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Value Capture to Fund Public Transportation: The Impact of Warm Springs BART Station on the Value of Neighboring Residential Properties in Fremont, CA

Shishir Mathur, Ph.D.

MINETA TRANSPORTATION INSTITUTE

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REPORT 19-11

VALUE CAPTURE TO FUND PUBLIC TRANSPORTATION: THE IMPACT OF WARM SPRINGS BART STATION ON THE VALUE OF NEIGHBORING RESIDENTIAL PROPERTIES IN FREMONT, CA

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16. Abstract

This study estimates households' willingness to pay for single-family houses and condominiums/townhouses located within 2 miles of Warm Springs (WS) BART Station in Fremont, CA. The study finds that, compared to the houses sold in the referent category (2 to 5 miles away and sold during the pre-project-announcement period of 2000-2001), an average-priced single-family house within two miles of the WS BART Station was higher in price by 9% to 15%. The total property value increment for the single-family houses is large enough to fund the $802 million Warm Springs BART Extension Project cost five times over.

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OVERVIEW

Public transit systems typically require significant operating and capital subsidies. For example, in the US, approximately half (48%) of these systems' operating expenditures and one-third (35%) of the capital expenditures are subsidized by local and state governments.[1] With both levels of governments already facing significant fiscal stress, any new revenue source that helps to reduce public transit's subsidy requirements is welcome. Value capture (VC) is one such tool.

What is VC? Simply put, it is the identification and capture of increases in land value that are driven by public transit infrastructure. Normatively, VC is based upon the "benefits received" principle—that those who benefit from a particular infrastructure or service should also pay for it. In the context of public transit, provision of or enhancements to public transit systems lead to accessibility-related benefits to the neighboring properties. These benefits are positively capitalized into higher land values. It is argued that since the neighboring properties benefit from public transit systems, their owners should also contribute toward funding these systems.[2]

The increased land value can be captured through various means, including increased property tax revenues, sale or joint development of public land in proximity to the transit system, lease or sale of air rights above the transit stations, levy of special assessments, imposition of public transportation impact fees, land value taxation, and capture of property tax increments through a Tax Increment Financing (TIF) district.[3] Irrespective of which VC mechanism is used, the first step is to demonstrate empirically that the public infrastructure has indeed increased neighboring property values. The recent Warm Springs BART Extension Project, the WSX Project, opened for service in March 2017[4] and provides just such a research opportunity. The WSX Project consists of 5.4 miles of railway tracks that run south from the Fremont BART Station to the Warm Springs (WS) BART Station. Both stations are located within the City of Fremont in Alameda County, CA.

STUDY OBJECTIVES AND OUTCOMES

The overall objective of this research is two-fold: first, to assist policy makers and practitioners in gauging the economic benefit accrued to the owners of neighboring properties in a suburban setting by a heavy-rail-based rapid transit system; and second, to estimate the proportion of the cost of a heavy-rail-based rapid transit project that can be typically funded using VC mechanisms. This research meets these objectives by a) empirically estimating the property value impacts of the WS BART Station (Fremont, CA) on single-family houses and condominiums/townhouses; b) estimating the total property value increase; and c) showing how much of the property value increase is adequate to fund the WSX Project. Indeed, the study finds that the entire WSX Project could have been funded if owners of single-family houses had shared around 18% of the property value increase, after accounting for the property value increase already captured by property taxes.

EMPIRICAL FRAMEWORK

This study uses the Tax Assessors' data for Alameda and Santa Clara Counties in order to estimate owner households' marginal willingness to pay for houses within 2 miles of the WS BART Station compared to the referent category (those located 2–5 miles away from the station and sold in the pre-project-announcement period of 2000-2001). Two sets of regression models were run—the first set to estimate the impact of the WS BART Station on the prices of single-family houses, and the second set to estimate the impact on the prices of condominiums/townhouses. The basic econometric approach is a fixed effect ordinary least squares (OLS) regression. The main estimation equation regresses the price of a house on its structural and locational attributes—including whether the house is located within 2 miles of the WS BART Station.

Further, to account for heteroscedasticity, or non-constant variance of the error term, the author estimated regression models with White's heteroscedasticity-consistent standard error estimator as well as with the robust standard error estimator. Additionally, the spatial nature of the data increases the likelihood of spatial dependence; i.e., spatial error and spatial lag dependence. Therefore, corrections were made for spatial dependence when necessary by estimating spatial lag and spatial error regression models.

FINDINGS AND POLICY IMPLICATIONS

The study finds that compared to the houses sold in the referent category (houses sold in the 2000–2001 period and located 2 to 5 miles from the WS BART Station), an average-priced single-family house within 2 miles of the WS BART Station was higher in price by 9% to 15% at various time periods during 2007–April 2018—a period that starts well before March 2017, when the station opened for commercial service. The total property value increment for the single-family houses within a 2-mile radius of WS BART Station is large enough to fund the entire $802 million WSX Project (in 2018 dollars) five times over.

The study findings support advocacy efforts for enhancing transit service in the San Francisco Bay Area. Nationally, the results should help build strong consensus that VC tools can be used to fund transit projects. The findings also address the concerns expressed by the NIMBYs ("Not in My Back Yard") regarding rail transit's negative impact on property values.

Furthermore, the estimation of the magnitude of BART-induced property value increase should help advocate for the use of VC tools to fund other BART extension projects. A few examples include the BART extension from Berryessa to downtown San Jose and onward to Santa Clara and from Dublin/Pleasanton Station to Livermore in the East Bay—after all, the entire WSX Project could have been financed with less than 20% share of the BART-induced property value increment for single-family houses. Therefore, the author urges transit agencies, elected officials, and policy makers to proactively pursue land value capture (LVC) tools to fund transit projects. Further, they should consider changing their approach to interacting with the community about transit provision—from an almost complete focus on alleviating property owner concerns about transit's negative property value impacts to engaging the community to share the property value increment to fund transit, while addressing community members' genuine concerns—for example, concerns around sound and station area vehicular traffic. Apart from providing much needed transit funds, such a local share would also help secure state and federal funds, which require local commitment and local funding.

I. INTRODUCTION

The federal government has reinforced the need to integrate land use and transportation planning, and to promote public transit, through legislation such as ISTEA (Intermodal Surface Transportation Efficiency Act), TEA-21 (Transportation Equity Act for the 21st Century), and more recently, SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users), MAP-21 (Moving Ahead for Progress in the 21st Century Act), and FAST (Fixing America's Surface Transportation Act). Other federal programs like the "Livable and Sustainable Communities Program" and the "New Starts Program" have provided additional impetus to the development of public transit. At the state and regional level, too, the last three decades have seen increased calls for public transit. However, public transit systems typically require significant operating and capital subsidies. For example, approximately half (48%) of these systems' operating and one-third (35%) of the capital expenditures are subsidized by the local and state governments.[5] With both these levels of governments under significant fiscal stress, any new revenue source that helps reduce public transit's subsidy requirements is welcome. Value capture (VC) is one such tool.

What is VC? Simply put, it is the identification and capture of public-infrastructure-led increase in land value. Normatively, VC is based upon the "benefits received" principle—those who benefit from a particular infrastructure/service should also pay for it. In the context of public transit, provision of or enhancements to public transit systems lead to accessibility-related benefits to the neighboring properties. These benefits get positively capitalized into higher land values. It is argued that since the neighboring properties benefit from public transit systems they should also contribute toward funding these systems.[6]

The increased land value can be captured through various means. These include, increased property tax revenues, sale or joint development of public land that is in proximity to the transit system, lease or sale of air rights above the transit stations, levy of special assessments, imposition of public transportation impact fees, land value taxation, and capture of property tax increments through a Tax Increment Financing (TIF) district.[7] Irrespective of which VC mechanism is used, the first step is to demonstrate empirically that the public infrastructure has indeed increased neighboring property values.

WHY THIS STUDY?

While extant literature has established the property value impacts of transit investments, and a couple of studies have empirically simulated the potential magnitude of VC revenues for financing transit facilities,[8, 9] most recent studies focus on light rail systems,[10,11,12,13,14,15,16] with very little recent research documenting the impact of heavy-rail-based rapid transit systems—such as the Bay Area Rapid Transit (BART)—on property values (the older studies include Nelson 1992; Gatzlaff and Smith 1993; Benjamin and Sirmans 1996; Lewis-Workman and Brod 1997; Cervero and Landis 1997; Cervero and Duncan 2002b).[17,18,19,20,21,22] Furthermore, these studies—new or old—either only focus on single-family houses or group together various housing types, such as single-family houses, condominiums and townhouses. Moreover, the last peer-reviewed research on BART's property value impacts was published 15 years ago, in 2002,[23] and the study used twodecade-old data. Several structural shifts since then—such as people's travel behavior and attitudes towards public transit, changes in the socio-economic and demographic characteristics of the San Francisco Bay Area residents, and worsening traffic congestion—call for new research into the BART's property value impacts. Fortunately, the recent WSX Project, which opened for service in March 2017, provides such a research opportunity.[24]

RESEARCH OBJECTIVES

The overall objective of this research is two-fold: first, to assist policy makers and practitioners in gauging the economic benefit accrued to the owners of neighboring properties in a suburban setting by a heavy-rail-based rapid transit system; and second, to estimate the proportion of the cost of a sub-urban heavy-rail-based rapid transit project that can be typically funded using VC mechanisms in regions with strong real estate market.

Outcomes of this Research:

Outcome 1: Empirical estimates of the WS BART Station's property value impacts on the following two property types—single-family houses and condominiums/townhouses.

Outcome 2: Estimates of the total property value increase.

Outcome 3: Analysis that indicating how much of the property value increase would have been adequate to fund the WSX Project.

