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Land Use Impacts of Bus Rapid Transit

Phase II—Effects of BRT Station Proximity on Property Values along the Boston Silver Line Washington Street Corridor

JULY 2012

FTA Report No. 0022
Federal Transit Administration

PREPARED BY
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University of South Florida

U.S. Department of Transportation
Federal Transit Administration

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Victoria Perk, NBRTI/CUTR

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SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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13. ABSTRACT

The development of Bus Rapid Transit (BRT) systems is relatively recent in the U.S.; however, several systems are operating and many more are being planned. A comprehensive understanding of the relationship between land uses and BRT systems is needed, particularly in comparison to other fixed-guideway modes such as rail. This report describes an effort to quantify the impacts of access to BRT stations on the sale prices of surrounding condominiums located along Boston's Washington Street where Phase I of the Silver Line BRT began in 2002. To test the hypothesis that the BRT stations have an impact on market value that is commensurate with rail transit projects (considering the level and permanence of services and facilities), a hedonic regression methodology was used to estimate the impact of access to BRT station on sale prices of condo units. A key result is that for condo sales that occurred in 2007 or 2009, the BRT premium was approximately 7.6 percent. For condo sales in 2000 and 2001, prior to the opening of the Silver Line, no sales premium existed for proximity to the corridor. Further, changes in land uses along the corridor were examined over the period from 2003 to 2009. As more BRT systems continue operating in the U.S., this methodology should be applied to other cities as well as to other types of properties. These studies can help policymakers and those in the transit industry gain a better understanding of the overall impacts of proximity to BRT stations on property values, land uses, and economic development.

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ABSTRACT

The development of Bus Rapid Transit (BRT) systems is relatively recent in the U.S.; however, several systems are operating and many more are being planned. A comprehensive understanding of the relationship between land uses and BRT systems is needed, particularly in comparison to other fixed-guideway modes such as rail. This report describes an effort to quantify the impacts of access to BRT stations on the sale prices of surrounding condominiums located along Boston's Washington Street where Phase I of the Silver Line BRT began in 2002. To test the hypothesis that the BRT stations have an impact on market value that is commensurate with rail transit projects (considering the level and permanence of services and facilities), a hedonic regression methodology was used to estimate the impact of access to BRT station on sale prices of condo units. A key result is that for condo sales that occurred in 2007 or 2009, the BRT premium was approximately 7.6 percent. For condo sales in 2000 and 2001, prior to the opening of the Silver Line, no sales premium existed for proximity to the corridor. Further, changes in land uses along the corridor were examined over the period from 2003 to 2009. As more BRT systems continue operating in the U.S., this methodology should be applied to other cities as well as to other types of properties. These studies can help policymakers and those in the transit industry gain a better understanding of the overall impacts of proximity to BRT stations on property values, land uses, and economic development.

EXECUTIVE SUMMARY

The development of Bus Rapid Transit (BRT) systems is relatively recent in the United States; however, several systems are operating and many more are being planned. A more comprehensive understanding of the relationship between land uses and BRT systems is needed, particularly in comparison to other fixed-guideway modes such as heavy and light rail. While recognizing that existing land uses have an important and complex influence on the development costs and benefits of fixed-guideway projects, this research focuses on the impacts that BRT projects have on surrounding property values and land uses.

This research sought to begin the understanding of the extent to which access to BRT services is considered in the location decision, whether commercial or residential. Is the availability of BRT service a factor in an investment decision such as a home purchase? With the appropriate data and methodology, the marginal effect of proximity to BRT access on property values can be estimated.

Indeed, there is a large amount of qualitative and anecdotal evidence that the implementation of BRT services can lead to economic development and increased land values (Breakthrough Technologies Institute 2008). This work goes beyond the qualitative evidence in an attempt to find a positive, statistically-significant impact on property values from proximity to BRT access.

Up until recently, no quantitative modeling studies on the property value impacts of BRT access for systems operating in the United States were available. In 2009, the Federal Transit Administration (FTA) published a study conducted by the National Bus Rapid Transit Institute (NBRTI) on the Pittsburgh Martin Luther King, Jr. East Busway. The findings showed that proximity to East Busway stops provided a positive, statistically-significant impact on the assessed values of single-family homes located along the East Busway corridor (Perk and Catalá 2009).

In the U.S., studies on impacts of proximity to transit on property or land values have focused on rail modes. As described in the literature review contained in this report, these studies attempted to isolate the effect of distance from rail transit (right-of-way, stations, or both) on property or land values. Most of the studies found positive impacts on property values from nearby rail transit; however, the magnitudes were relatively small. Certainly, a relatively small marginal impact would be expected from access to transit when the myriad factors that influence the price of a property are considered.

The study described in this report follows up on the work conducted on the Pittsburgh East Busway by examining land use and property value changes that have occurred along the Boston Silver Line Washington Street corridor. This report describes an effort to quantify the impacts of access to BRT stations on the sale prices of surrounding condominium units. The hypothesis, similar to the Pittsburgh study, is that the BRT stations have an impact on market value that is commensurate with rail transit projects considering the level and permanence of services and facilities: does the home-buyer or other decisionmaker consider BRT service to be attractive and as permanent as a rail mode? To test this hypothesis, hedonic price regression models were used to estimate the impact of access to a BRT station on the sale prices of condominium units. In addition, changes in land uses along the corridor were examined over the period from 2003 to 2009, which encompasses the years since the implementation of the Silver Line Washington Street BRT service.

The data used for this study consist of all condominium units within 1/4 mile of the Washington Street corridor. Condominium units were selected as the focus of this study because of their relatively large number located along the corridor. The City of Boston provided parcel data for the years 2003 to 2009. Sales data from the City of Boston were available from 2000 to 2009, which includes the time period before and after the BRT service began operating along Washington Street.

Analysis of the changes in sale price per square foot from before and after the implementation of the Silver Line Washington Street BRT service indicates an impact that is positive, yet relatively small in magnitude, as would be expected. Specifically, for condo sales that occurred in 2007 or 2009, a condo at the mean distance to a BRT station had a sale price per square foot that is approximately $45.82 less than one that is adjacent to a station, all else constant. The mean sale price per square foot in the 2007/2009 data was about $600, so the BRT premium was approximately 7.6 percent. In a similar model using condo sales from 2000 and 2001, prior to the opening of the Silver Line, a different relationship was found, wherein sale price per square foot increased with distance from the Washington Street corridor.

The key variable in these results is the network distance in feet from the unit (or its parcel) to the nearest Silver Line BRT station. For the before dataset representing sales in 2000 and 2001, prior to the opening of the Silver Line, the relationship between the distance to the Washington Street corridor and sale price was positive and increasing as distance from a station increased. These results are statistically significant at the 5% level of significance using robust standard errors. Specifically, the variable coefficients show this relationship by indicating the marginal impact on sale price per square foot from a one-foot increase in distance. These marginal effects can be summed to estimate the impact on sale price for a condo at any given distance from the corridor, prior to the opening of the Silver Line. For example, moving from 101 to 100 feet from the corridor decreased sale price per square foot by approximately $0.12; moving from 961 to 960 feet away (the mean distance in the 2000/2001 data) decreased sale price per square foot by approximately $0.06; and moving from 1,321 to 1,320 feet away (one-quarter mile away) decreased sale price per square foot by approximately $0.04. Summing these marginal effects results in a premium of approximately $89 per square foot for a condo at the mean distance from the corridor compared to one on the corridor, all else constant, for the time period before the Silver Line was open.

The relationship described in the previous paragraph, with sale price per square foot increasing as distance from the corridor increases, is the opposite of the relationship hypothesized with the presence of BRT. Looking at the after dataset, beginning five years after the implementation of the Silver Line, a different relationship emerges. For the dataset that represents sales in 2007 and 2009, the relationship between the distance to the nearest Silver Line BRT station and the sale price per square foot was inverse and decreasing as distance from a station increases. Moving from 101 to 100 feet away from a BRT station increases sale price per square foot by approximately $0.06; moving from 871 to 870 feet away (the mean distance in the 2007/2009 dataset) increased sale price per square foot by approximately $0.04; and moving from 1,321 to 13,20 feet away increased sale price per square foot by approximately $0.02. Again, these marginal effects can be summed to reveal that a condo at the mean distance to a BRT station had a sale price per square foot that was approximately $45.82 less than one that is adjacent to a station (the mean sale price per square foot in the 2007/2009 data was $600), representing a BRT premium of approximately 7.6 percent.

The results from the before dataset and the after dataset confirm the hypothesis that there exists a sale price premium for walking access to a Silver Line BRT station. The coefficients on distance are statistically significant at the 5% level of significance using heteroskedastic-robust standard errors.

Further, a separate analysis of land use changes along the Washington Street corridor revealed an increase in the number of parcels that converted to Condominium classification over the period from 2003 to 2009. It is clear that the City's efforts at redeveloping the Washington Street corridor have impacted land uses and sale prices in the area. Access to the Silver Line BRT service is likely one key aspect of the positive changes observed along the corridor.

This research worked to further refine the methodology from Phase I by examining actual sales data rather than assessed values, by analyzing repeat sales of similar condo units, and by using network distances to the nearest BRT station rather than straight-line distances. Future research should explore a refined methodology and include applications to other U.S. cities with BRT. It should be noted, however, that the results described in this report are valid only for the data used in the Boston case and represent only the second study of the impacts of BRT stations on surrounding properties in recent years in the United States. Results from quantitative modeling efforts can be used along with other types of studies as well as anecdotal evidence to develop overall assessments of BRT's impacts on land uses and property values. As more BRT systems continue operating over time in the United States, the methodology used for this effort needs to be applied to other cities as well as to other types of properties (both residential and commercial). Future research should more deeply explore the question of what characteristics induce the premium found in these results. Do these characteristics relate to a specific mode or just to the availability of certain factors such as high-quality, rapid, and reliable transit, regardless of mode? Further applications will grow the body of literature and help policymakers and those in the transit industry gain a better understanding of the overall impacts of proximity to BRT stations on property values, land uses, and economic development.

SECTION

1

Introduction

The development of Bus Rapid Transit (BRT) systems is relatively recent in the United States; however, several systems are operating and many more are being planned. A more comprehensive understanding of the relationship between land uses and BRT systems is needed, particularly in comparison to other fixed-guideway modes such as heavy and light rail. While recognizing that existing land uses have an important and complex influence on the development costs and benefits of fixed-guideway projects, this research focuses on the impacts that BRT projects have on surrounding property values.

This research sought to begin the understanding of the extent to which access to BRT services is considered in the location decision, whether commercial or residential. Is BRT service a factor in an investment decision such as a home purchase? With the appropriate data and methodology, the marginal effect of proximity to BRT access on property values can be estimated.

Indeed, there is a large amount of qualitative and anecdotal evidence that the implementation of BRT services can lead to development and increased land values (Breakthrough Technologies Institute 2008). This work goes beyond the qualitative evidence in an attempt to find a positive, statistically-significant impact on property values from proximity to BRT access.

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Previously, in 1990, a study examined some operating busways (including Pittsburgh, but did not find any impacts (Mullins et al. 1990). Also, recent studies have been conducted on the BRT systems operating in Bogotá, Colombia (Rodriguez and Targa 2004; Rodriguez and Mojica 2009) and Seoul, South Korea (Cervero and Kang 2009). In the U.S., studies on impacts of proximity to transit on property or land values have focused on rail modes. As described in the literature review contained in this report, these studies attempted to isolate the effect of distance from rail transit (either right-of-way, stations, or both) on property or land values. Most of the studies found positive impacts on property values from nearby rail transit; however, the magnitudes were relatively small.

