proximity to commuter rail grade crossings does not appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically insignificant effect upon property values.

7.5.2 Quasi-Experimental Hedonic Models

Acton

Quasi-experimental hedonic models for Acton incorporating the distance measures lnCROWFT and lnXINGFT performed moderately well, with twelve of nineteen variables statistically significant, and none of these exhibiting signs opposite those anticipated. Both lnCROWFT and lnXINGFT were statistically insignificant, and inspection of the correlation coefficients in the variance-covariance matrix revealed that lnCROWFT and lnXINGFT were also highly collinear, as anticipated. A similar model incorporating only lnCROWFT, presented in Table 7.10, improved the collinearity problem, however lnCROWFT was still statistically insignificant. Models incorporating the XING1000 and CROW1000 dummy variables performed no better, with these variables consistently being statistically insignificant.

Winchester

Quasi-experimental hedonic models for Winchester incorporating the distance measure lnCROWFT performed moderately well, with eleven of eighteen variables statistically significant, and only one of these exhibiting a sign opposite that anticipated. As presented in Table 7.10, the variable lnCROWFT is statistically significant. The estimated coefficient of .06797 for the right-of-way impact variable lnCROWFT can be interpreted to imply that for every one percent increase in distance from the right-of-way, single-family residential property values increase by .067 percent. Inspection of the correlation coefficients in the variance-covariance matrix revealed relatively low levels of multicollinearity.

A second model, not presented here, incorporating the CROW750 dummy variable performed equally as well, with the CROW750 variable statistically significant at the 0.01 level and exhibiting the anticipated sign. The estimated coefficient for CROW750 of -0.12878 indicates that single-family residential properties located within 750 feet of the Winchester Line sell for about 12.9 percent less than otherwise comparable properties in Winchester.

Table 7.9: Paired Data Analysis Results for Proximity Related Externalities - Commuter Rail/Freight Rail Mixed Traffic

Sign Test

Right-of-Way		*Grade Crossings*	
n =	66	n =	18
number of negative differences =	36	number of negative differences =	10
level of significance =	0.05	level of significance =	0.05
lower bound of the critical region =	40	lower bound of the critical region =	12

Wilcoxon Signed-Rank Test

Right-of-Way		*Grade Crossings*	
n =	66	n =	18
S_n =	1,082	S_n =	106
$E(S_n)$ =	1,106	$E(S_n)$ =	86
$Var(S_n)$ =	24,505	$Var(S_n)$ =	527
level of significance =	0.05	level of significance =	0.05
test statistic Z_n =	-0.150	test statistic Z_n =	0.893
critical Z_n =	-1.645	critical Z_n =	-1.645

* statistically significant at the indicated level of significance (one-tailed test)

7.6 Proximity Related Externalities - Freight Rail Only

Again, as with the commuter rail only and mixed rail traffic study towns, rights-of-way and grade crossings are the focus of the proximity related externalities analysis that follows. The study town of Westford analyzed here is characterized as having a relatively large high volume freight rail line passing through it, but not having any commuter rail service operating over this line or serving the town in any other way.

7.6.1 Paired Data Analysis

Control properties not located in close proximity to either the right-of-way or grade crossings were then identified. For both the right-of-way analyses and the grade crossing analyses, control properties were chosen such that they were located at greater than 1,000 feet from the right-of-way, and thus 1,000 feet from grade crossings as well.

As before, matched property pairs from with each town were then identified from the study and control groups of each town on the basis of assessed value. For the right-of-way analysis, there were three study and control property pairs that had exactly matching assessed values, and for the grade crossing analysis, there were two property pairs whose assessed value matched exactly. The two properties having assessed values that bracketed the study property assessed value when rank ordered were also chosen in order to increase the number of pairs to

Table 7.10: Regression Results for Proximity Related Externalities - Commuter Rail/Freight Rail Mixed Traffic