II. LITERATURE REVIEW

Among the recent US-focused research published in peer-reviewed journals that examines rail transportation's impact on residential property values, a large proportion focuses on light rail or commuter rail systems. Only a handful of such studies focus on heavy-rail-based rapid transit systems, such as BART. Furthermore, with a few exceptions,[25] most scholarly examinations of heavy-rail-based rapid transit systems are dated.[26,27,28,29,30,31,32] Finally, many of these studies do not exclusively focus on heavy-rail-based rapid transit but rather investigate a mix of transit types (for example, heavy-rail-based rapid transit, commuter rail, and light rail), making it difficult to parse the property value effect of heavy-rail-based rapid transit, which is the focus of this research study.

A review follows of recent studies that estimate the impact of heavy-rail-based rapid transit, individually or along with other rail transit types, on residential property values. These studies and the older journal articles are summarized in Table 1, which also summarizes two research reports which either entirely focus on BART's property value impacts[33] or include BART among other transit systems.[34]

CAPITALIZATION EFFECTS OF HEAVY-RAIL-BASED RAPID TRANSIT

Bowes and Ihlanfeldt[35] use OLS estimators under the hedonic price modeling (HPM) approach to estimate the impact of 31 Metropolitan Atlanta Rapid Transit Authority (MARTA) stations (heavy rail, light rail, and bus stations) in the Atlanta, GA metropolitan area on prices of single-family houses sold during the period 1991–1994. Using parcel-level data, the study compares houses at distances from the station of 0 to $^1/_4$ mile, $^1/_4$ to $^1/_2$ mile, $^1/_2$ to 1 mile, 1 to 2 miles, and 2 to 3 miles to the control distance band (houses located more than three miles away from a station). They find that the impact varies by station location, neighborhood characteristics, and distance to the central business district (CBD). The largest impact was found in the $^1/_2$- to 1-mile distance band in the high-income neighborhoods that are 12 miles away from the CBD. The paper also finds a negative property value impact for houses within $^1/_4$ mile of a station, and the authors argue that the negative impact could be due to the disamenity effects, such as noise and traffic congestion, that come with close proximity to a station.

Using data at the census-tract level from fourteen cities from 1970 to 2000, Kahn[36] estimates the impact of a mix of rail systems (e.g., light rail in Portland and commuter rail in Washington, DC) on a census tract's average house price. The study finds a wide range of price effects depending on the city and the station type ("Walk and Ride" and "Park and Ride" stations). For example, in Boston, compared to census tracts with no stations, the average house price is 5% lower in census tracts with "Walk and Ride" stations, while it is 7% higher in census tracts with "Park and Ride" stations. However, "Park and Ride" stations were found to decrease house prices in Portland and San Francisco. Overall, house prices are 3% higher in census tracts with "Walk and Ride" stations in tracts with median income below the metro-area median. Kahn's study is ambitious in scope: it covers a large number of cities and a four-decade period. However, it pools various transit types (such as light rail, commuter rail, and heavy-rail-based rapid transit), thereby failing to tease out their individual property value impacts. Furthermore, since the study examines house price at the census-tract level, it pools together various property types (e.g., single-family houses, condominiums, and townhouses).

Another study[37] that used five cities that made rail transit improvements in the 1980s—Boston, Atlanta, Chicago, Portland, and Washington, DC—finds that access to transit is positively capitalized in rents and house values. Specifically, a 2-km decrease (from 3 km to 1 km) in the distance of a house to a train station increases rents by an average of $19/sq.ft. and house values by an average of $4,972. This study, too, pools cities with different transit types (light rail, commuter rail, and heavy-rail-based rapid transit). Therefore, it is not possible to discern transit-type-specific capitalization effects. Furthermore, the study suffers from aggregation bias due to its census-tract-level data: the dependent variables are each census tract's median rent and home value. Finally, the study does not parse the capitalization effects by property type. Like Kahn,[38] it groups together all owner-occupied property types (single-family houses, condominiums, and townhouses).

A recent study of Los Angeles Metro light- and heavy-rail-based rapid transit stations conducted by Zhong and Li[39] parses the effect of light and heavy rail stations on multi-family and single-family houses by using dummy distance variables for each type of station (light rail stations, light rail park-and-ride stations, and heavy-rail-based rapid-transit stations). The study uses a hedonic price modeling (HPM) approach and finds that for the mature heavy-rail rapid-transit stations, compared to single-family houses located more than 1600m (1 mile) away from a station, prices are higher by 22% and 16%, respectively, for houses located 0 to 400m (0 to $^1/_4$ mile) and 400m to 800m ($^1/_4$ to $^1/_2$ mile) away from a train station.

However, the impact of mature light rail stations is found to be the opposite—the single-family house prices are lower by 10% for houses located in the 400m–800m distance band and are statistically equivalent for the 0–400m and 800m–1600m distance bands. Zhong and Li[40] use a distance band of 1–3 miles as the control group, citing the finding of Debrezion et al.[41] that the property value impacts are likely to dissipate after 2 miles. Overall, Zhong and Li[42] find that close proximity to light rail stations (0–400m band) tends to increase the value of multi-family properties and decrease those of single-family properties. Wagner, Komarek and Martin[43] also find negative property value impacts on single-family houses in their study of the light rail system in Hampton Roads, Virginia. However, this finding contradicts several studies which find that proximity to light rail stations tends to increase the value of single-family houses or to have no impact. For example, Billings[44] finds that light rail system in Charlotte, NC increased single-family house prices by 4% in the neighborhoods around the stations. Bardaka, Delgado and Florax[45] find a similar effect for Denver's light rail system, as did Kim and Lahr[46] for urban commuting stations along the Hudson-Bergen Light Rail (HBLR) corridor. However, focusing on a single, southern section of HBLR, Camins-Esakov and Vandergift[47] find no property value impact attributable to the station.

Limitations of Zhong and Li's study[48] include the use of cross-sectional data (2003–2004 period). Furthermore, the use of dummy variables to tease out the effect of each type of station simplistically assumes that the overall structure of the housing market is similar for areas around various transit lines spread across the Los Angeles metropolitan area.

On a positive note, the study uses sophisticated econometric methods—Spatial Durbin Model (SDM) and Geographically Weighted Regression (GWR)—to address spatial dependence and spatial heterogeneity, respectively. Spatial dependence refers to the phenomenon wherein observations in close spatial proximity impact each other. For example, the value of a house might impact the value of neighboring houses. Spatial heterogeneity refers to the uneven distribution of a relationship, often between the dependent and the independent variables, across the study area. For example, the quality of public schools might impact house prices differently across a region. Indeed, the GWR model estimated by Zhong and Li shows that the coefficient values for the distance dummy variables vary across the region, reinforcing the need to address spatial heterogeneity.

Some recent studies also address spatial heterogeneity as well as spatial dependence. Few of these studies are based in the US, however. For example, Mulley, Ma, Clifton, Yen and Burke[49] examine the property value effects of bus rapid transit system (BRTS) and the heavy rail system in Brisbane, Australia; Du and Mulley[50] and Ibeas, Cordera, dell'Olio, Copolla, and Dominguez[51] estimate overall transportation accessibility's property value impacts for study areas in the UK and Spain, respectively; Mulley[52] studies buses' accessibility impacts in Sydney, Australia; Dziauddin, Powe and Alvanides[53] examine the light rail system in Kuala Lumpur, Malaysia; and Haider and Miller[54] study the transportation infrastructure of Toronto, Canada.

There are very few such US-based studies. Moreover, they do not focus on heavy-rail-based rapid transit systems. In fact, the author's literature research found two such studies that both focus on commuter rail systems—Yu, Pang and Zhang[55] study Austin MetroRail, and Kay, Noland and DiPetrillo[56] study New Jersey Transit.

Finally, one study—by McMillen and McDonald[57]—focuses solely on the property value impacts of a heavy-rail-based rapid-transit system—the Orange Line of Chicago's rapid transit system, called "L". The line alignment was announced in 1984 and construction was completed in 1993. McMillen and McDonald's study uses sales and property characteristics data for a 16-year period, 1983–1999, to estimate the house price impacts of the train stations on the Orange Line. The study divides the 16-year period into four sub-periods: 1983–1986, 1987–1990, 1991–1996, and 1997–1999. Running a hedonic price regression model and a repeat sales regression model that include an interaction variable of the distance to the station and the dummy variable for each time sub-period, the study finds that, overall, the stations positively impact house prices throughout the study period, with significant price increase identifiable as early as the 1987–1990 sub-period. The study attributes this increase to anticipation of the rail line. The prices rose the most in the 1991–1996 period and stabilized after that. Furthermore, the study finds that stations with on-site parking impact house prices the most. From a research design perspective, the study is commendable for spanning pre- and post-construction periods. However, it does not address spatial dependence.

LITERATURE SYNTHESIS AND TAKEAWAYS

A synthesis of the literature reviewed above and summarized in Table 1 provides several takeaways:

- Need to parse the effect of heavy-rail-based transit on property values. Very few studies investigate the property value impacts by transit type. Most group together all transit types. This research design is problematic, because the impact of a light rail station can be different from that of a heavy-rail-based rapid transit station.

- Transit's capitalization effects might differ by real estate market conditions. Many studies pool data from various regions to enhance their findings' generalizability. Such data pooling simplistically assumes a similar real estate market structure for all regions.

- Need to parse the effect of transit on each property type. Several studies either do not tease out the effect of transit on each property type or do it inadequately. For example, some studies estimate transit's impact on average home value. This mean value can represent a mix of single-family houses, condominiums, and townhouses. Since transit's capitalization effects can vary by property type, studies could run one regression model per property type.

- Paucity of studies estimating heavy-rail-based rapid transit's impact on non-single-family residences. Among the studies estimating transit's impact on residential property values, a majority focus on single-family houses. Only a few focus on multi-family housing, while a still smaller number focus on condominiums.