Certainly, a relatively small marginal impact would be expected from access to transit when the myriad factors that influence the price of a property are considered.

The study described in this report follows up on the work conducted on the Pittsburgh East Busway by examining land use and property value changes that have occurred along the Boston Silver Line Washington Street Corridor. This report describes an effort to quantify the impacts of access to BRT stations on the sale prices of surrounding condominium units. The hypothesis, similar to the Pittsburgh study, is that the BRT stations have an impact on market value that is commensurate with rail transit projects, considering the level and permanence of services and facilities: does the home-buyer or other decisionmaker consider BRT service to be attractive and as permanent as a rail mode? To test this hypothesis, hedonic price regression models were used to estimate the impact of access to a BRT station on the sale prices of condominium units.

This report is organized into sections that describe the study effort, data used, and results. A summary of literature on the topic is included following this introduction. Other sections describe the study area encompassing Boston's Silver Line Washington Street Corridor, the Silver Line transit service, the types of data required for the modeling effort and variables used, the methodology, and a full interpretation of the data analysis results. A concluding section summarizes the project and addresses the need to continue research on this topic.

SECTION 2

Literature Review

Phase I of this research on the Pittsburgh Martin Luther King, Jr. East Busway contained a comprehensive review of previous literature on the topics of transit-oriented development, the quantification of development effects of transit, and property value impacts of transit (Perk and Catalá 2009). In this Phase II study, a condensed version of that literature review is presented, along with a review of some additional research conducted since Phase I was published in 2009. Though most of the studies reviewed focus on the effects of rail transit on development, they provide the necessary background for this research because they provide a theoretical foundation and a basis for a methodology to estimate the effect of BRT on development.

An effort to quantify the impacts of BRT stations along the Pittsburgh Martin Luther King, Jr. East Busway on the values of surrounding single-family homes comprised Phase 1 of this research (Perk and Catalá 2009). Many BRT systems operating in the U.S. might have been considered, at the commencement of the Phase I study, to be too new to find evidence of capitalization into property values. As such, data from Pittsburgh's Martin Luther King, Jr. East Busway, one of the oldest operating BRT systems in the country, were used. The hypothesis, as in the current Phase II, was that BRT stations have an impact on property value that is commensurate with rail transit projects, considering the level and permanence of services and facilities. To test this hypothesis, the method of a hedonic price regression model was used to estimate the impact of distance to a BRT station on the fair market value of single-family homes. Using this regression framework, it was expected that, as the distance to a BRT station decreased, the property value would increase, all else constant.

For the Pittsburgh phase of the study, data from the Allegheny County Property Appraiser were used in conjunction with U.S. Census data. Data on actual sales were not available, so assessed market values were used instead. It is more desirable to use data on actual sales, if available, and Phase II made use of data from actual market transactions, thus representing an improvement in the methodology from Phase I. For Phase I, it was found that the relationship between the distance to a station and property value is inverse and decreasing as distance from a station increases. Decreasing marginal effects were found; for example, moving from 101 to 100 feet away from a station, property values increased approximately $19, while moving from 1,001 to 1,000 feet away from a station increased property value approximately $2.75. Another way to interpret this result is to say that a property that is 1,000 feet away from a station is valued approximately $9,745 less than a property 100 feet away, all else constant (this figure is determined by summing the marginal effects for each foot of distance from the property to the nearest BRT station). In the Pittsburgh study, distances between properties and the BRT stations were calculated using straight-line distances, while the Phase II study used network distances calculated using geographic information systems (GIS) methods. The use of network distances represents another improvement in the methodology used previously.

The Phase I work represents one of the first recent attempts to study the impacts of BRT on surrounding property values. Nonetheless, there have been recent studies to assess the impact of BRT on real estate values in Bogotá, Colombia, a city with very extensive BRT service, and Seoul, Korea. In one study, a spatial hedonic model was used to determine the extent to which access to BRT stations in Bogotá is capitalized into rental asking prices (Rodriguez and Targa 2004). They found that for every 5 minutes of additional walking time to a BRT station, the rental price of a property decreased by between 6.8 and 9.3 percent, after controlling for structural characteristics, neighborhood attributes, and proximity to the BRT corridor. Rodriguez and Mojica summarized the findings of Mendieta and Perdomo (2007) who found that, assuming walking speeds of 4.39 km/h (14,403 ft/h), property prices increased between 0.12 percent and 0.38 percent, depending on the distance from the BRT, for every 5 minutes of walking time closer to a BRT station. Another study reviewed by Rodriguez and Mojica used propensity score matching to compare asking prices of residential and commercial properties in two zones, one with and one without BRT access (Perdomo, et al. 2007). The results were mixed, with most comparisons yielding statistically-insignificant results. In only one case, a premium of 22 percent for residential properties with BRT access was detected with a 95% level of confidence. Rodriguez and Mojica used a before-and-after hedonic model to value the network effects of an extension to Bogotá's BRT system. Focusing on the asking prices of residential properties, they found that properties offered during the year of the extension and in subsequent years had prices that were between 13 and 14 percent higher than prices for properties in the control area. In addition, the appreciation was similar for properties within 500 meters (1,640.42 feet) and properties between 500 meters and 1 kilometer (3,280.84 feet) of BRT. Finally, Cervero and Kang (2009) found land price premiums of 5 to 10 percent for residences within 300 meters (984.25 feet) of BRT stations. For retail and other non-residential land uses, impacts ranged from 3 to 26 percent within 150 meters (492.13 feet) of BRT stations.

Impacts from Rail Transit

Several research efforts have dealt with the impact of Dallas Area Rapid Transit (DART). One study examined how proximity to a DART station affected property values (Weinstein and Clower 2003). The study compared median property values in 1997 and 2001 for properties with similar characteristics within one-half mile of DART stations, separating properties by category (Residential, Industrial, Commercial, and Retail). The study found that residential properties experienced faster property value growth than the control group. In a later paper, the same authors attempted to estimate the value of total new investments or re-investments in properties adjacent to or near DART LRT stations occurring between 1999 and 2005 (Weinstein and Clower 2005). They found that new investments completed, underway, or planned near LRT stations since 1999 totaled more than $3.3 billion. The study, however, controlled only for location and market characteristics; additional variables would need to have been controlled for to test for the causal effect of proximity to transit.

One study conducted by the Rappaport Institute used GIS data to analyze land use changes in the areas surrounding all current and former commuter rail stations in the greater Boston area between 1970 and 1999 (Beaton 2006). Essentially, the author compared land use patterns in commuter rail stations to land use patterns in the greater Boston area over this time period. Rather than use the conventional definition of a station area as the surrounding half-mile radius, the author defined them as areas within 5- and 10-minute drives of a station, believing that it would more accurately take into account actual land use patterns. It was found that roughly 90 percent of the land had the same land use in 1999 as it did in 1971. Beaton compared changes in land use of the remaining 10 percent in both the commuter rail and greater Boston areas for his results and concluded that commuter rail service had only a modest impact on the land uses in the areas of commuter rail stations. Interestingly, he also found that pre-existing land use patterns seemed to have had a bigger effect in some areas than any changes in rail station status after 1970; some areas that lost rail stations showed greater development than the overall region.

Statistical Models

The literature discussed in this section concerns the development of economic models. Modeling enables researchers to control for a number of variables that affect property values, permitting the estimation of a causal effect for the distance from transit. Essentially, the effect of distance from transit, at the means of the other variables included in the regression model, can be estimated. Of the 13 papers reviewed using modeling, 5 focus on the effects on commercial property values and the remainder focus on residential property values.

The research reviewed for this effort generally attributes impacts of rail transit on property values to two sets of factors—one that increases property values and one that leads to decreases. Property values could increase if the transit system is an effective and favorable alternative to driving. Commuters who find the transit system to be a faster and more pleasant experience than driving to work would presumably pay more to be within walking distance. Additionally, property values may increase as a result of developers adding commercial and retail establishments. Conversely, being in close proximity to a rail line may also introduce perceived negative externalities—notably noise, pollution, and crime—which could discourage people from living there.

Gatzlaff and Smith (1993) used two methods to analyze the magnitude and pricing impacts of the development of Metrorail stations in Miami. First, a repeat-sales index was constructed using the pooled sample of the properties surrounding the stations, which was compared to an identically-constructed index representing the entire county. Second, a hedonic regression model was used to examine property values before and after the development of the Metrorail system. The authors acknowledge that the repeat-sales index, estimated using regression analysis, can be impacted by sampling bias; however, they note that the emphasis is on the relative price changes, not the level of the index itself. They used Miami-Dade County Property Tax Records data on sales for a pooled sample of properties surrounding Miami Metrorail stations and found no significant change in the sales index of homes before and after establishing Metrorail. Overall, they found weak evidence of positive residential property impacts, with high-income households accruing greater net benefits than low-income households.

Another study examined the impacts of the light rail system (MAX) in Portland, Oregon, on the values of single-family homes near the stations (Chen et al. 1998). Distance to the stations was used as a proxy for accessibility, while distance to the rail line itself was used as a proxy for nuisance effects, or negative externalities such as noise, traffic, and pollution. Prices of single-family homes sold from 1992 to 1994, compiled from two regional databases, were used in this study, along with U.S. Census data. They found that as distance to a MAX station increased, housing price decreased, but at a decreasing rate.

In a separate study assessing the effect of Chicago Transit Authority (CTA) and Metra stations on single-family residential property values in the Chicago metropolitan region, Gruen, Gruen and Associates (1997) found similar results. They used data on sale prices of single family homes, structural data (living area, lot size, property age), social data (median income, percentage of minorities), and station and transportation access data for the CTA and found that proximity to stations had a positive effect on home prices. Home prices decreased as distance from a station increased for both low- and high-income neighborhoods.

Two other studies used different approaches to determine the impact of the MARTA heavy-rail line on housing prices in Atlanta. Bollinger and Ihlanfeldt (1997) used U.S. Census data to measure changes in population and employment in Atlanta from 1980 to 1990. They found that MARTA shifted the employment mix to favor the public sector, although, overall, the effects of MARTA on total employment were negligible. A second study on the impact of MARTA examined Atlanta sales of single-family homes and crime density of the Census tract from 1991 to 1994 (Bowes and Ihlanfeldt 2001). They found that proximity to MARTA stations had a positive effect on the value of single-family homes, with crime density and retail employment affected by station proximity.

Another study used a panel data set for five major cities that implemented or expanded urban rail transit in the 1980s to examine the impacts on housing values as well as transit usage (Baum-Snow and Kahn 2000). Specifically, the study sought to determine the extent to which commuters were induced to switch modes to transit, which demographic groups benefitted most from the transit improvements, and how housing prices were affected by the improvements. Using 1980 and 1990 U.S. Census tract-level data for Boston, Atlanta, Chicago, Portland, and Washington D.C, the authors found that, all else constant, decreasing transit distance from 3 to 1 km (9,843 to 3,281 feet) increased monthly rents by $19 and home values by $4,972.

One paper presented an analysis of the impact of St. Louis's Metrolink, a light rail system, on residential property values in St. Louis County (Garrett 2004). Garrett used data on 1,516 single-family homes in St. Louis County that were sold from 1998 to 2001 and located within one mile of a Metrolink station. He regressed sale prices on a vector of house and neighborhood characteristics, city and year dummy variables, variables accounting for spatial correlation in both home prices and the error term, and variables for distance to the track and distance to the station. Ultimately, he found no relationship between the distance to the track and home prices and concluded that there was no general nuisance effect and only slight evidence that distance from Metrolink's track impacted home values. However, he did find evidence that distance from a Metrolink station (rather than just the track or right-of-way) had a significant impact on property values. Specifically, home values increased, on average, $139.92 for every 10 feet closer they were to a station, beginning at 1,460 feet.