	Acton			Winchester		
Variable	Coefficient	Std. Error	t-ratio	Coefficient	Std. Error	t-ratio
lnULAREA	0.33468	0.06534	5.122 †††	0.40378	0.04685	8.619 †††
lnBEDS	0.01992	0.07148	0.279	0.04261	0.04433	0.961
lnBATHS	0.30183	0.07474	4.039 †††	0.09070	0.04251	2.134 ††
lnAGE	-0.00999	0.01200	-0.832	-0.06649	0.02026	-3.283 †††
AGE100	0.15307	0.08076	1.804 ††	0.03767	0.03525	1.067
CAPE	-0.05981	0.04550	-1.333 †	-0.02461	0.03112	-0.785
RANCH	-0.08872	0.03732	-2.471 †††	-0.11966	0.04277	-2.958 †††
CONTMP	-0.14369	0.04506	-3.189 †††	0.14434	0.03407	3.975 ***
STLOTH	-0.14547	0.06089	-2.551 †††	-0.03131	0.02834	-1.108
lnLTSQFT	0.05201	0.01969	2.642 †††	0.15101	0.02576	5.862 †††
lnPOPDEN	-0.04668	0.03011	-1.551 †	0.05077	0.04869	1.043
lnHHINC	-0.02961	0.06876	-0.431	0.41110	0.05837	7.043 †††
lnAUTO1	0.01896	0.02931	0.647	-0.05338	0.03815	-1.399 †
lnRAIL1	0.06236	0.04635	1.346	-0.16017	0.04661	-3.436 †††
WLK12M				-0.01281	0.03613	-0.339
WLK34M	0.09135	0.06914	1.299 †			
TRFHVY	-0.27271	0.05222	-6.071 †††	-0.09135	0.05640	-1.670 ††
TRFMED	-0.08204	0.03079	-2.765 †††	-0.06263	0.04406	-1.446 †
lnCROWFT	0.02096	0.01770	1.184	0.06798	0.02458	2.766 †††
Constant	2.54516	0.93674	2.717 †††	-3.93120	1.04001	-3.780 ***
	Dependent Variable = lnSLPRIC			Dependent Variable = lnSLPRIC		
	Observations =		470	Observations =		410
	R^2 =		0.571	R^2 =		0.751
	Adjusted R^2 =		0.554	Adjusted R^2 =		0.739
	Std. Error =		0.245	Std. Error =		0.197
	F-ratio =		33.332	F-ratio =		65.256

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1982. pg. 801.

be used for the nonparametric tests. In this way, a total of 25 property pairs were identified for the right-of-way analysis, and a total of 12 property pairs were identified for the grade crossing analysis.

Viewed representing 25 and 12 Bernoulli trials as discussed earlier, both a sign test and a Wilcoxon signed-rank test were applied to determine whether the primary attribute, in this case proximity to either a right-of-way or grade crossing, has a statistically significant effect upon sales prices. For 8 (32%) of the 25 property pairs in the right-of-way analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.11 show that the null hypothesis cannot be rejected, and therefore proximity to freight rail rights-of-way does not appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically insignificant effect upon property values.

For 8 (67%) of the 12 property pairs in the grade crossing analysis, the impacted study property exhibited a lower sales price than the non-impacted control properties. Using a sign test at the 0.05 level of significance, the findings in Table 7.11 show that the null hypothesis cannot be rejected, and therefore proximity to freight rail grade crossings does not appear to have a statistically significant impact upon property values. Evaluation of the Wilcoxon signed-rank test is consistent with the findings of the sign test, again indicating a statistically insignificant effect upon property values.

7.6.2 Quasi-Experimental Hedonic Models

Westford

Quasi-experimental hedonic models for Westford incorporating the distance measures lnCROWFT and lnXINGFT performed poorly, with only three of seventeen variables statistically significant. None of these three significant variables, however, exhibited signs opposite those anticipated. Both lnCROWFT and lnXINGFT were statistically insignificant, and inspection of the correlation coefficients in the variance-covariance matrix revealed that lnCROWFT and lnXINGFT were also highly collinear. A similar model incorporating only lnCROWFT, presented in Table 7.12, improved the collinearity problem, however lnCROWFT was still statistically insignificant. Models incorporating the XING1000 and CROW1000 dummy variables performed no better, with these variables consistently being statistically insignificant.