- Need for a robust research design. A very large proportion of studies are cross-sectional in nature, often including property sales data for a single year. On the other hand, studies using multi-year data often do not include data from both the pre- and the post-transit-construction periods.

- Need for econometric sophistication. A large number of studies use simple OLS estimation under the HPM framework without any tests or corrections for OLS violations such as heteroscedasticity and multicollinearity. A few suffer from omitted variable (OV) bias because they do not adequately control for locational and neighborhood characteristics that might impact property values. Only one study addresses spatial dependence.

- Properties further away could be used as the control group. It is common to use properties further away from the train stations as the control group. However, a large proportion of studies reviewed for this research do not employ such control groups.

- Proximity to a rail line, to highways, and in some cases, to the station, can be a nuisance. Brandt and Maennig[58] note that a large proportion of studies on the impact of train stations on property prices find a positive price effect, and they note that the zero or negative price impacts found in some studies likely arise due to the failure to control for undesirable factors that are correlated with the proximity to train stations. Examples of such factors include crime, railway lines, major streets, busy intersections, and undesirable land uses close to the station, such as warehouses and industries. Therefore, while estimating the impact of a railway station, it is important to control for such undesirable factors. Much extant literature uses a distance dummy variable (for example, dummy for properties within $^{1}/_{8}$ or $^{1}/_{4}$ mile from a rail line, a highway, and/or a station) and includes variables that measure the distance of properties from uses such as commercial and industrial.

Table 1. Studies Examining Impact of Heavy-Rail-Based Rapid Transit Systems on Residential Property Values

Study	Study Area	Study Period	Pre- and Post-Construction Period Included?	Level of Spatial Aggregation for the Dependent Variable	Effect of Heavy-Rail-Based Rapid Transit Teased Out?	Property Type(s)	Effect on Each Property Type Teased Out?	Positive Property Value Impacts of Heavy-Rail-Based Rapid Transit?	Addresses Spatial Dependency and/ or Heterogeneity
Peer-reviewed journal articles									
Damm, Lerman, Lerner-Lam and Young, 1980	Washington Metropolitan Area: Washington Metro	1969 to 1976	No	Property Parcel	Not applicable. Only one transit type studied.	Single- family houses, multi-family buildings and retail	Yes	Yes, for all property types.	No
Nelson, 1992	DeKalb County, GA: MARTA	1986	No. Only one-year data	Property Parcel	Not applicable. Only one transit type studied.	Single-family houses	Not applicable. Only one property type included.	Varies. Positive impact in the lower income, southern section and negative impact in the higher income, northern section.	No
Gatzlaff and Smith, 1993	Miami Metropolitan Area, FL: Miami Metrorail	1971 to 1990	Yes	Property Parcel	Not applicable. Only one transit type studied.	Single-family houses	Not applicable. Only one property type included.	Varies by station.	No
McDonald and Osuji (1995)	Chicago, IL: Orange Line	1980 and 1990 data	No. The construction completed in 1993.	Census Block	Not applicable. Only one transit type studied.	Residential land	Not applicable. Only one property type included.	Yes	No
Baum-Snow and Kahn, 2000	Boston, Atlanta, Chicago, Portland, and Washington, DC	1980 and 1990 Census data	Yes. The transit improvements were made in the 1980s.	Census Tract	No.	Owner-occupied and rental properties.	Separate models for rental and owner-occupied properties, but property types not teased out (e.g., single-family, condominiums townhouses, etc.)	Yes, for both rental and owner-occupied properties.	No

Study	Study Area	Study Period	Pre- and Post-Construction Period Included?	Level of Spatial Aggregation for the Dependent Variable	Effect of Heavy-Rail-Based Rapid Transit Teased Out?	Property Type(s)	Effect on Each Property Type Teased Out?	Positive Property Value Impacts of Heavy-Rail-Based Rapid Transit?	Addresses Spatial Dependency and/ or Heterogeneity
McMillen and McDonald (2004)	Chicago, IL: Orange Line	1983 to 1999	Yes	Property Parcel	Not applicable. Only one transit type studied.	Single-family houses	Not applicable. Only one property type included.	Yes	No
Kahn, 2007	14 cities	1970, 1980, 1990 and 2000 Census data	Yes	Census Tract	No.	Owner-occupied properties	No.	Varies by city and station location.	No
Zhong and Lei, 2016	Los Angeles metropolitan area, CA: Los Angeles Metro	2003-2004	No	Property Parcel	Yes.	Multi-family properties and single-family houses	Yes	Yes	Yes
Research reports									
Lands, Guhathakurta and Zhang, 1994	Several counties and cities in California. Alameda and Contra Costa Counties for BART	2nd quarter of 1990	No	Property Parcel	Yes. Separate models.	Single-family houses	Not applicable. Only one property type included.	Yes	No
Fogarty and Nemirow, 2014	Alameda, Contra Costa and San Mateo Counties, CA: BART	2002 to 2012	No	Property Parcel	Not applicable. Only one transit type studied.	Condominiums and single-family houses	Yes.	Yes	No

III. WARM SPRINGS BART STATION CASE STUDY

BART BACKGROUND INFORMATION

Overview

Bay Area Rapid Transit (BART) is a heavy-rail-based rapid transit system that serves the San Francisco Bay Area in California. The construction for BART began on June 19th, 1964, with a groundbreaking ceremony for the Diablo Test Track, which consisted of a 4.4-mile track located between Concord and Walnut Creek (see Figure 1).[59] In the following years, the development of BART continued. The first transit line began operating on September 11th, 1972, between the cities of Fremont and Oakland—a 28-mile stretch connecting the Fremont and MacArthur stations.[60]

Mileage

BART currently includes 112 miles of rail tracks, of which 32 miles are elevated, 52 miles are at grade, and approximately 28 miles are below ground (subway), including the 6-mile long trans-bay tube which goes under the San Francisco Bay, connecting BART from San Francisco to Oakland.[61]

Stations

There are currently 46 stations within BART, of which 17 are at surface, 14 are elevated, and 15 are below ground (subway). Four stations—Embarcadero, Montgomery, Powell, and the Civic Center, all located in downtown San Francisco—serve both BART and MUNI.[62] MUNI Metro is a light rail system that serves the San Francisco area and is operated by the San Francisco Municipal Railway. Similarly, BART's Millbrae station serves BART and Caltrain (a commuter rail line connecting San Francisco in the north to Gilroy in the south).[63]

Line Information

BART has a total of five rapid transit lines and one automated guideway transit (AGT) line (see Table 2). Each rapid transit line corresponds to a specific color (orange, yellow, green, red, and blue). More information on each of the six lines is provided in Table 2; a BART system map is presented in Figure 1.[64]

Table 2. BART Line Information

Line	Date of First Operation	Number of Stations	Track Type	Line Length (miles)	Comments
Orange Line: Richmond–Warm Springs/South Fremont line	September 11, 1972 (First BART line to open. Originally serviced from MacArthur to Fremont.)	19	At grade, elevated, underground. The only line that does not travel through the Transbay Tube. Line passes under Lake Elizabeth in Fremont.[65]	41	Two additional lines under construction. Line will be extended to Berryessa station in San Jose during Fall of 2018. Line will also be extended to the Santa Clara station.
Yellow Line: The Pittsburg/ Bay Point–SFO/ Millbrae line	May 21, 1973	26	At grade, elevated, underground, and underwater (Transbay Tube).	55.2	
Green Line: Warm Springs/South Fremont–Daly City	November 16, 1974	19 (2 additional lines under construction)	At grade, elevated, underground, underwater (Transbay Tube)	TBD	
Red Line: Richmond–Daly City/Millbrae line	April 19, 1976 (limited service) July 7, 1980 (all-day service)	24	At grade, elevated, underground, underwater (Transbay Tube)	36.5	
Blue Line: Dublin/ Pleasanton–Daly City line	May 10, 1997	18	At grade, elevated, underground, and underwater (Transbay Tube).	35.7	
AGT Line: BART to Oakland International Airport	November 22, 2014	2	Mostly elevated, with at-grade and underground sections	3.2	