Another study assessed the impact of proximity to light rail transit stations on residential property values in Buffalo, New York (Hess and Almeida 2007). This study is unique in that it focused on an older American city where the population is declining and ridership is decreasing. The authors used two methods for measuring the distance from a property to a transit station. The data included 7,357 single-family and multi-family parcels located within a half-mile radius of the transit stations. The findings indicated that a property located within the half-mile radius of a transit station was valued $2.31 higher (using the linear distance) and $0.99 higher (using the network distance) for every foot closer to a light rail station. Consequently, an average home located within the half-mile radius was generally worth between $990 and $2,310 more than the average home if it were 1,000 feet from the station.

Several other studies addressed how proximity to transit impacted the value of commercial properties (rather than residential). One study sought to determine if commercial property premiums were associated with proximity to the BART line in San Francisco, but showed no major commercial price or rent premiums associated with proximity to BART rail stations. Another study pooled data for 1978 to 1989 from both Washington, D.C., and Atlanta, covering five rail station areas with large commercial development. The study was concerned solely with commercial and office properties exceeding 100,000 square feet that were located within one-quarter mile of a rail station. The study concluded that joint development and rail transit investments showed measurable, positive land value benefits. Not only did the study find that the presence of joint development projects at rail stations increased rents by approximately $3.00 per square foot, but vacancy rates were also approximately 11 percent lower in station areas with joint development projects (Cervero 1994).

Another study was commissioned to settle damage claims pending against Santa Clara County, California. Multiple property owners with property along the Santa Clara light rail line's right-of-way sued the County, claiming it devalued their property. The study used a hedonic regression to analyze lease transactions by large brokerage firms between 1984 and 2000 and found a rental premium on office properties located within one-half mile of light rail stations (Weinberger 2001). A second study focusing on Santa Clara County transportation sought to determine the impact not only of the light rail system but also the commuter rail systems, CalTrain and the Altamont Commuter Express (Cervero and Duncan 2002b). Commuter rail is characterized by higher traveling speeds than heavy or light rail and greater distances between stations. Proximity to commuter rail stations was found to yield the biggest benefits; land parcels within one-quarter mile of a commuter rail station in a business district were worth more than $25 per square foot more than comparable properties away from stations. For light rail, the premium was only an additional $4 per square foot.

Cervero and Duncan performed a similar analysis of the commuter and light rail lines of San Diego County (Cervero and Duncan 2002a). Using hedonic price models to determine the land value premiums associated with land use in the rail corridors, they assessed the impact of rail transit on single-family housing, multi-family housing, condominiums, and commercial properties. They found the greatest amenity and disamenity effects for commercial properties, although single-family, multi-family, and condominiums also showed amenity and disamenity effects of lesser magnitudes. Cervero and Duncan used land values rather than rents to measure benefits, a unique methodology.

Tables 2-1 and 2-2 summarize the research described above for transit in the United States. Table 2-1 contains information on research addressing residential properties, and Table 2-2 lists results of research on commercial properties.

Table 2-1

Summary of Research Estimating Transit's Impacts on Residential Property Values

Study Authors and Year	Study Information	Key Findings
Gatzlaff and Smith, 1993	Dade County property tax records data on sales for a pooled sample of properties surrounding Miami Metrorail stations	No significant change in sales index of homes before and after establishing Metrorail. Overall, weak evidence of positive residential property impacts, with high-income households accruing greater net benefits than low-income households.
Chen, et al., 1998	Prices of single-family homes sold from 1992–1994 in Portland, OR	As distance to a MAX station increased, housing price decreased, but at a decreasing rate.
Gruen, Gruen and Associates, 1997	Data on sale price of single-family homes, structural data, social data, station and transportation access data for Chicago Transit Authority	Home prices decreased as distance from a station increased, for both low- and high-income neighborhoods.
Bollinger and Ihlanfeldt, 1997	Measured changes in population and employment in Atlanta from 1980 to 1990 using U.S. Census data.	MARTA shifted employment mix to favor public sector, although overall the effects of MARTA on total employment were negligible.
Bowes and Ihlanfeldt, 2001	Atlanta sales of single-family homes and crime density of Census tract from 1991–94	Proximity to MARTA stations had a positive effect on value of single-family homes.
Baum-Snow and Kahn, 2000	1980 and 1990 U.S. Census tract-level data for Boston, Atlanta, Chicago, Portland, and Washington, D.C.	Decreasing transit distance from 3 to 1 km (9,843 to 3,281 ft) increased monthly rents by $19 and home values by $4,972.
Garrett, 2004	1,516 single-family homes in St. Louis County within one mile of a Metrolink station, sold from 1998–2001	Home values increased an average of $139.92 for every 10 feet closer to a station, starting at 1,460 feet. The nuisance effect associated with the Metrolink was weak.
Hess and Almeida, 2007	City of Buffalo 2002 assessed value of properties, 1990 and 2000 U.S. Census	A property increased $0.99–$2.31 for every foot closer to an LRT station.
Perk and Catalá, 2009	2007 assessed values of single-family homes from Allegheny County Property Appraiser	Decreasing marginal effects; moving from 101 to 100 feet from a station increased property value $19, while moving from 1001 to 1000 feet away from a station increased property value $2.75.

Table 2-2

Summary of Research Estimating Impacts of LRT on Commercial Property Values

Study Authors and Year	Study Information	Key Findings
Cervero and Landis, 1995	On-line database of property tax records (TRW-REDI) and U.S. Census data for population and employment statistics	No major commercial price or rent premiums associated with proximity to BART rail stations.
Cervero 1994	Pooled data for five rail station areas, with large commercial development from 1978–1989 in Washington, D.C., and Atlanta	Overall, empirical evidence supported a measurable land value benefit from rail transit investments and joint development projects. Vacancy rates were 11% lower in station areas with joint development projects.
Weinberger 2001	Santa Clara County lease transactions from 1984–2000 collected from a large brokerage firm	Rental premium existed on office properties located within one-half mile of light rail stations.
Cervero and Duncan, 2002b	1998–1999 Santa Clara County commercial property data	Being near rail transit increased commercial land values. Land parcels within a quarter mile of a rail station in a business district were worth $25 per square foot more than comparable properties away from stations.
Cervero and Duncan, 2002a	San Diego County sale prices from Metroscan database (maintained by First American Real Estate Solutions), 2000 U.S. Census, GIS	Greatest amenity and disamenity factors for commercial properties, claimed rents to be an inaccurate way to measure benefits.

Summary and Other Work

The articles reviewed for this effort have focused largely on the impact of rail on real estate values in the U.S. This focus facilitates comparison with the analysis that is undertaken in this research to assess the impacts of BRT on real estate values better than international assessments, since the latter reflect different political, cultural, and social environments. Additional modeling results that are acknowledged but were not reviewed in detail and focus on the effects of LRT on property values include those shown in Table 2-3.

Table 2-3

Summary of Other Literature Estimating Impacts of LRT on Property Values

Study Authors and Year	Study Information	Key Findings
Dueker and Bianco, 1999	Population Census's median house value in Portland between 1980 and 1990	Premium of $2,300 for properties within 0.06 km (197 ft) of a MAX station.
Lewis-Workmann and Brod, 1997	Cadastral information for all properties (4,170) within 1.7 km (5577.43 ft) of three MAX stations in Portland	Premium of $75 per 0.03 km (98.43 ft) closer to the station.
Forrest et al., 1995	795 house sales in Manchester (UK) during 1990	Premium ranging from 2.1– 8.1%, depending on distance from station.
Landis et al., 1995	134 single-family sales in San Diego during 1990	Premium of $272 for every 0.1 km (328 ft) closer to station.
Dabinett, 1998	Sheffield (UK) Supertram	No evidence of appreciable effects.
Al-Mosaind et al., 1993	235 single-family home sales in Portland during 1988	Premium of $663 per 0.03 km (98.43 ft) closer to station.

Source: TCRP A23A, 2006

Overall, 13 of the 14 papers reviewed using modeling found positive impacts on property values from nearby rail transit; however, the magnitudes varied. Eight of these studies focused on residential property values, while five emphasized commercial properties. Most impacts were found to be statistically significant, yet relatively small in magnitude. The 14th paper does not specifically address impacts on property values, but rather the issue of population and employment densification around transit stations. This paper found no impact on total population or employment density around stations, but did find an impact on the mix of employment.

The majority of the studies reviewed, whether including statistical modeling in their analyses or not, found small but positive effects of transit on development. Though most of these studies focused on the impact of rail transit on development, they provide a valuable framework of reference for continuing research attempting to quantify the impact of BRT on development.

SECTION

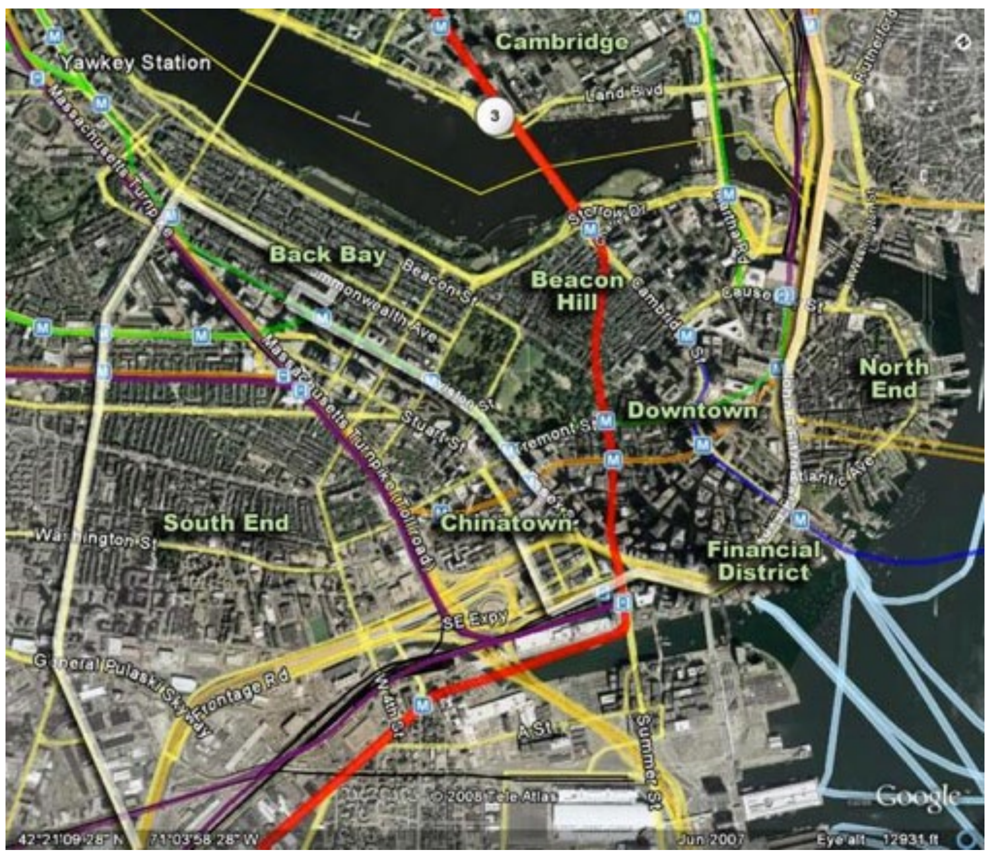
3

Study Area Description

The city of Boston is the major economic and cultural hub of New England. It is the 10th most populous metropolitan area in the United States, with a population of 4,588,680 as of 2009, which represents an increase of 4.5 percent from the 2000 Census. This port city was founded on the Shawmut peninsula in 1630 and has tripled its geographic size since its founding via land reclamation projects. Originally, the city was surrounded by a trimount of hills and substantial wetlands, greatly impacting its layout during construction. Roads had to be designed around marsh and wetlands, resulting in an extremely convoluted and winding city layout not at all resembling a standard grid. Eventually, nearly all of this was used as landfill material to increase the size of the peninsula, leaving only a portion of one of the three original hills, Beacon Hill, intact today. However, regardless of this extensive land reclamation, Boston remains one of the most densely-populated cities in the United States, owing to its early founding, which, for practical purposes, had to be compact (see Figure 3-1).