Table 7.11: Paired Data Analysis Results for Proximity Related Externalities - Freight Rail Only

Sign Test

Right-of-Way		*Grade Crossings*	
n =	25	n =	12
number of negative differences =	8	number of negative differences =	8
level of significance =	0.05	level of significance =	0.05
lower bound of the critical region =	17	lower bound of the critical region =	9

Wilcoxon Signed-Rank Test

Right-of-Way		*Grade Crossings*	
n =	25	n =	12
S_n =	247	S_n =	26
$E(S_n)$ =	163	$E(S_n)$ =	39
$Var(S_n)$ =	1,381	$Var(S_n)$ =	163
level of significance =	0.05	level of significance =	0.05
test statistic Z_n =	2.274	test statistic Z_n =	-1.020
critical Z_n =	-1.645	critical Z_n =	-1.645

* statistically significant at the indicated level of significance (one-tailed test)

7.7 Summary of Proximity Related Externalities Findings

Regarding the proximity related impacts analyses, for the commuter rail only study areas, the paired data analyses presented earlier in Table 7.7, Table 7.9, and Table 7.11 consistently indicate no statistically significant impact for either rights-of-way or grade crossings upon property values. Only for the commuter rail right-of-way paired data analysis presented in Table 7.7 is there a statistically significant negative impact upon property values, of about -10% on average for the mean control property sales price, resulting from a property being located with 750 feet of a right-of-way.

As for the quasi-experimental hedonic models, for the town of Needham, both lnCROWFT and lnXINGFT were statistically significant, however lnXINGFT exhibits a sign opposite that anticipated. The estimated coefficient of .0423 for the right-of-way impact variable lnCROWFT indicates that for every one percent increase in distance from the right-of-way, single-family residential property values increase by .04 percent. In a second Needham model, not presented, CROW750 had a statistically significant estimated coefficient of -0.06902, indicating that single-family residential properties located within 750 feet of the Needham Line right-of-way sell for about 6.9 percent less than otherwise comparable properties in Needham.

Table 7.12: Regression Results for Proximity Related Externalities - Freight Rail Only

Variable	Westford Coefficient	Std. Error	t-ratio
lnULAREA	0.44486	0.06759	6.582 †††
lnBEDS	0.00531	0.07921	0.067
lnBATHS	0.16974	0.06115	2.776 †††
lnAGE	-0.05452	0.01360	-4.008 †††
AGE100	-0.07067	0.07508	-0.939
CAPE	0.03128	0.04863	0.658
RANCH	0.01242	0.04825	0.280
CONTMP	-0.00259	0.07045	-0.002
STLOTH	-0.04817	0.04868	-0.990
lnLTSQFT	0.02587	0.02965	0.873
lnPOPDEN	-0.00839	0.03395	-0.247
lnHHINC	0.08901	0.08689	1.024
lnAUTO1	-0.04453	0.03735	-1.192
TRFHVY	-0.04929	0.04872	-1.013
TRFMED	-0.01163	0.04079	-0.266
lnFROWFT	0.01108	0.01579	0.702
Constant	7.74269	1.20352	6.433 †††

Dependent Variable =	lnSLPRIC
Observations =	205
R^2 =	0.723
Adjusted R^2 =	0.699
Std. Error =	0.175
F-ratio =	30.454

***,**,* denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tailed test), respectively

†††,††,† denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (one-tailed test), respectively

Note: Coefficient estimates for dummy variables are adjusted for correct interpretation as per Kennedy, Peter E. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review*, September 1982. pg. 801.

For the commuter rail/freight rail mixed traffic areas, for the town of Winchester the variable lnCROWFT is statistically insignificant at the .01 level. The estimated coefficient of .06797 for the right-of-way impact variable lnCROWFT can be interpreted to imply that for every one percent increase in distance from the right-of-way, single-family residential property values increase by .067 percent. For the freight only model for Westford, there was no statistically significant impact related to proximity to the right-of-way.