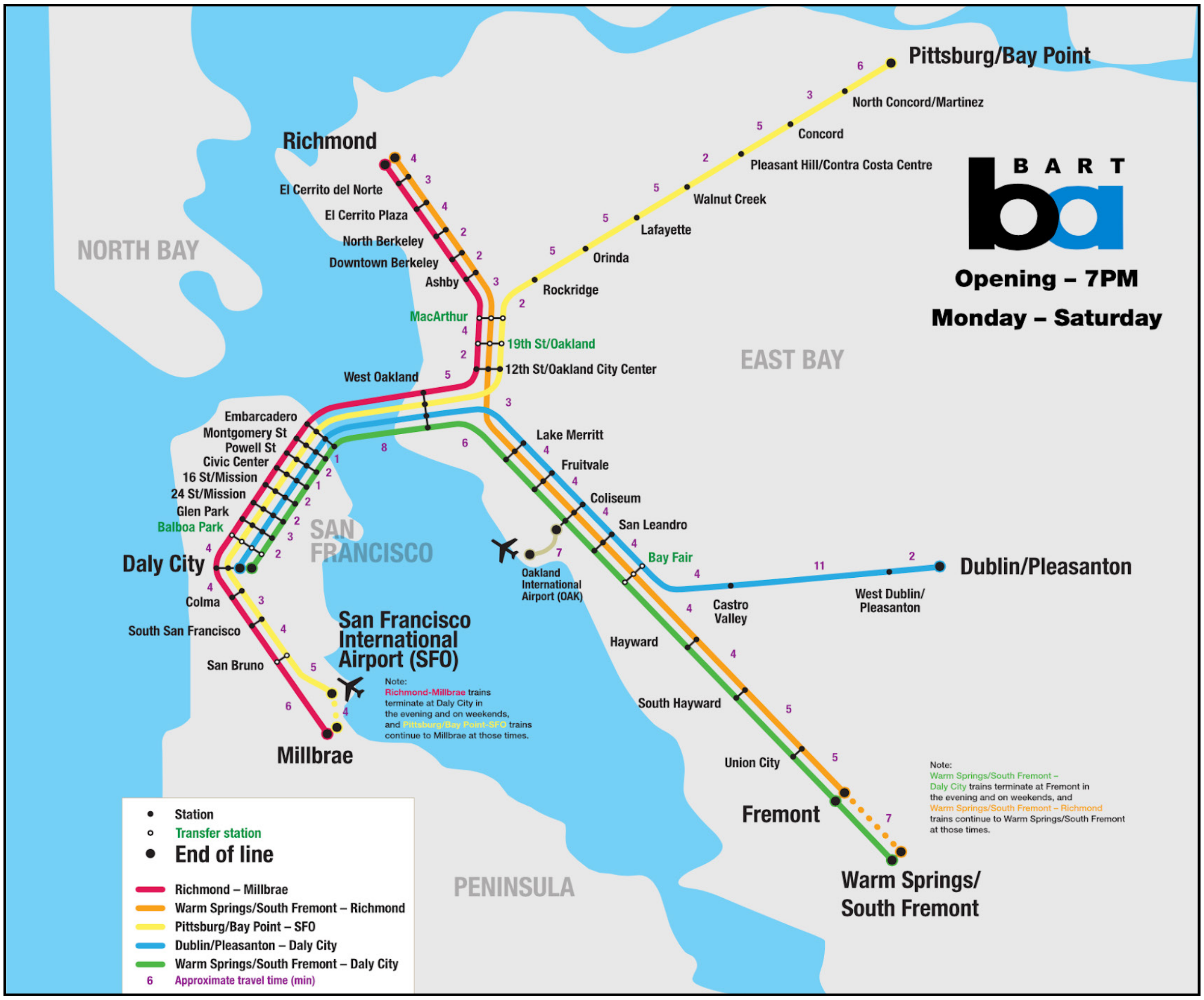

Figure 1. Map of BART Operating Lines and Stations[66]

There are nine segments within the BART system. Each segment has a letter name and specific start- and end-points. Table 3 notes each segment, the endpoints, the operating date, and the segment's right-of-way. The table also lists where the elevated and underground sections of BART rails are located by segment.

Table 3. BART Line Segments[67]

Segment	Endpoints	Opening Date	Right of Way
A-Line	Oakland Wye to Fremont	September 11, 1972	Former Western Pacific Railroad right-of-way (UP Oakland Subdivision), tunnel near the Oakland Wye
C-Line	Rockridge to Pittsburg/ Bay Point	May 21, 1973 (to Concord) December 16, 1995 (to North Concord/Martinez) December 7, 1996 (to Pittsburg/Bay Point)	SR 24 median, Berkeley Hills Tunnel, former Sacramento Northern Railroad right-of-way
K-Line	Oakland Wye to Rockridge	September 11, 1972 (to MacArthur) May 21, 1973 (to Rockridge)	Tunnel under Broadway, SR 24 median
L-Line	Bay Fair to Dublin/ Pleasanton	May 10, 1997	Median of I-238, median of I-580
M-Line	Oakland Wye to Daly City Yard	September 11, 1972	Elevated above 5th Street and 7th Street, Transbay Tube, tunnel under Market Street and Mission Street, former Southern Pacific Railroad right-of-way (SF&SJ)
R-Line	MacArthur to Richmond	January 29, 1973	Elevated above Martin Luther King Jr. Way, tunnel under Adeline Street and Shattuck Avenue, former Atchison, Topeka and Santa Fe Railway right-of-way
S-Line	Fremont to Berryessa/ North San Jose	March 25, 2017 (to Warm Springs) 2018 (to Berryessa/ North San Jose)	Tunnel under Fremont Central Park, former Union Pacific right-of-way
W-Line	Daly City Yard to Millbrae	February 24, 1996 (to Colma) June 22, 2003 (to Millbrae)	Former Southern Pacific Railroad right-of-way (SF&SJ), shared Caltrain right-of-way
Y-Line	W-Line to San Francisco International Airport	June 22, 2003	Elevated wye into San Francisco International Airport

WARM SPRINGS BART STATION

Service Opening

The Warm Springs (WS) BART Station falls on the Green Line and opened for commercial service in March 2017.[68] The station is part of BART's Warm Springs Extension (WSX) Project and is the first phase of the Silicon Valley extension project.[69]

Location and Length of Project Extension

The WS BART Station is located within the City of Fremont in Alameda County, CA. The station encompasses 34 acres and includes an at-grade island platform, an overhead concourse, and 2,082 parking spaces on expansive surface parking lots that surround the station on two sides. The station has intermodal access to Santa Clara Valley Transport Authority (VTA) and the Alameda-Contra Costa Transit buses. Apart from the station, the WSX Project also consists of 5.4 miles of railway tracks that run from the Fremont BART Station to the WS BART Station.[70]

Frequency of Trains and Period of Service

During the peak hours (weekdays before 6:00 pm), the Warm Springs/South Fremont–Daly City line[71] serves this station with four trains per hour. During off-peak hours (weekdays after 6:00 pm and on weekends), the Richmond-Warm Springs/South Fremont line serves the stations with three trains per hour.[72]

Daily Ridership

To determine whether and how the opening of the WS BART Station affected BART ridership, the monthly ridership data for the Fremont Station and the WS BART Station are presented here in two tables. Table 4 compares the number of riders using the Fremont and the WS BART stations as entry and exit stations. For the sake of consistency, ridership data for the month of October are reported for each year from 2001 to 2017. Table 5 compares the same type of data (entry and exit numbers). However, Table 5 uses data from April 2017 to February 2018.

Table 4. WS BART Station Ridership Data for the Month of October for the Period 2001–2017[73]

Station	Date	Entry from Station	Exit from Station
Fremont	October 2001	5,662	5,833
Fremont	October 2002	5,796	5,823
Fremont	October 2003	6,089	6,074
Fremont	October 2004	6,199	6,131
Fremont	October 2005	6,581	6,639
Fremont	October 2006	6,926	6,925
Fremont	October 2007	7,142	7,119
Fremont	October 2008	7,434	7,508
Fremont	October 2009	6,930	7,029
Fremont	October 2010	7,264	7,392
Fremont	October 2011	7,799	7,866
Fremont	October 2012	8,740	8,735
Fremont	October 2013	7,525	7,548
Fremont	October 2014	9,186	9,190
Fremont	October 2015	9,589	9,591
Fremont	October 2016	9,676	9,633
Fremont	October 2017	7,236	7,230
Warm Springs	October 2017	3,254	3,211

Examination of Table 4 and Table 5 reveals three key findings. First, through the years 2001 to 2016, there was a steady increase in ridership at the Fremont station. Second, a decrease in ridership at the Fremont station can be observed after the WS BART Station opened: note the ridership decrease from 9,676 to 7,236 from October 2016 to October 2017 in Table 4. Meanwhile, the WS BART Station gained riders (see Table 5). Third, the total ridership at the WS BART Station (approximately 3,000) is more than the ridership loss at the Fremont station (approximately 2,000). The second and the third findings combined indicate that while a large proportion of the WS BART Station users probably shifted from the Fremont station, the WS BART Station has also attracted new riders. For the riders who switched stations, perhaps the WS BART Station is more convenient than the Fremont station. Furthermore, many people who did not initially ride on BART, possibly because the Fremont station was far from their origin or destination, now ride BART using the WS BART Station. In both cases, the WS BART Station has enhanced utility of transit for residents, which is expected to be capitalized into property values. Since the entry and exit data are very similar and show the same shift (from the Fremont Station to the WS BART Station) and increase (for the WS BART Station), the author hypothesizes that the WS BART Station largely serves commuters who live around the station. Therefore, the WS BART Station should increase neighboring residential property values.

Table 5. Ridership Data for April 2017–February 2018[74]

	Fremont Station		Warm Springs Station	
Date	**Entry from Station**	**Exit from Station**	**Entry from Station**	**Exit from Station**
April 2017	7,412	7,409	2,490	2,513
May 2017	7,390	7,253	2,760	2,719
June 2017	7,398	7,282	3,099	3,035
July 2017	7,249	7,202	3,105	3,050
August 2017	7,106	7,013	3,101	3,040
September 2017	7,174	7,149	3,081	3,087
October 2017	7,236	7,230	3,254	3,211
November 2017	7,023	7,026	3,221	3,200
December 2017	6,219	6,180	2,915	2,835
January 2018	6,495	6,513	3,135	3,042
February 2018	6,811	6,806	3,217	3,156

TIMELINE FOR THE WSX PROJECT AND THE WS BART STATION

1991–2001: Preliminary Interest

In 1991, the WSX Project was initially proposed to relieve traffic congestion on highway I-880. I-880 is a major freeway in the region running north-south, connecting San Jose in the Santa Clara County in the south to Oakland in the Alameda County in the north. An Environmental Impact Report (EIR) was prepared for the WSX Project that year.[75]

In 1992, the BART'S Board of Directors certified the EIR. However, in spite of strong public interest, construction could not begin because funds were unavailable. The project gained momentum in 1994 when the region's metropolitan transportation organization (MPO)—the Metropolitan Transportation Commission (MTC)—prepared the Fremont-South Bay Corridor Report.[76] This report, among others, analyzed several alignment options for the WSX Project.