Figure 3-1

Boston Central Business District



Source: http://www.metrojacksonville.com/photos/thumbs/lrg-7345-aerial_boston.jpg

Historically a bustling port city, Boston's economic focus has over time shifted away from shipbuilding and maritime commerce and towards a much more diversified portfolio of industries. The technological sector, specifically biotechnology, is thriving in Boston, as is the tourism industry, which garnered $7.9 billion in 2004 alone. Additionally, Boston is home to a number of prestigious universities, including Harvard and the Massachusetts Institute of Technology (MIT), which attract substantial investments and supply a multitude of employment opportunities. A number of established publishing companies are headquartered in Boston, including Houghton Mifflin, as are several other large corporations, including Gillette and New Balance. The financial sector has also become prominent, and the establishment of mutual funds and investment companies in the 1980s helped transform Boston into a leading U.S. financial center (www.city-data.com/Boston).

The Massachusetts Bay Transportation Authority (MBTA), commonly referred to simply as the T, is a publicly-operated agency that is in charge of Boston's public transit, including buses, the subway, commuter rail, and ferry transportation. Boston's public transit operates on a massive scale, boasting the fourth largest weekday subway ridership in the country, as well as the busiest light rail system in the U.S., according to MBTA's website (http://www.mbta.com). The MBTA bus system also services a large daily ridership of some 350,000, making it the sixth largest bus system in the U.S. in terms of passenger trips.

Phase 1 of the Silver Line was Boston's first attempt at a BRT line. Prior to 1987, Washington Street had been served by the elevated Orange Line rail service. When the Orange Line was relocated in 1987, the Route 49 bus was established to provide local service along Washington Street. Route 49 was designed to be a temporary replacement for the Orange Line, offering high-frequency bus service until a replacement mode of transit was established. The Silver Line, the permanent replacement line for the Route 49, took years to become a reality. This was due, in part, to infighting over the fact that many wanted a new light rail service as opposed to BRT. In 1992, plans for a light rail line were rejected by FTA as cost-ineffective. In 1996, nearly 20 years after the relocation of the Orange Line and the establishment of the temporary Route 49 bus route, plans were finally approved to begin developing a BRT service, to be known as the Silver Line (http://www.mbta.com/history).

The Silver Line, categorized as a rapid transit line, features high-frequency service and a dedicated bus-only traffic lane. As a rapid transit line, the Silver Line is included on the system map detailing rapid transit (rail) routes and offers free transfers to the other rapid transit lines. Due to this, the Silver Line namesake was established to identify the new BRT with the other rapid transit rail lines, which are also color-coded (Red Line, Green Line, Orange Line, and Blue Line), thereby distinguishing it from the T's other bus lines and establishing its identify as rapid transit. Figure 3-2 is a map of MBTA's rapid transit lines.

Source: MBTA

Figure 3-2 *Map of MBTA's Rapid Transit Lines including Silver Line*

Construction of the Silver Line Phase 1 began in 2001, and the new BRT system opened on July 20, 2002. Phase 1 of the Silver Line Washington Street section, the focus of this study, operates two lines, dubbed SL4 and SL5. Both begin at Dudley Station and run along Washington Street in a designated bus-only lane up past the Tufts Medical Center and into Chinatown, where the two routes diverge. From there, the SL 5 route continues northbound along Washington to the Downtown Crossing and Boylston stations, where riders can transfer onto other rapid transit lines (the Red and Orange lines at Downtown Crossing, and the Green Line at Boyleton). SL4 diverges at the intersection of Washington and Kneeland streets in Chinatown, where the SL4 turns right, heading eastbound and making a critical connecting stop at South Station, an important juncture where riders can transfer to the Red Line or to the other phase of the Silver Line (Phase II), SL1 and SL2, with access to Logan International Airport (http://www.mbta.com/Silverline). Figure 3-3 shows a 60-foot articulated compressed natural gas (CNG) Silver Line vehicle operating along Washington Street.

Figure 3-3

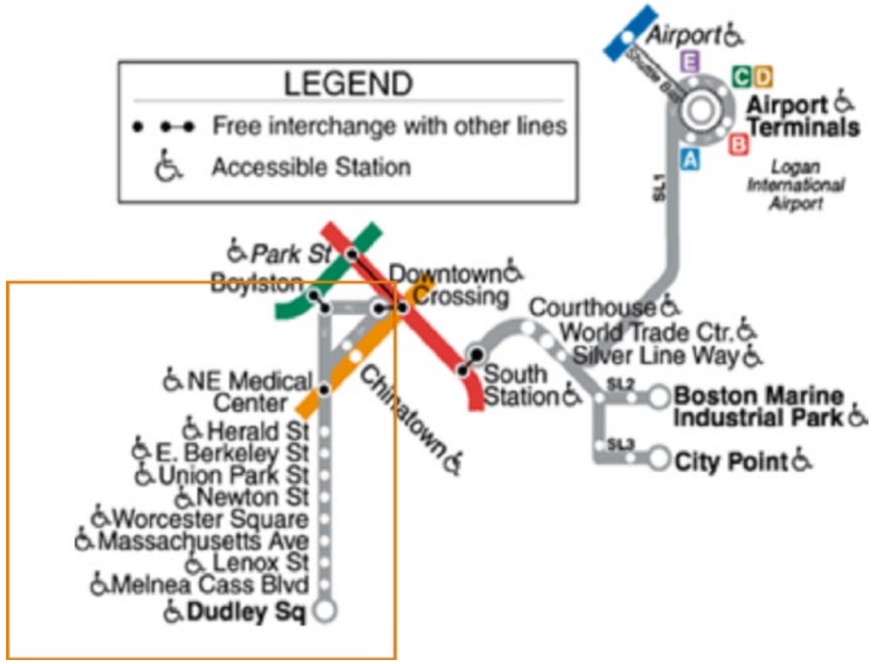
CNG Silver Line vehicle on Washington Street

Photo credit: Victoria Perk

The Silver Line's Washington Street predecessor, the Route 49 bus, included 20 stops going in each direction. The Washington Street Silver Line reduced this to 11 stops, enabling faster service and fewer loading/unloading delays. Despite the decrease in the number of stops, walking distances between stations are relatively minimal, with an average 0.2 mile distance between stops. A 12th stop was added at Worcester Square (which previously had a station under the Route 49 bus) shortly after implementation of the Silver Line, as a result of citizen demand. Figure 3-4 shows a map of the Silver Line stations, with the Phase I Washington Street Corridor highlighted in the orange box. Figure 3-5 shows the alignment in relation to the Boston central business district (CBD).

Figure 3-4

Silver Line Map (SL4 & SL5 Washington Street in orange box)



Source: MBTA

Figure 3-5

Silver Line Washington Street and Boston CBD

Washington Street has experienced significant land development and urban renewal projects in the past decade. The area had been in decline for the better half of the 20th century, experiencing significant declines in population and problems with drugs and prostitution. Urban renewal projects beginning in the late 1990s have done much to improve the image and appeal of the Washington Street area. In 1997, the Washington Gateway Main Streets program was initiated, involving spending amounting to $571 million between 1996 and 2003 for urban improvement along much of the Washington Street Corridor, from Herald Street to Melnea Cass Boulevard, which represents a significant portion of the Silver Line alignment (Breakthrough Technologies Institute 2008). The Washington Gateway program, spearheaded by a local non-profit community group, heavily involved the input of residents in making decisions on proposed development projects. Involvement at this stage from locals, who arguably know the traffic patterns of their own neighborhood best, helped to gauge appropriate densities, ensure transit and pedestrian accessibility, and even provided input on station placement and design. Sidewalks were widened, the roadway was entirely resurfaced, and more than $300 million has been spent on new real estate construction alone. In addition, nearly 2,000 housing units were constructed or renovated, along with the establishment of numerous real estate projects, including the Alexandra Hotel and multiple condominium complexes (Thole 2009). This healthy mix of residential housing renovation and improvements to commercial establishments has played a key role in the renewal of the South End. Figures 3-6 and 3-7 depict stations along the Silver Line Washington Street Corridor. The stations include markers with historical information as well as transit maps and real-time transit information.

Figure 3-6

Lenox Street Station Inbound

Photo credit: Victoria Perk

Figure 3-7

Historic marker at the Newton Street Station

Photo credit: Victoria Perk

Other areas along the Washington Street Corridor have seen recent, marked improvements in land development and renewal as well. Dudley Square enjoyed a similar spike in redevelopment efforts beginning in 2004, albeit to a lesser extent. Several notable projects have been undertaken, including a $20 million renovation of the Dartmouth Hotel, now featuring a combination of subsidized housing units and retail establishments. The nearly-100-year-old Hiberian Hall was also renovated, reopening as the Roxbury Center for the Arts in 2004, and the Gordon-Conwell Theological Seminary moved its Boston campus to Dudley Square by renovating a 24,000 square foot building in 2006.

Downtown-Chinatown, covering the northernmost portion of the Silver Line Phase I alignment, likewise has seen extensive development in the past decade. Multiple large-scale office buildings and residential apartment buildings have been constructed, including a multitude of new retail establishments such as a movie theater, health club, restaurants, retail stores, and even a renovated historic theater, the Opera House.

The establishment of the Silver Line has brought rapid public transit to the Washington Street area, along with improved roads, nicer aesthetics, and wider sidewalks. The investments in renovation and construction efforts, summarized above, have brought a multitude of new retail, residential, commercial, and entertainment establishments to the corridor. Figure 3-8 shows a Silver Line vehicle operating northbound along Washington Street.

Figure 3-8

Silver Line vehicle operating along Washington Street

Photo credit: Victoria Perk

SECTION

4

Methodology

As first discussed in the Introduction, many qualitative studies and other anecdotal information are available on the impacts of BRT, much of which describe the myriad types and amounts of development that have occurred along BRT corridors and near BRT stations. Although this information is tremendously useful to the industry and to policymakers and others in communities that have implemented or are considering BRT investments, it does not suggest a causal relationship between transit and development and is difficult to place into a modeling framework. Economic impact studies are one method for gauging the relative success of an investment by measuring the net economic benefits that accrue to the community that made the investment. Such studies are complex and require large amounts of detailed data and can sometimes require specialized software to complete. While economic impact studies of BRT investments may be useful endeavors, they do not address the needs of either phase of this study, which focuses on land use and property value impacts.

The literature reviewed for this study included several papers that described the use of hedonic price regression models to determine the marginal impact of distance to a rail transit station on property values. It was thus determined that a similar methodology would be appropriate as an application to BRT stations. To date, there has been only one hedonic regression model estimated for impacts of BRT stations on property values for services operating in the U.S. (Perk and Catalá 2009). Therefore, one of the methodologies applied for this effort is a hedonic price regression model. This type of analysis is essentially ordinary least squares regression analysis and estimates a price—in this case, a housing value—based on a number of variables believed to influence that price. Additional methods used in the research include an analysis of repeat sales and the use of GIS to analyze changes in land uses along Boston's Washington Street Corridor since the implementation of the Silver Line.