Chapter 8
Conclusions and Implications for Policy Development

This thesis has examined the impact of commuter rail service upon communities via the analysis of single-family residential properties, with both the beneficial impacts arising from superior accessibility and the deleterious impacts arising from proximity to commuter rail facilities and operations evaluated. Empirical results suggest that commuter rail service does indeed influence single-family residential property values. At the regional level, there is strong evidence of a statistically significant appreciative impact upon single-family residential property values. Estimates of the elasticity of single-family residential property sales price with respect to commuter rail line haul travel time range from -0.16 to -0.18. A statistically significant sales price premium of about 3.8 percent is also observed for single-family residential properties by virtue of their being located within a community directly served by commuter rail. At the local level, however, findings are not as convincing. Using paired data analyses, local accessibility to commuter rail stations from within a given community is also observed to have a statistically significant positive impact upon single-family residential property values. Quasi-experimental hedonic price models yield inconsistent findings, with statistically significant property value premiums of 3.0 percent and 9.9 percent observed for homes within walking distance of commuter rail stations in only two of the five study areas. This finding of a significant regional impact and a weaker local impact is generally consistent with the way in which residential properties are marketed by real estate firms. Often, the fact that the home is located within a community having commuter rail access to Boston may be extolled, and whether the property is three minutes from the station or eight minutes from the station, for example, is not emphasized.

Regarding proximity related externalities and their effect upon property values, both paired data analyses and hedonic price models reveal no consistent statistically significant reductions in property values in proximity to commuter rail, mixed traffic and freight rail rights-of-way. Of the three paired data analyses conducted, only the paired data analysis of commuter rail only rights-of-way revealed a statistically significant negative effect upon property values. For the grade crossing analyses, there were no statistically significant effects upon property values identified.

Although based upon a case study of MBTA commuter rail service in the metropolitan Boston area, the implications of these findings extend well beyond the MBTA service district. With continued expansion of commuter rail services anticipated throughout North America, it seems likely that issues related to both the beneficial and deleterious effects of commuter rail service may become a growing concern to both the affected public and to transit agencies engaged in the planning, design, and operation of new or expanded commuter rail facilities. Because of differences in housing market characteristics and commuter rail operating practices, among other variables, the findings of this analysis are not directly transferable to other locations and commuter rail systems. However, these findings are at a minimum illustrative of the types of possible impacts that may exist under a variety of conditions. With continuing improvements in the availability and quality of machine-readable data sources, methods similar to those used in this thesis could potentially be applied to other regions in an attempt to offer additional insights regarding the impacts of specific commuter rail systems and their operating practices upon communities.

8.1 Background for Policy Development

In the context of current planning practice in the U.S., actual and perceived negative impacts of type described earlier in Chapter 2, such as noise, visual intrusion, transit generated crime and others, often lead to protracted delays and substantial modifications to otherwise desirable transportation projects. Although the more enlightened environmental and planning laws of the past three decades have helped to prevent much of the transportation related environmental degradation and negative social impacts upon communities that were more widespread during the 1950's and 1960's, in recent years it has become increasingly difficult and in some cases impossible to build facilities that are often highly desirable for cities and regions.

Possible modifications to existing planning processes that may provide for a more effective and equitable outcome are considered here. First, the methods by which similar difficulties are resolved in other countries are briefly examined in the hope that they may offer some insight into how policy in the U.S. might be modified. Relevant legal issues related to possible policy changes are also briefly reviewed.

8.1.1 International Experience

The planning of rail facilities in other countries involves a wide variety of environmental impact assessment methods. Often, a public consultation process that must relate to the differing public attitudes present in different regions, for instance car oriented development in the U.S. and Britain or more urban oriented societies such as Japan, is an element of the overall assessment process. As in the U.S., other democratic societies generally require that information from environmental impact assessments be made available to all impacted and interested parties. Participants in the planning process, including elected governments, technical bodies (e.g. environmental protection agencies), and individual persons such as local property owners operate at both national and local levels. Among countries, differences exist regarding the local and national perception of rail projects, and project promoters often need to deal with both levels in order to gain approval for a given project. For instance, in France, as many as five levels of elected bodies can be involved in planning decisions, with decisions often made primarily at the lower levels of government by smaller communities. These smaller communities tend to make decisions based upon practical economic reasoning, rather than based upon the feelings of residents in general. In the planning for the Channel Tunnel, for instance, planning at the Calàis end primarily concerned local jobs and development impacts, whereas in Kent on the English side of the tunnel, local concerns primarily focused on the environment and quality of life issues.[205] In Europe generally, although both national and local concerns are considered, they are not always given equal weight. Under some circumstances, excessive local demands can sometimes increase project costs beyond what national interests perceive as prudent. This is generally consistent with recent experiences in the U.S. concerning commuter rail as presented earlier in Chapter 2.