In 2000, the next important milestone was reached: BART and the Santa Clara VTA collaborated on the BART Extension Study from Fremont to Milpitas, San Jose, and Santa Clara, examining BART alignment along the Union Pacific railroad right-of-way. The same year, Alameda County voters reauthorized Alameda County's Measure B, which provided funding for a variety of transportation-related projects, including a BART extension from the Fremont Station to Warm Springs.[77]

2002–2012: Project Announcement; Environmental Review; Other Related Projects

In 2002, the VTA purchased the former Western Pacific (WP) Milpitas Line from UP.[78] The same year, the Warm Springs BART extension became general knowledge.[79]

In 2003, the state environmental review process concluded for this project as required by the California Environmental Quality Act (CEQA),[80] and in 2004, BART approved the Warm Springs Extension as a state- and locally-funded project.[81] 2003 was also the year it became eligible for federal funding. Therefore, during the period 2005–2006, the draft and final Supplemental Environmental Impact Reports were prepared, approved, and released.

During the period 2005–2009, Caltrans undertook the I-880 Project to enhance regional-level transportation mobility that would also enhance access to Warm Springs BART station. The projects included widening the I-880 freeway and improving a few freeway interchanges.

Primarily during the period 2007–2009, the City of Fremont undertook the Washington Boulevard / Paseo Padre Grade Separation Project to eliminate at-grade railroad crossings.[82] The project involved reconfiguring Paseo Padre Parkway as a vehicular underpass with the BART line passing over Paseo Padre Parkway on a bridge structure. Washington Boulevard was reconfigured as a vehicular overpass with the BART line passing under it.[83] See Figure 2 for project location.

2010–2014: Major Construction, Including Along the BART Line

Major construction along the BART line began toward the end of 2009 with the Central Park Subway Project.[84] Central Park is Fremont's main city park and lies immediately to the south of the Fremont BART Station (see Figure 3). The BART line goes beneath Central Park. The major tunneling work began in 2010,[85] and the tunnel was completed in October 2012.[86] The entire project was completed in April 2013.[87, 88]

Track work, construction, and work on related systems for the Warm Springs Station began toward the end of 2011. Major construction was over by 2014, and the testing began in early 2015.[89]

2015–2016: System Testing and Integration; Service Anticipation Period

Line and track testing and system integration continued during this period.[90]

March 2017–Present: Station Operational

The Warm Springs Station opened for commercial service on Marh 25th, 2017.[91]

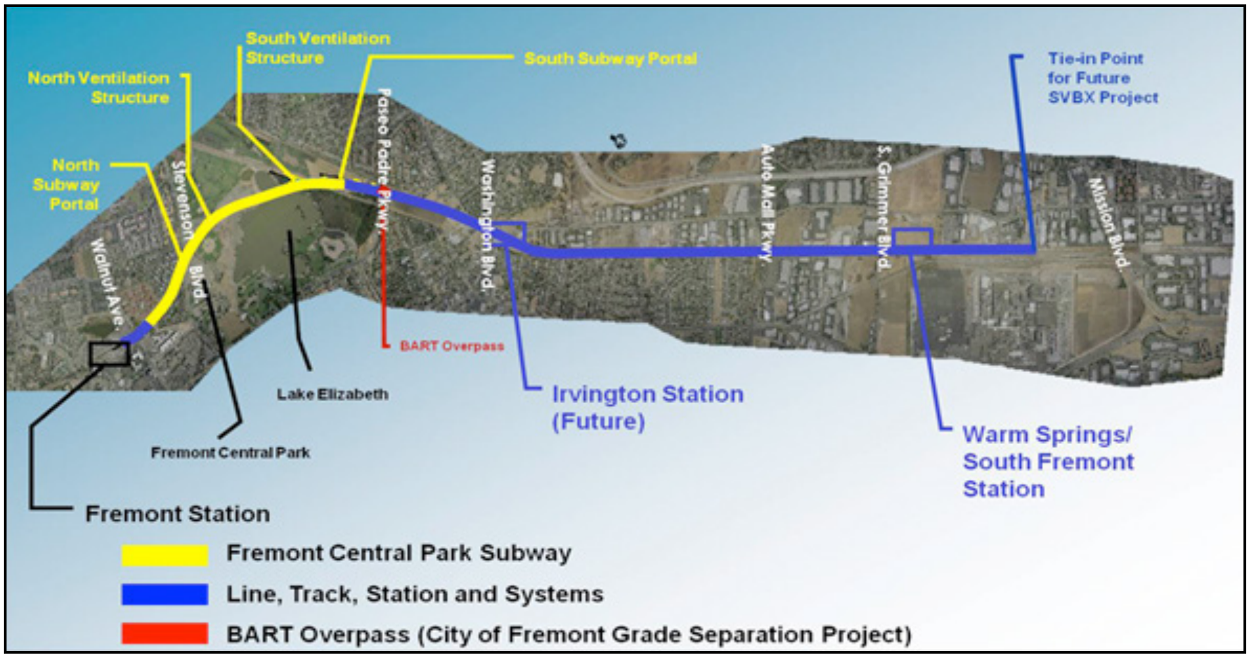

Figure 2. Map of Washington Blvd. / Paseo Padre Grade Separation Project

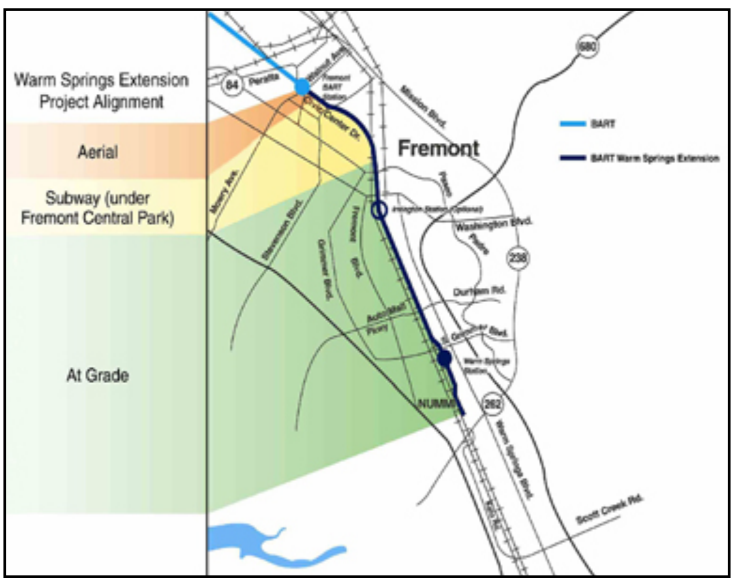

Figure 3. Map of Central Park Subway Project

COMMUNITY RESPONSE TO THE WS BART STATION

BART users eagerly awaited the opening of the WS BART Station. News sources show that Bay Area residents felt that the station would a) provide more parking (parking is limited at the Fremont station), since the new station would include more than 2,000 parking spaces, and b) shorten commutes.[92] In a *Mercury News* article, former mayor of Fremont, Bill Harrison, notes, “The city of Fremont as well as its residents, commuters and businesses have been looking forward to the opening of the Warm Springs/South Fremont BART Station for some time now … Today, we’re seeing healthy progress and the new BART station is a huge step forward.”[93] Despite the predominantly positive outlook on the project, some residents were concerned that the new station would lead to a surge in the number of new passengers, making it difficult to find space to sit during the weekday commute. The *East Bay Times* quoted one Fremont resident, who stated, “...the BART system needs to think about increasing the capacity or the frequency of the trains.”[94]

LAND USES SURROUNDING THE WS BART STATION

A variety of different land uses surround the Warm Springs BART station. Noticeably, heavy and light industrial uses lie to the west of the Warm Springs Boulevard. Further west (west of I-880) lie multiple waste management and recycling centers, including Tri Cities Landfill and Fremont Transfer Station, Newby Island Resource Recovery Park, and Fremont Recycling and Transfer. TESLA Corporation’s offices and manufacturing center are also located to the west of the study area. Predominantly residential areas lie to the east of Warm Springs Boulevard and to the north of Grimmer Boulevard (see Figure 4).