To attempt to attribute causation between proximity to BRT stations and surrounding property values, the ideal method would comprise a before-and-after scenario to estimate the marginal change in value after a new BRT service is implemented. This study used data from before and after the implementation of the Boston Silver Line Phase I that operates along the Washington Street Corridor.

The regression models used in this study used sales data on condominium units along the Washington Street corridor. Condominiums were selected for this analysis due to the large number of them located in the corridor. First, the sale prices per square foot of condo units were estimated for the years 2000 through 2002, prior to the implementation and establishment of the Silver Line service. Then, regression models were run to estimate the sale price per square foot of condo units that sold in 2007 and 2009 (2008 data were incomplete), representing five and seven years, respectively, after the Silver Line began operation. The regression models control for other property and neighborhood characteristics, including the local condo price indices.

GIS methods also were used to analyze changes in land uses along the Washington Street corridor from 2003 to 2009. Specifically, the analysis focused on properties that converted to Condominium classifications or to office uses.

Hypothesis

This research applied the assumption that accessibility benefits accrue for properties with proximity to a public transit station. These benefits, in turn, were hypothesized to capitalize into land values and sale prices. Therefore, this research aimed to show that, as the distance to a BRT transit station decreases, the accessibility benefits accrued by property owners will be greater, resulting in a higher property values. The null hypothesis was that, as the distance to the transit station increases, there will be no impact on sale prices; this implies that proximity to a transit station accrues insignificant accessibility benefits for nearby properties. Further, this research hypothesized that sale prices along Boston's Washington Street Corridor have increased since the opening of the Silver Line Phase I BRT, all else held constant.

The Silver Line Phase I has been operating since 2002. Given the time that has passed, it can be assumed that adjustments have been made in travel behavior and the transformation in land use along the corridor has begun (although it may not be near complete). Likewise, though real estate development effects from transportation improvements are generally expected to take place over a long period of time, this effort estimated the responses to date.

The Model

As in much of the previous research reviewed, a part of this effort involved the use of hedonic price models to estimate the mean effect of distance to the nearest transit station on property sale prices and to estimate the change in prices per square foot since before the opening of the Boston Silver Line Phase 1. Using such a model allows for control of the other variables that affect property sale prices and thereby allows for the isolation of the effect of distance.

Sale price (price per square foot) was regressed on vectors of variables controlling for distance, property characteristics, locational amenities, and neighborhood characteristics. The conceptual hedonic model is:

$P = f(\mathbf{D}, \mathbf{H}, \mathbf{L}, \mathbf{N})$

where the dependent variable, P, is the price per square foot in dollars, which is a function of four vectors of independent variables. The four vectors are $\boldsymbol{D}$, a vector of variables that measures the distance of parcels to transit stations; $\boldsymbol{H}$, a vector of variables that describes housing characteristics; ***L***, a vector of variables that describes locational amenities; and ***N***, a vector of variables that describes neighborhood characteristics. Each of the variables included in these categories is discussed further below.

Economic theory does not indicate an appropriate functional form for the model. This being the case, a levels model was estimated to determine the mean effect on the price per square foot of a property being one additional foot closer to a BRT station. A levels model will measure the dependent variable, price per square foot in unit dollars, and the coefficients on the independent variables (representing slopes) will measure the change in price per square foot in dollars in response to a one-unit change in the given independent variable.

SECTION 5

Data

This section describes the data that were used in the study analysis, as well as the GIS processes that were applied to prepare the data for analysis. Also included in this section is a description of the variables included in the final models. Finally, it must be noted that this analysis focused exclusively on sale prices of condominium units along Boston's Washington Street corridor. Future research could include other types of residences as well as commercial properties.

The data consist of all condominium units within one-quarter mile of the Washington Street corridor. Condominium units were selected as the focus of this study because of the relatively large number of them that are located along the study corridor.

Sources

The City of Boston provided most of the data used in this effort. The City of Boston Assessing Department provided CD-ROMs of parcel data for the years 2003 through 2009. In addition, GIS files were provided for the properties located within one-quarter mile of the Washington Street corridor. Sales data were available in PDF format from the City's Assessing Department for the years 2000 through 2009. U.S. Census data were also used in this study.

Use of GIS

The analysis in this study required a variety of data resources. Various demographic and real estate statistics were collected for the purposes of this analysis. Geo-spatial analyses were conducted to add further value to the data. Additionally, transportation facilities including BRT route alignments were identified and coded into GIS software.

As stated above, the property parcel sales data were obtained from the City of Boston Assessing Department. The property parcel data included all the necessary descriptive variables, including living area size (in square feet), year built (and year remodeled), numbers of bedrooms and bathrooms, and an individual parcel identification number (PID) for each condominium unit, among others. A separate GIS-based database measured the distance from each parcel to the nearest station on the Silver Line. To link the specific sales data from the City of Boston with the property characteristics data, the GIS dataset required an additional variable, a unique identifier (the PID, or parcel ID) in order to link and precisely map each individual sale. This had to be done manually for sales in each year of the study, 2003 to 2009, and proved to be a time-consuming task. Sales that occurred in 2000, 2001, and 2002 were also matched manually, by address, to the correct PID in the 2003 database under the assumption that the major characteristics of concern (living area size, number of rooms, orientation, etc.) would not change in such a short time for condominium units.

Essentially, the task required manually searching both the sales database and the parcel (GIS) database for a matching building code (CM_ID) or address, for each individual sale over the entire seven-year period. Once a specific parcel—for example, 2 Akron St, Unit 5A—was successfully matched, the individualized PID number in the City of Boston sales data was cut and pasted into the corresponding 2 Akron St, Unit 5A in the GIS data. This enabled the GIS software to link individual sales to their precise geographic location and accurately measure exact distance from the nearest Silver Line station. Mapping these sales data also allowed closer examination of exactly where and when (what years) sales were occurring.

Data were also sorted by building code to further examine sales activity by condominium complex. Condo units in each building or complex were grouped according to the number of bedrooms, number of bathrooms, number of parking spaces assigned to the unit, and whether or not the unit was a corner unit. Sales of condos over the course of the study period, 2000 to 2009, were considered to be repeat sales.

Variables

Table 5-1 provides descriptive statistics for each variable included in the analysis. Information shown includes the variable minimum, maximum, mean, and standard deviation.

As described in the Methodology section, the dependent variable in this analysis was the sale price per square foot of a condominium unit. The use of actual sale transactions represents an improvement in the methodology from Phase I of this study. Such data were not available for use in Phase I but were found to be available for the City of Boston for the current Phase II. Summary information for both total sale price (PRICE) and sale price per square foot (PRICE_SQFT) is shown in Table 5-1. As shown in the table, the mean sale price per square foot in the 2000–2001 data was $402.63, and the mean sale price per square foot in the 2007/2009 data was $601.24

Table 5-1 *Descriptive Statistics*

Variable Name	Description	2000/2001 (n=437)				2007/2009 (n=895)			
		Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.
PRICE	Sale price of condo unit	$50,000	$1,275,000	$348,422	$160,870	$70,000	$4,750,000	$687197	$505,225
PRICE_SQFT	Sale price per sq. ft. of condo unit	$53.88	$1267.97	$402.63	$105.09	$103.75	$1463.34	$601.24	$183.68
DIST	Network distance (in ft) of parcel to nearest BRT station	191.02	1,818.47	960.94	462.86	122.12	2653.11	867.47	462.15
NBRPRKSP	Number of parking spaces assigned to condo unit	0	3	0.20	0.44	0	3	0.45	0.62
BEDRMS	Number of bedrooms	0	4	1.53	0.67	0	4	1.56	0.72
BATHRMS	Number of full bathrooms	1	3	1.16	0.39	1	5	1.39	0.61
HALFBATHS	Number of half-bathrooms	0	1	0.10	0.30	0	2	0.20	0.41
YRBUILT	Year structure was built; represents age of unit	1850	1996	1914	34.83	1820	2006	1944	51.78
MDHHINC	Median household income for Census tract within which parcel located	$12,165	$89,056	$41,740	$17,256	$12,165	$89,056	$35,716	$16,060
CONDOIND	Average value of Case-Shiller Condo Price Index in quarter sale was made	100.56	130.50	114.84	10.00	148.44	171.11	162.98	8.68

There is one key variable in the vector of distance variables (***D***). The network distance (DIST) between a parcel and the nearest Silver Line BRT station was included in this analysis. The network distance method also represents an improvement over the Phase I research, which used straight-line distances. The network distance corresponds to the actual path one would travel, or walk, along existing streets and pedestrian facilities and is the best measure of access to the BRT stations. Table 5-1 indicates that the average distance of a property in the data to the nearest Silver Line station was approximately 900 feet. A variable for the squared distance (DISTSQ) is included in the model to control for possible increasing or decreasing marginal effects of distance on the sales price per square foot.

The property characteristics (***H***) include several variables that describe the individual condo unit. Variables are included indicating the number of bedrooms (BEDRMS), bathrooms (BATHRMS), and half-bathrooms (HALFBATHS) in a condo unit. A variable for the year the property was built (YRBUILT) is used to further describe the condos. The living area of a condo unit, as measured by square feet, is controlled for in the dependent variable described previously, price per square foot (PRICE_SQFT).

The neighborhood characteristics (***N***) include variables that describe individual communities and thereby may affect sales prices. The median household income (MDHHINC) provides effective information on income differences across the neighborhoods served by the Silver Line. These differences may be reflected in condo sale prices. In addition, dummy variables were used to indicate the city wards associated with each property, as summarized in Table 5-2. To further control for housing price changes in the greater Boston area during the study period, the Case-Shiller Condo Price Index for greater Boston was used (CONDOIND).

Table 5-2

Condominium Sales by Boston City Ward

Area Name	2000/2001 Data		2007/2009 Data	
	Quarter-Mile Buffer			
	Frequency	Percent	Frequency	Percent
3rd Ward	198	45.3	423	47.3
4th Ward	40	9.2	27	3
5th Ward	17	3.9	91	10.2
8th Ward	61	14	183	20.4
9th Ward	121	27.7	171	19.1
TOTAL	437	100	895	100

The data described in this section were used to run a series of hedonic regression models to estimate the marginal effect of distance to the nearest BRT station on the sale price per square foot of nearby condominium units. In addition, changes in the sale price per square foot were analyzed before and after the opening of the Silver Line Washington Street corridor and compared to the local housing price index for the same time period. Finally, various land use changes along the Washington Street corridor were analyzed from the period 2003 to 2009. Key results from these efforts are described in the following section.

SECTION
6

Results

This section summarizes this Phase II research effort on the land use impacts of BRT using the Boston Silver Line Washington Street corridor as a case study. One part of these results involved the estimation of the marginal effect of distance to the nearest BRT station on the sale price per square foot of nearby condominium units. In addition, changes in the sale price per square foot were analyzed before and after the opening of the Silver Line Washington Street corridor and compared to the local condo price index for the same time period. Finally, various land use changes along the Washington Street corridor were analyzed from 2003 to 2009.