The public involvement process in many countries often involves the use of compensatory environmental agreements, in which an inducement or benefit is sometimes offered to a local community to gain, if not its acceptance of project, at least neutrality. The cost of such incentives is likely to be modest in comparison to having to negotiate with a less receptive community. In the use of any public consultation procedure, there is a danger of placing greater emphasis on local agreement than on objective assessment and national and regional environmental interests. The use of a straightforward democratic procedure in public consultation, then, may unnecessarily delay the planning process, and economically unsound and perhaps environmentally unsuitable solutions may also result. For instance, in Germany and Switzerland, the proposed use of tunnels as a means of satisfying the objections of those

[205] Carpenter, T.G. *The Environmental Impact of Railways*. New York, NY: John Wiley & Sons, 1994. pg. 19.

affected by rail lines has become quite common, so much so that if all of the requests were met, in some cases entire lines would end up being in a tunnel.[206]

Finally, in the United Kingdom, if there are impacts other than land takings which reduce the value of property that is near but not within the taken right-of-way, then compensation to affected land owners can be obtained under the Land Compensation Act of 1973. In practice, however, the only compensation provided is noise insulation to properties where noise limits are exceeded.

8.1.2 Implementation and Legal Issues for Possible Policy Modifications

In the U.S., planning processes do not explicitly or systematically incorporate compensatory actions such as those described above in order to facilitate the planning process. Legal action by an aggrieved land owner impacted by noise or other nuisances related to a transportation project may, however, eventually lead to individual cases of compensation on the basis of the doctrine of inverse condemnation. Under the doctrine of "inverse condemnation," if private property is destroyed or substantially diminished in value by governmental action, the conduct of the government may be regarded as a taking and thus require compensation under the Fifth Amendment to the Constitution of the United States. "Condemnation", often referred to as "eminent domain," refers to the physical taking of private property for public use. Under the Fifth Amendment, when the federal government takes private property, it must pay the owner its fair value. The same requirement is imposed upon state and local governments by the Fourteenth Amendment.

There do exist legal precedents in which the Supreme Court and lower courts have held that the destruction of the value of neighboring property by noisy overflights of aircraft, for instance, to or from a publicly owned airport subjects the governmental entity owning the airport to liability for the value of the property thus "taken" for a public use, under the doctrine of inverse condemnation.[207] Similar principles could apply in other contexts, such as that of a new commuter rail service and its impacts upon properties located within close proximity to the right-of-way.

Regarding property value increases due to superior accessibility provided by a transportation facility, value capture techniques have often been studied in the literature, however the actual implementation of such policies faces a number of legal issues that have limited their use in practice. Often, state enabling legislation is required, since typically there

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[206] *Ibid.* pg. 123.

[207] Harris, Cyril M., Ph.D., ed. *Handbook of Noise Control*. New York, NY: McGraw-Hill Book Company, 1979. pg. 38-4. See *Griggs v. Allegheny County*, and *Aaron v. City of Los Angeles*.

exist legal constraints on the power of local governments to impose charges upon particular parcels of development. Even with enabling legislation at the state level, difficulty can still be encountered in attempting to implement a value capture policy. For instance, recent experiences with value capture policies in the Los Angeles area with the Metro Rail project have been less than entirely successful, even though enabling legislation had been passed by the state legislature. Although establishment of benefit assessment districts near Metro stations survived early legal challenges, later appeals resulted in the policies being set aside, and amendments to the enabling legislation are being considered in order to correct flaws that resulted in the successful legal action against the value capture policy. Simply the fear of becoming involved in a lengthy and costly legal dispute over the implementation of a value capture policy, even if the dispute is eventually resolved favorably, tends to discourage the implementation of such policies.