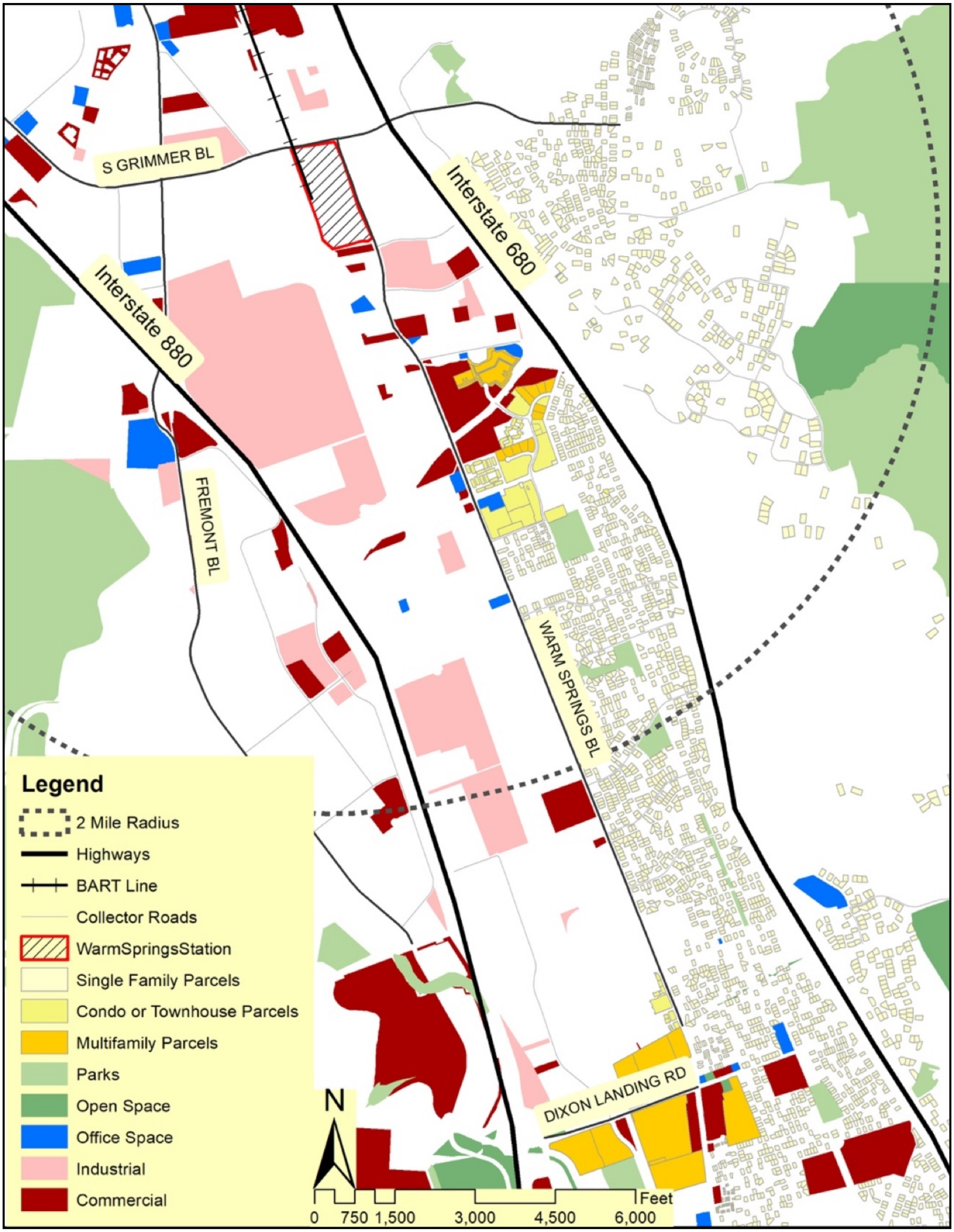

Figure 4. Map of Study Area

IV. RESEARCH DESIGN, DATA DESCRIPTION, AND MODEL SPECIFICATION

Research Design and Study Hypothesis

This study used data on sales and property characteristics for the period 2000–2018 to estimate the price impacts of the WS BART Station on houses within 2 miles of the BART station compared to the control group, i.e., houses in the 2–5-mile distance band. Since the extant literature has used one to three miles as the area of influence for a heavy-rail train station, for this study both the 2-mile and 3-mile distance bands were tried. Since the 3-mile distance band showed significant multicollinearity with other independent variables, the final models are run for the 2-mile distance band. Additionally, the smaller (2-mile) distance band will provide more conservative estimates of the total station-induced property value increase. Moreover, since the overall 5-mile distance band includes another, much older, BART station to the north—the Fremont BART Station—the investigation only included properties that were primarily to the south of the WS BART Station by filtering out properties that were within 4.5 miles of the Fremont BART Station, because these properties are likely to benefit from the Fremont BART Station as well. Finally, as Section III notes, significant improvements were made to the I-880 freeway during the study period. I-880 lies to the west of the WS BART Station. Therefore, the only properties included were those located to the east of a major arterial road—the Warm Springs Boulevard, which itself lies to the east of I-880 (see Figure 4). Since people living in these properties are located much closer to the I-680 freeway, they are likely to benefit to a lesser extent from improvements to I-880.

Since a transit station could impact property values long before the commencement of the transit service, or even before the station is constructed, the 18-year study period is divided into six sub-periods—2000–2001, 2002–2006, 2007–2009, 2010–2014, 2015–February 2017, and March 2017–April 2018. As noted in Section III, the WSX Project became general knowledge in 2002. Therefore, the 2000–2001 period serves as the pre-announcement period. The 2002–2006 period serves as the post-announcement period during which major environment reviews were conducted and approved; 2007–2009 was the period during which some construction projects were undertaken; 2010–2014 was the major BART construction period; 2015–2016 was the post-construction but pre-operations period; March 2017–April 2018 represents the post-operations period.

To estimate the property value impacts of the WS BART Station, the researcher interacted a dummy variable for houses within 2 miles of the WS BART Station with the dummy variables for each time sub-period, taking the sub-period 2000–2001 as the referent category. As discussed in Section II, transit's capitalization effects can vary by property type, and as a result, there is a need to run one regression model for each property type. Therefore, the researcher ran two sets of regression models for this study: the first set estimates the impact of the proximity of the WS BART Station on single-family houses, and the second set estimates this impact on condominiums/townhouses.

Study Hypothesis

The hypothesis is that one or more interaction terms (created by interacting the dummy variable for houses within 2 miles of the WS BART Station with the dummy variable for each time sub-period) included in the regression models will be statistically significant and will have a positive coefficient—indicating that for those sub-periods in time, the WS BART Station increased property prices for houses within 2 miles of the station compared to the referent category (houses in the 2–5-mile radius sold during the period 2001-2002). Which interaction terms are significant is an empirical question, since extant literature suggests that a new transit station is likely to impact property values any time after project announcement.

Data Description

Tax Assessor data from Alameda and Santa Clara Counties were obtained from a private vendor. These data include the location and use of each parcel, the size of the parcel and of the house, the number of bedrooms and bathrooms in the house, the age of the house, the date and year of the most recent sale, and the sale price. GIS software was used to include other variables that might impact house prices, such as: a) the distance from each house to the nearest arterial road, freeway, and neighborhood park, b) US Census data such as the economic and demographic characteristics at the levels of census block and block-group, and c) elementary school attendance zones. Google Earth imagery was used to determine where BART lines were above, at, and below grade, and shape files were created to reflect the appropriate grade separation. A separate shape file was created for the rail crossing reconstruction projects at Washington Boulevard and Paseo Padre Parkway.[95]

Next, the data were divided into two datasets by filtering using land use codes: a) the single-family dataset and b) the condominium/townhouse dataset. The single-family dataset includes houses with land use code equal to single family residence. The condominium/townhouse dataset includes houses with land use code equal to one of the following: townhouse/rowhouse, condominium, condominium project, high-rise condo, and mid-rise condo. Thereafter, the data were clipped to include only houses within a 5-mile radius around the WS BART Station, more than 4.5 miles from the Fremont BART Station, and to the east of Warm Springs Boulevard.

Furthermore, several precautions were taken to reduce the effects of outliers, miscoded extreme values, and other data errors. These precautions include removing observations with a) no sale price data, b) no sale date or no effective-year-built date, c) sale year earlier than year built, d) zero house size, zero lot size (for single-family dataset), zero bedrooms and zero bathrooms, and d) more than six bedrooms and four bathrooms. Moreover, the top and bottom one percent of the records were dropped with respect to the sale price; the size of the house; and for single-family dataset, the size of the lot. Even then, several observations showed a very low sale price compared to the assessed value of the house. In California, due to Proposition 13, assessed values typically go up by a maximum of two percent annually. The assessed value equals the sale price for the year the house is sold or the property is reassessed when major renovations are made. Therefore, even for a house sold at the beginning of the study period, 2000, the maximum assessed value increase should be about 45%. Therefore, only observations with a maximum assessed-value-to-sale-price ratio of 1.5 were included. Finally, since the dataset included sales over 18-year period, the sale price was normalized using the Bureau of Labor Studies' (BLS) non-housing CPI for the San Francisco-Oakland-Hayward area. The final single-family dataset included 3,384 observations; the final condominium/townhouse dataset included 974 observations. The descriptive statistics of the continuous variables used in the final models are in Table 6 and Table 7. The frequency distribution of nominal and ordinal variables used in the final models are in Table 8 and Table 9.

Table 6. Descriptive Statistics for Continuous Variables: Single-Family Model

	Minimum	Maximum	Mean	Std. Deviation
Lot size (sq. m)	144.56	2,180.43	698.88	286.37
Size of living space (sq. m)	82.78	338.26	181.96	56.89
Age of house (years)	0.00	63.00	30.81	12.27
Number of bedrooms	2	6	3.71	0.72
Number of bathrooms	1.00	4.00	2.45	0.55
Distance to commercial (m)	1.00	2,082.00	480.89	381.81
Distance to neighborhood park (m)	1.00	1,807.60	339.47	264.25
Distance to multi-family (m)	1	2,399	640.72	332.45
Distance to nearest highway	5	1,998	567.77	382.08
Percent Asian (ACS 2000, block groups)	0.00	100.00	51.82	18.66

(N=3,384)
(1 sq. m = 10.76 sq. ft.)
Age of house = year sold – effective year built (if known)
Age of house = year sold – year built (when effective year built is not known)

Table 7. Descriptive Statistics for Continuous Variables: Condominium/Townhouse Model

	Minimum	Maximum	Mean	Std. Deviation
Sale price in 2018 USD	$154,560	$1,210,765	$515,098.39	$165,405.86
Total living space (sq. m)	62	187	1,116	104
Number of bedrooms	1	4	2.24	0.62
Number of bathrooms	1.0	3.50	1.93	0.59
Distance to commercial (m)	0.00	624	119.13	100.526
Distance to neighborhood park (m)	0.00	710.20	348.95	195.27

(N=974)
(1 sq. m = 10.76 sq. ft.)