Before and After Analysis

In Phase I of this research, the marginal effect of distance of a property (single-family home) to the nearest Pittsburgh East Busway station on property value was estimated for one point in time. To gain a better understanding of the effect of access to BRT stations on property values, it was necessary to examine data from both before and after the implementation of a BRT system. In this Phase II research, a before and after analysis was possible due to the acquisition of real estate data spanning years before and after the implementation of the Boston Silver Line's Washington Street corridor. Data on sales transactions were available from the years 2000 to 2009. With the opening of the Silver Line's Washington Street service in 2002, these available data provided a comprehensive look at sales trends in the years before and after this service was implemented.

Comparison with Condo Price Index Changes

One key result involves the analysis of the change in sale price per square foot over the time period of this study. These results are summarized in Table 6-1. In the first quarter of 2000, nearly three years prior to the opening of the Silver Line Washington Street service, the average sale price per square foot of a condominium within one-quarter mile of the corridor was $344.59. In 2005, this value jumped to $590.55 per square foot and settled at $522.83 per square foot by the first quarter of 2009. The Case-Shiller Condo Price Index for the greater Boston area followed a similar trend, rising 73 percent, from 100.26 in the first quarter of 2000 to 173.74 in the first quarter of 2005. The Index then dropped more than 11 percent, to 154.40, in the first quarter of 2009.

It is interesting to compare the percent changes in the sale prices per square foot with the percent changes in the condo price index over the same time period. As Table 6-1 shows, condo sale prices per square foot along the Washington Street corridor increased slightly less, proportionately, than the overall index for the

Boston between 2000 and 2005. However, both the sale prices per square foot and the condo index fell proportionately after the start of the housing downturn, falling approximately 11 percent between 2005 and 2009. Overall, between 2000 and 2009, encompassing the time period before and after the implementation of the Silver Line Washington Street BRT service, sale prices per square foot of surrounding condominium units increased approximately 52 percent, while the condo price index for the greater Boston area increased 54 percent. That these changes are similar indicates that the condos along the Washington Street corridor fared, on average, not much worse or better than other condos in the greater Boston area over the time period of this study.

Table 6-1

Changes in Sale Price per Square Foot and Condo Price Index, 2000–2009

Variable	2000	2005	2009	% Change 2000–2005	% Change 2005–2009	% Change 2000–2009
Sale price per sq. ft.*	$344.59	$590.55	$522.83	71.4%	-11.5%	51.7%
Boston Condo Price Index**	100.26	173.74	154.40	73.3%	-11.1%	54.0%

*Represents the average sale price per square foot of condo units located within 0.25 mile of the Washington Street corridor in the first quarter of the year listed.

**Represents the Case-Shiller Condo Price Index for the greater Boston area in the first quarter of the year listed.

Regression Analysis

Tables 6-2 and 6-3 present the regression results from the hedonic models estimated before and after the implementation of the Silver Line Washington Street corridor. The first model (before) was estimated using data from 2000 and 2001, and the second model (after) was estimated using data from 2007 and 2009.

The key variable in this analysis is the network distance in feet from the unit (or its parcel) to the nearest Silver Line BRT station. For the dataset representing sales in 2000 and 2001, prior to the opening of the Silver Line, the relationship between the distance to the Washington Street corridor and sale price was positive and increasing as distance from a station increases. These results are statistically significant at the 5% level of significance. Specifically, the coefficients for DIST of 0.123 and for DIST_SQ of -6.32E-5, shown in Table 6-1, show this relationship by indicating the marginal impact on sale price per square foot from a one-foot increase in distance. These marginal effects can be summed to estimate the impact on sale price for a condo at any given distance from the corridor. For example, moving from 101 to 100 feet from the corridor decreased sale price per square foot by approximately $0.12 (=0.123-0.0000632[100]). Moving from 961 to 960 feet away (the mean distance in the 2000/2001 data) decreased sale price per square foot by approximately $0.06 (=0.123-0.0000632[960]). Moving from 1,321 to 1,320 feet away (one-quarter mile away) decreased sale price per square foot by approximately $0.04 (=0.123-0.0000632[1320]). Summing these marginal effects resulted in a premium of approximately $89 per square foot for a condo at the mean distance from the corridor compared to one on the corridor, all else constant.

The relationship described above, with sale price per square foot increasing as distance from the corridor increases, is the opposite of the relationship hypothesized with the presence of BRT. Looking at another dataset, beginning five years after the implementation of the Silver Line, a different relationship emerges. For the dataset that represents sales in 2007 and 2009, the relationship between the distance to the nearest Silver Line BRT station and the sale price per square foot is inverse and decreasing as distance from a station increases. Moving from 101 to 100 feet away from a BRT station increased sale price per square foot by approximately $0.06 (=-0.067+0.0000326[100]]). Moving from 871 to 870 feet away (the mean distance in the 2007/2009 dataset) increased sale price per square foot by approximately $0.04 (=-0.067+0.0000326[100]). Moving from 1,321 to 1,320 feet away increased sale price per square foot by approximately $0.02 (=-0.067+0.0000326[100]). As before, these marginal effects can be summed to estimate the impact on sale price for a condo at a given distance from the nearest BRT station. For these data, a condo at the mean distance to a BRT station had a sale price per square foot that is approximately $45.82 less than one that is adjacent to a station. The mean sale price per square foot in the 2007/2009 data was about $600, so the BRT premium was approximately 7.6 percent.

Both of these results from the before dataset and the after dataset confirm the hypothesis that there exists a sale price premium for walking access to a Silver Line BRT station. The coefficients on distance are statistically significant at the 5% level of significance using heteroskedastic-robust standard errors, as shown in Table 6-2.

Table 6-2

Regression Results, 2000/2001 and 2007/2009

Variable	Description	2000/2001 Data	2007/2009 Data
		Coefficient *Standard Error*	
Constant	Constant term in regression equation	-883.576* *336.081*	805.978* *32.2853*
DIST	Distance (in ft) of parcel to nearest BRT station	**0.123*** ***0.052***	**-0.067*** ***0.031***
DIST_SQ	Distance (in ft) of parcel to nearest BRT station squared	-6.32E-5* *2.48E-5*	1.63E-5 *1.36E-5*
BEDRMS	Number of bedrooms	9.644 *13.044*	22.364 *14.283*
LA_X_BED	Interaction term with number of bedrooms and sq. ft. of living area	-0.010** *0.006*	-0.010 *0.007*
BATHRMS	Number of full bathrooms	12.572 *10.807*	*(dropped)*
HALFBATHS	Number of half-bathrooms	-31.423** *17.110*	*(dropped)*
YRBUILT	Year structure was built; represents age of residence	0.412* *0.172*	*(dropped)*
MEDIANHHINC	Median household income for Census tract that includes parcel	0.001** *0.001*	*(dropped)*
NBRPRKSP	Number of available parking spaces	59.592* *12.904*	80.632* *9.524*
CONDOIND	Case-Shiller Condo Price Index for greater Boston (average for quarter a sale took place)	3.108* *0.462*	*(dropped)*
3rd Ward		47.404** *22.765*	-228.723* *25.212*
4th Ward		*(dropped)*	-158.026* *27.152*
5th Ward	Takes value of 1 if unit is located in listed area; 0 otherwise.	-44.246 *33.114*	*(dropped)*
8th Ward		-5.716 *27.205*	-323.001* *25.031*
9th Ward		5.527 *24.733*	-255.998* *25.699*

*Significant at the 5% level of significance with robust standard errors.

**Significant at the 10% level of significance with robust standard errors. Ward variables are jointly significant at the 5% level of significance with robust standard errors.

To further explore the strength of the model, the magnitudes of the other coefficients were observed and interpreted. For both models, the number of bedrooms and full bathrooms were not found to be statistically significant in the determination of sale price per square foot. In the 2000/2001 model, an additional half bath was found to decrease the sale price per square foot, and this was statistically significant.

Several dummy variables were used to control for the city ward in which a condo was located (the variables would take the value of 1 if a condo is located in a particular ward, and 0 otherwise). It was found that they were jointly significant at the 5% level of significance, indicating that, as a group, they were statistically-significant determinants of the sale price. Generally, these coefficients were interpreted in relation to a base category. For example, in the 2007/2009 data, a condo located in Boston's 4th Ward sold for, on average, $158 per square foot less than a condo in the 5th Ward, with all other variables held constant. As mentioned previously, the mean sale price per square foot in the 2007/2009 data was approximately $600.

In both models, the strongest predictor of sale price per square foot was the number of available parking spaces for a given condo unit. In the 2000/2001 model, an additional parking space increased the sale price per square foot by $59.59. In the 2007/2009 data, an additional parking space resulted in a sales premium of $80.63 per square foot. It seems condo buyers near Washington Street have a strong preference for having a place to park their vehicles, but also have some preference for being located within close walking distance to the Silver Line BRT.

In these models, the use of robust standard errors control for the presence of heteroskedasticity in the data, which is common in hedonic housing price models. Heteroskedasticity will be present if, for example, the variance of the unobserved factors affecting sale prices increases or decreases with one or more of the independent variables (Wooldridge 2003).

Another issue that can affect housing price models is spatial autocorrelation, which can bias the coefficients. Spatial autocorrelation is related to the idea that sale prices are also determined by the sale prices of other units located very nearby in addition to specific property characteristics and other broad geographic characteristics. To attempt to correct for this issue, residuals were examined spatially from the regression models (in this case a residual is the difference between the actual sale price per square foot of a unit and the price predicted by the regression equation). Condos with residuals having large, similar magnitudes and direction that were also located near each other were grouped into clusters. The clusters were entered as dummy variables in the regression models (the variables would take the value of 1 if a condo is located in a given cluster, and 0 otherwise). In the 2000/2001 model, the clusters were not jointly significant and were not included in the final model. For the 2007/2009 model, the clusters were jointly significant at the 5% level of significance, and the results are presented in Table 6-3.

Table 6-3

Regression Results (continued), 2000/2001 and 2007/2009

Variable	Description	Quarter-Mile Buffer 2000/2001 Data	Quarter-Mile Buffer 2007/2009 Data
		Coefficient	*Standard Error*
Cluster1_2007	Geographic clusters based on similar residuals from 2007 sales from initial regression. Takes value of 1 if unit is located in the cluster; 0 otherwise.	-	-101.907* *18.034*
Cluster2_2007		-	295.611* *33.421*
Cluster3_2007		-	387.944* *46.072*
Cluster4_2007		-	-156.209* *29.601*
Cluster5_2007		-	93.320* *19.169*
Cluster1_2009	Geographic clusters based on similar residuals from 2009 sales from initial regression. Takes value of 1 if unit is located in the cluster; 0 otherwise.	-	-59.533* *24.862*
Cluster2_2009		-	-99.921* *28.962*
Cluster3_2009		-	255.743* *37.194*
Cluster4_2009		-	134.832* *22.258*
Cluster5_2009		-	*(dropped)*
Cluster6_2009		-	-120.749* *19.699*
Cluster7_2009		-	58.588* *28.855*

*Significant at the 5% level of significance with robust standard errors. Cluster variables are jointly significant at the 5% level of significance with robust standard errors. Cluster variables for 2000/2001 data were not individually or jointly significant and were not included in the final 2000/20001 regression model.

Analysis of Land Use Changes

This section presents several maps and a discussion of land use changes that have occurred along the Washington Street corridor from 2003 to 2009. While data on sales transactions were available from 2000, GIS data were available beginning in 2003. As a result, this section describes land use changes that occurred since the opening of the Boston Silver Line Washington Street BRT service.