Finally, the methodologies available for use in attempting to estimate either value decreases or value increases resulting from transportation projects are far from ideal. Many of the methods are similar to those used earlier in this thesis, and thus as reviewed in Chapter 3 have various weaknesses for which there are no straightforward solutions. Similar methodological difficulties in measuring value changes exist in the related field of regulatory takings, where regulatory actions are evaluated as to the extent to which they constitute a taking under the Fifth Amendment and thus require compensation.[208]

8.2 Possible Policy Modifications Related to the Impact of Commuter Rail Service

In some cases, the discord between planners and local property owners over a specific project might be eased by enhanced public outreach, educational efforts, and public relations on the part of the agency proposing the project. Additional costs incurred by implementing such efforts will likely be modest in comparison to a repeatedly delayed planning process and the substantial costs that can be incurred as a result of continued redesign of a project to accommodate sometimes excessive local demands.

If local perceptions of the possible impacts of a project are inconsistent with reality, a well designed educational program as part of an overall participatory program of citizen involvement may help to clarify the issues with the public. This type of approach may be as effective or more effective than the promise of actual physical improvements such as noise barriers. Recent advances in multimedia representational aids can allow planning agencies to combine existing representational formats such as maps and documents into far richer and

[208] Walter, William S. "Appraisal Methods and Regulatory Takings: New Directions for Appraisers, Judges, and Economists." *The Appraisal Journal*, Volume LXIII, Number 3, July 1995. pp. 331-349.

compelling a medium, thus facilitating comprehension of an environment by the potentially affected public. Far more sophisticated public relations efforts than are currently possible, perhaps carried out by hired consultants to the planning agency, could help to maximize the positive exposure of the project in the local media, and minimize any delay to a project resulting from any misinformation or misunderstanding. Again, although such an approach seems somewhat unusual and perhaps extravagant at first, its costs may be modest in comparison to that incurred by the delay and redesign of a large project. All of the above mentioned educational and public relations measures could potentially be highly cost-effective when compared to the alternative of a long delayed, heavily redesigned and much costlier project.

Compensatory policies of the type more typical in other countries, in which communities are provided compensatory agreements, or compensatory policies aimed at compensating property owners located in close proximity to a right-of-way or other facility, which under the doctrine of inverse condemnation may incur legal action anyway, might offer planners an additional tool with which to facilitate projects in a cost effective manner. Such a policy would be in addition to current practice in the U.S. regarding the partial mitigation of proximity impacts by means of application of noise treatments and construction of noise barriers. Options for financing such a policy might include a limited value capture policy by using special assessments to capture a portion of the community wide increase in property values indicated in this study. The equity implications of using special assessments as part of a value capture policy are generally innocuous, since the conventional wisdom that property taxes and related special assessments are regressive because housing is a "necessity" is in actuality not true. Sufficient empirical evidence exists that suggests that the income elasticity of demand for housing is greater than unity, thus housing expenditures increase more rapidly than income, and property taxes are in fact relatively progressive.[209] However, the legal difficulties encountered in applying value capture policies elsewhere in the U.S. as presented earlier would likely discourage the use of such a policy. Although the cost of implementing such a policy may seem excessive, from a social benefit-cost perspective, compensatory payments made to the affected property owners can be viewed as a transfer rather than a net loss or cost to society, since the actual cost to society is the cost imposed on negatively affected property owners in proximity to the right-of-way.

Recently, large transportation infrastructure projects such as the Central Artery Project in Boston have been faulted for expending relatively large sums upon project abutters and

[209] Nicholson, Walter. *Microeconomic Theory: Basic Principles and Extensions*. New York, NY: The Dryden Press, 1992. pg. 211.

other affected stakeholders in what some have viewed as an attempt to appease abutters and other affected parties and thus expedite the progress of the project. In the case of the Central Artery Project, although many agree that these expenditures have been substantial and in some cases unwarranted, it is not entirely clear whether the project would have been able to achieve a similar level of progress if, in the absence of these expenditures being made, it had become encumbered with additional legal actions, particularly given the generally litigious nature of society in the U.S..