Table 8. Frequency Distribution of Categorical Variables: Condominium/Townhouse Model

	Frequency	Percent (%)
Within 2 miles of Warm Springs BART Station	587	60.3
Within 400m of educational institution	223	22.9
Within 800m of open space over 40 acres	7	0.7
Within 100m of the nearest arterial or a 45 or 50 mph road	546	56.1
Within 100m of nearest freeway	30	3.1
Within 100m of bus stop	359	36.9
Within 100m of light industrial	128	13.1
Winter	193	19.8
Spring	301	30.9
Summer	261	26.8
Anthony Spangler Elementary School	110	11.3
Curtner Elementary School	37	3.8
James Leitch Elementary School	740	76.0
Joseph Weller Elementary School	8	0.8
Marshall Pomeroy Elementary School	56	5.7
William Burnett Elementary School	23	2.4
Sale between 2002 and 2006	186	19.1
Sale between 2007 and 2009	186	19.1
Sale between 2010 and 2014	282	29.0
Sale between 2015 and February 2017	135	13.9
Sale March 2017 onwards	82	8.4
Interaction within 2 miles of WS BART Station and sale between 2002 and 2006	147	15.1
Interaction within 2 miles of WS BART Station and sale between 2007 and 2009	72	7.4
Interaction within 2 miles of WS BART Station and sale between 2010 and 2014	177	18.2
Interaction within 2 miles of WS BART Station and sale between 2015 and Feb 2017	100	10.3
Interaction within 2 miles of WS BART Station and sale March 2017 onward	59	6.1

(N=974)
(1 sq. m = 10.76 sq. ft.)

Table 9. Frequency Distribution of Categorical Variables: Single-Family Model

	Frequency	Percent (%)
Within 2 miles of the Warm Springs Bart Station	1,274	37.6
Within 100m of the nearest arterial or a 45 or 50mph road	489	14.5
Winter	658	658
Spring	19.4	19.4
Summer	1,045	1045
Fred Weibel Elementary School	635	635
James Leitch Elementary School	18.8	18.8
Anthony Spangler Elementary School	47	1.4
Curtner Elementary School	439	13.0
Joseph Weller Elementary School	467	13.8
Marshall Pomeroy Elementary School	434	12.8

	Frequency	Percent (%)
William Burnett Elementary School	158	4.7
Sale between 2002 and 2006	983	29.0
Sale between 2007 and 2009	488	14.4
Sale between 2010 and 2014	986	29.1
Sale between 2015 and February 2017	403	11.9
Sale March 2017 onwards	215	6.4
Interaction within 2 miles of WS BART Station and sale between 2002 and 2006	389	11.5
Interaction within 2 miles of WS BART Station and sale between 2007 and 2009	196	5.8
Interaction within 2 miles of WS BART Station and sale between 2010 and 2014	371	11.0
Interaction within 2 miles of WS BART Station and sale between 2015 and Feb. ‘17	140	4.1
Interaction within 2 miles of WS BART Station and sale March ‘17 onwards	68	2.0

(N=3,384)

(1 sq. m = 10.76 sq. ft.)

Model Specification

This study estimates owner households' marginal willingness to pay for houses within 2 miles of the WS BART Station, compared to those properties located 2–5 miles away from the station. The basic econometric approach is a fixed effect (FE) ordinary least squares (OLS) regression.

The main estimation equation regresses the price of a house i (p_i) on its structural and locational attributes (x_i), including whether the house is located within 2 miles of the WS BART Station, using Eq. (1). β_0 is the constant, β_i is the coefficient of x_i, and ξ_i is the error term that is assumed to be independent of x_i and to be normally distributed.

$$p_i = \beta_0 + \beta_i x_i + \xi_i \quad (1)$$

Estimation of Eq. (1) using OLS regression assumes homoscedasticity, or constant variance of the error term, as shown in Eq. (2).

$$V(\xi_i) = \sigma^2 \text{ for all } i \quad (2)$$

Violation of this assumption could lead to biased standard errors of the coefficients: that is, over- or under-estimation of the standard errors. Such violations typically occur when the variance of the error term is a function of a vector of explanatory variables. Indeed, the Breusch-Pagan test for heteroscedasticity indicated non-constant variance of the error term for the preliminary OLS regression models estimated in this study. As a remedy, the regression models were estimated with White's heteroscedasticity-consistent standard error estimator. The researcher further used the robust standard errors estimator with the standard errors clustered at the school attendance zone level, because the independent variable of interest, proximity to the WS BART Station, is likely to vary at this level.

Additionally, the spatial nature of the data increases the likelihood of spatial dependence—spatial error and spatial lag dependence. Spatial *error* dependence means that the error terms may be correlated across space, thereby violating the assumption of uncorrelated error terms in OLS. This violation results in biased coefficient estimates, often due to omitted spatial variables. For example, in this study, such biased estimates could be attributed to the omitted neighborhood-level variables. With spatial *lag* dependence, the dependent variable for an observation in one location is affected by the dependent and independent variables for observations in other locations,[96] because (for instance) the sale price of a house might be influenced by the sale price and characteristics of houses sold in its vicinity. The presence of spatial lag dependence violates the assumptions of uncorrelated errors as well as the independence of observations, and like spatial lag dependence, it could lead to biased and inefficient estimates.

Checking and correcting for spatial dependence is therefore necessary to address the OV problem (if spatial error dependence exists) and identify the underlying spatial nature of the data. The first step is to create a spatial weights matrix, W, in order to weight the sale price (p) by accounting for both the spatial and temporal proximity of the sale transactions. Using the methodology employed by Di, Ma and Murdoch,[97] the four sale transactions nearest in space to a given house were included in the spatial weights calculation. The transactions were further weighted by the proximity of the sale year. Transactions in the same year were assigned a weight of 1.0, transactions two years apart assigned a weight of 0.5, and transactions three years apart assigned a weight of 0.33.

Second, the researcher employed Lagrange multiplier (LM) tests to ascertain the type of spatial dependence that the model exhibited: spatial lag, spatial error, or both.[98] The simple LM test was used for error dependence (LMerr) and for a missing spatially-lagged dependent variable (LMlag); the RLMerr test was used for error dependence in the presence of a missing lagged dependent variable; and the RLMlag test was used for a missing lagged dependent variable in the presence of error dependence.[99] For this dataset, the LM tests indicate the presence of spatial error dependence for the condominium/townhouse model. No spatial dependence was detected for the single-family model.

The spatial error model equation is estimated as follows:

$$p_i = \beta_0 + \beta_i x_i + \xi \qquad (3)$$

where

$$\xi = \lambda W \xi + \varepsilon$$

and ξ is a vector of error terms that is spatially weighted using the weights matrix, W; λ is an autoregressive parameter; ε is a vector of uncorrelated error terms.

REGRESSION RESULTS

Single-Family Regression Model Results

Table 10 provides regression results. The models' adjusted R^2 is 0.79. Since the Global Moran I's test and the Lagrange multiplier diagnostics show no spatial dependence, further discussion will focus on the clustered robust stand error estimates.

The coefficients for all variables that were statistically significant at p=0.05 level have the expected signs, except for the number of bathrooms variable. The house price increases with the size of the house and the size of the lot, and it decreases with the age of the house as well as the proximity to commercial uses and to multi-family housing. Further, houses sell for a discount in winter, reflecting the seasonal nature of the housing market. Proximity to arterial roads (within 100 meters) and freeways negatively impact prices, which may be reflective of the noise and air pollution. The counterintuitive finding of a negative sign for the bathrooms could arise because after controlling for the house size and the number of bedrooms, more bathrooms might indicate a) less space for bedrooms and/or other living spaces, and/or b) other design issues.

Several variables of primary interest—the interaction terms for houses within 2 miles of the WS BART Station and the sub-period dummies—have the expected positive sign and are statistically significant. Specifically, the model suggests that compared to the referent category (houses sold during the period 2000–2001 in the control distance band [2 to 5 miles from the WS BART Station]), an average-priced single-family house within 2 miles of WS BART Station was higher in price by a) $98,177 when sold during the 2007–09 period, b) $105,060 when sold during the 2010–2014 period, c) $205,920 when sold during the 2015–February 2017 period, and d) $157,880 when sold during the March 2017–April 2018 period. All these price increases are statistically significant at the p=0.05 level. These results also indicate that house price increase started with the commencement of the construction in the 2007–2009 period and continued through the commencement of the rail service in March 2017.

Table 10. Single-Family Model Regression Results

	OLS	
Variables	**Coefficient (Clustered Robust Standard Error) (White's Standard Error)**	**p value**
Intercept	-214,090	
	(176,730)	
	(55,733)	****
Within 2 miles of Warm Springs BART station	-49,625	
	(30,050)	*
	(22,251)	**
Lot size (sq. ft.)	19.58	
	(3.8112)	****
	(1.5504)	****

Variables	OLS Coefficient (Clustered Robust Standard Error) (White's Standard Error)	p value
Size of living space (sq. ft.)	274.1	
	(29.631)	****
	(9.8184)	****
Age of house	-4,048	
	(736.14)	****
	(402.26)	****
Number of bedrooms	-2,365	
	(8,208.8)	
	(5,077.9)	
Number of bathrooms	-33,226	
	(16,864)	**
	(8,153.7)	****
Within 100m of the nearest arterial or a 45 or 50 mph road	-16,369	
	(9,813.5)	*
	(8,651.3)	*
Natural log of distance to the nearest commercial parcel	14,524	
	(3,630.7)	****
	(2,732.2)	****
Natural log of distance to the nearest neighborhood park	-3,035.6	
	(3,961.8)	
	(2,330.5)	
Natural log of distance to the nearest multi-family parcel	13,404	
	(6,787.4)	**
	(3,306.1)	****
Natural log of distance to the nearest highway	46,034	
	(7,871.0)	****
	(3,615.5)	****
Percent Asian (ACS 2000, block groups)	1,025.4	
	(273.36)	****
	(248.98)	****
Winter	-31,781	
	(3,959.9)	****
	(8,387.3)	****
Spring	190	
	(7,260.3)	
	(7,732.4)	
Summer	1,603.2	
	(4,648.5)	
	(75,88.4)	
Sale year between 2002 and 2006	129,040	
	(11,108)	****
	(12,757)	****