Figures 6-1 and 6-2 illustrate the parcels that were classified as Condominiums in 2003 and 2009, respectively, according to the Boston Assessing Department's Property Classification System. The parcels included in the maps are located within one-quarter mile of the Washington Street corridor. The Silver Line route alignment and stations are also shown on the maps. These two maps clearly show an increase in the number of parcels classified as condominiums over the seven-year period, particularly in the northern portion of the corridor. Such a change could be at least partially due to an increased interest in multi-family residential development along the corridor, with the benefit of access to the Silver Line BRT service.

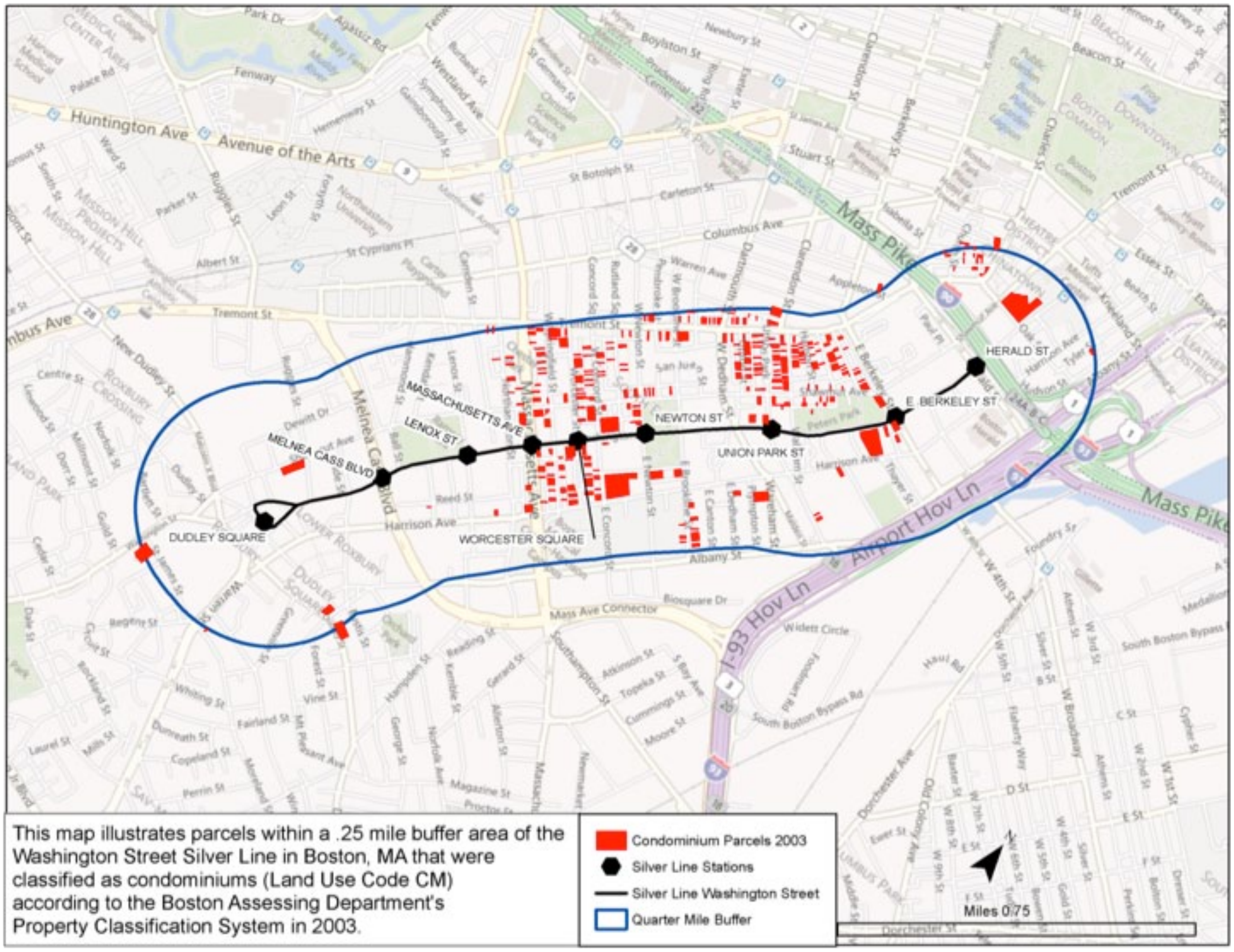


Figure 6-1 *Parcels classified as Condominium, 2003*

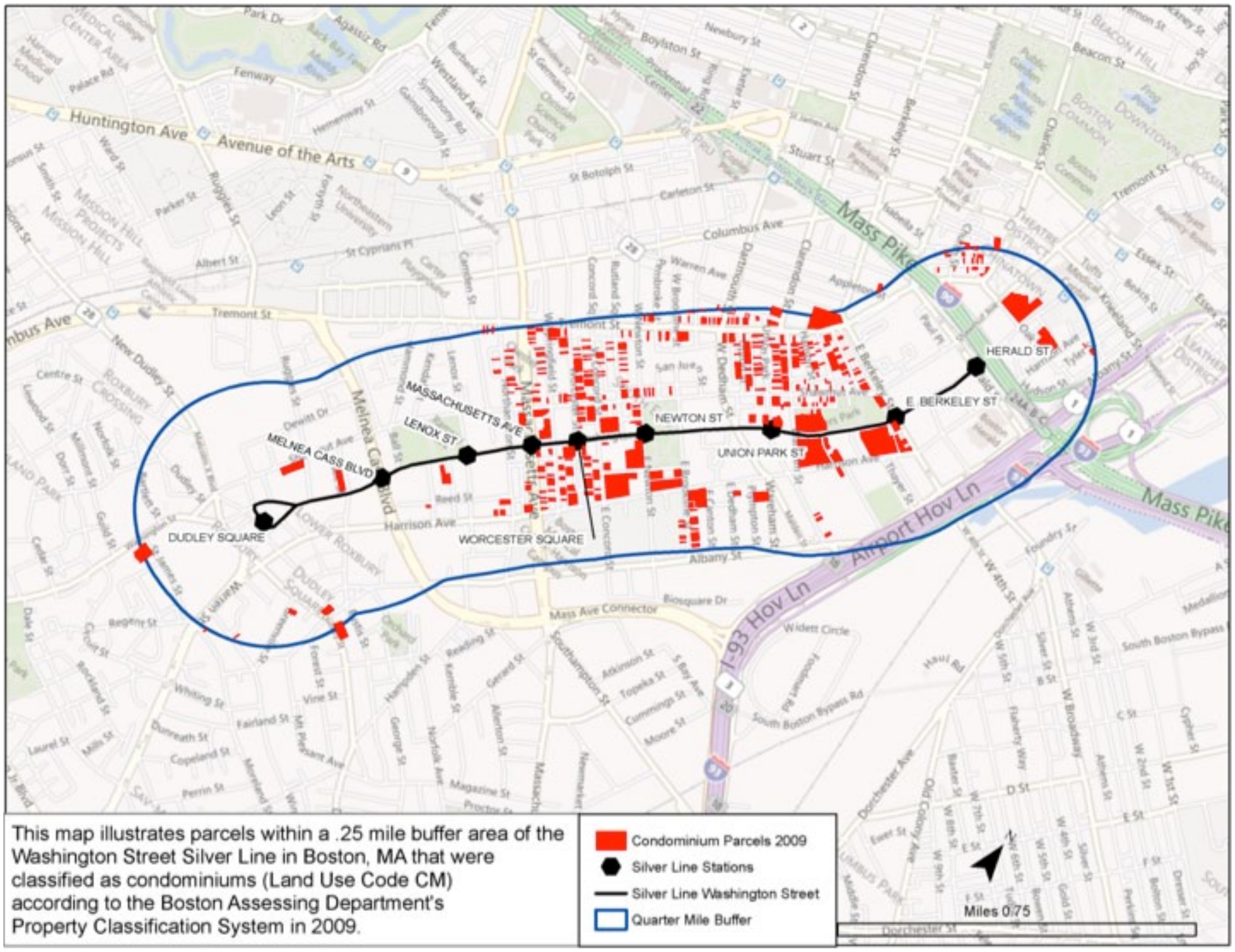


Figure 6-2 *Parcels classified as Condominium, 2009*

Figure 6-3 shows the parcels that changed classification to Condominium in each year from 2003 to 2009. It is likely that some of the changes in classification were due to the changes in the housing market in the early years of this time period, particularly 2003 to 2005. However, Figure 6-2 shows that these changes in classification continued throughout the time period to 2009.

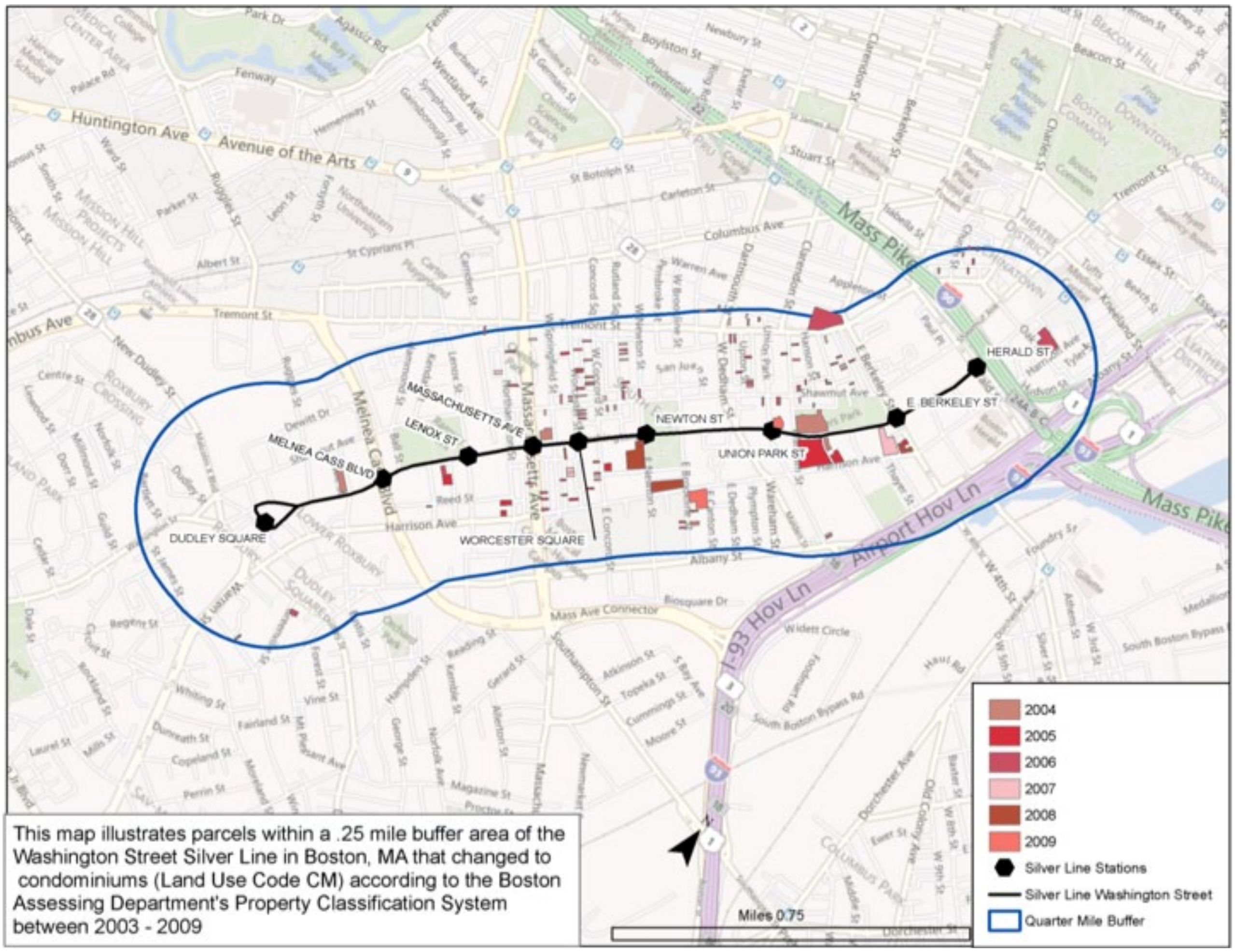


Figure 6-3 *Parcels that changed classification to Condominium, 2003–2009*

Parcels that changed classification to either office or commercial over the time period from 2003 to 2009 are shown in Figure 6-4. While there are mixed uses along the Washington Street corridor, the figure shows only a small number of parcels that changed to these classifications during the study period.