Although the establishment of compensatory policies aimed at compensating property owners seems highly unlikely at a time when the political climate in the U.S. could be characterized as being dominated by anti big-government and anti government spending attitudes and sentiments, recent legislative developments actually suggest otherwise. A bill currently under consideration in Congress, entitled the "Private Property Protection Act of 1995," would require the government to reimburse owners of property who are adversely affected by certain government actions or regulations.[210] Somewhat surprisingly, this bill has been supported by Republicans, however Democrats, including President Clinton and Senator John F. Kerry of Massachusetts, oppose the bill, saying that it would harm the budget, reward wealthy developers and polluters, and create a larger federal bureaucracy. Although intended to provide compensation for government regulations that limit "the use of privately owned property so as to diminish its value," this bill would seem to indicate an apparent willingness at least on the part of Republicans to provide fair compensation related to property value impacts resulting from government actions. Thus, even given the prevailing political climate and attitudes towards government, such compensatory policies related to the property value impacts of government regulations and actions do not seem outside the realm of political and institutional reality.

8.3 Recommendations for Future Research

With continued expansion of commuter rail services anticipated throughout North America, it seems likely that issues related to both the beneficial and deleterious effects of commuter rail service may become a growing concern to both the affected public and to transit properties and planning agencies. As well as perhaps creating the need for further insights into these types of issues, new commuter rail facilities may offer opportunities for additional analyses, possibly under more controlled circumstances. Alternative model specifications and methodologies, such as the use of repeat-sales indices, may also provide additional insights into

[210] *Private Property Protection Act of 1995*. 104th Congress, 1st Session. HR 925 EH.

the nature and extent of commuter rail impacts upon communities. Finally, the possible time series effects of the planning, construction and operation of new commuter rail facilities might be explored.

Additional future research may not, however, result in substantial insights into the question of the effects of commuter rail upon property values. Extensive review of the literature presented in Chapter 4 shows that historically, findings regarding the impact of rail transit upon property values have been mixed. The question of whether commuter rail or other modes of transit affect residential property is in fact a very complex problem, and one that is often dramatically oversimplified in much of the existing literature, to the extent that the insights that can be gained from the findings of such research are limited. Also, in much of the existing literature researchers take far too many liberties in interpreting the results of their research, often overstating the results from analyses which in fact likely suffer from a variety of methodological problems, such as poor quality data or estimation difficulties in using multiple regression analysis. Previous analytical approaches utilized in attempting to address the issue of transit property values impacts, as reviewed in Chapter 4, suffer from many of these shortcomings. Even with the great care taken in this thesis to avoid the many methodological problems that can arise, it is extremely difficult, if not impossible, to prove that these effects exist. However, regardless of whether these effects in fact exist, simply the perception that they do may be enough to result in a community response, either positive or negative, to proposed commuter rail service.

In a democratic society such as that in the U.S., special interest groups are capable of speaking with loud and powerful voices. Planning and economic analysis is designed to reflect the aggregate economic welfare of society, however. Naturally, those groups and individuals who wish that their demands could have been more fully satisfied will be disappointed. However, their failure to attain complete satisfaction should not serve as a reasonable indication of the value of a planning process that should more broadly benefit society. A proper balance must be achieved between often short-term but genuine popular objections, and longer term goals that affect a broader area. The application of enhanced educational programs, more extensive public relations efforts, and the use of possible compensatory policies in the planning of commuter rail facilities, although themselves resulting in increased project cost, may help to prevent additional costs of a far greater magnitude that might otherwise result from protracted delays and extensive redesign. Thus, such policies may prove to be highly cost-effective in solving the problems associated with commuter rail service, leading to a reduction in public opposition to needed transportation improvements while fairly compensating affected land owners. Through the use of such policies, the relationship between transportation planners and the public can continue to be one which is less adversarial, resulting in a more effective and less costly transportation planning process, as well as an improved transportation system.

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