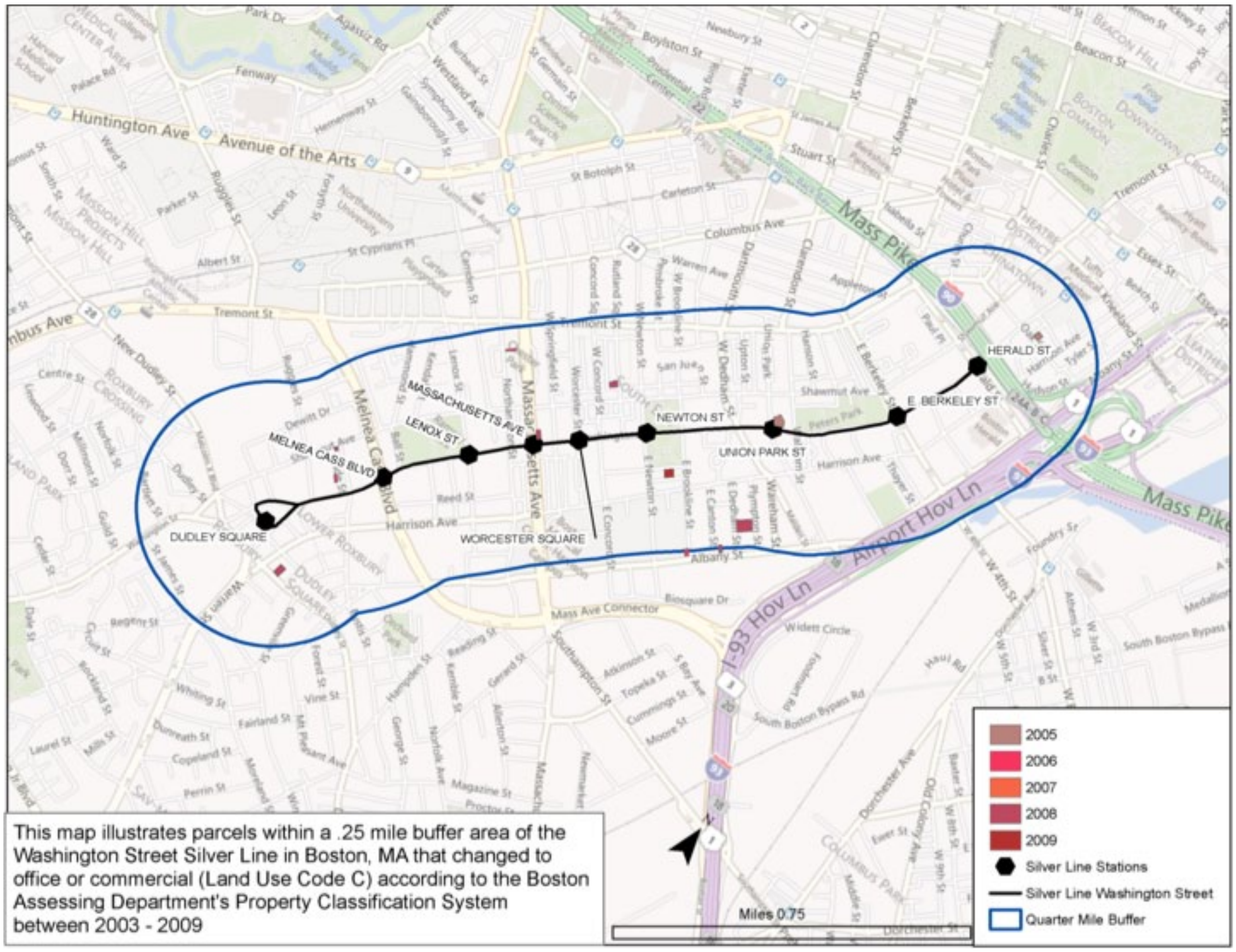


Figure 6-4 *Parcels that changed classification to Office or Commercial, 2003–2009*

Figure 6-5 illustrates, by color and year, the parcels located along the Washington Street corridor that changed property type classification from 2003 to 2009. The changes shown in the figure represent all classifications, not just Condominium. The information is based on data from the Boston Assessing Department's Property Classification System. The years 2005 to 2006 (shown in yellow) and the years 2008 to 2009 (shown in dark blue) appear to have the most changes of the time period shown. Both of these years are after the implementation of the Silver Line Washington Street BRT service.

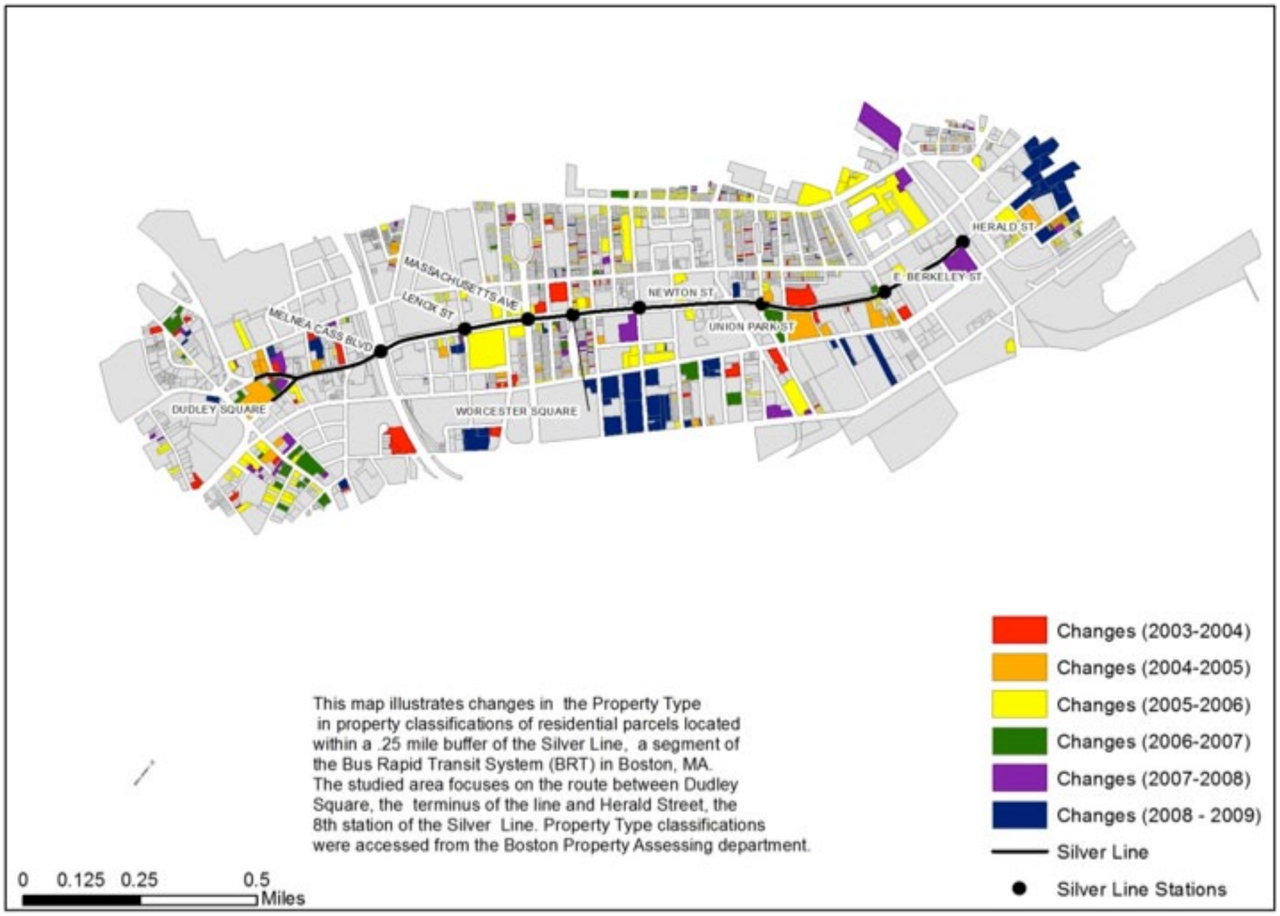


Figure 6-5 *Parcels that changed property type classification, 2003–2009*

SECTION

7

Conclusion

This report describes a continuing effort to quantify the impacts of BRT stations on surrounding property values and land uses. Phase I of this research estimated the marginal effects of proximity to the stations along the Pittsburgh Martin Luther King, Jr. East Busway on the values of surrounding single-family homes. Phase II incorporated a before and after analyses of sale prices per square foot of condominium units located along the Boston Silver Line's Washington Street, which had new BRT service in 2002. In addition, land use changes along the corridor were analyzed for the years 2003 to 2009. The hypothesis was that BRT stations have an impact on property value or sale prices that is commensurate with rail transit projects, considering the level and permanence of services and facilities. Analysis of the changes in sale price per square foot from before and after the implementation of the Silver Line Washington Street BRT service indicated an impact that is positive, yet relatively small in magnitude, as would be expected. Specifically, for condo sales that occurred in 2007 or 2009, a condo at the mean distance to a BRT station had a sale price per square foot that is approximately $45.82 less than one adjacent to a station, all else constant. The mean sale price per square foot in the 2007/2009 data was about $600, so the BRT premium was approximately 7.6 percent. In a similar model using condo sales from 2000 and 2001, prior to the opening of the Silver Line, a different relationship was found, wherein sale price per square foot increased with distance from the Washington Street corridor.

In addition, a separate analysis of land use changes along the Washington Street corridor revealed an increase in the number of parcels that converted to Condominium classification over the period from 2003 to 2009. It is clear that the City's efforts at redeveloping the Washington Street corridor have impacted land uses and sale prices in the area. Access to the Silver Line BRT service is likely one key aspect of the positive changes observed along the corridor.

This research worked to further refine the methodology from Phase I by examining actual sales data rather than assessed values, by analyzing repeat sales of similar condo units, and by using network distances to the nearest BRT station rather than straight-line distances. Future research should explore applications to other U.S. cities with BRT. It should be noted, however, that the results described in this report are valid only for the data used in the Boston case and represent only the second study of the impacts of BRT stations on surrounding properties in recent years in the United States. Results from quantitative modeling efforts can be used along with other types of studies as well as anecdotal evidence to develop overall assessments of BRT's impacts on land uses and property values.

As more BRT systems continue operating over time in the United States, the methodology used for this effort needs to be applied to other cities as well as to other types of properties (both residential and commercial). Future research should more deeply explore the question of what characteristics induce the premium found in these results. Do these characteristics relate to a specific mode or just to the availability of certain factors such as high-quality, rapid, and reliable transit, regardless of mode? Further applications will grow the body of literature and help policymakers and those in the transit industry gain a better understanding of the overall impacts of proximity to BRT stations on property values, land uses, and economic development.

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