Variables	OLS Coefficient (Clustered Robust Standard Error) (White's Standard Error)	p value
Sale year between 2007 and 2009	105,770	
	(32,733)	***
	(13,751)	***
Sale year between 2010 and 2014	63,385	
	(39,276)	
	(13,371)	****
Sale year between 2015 and February 2017	363,580	
	(58,670)	****
	(16,136)	****
Sale year from March 2017 onwards	533,310	
	(48,556)	****
	(20,829)	****
Interaction within 2 miles of WS BART Station and sale between 2002 and 2006	-14,959	
	(26,553)	
	(23,411)	
Interaction within 2 miles of WS BART Station and sale between 2007 and 2009	98,177	
	(25,859)	****
	(24,368)	****
Interaction within 2 miles of WS BART Station and sale between 2010 and 2014	105,060	
	(49,007)	**
	(23,881)	****
Interaction within 2 miles of WS BART Station and sale between 2015 and February 2017	205,920	
	(45,695)	****
	(25,631)	****
Interaction within 2 miles of WS BART Station and sale from March 2017 onwards	157,880	
	(40,054)	****
	(33,341)	****
Curtner Elementary School	-17,267	
	(10,046)	*
	(27,765)	
Fred Weibel Elementary School	163,280	
	(32,317)	****
	(30,991)	****
James Leitch Elementary School	148,884	
	(22,668)	****
	(29,071)	****
Joseph Weller Elementary School	13,832	
	(20,092)	
	(28,105)	

Variables	OLS Coefficient (Clustered Robust Standard Error) (White's Standard Error)	p value
Marshall Pomeroy Elementary School	26,094	
	(13,496)	*
	(27,784)	
William Burnett Elementary School	17,992	
	(28,205)	
	(29,451)	
Adjusted R^2	0.79	
N	3,384	

(**** Significant at p = 0.001; *** Significant at p = 0.01; ** Significant at p = 0.05; * Significant at p = 0.1)

Condominium/Townhouse Regression Model Results

Table 11 provides regression results. The models' adjusted R^2 is 0.76. Since the Global Moran I's test and the Lagrange multiplier diagnostics show spatial dependence and because the spatial error model provides the best data fit, further discussion will focus on the spatial error model results.

The coefficients for all the variables that are statistically significant at p=0.05 level have the expected signs, except for the variable measuring proximity to the neighborhood parks and to freeways. The house price increases with the size of the house and the number of bedrooms and bathrooms, and it decreases with proximity to light industrial and commercial uses. Proximity to arterial roads (within 100 meters) negatively impacts prices, perhaps reflecting a distaste for noise and air pollution. The counterintuitive negative sign for the neighborhood parks and freeways could be because a few high-priced condominium/townhouse properties were sold away from neighborhood parks and close to freeways, skewing the data.

One interaction term—for houses within 2 miles of the WS BART Station and sold during the period 2007–2009—has the expected positive sign and is statistically significant at the p=0.05 level. The other interaction term—for the period 2010–2014—is statistically significant at the p=0.10 level. Specifically, the model suggests that compared to the referent category [houses sold during the period 2000–2001 and in the control distance band (2 to 5 miles from the WS BART Station)], an average-priced condominium/townhouse within 2 miles of the WS BART Station was higher in price by a) $99,116 when sold during the 2007–09 period, and b) $49,206 when sold during the 2010–2014 period. The regression model indicates that the price increase was sustained throughout the construction period from 2007 to 2014. Similar findings were obtained in other contexts by McMillen and McDonald,[100] who found that the rapid transit line from downtown Chicago, IL, to Midway Airport began impacting property values before the opening of the line for service and by Yen, Mulley, Shearer and Burke[101] who found similar property value impacts for the Gold Coast Light Rail system in Australia. Finally, the statistically insignificant interaction terms for the periods of 2015–February 2017 and March 2017–April 2018 suggest that the house price increases were similar in the 2-mile distance band and the 2–5-mile control band during these periods. Two competing reasons may explain for this statistical insignificance. First, the entire property value capitalization of the WS BART Station could have occurred before 2015; second, the WS BART Station's impact on property prices could have spilled over to the control band during this period.

Table 11. Condominium/Townhouse Model Regression Results

Condominium/Townhouse Model	OLS		Spatial Error Model	
Variables	Coefficient (Clustered Robust Std. Error) (White's Std. Error)	p value	Coefficient (Std. Error)	p value
Intercept	-884.59		-14,417.88	
	(43,266.24)		(47,272.54)	
	(51,427.81)			
Within 2 miles of Warm Springs BART station	8,314.06		-3,883.08	
	(53,457.38)		(35,786.26)	
	(34,962.21)			
Size of living space (sq. ft.)	294.92		284.46	****
	(49.37)	****	(27.00)	
	(35.51)	****		
Number of bedrooms	25,503.55		28,924.79	****
	(10,288.55)	**	(8,092.93)	
	(9,053.84)	***		
Number of bathrooms	23,622.89		26,159.71	****
	(16,872.25)		(7,658.59)	
	(7,063.73)	****		
Within 400m of educational institution	20,409.19		22,030.54	*
	(12,278.54)	*	(12,578.22)	
	(15,130.81)			
Within 800m of open space over 40 acres	73,865.04		72,788.93	*
	(6,771.66)	****	(38,141.75)	
	(42,019.62)	*		
Within 100m of the nearest arterial or 45 or 50 mph road	-30,304.51		-35,433.92	****
	(4,986.65)	****	(9,853.95)	
	(7,613.87)	****		
Within 100m of the nearest highway	51,976.22		57,824.31	**
	(10,173.02)	****	(24,066.51)	
	(21,090.97)	**		
Within 100m of the nearest bus stop	27,570.77		21,978.72	**
	(12,472.53)	**	(9,951.15)	
	(10,665.13)	***		
Within 100m of the nearest light industrial parcel	-57,054.69		-46,916.25	****
	(18,629.76)	***	(12,338.57)	
	(14,208.82)	****		

Condominium/Townhouse Model	OLS		Spatial Error Model	
Variables	Coefficient (Clustered Robust Std. Error) (White's Std. Error)	p value	Coefficient (Std. Error)	p value
Natural log of distance to the nearest commercial parcel	16,758.00		15,734.51	****
	(3,696.36)	****	(3,720.49)	
	(3,487.54)	****		
Natural log of distance to the nearest neighborhood park	10,292.27		10,799.21	**
	(3,503.18)	***	(3,686.50)	
	(2,888.47)	****		
Winter	-6,163.66		-4,876.13	
	(7,699.66)		(7,899.50)	
	(8,597.82)			
Spring	-1,558.28		61.46	
	(2,148.17)		(7,079.09)	
	(7,398.24)			
Summer	2,593.95		729.13	
	(10,961.25)		(7,186.04)	
	(7,721.83)			
Interaction 2 miles of WS BART Station and sale between 2002 and 2006	5,744.37		3,344.18	
	(28,201.02)		(28,781.88)	
	(24,236.66)			
Interaction 2 miles of WS BART Station and sale between 2007 and 2009	96,774.05		99,115.79	***
	(45,586.99)	**	(30,858.27)	
	(27,080.51)	****		
Interaction 2 miles of WS BART Station and sale between 2010 and 2014	59,912.96		49,206.46	*
	(39,212.29)		(29,641.11)	
	(24,844.11)	**		
Interaction within 2 miles of WS BART Station and sale between 2015 and February 2017	12,061.07		9,174.48	
	(42,665.41)		(31,965.07)	
	(25,153.95)			
Interaction within 2 miles of WS BART Station and sale from March 2017 onwards	-22,376.39		-23,414.15	
	(61,368.81)		(33,796.06)	
	(34,638.12)			
Sale year between 2002 and 2006	86,329.40		85,374.62	***
	(28,296.38)	***	(24,281.11)	
	(21,474.93)	****		

Condominium/Townhouse Model	OLS		Spatial Error Model	
Variables	Coefficient (Clustered Robust Std. Error) (White's Std. Error)	p value	Coefficient (Std. Error)	p value
Sale year between 2007 and 2009	-51,121.41		-53,566.37	*
	(45,430.85)		(25,479.11)	
	(23,875.57)	**		
Sale year between 2010 and 2014	-43,012.59		-31,891.15	
	(39,705.67)		(25,190.89)	
	(22,436.83)	*		
Sale year between 2015 and February 2017	198,568.11		197,681.99	****
	(43,039.08)	****	(27,426.04)	
	(22,701.25)	****		
Sale year from March 2017 onwards	278,167.06		277,356.28	****
	(60,530.87)	****	(28,721.93)	
	(32,170.25)	****		
Curtner Elementary School	-136,983.83		-117,916.08	****
	(23,550.70)	****	(22,107.29)	
	(24,612.34)	****		
James Leitch Elementary School	-123,810.54		-93,393.70	****
	(40,002.12)	***	(22,383.02)	
	(23,046.21)	****		
Joseph Weller Elementary School	-68,217.73		-71,216.07	
	(11,676.91)	****	(45,602.87)	
	(38,600.64)	*		
Marshall Pomeroy Elementary School	-99,208.14		-88,221.23	****
	(2,725.61)	****	(21,506.43)	
	(20,829.71)	****		
William Burnett Elementary School	-133,814.38		-115,355.84	****
	(12,520.80)	****	(27,560.81)	
	(27584.081)	****		

(R^2 = 0.76)
(N = 964)
(****Significant at p = 0.001; ***Significant at p = 0.01; **Significant at p = 0.05; *Significant at p = 0.1)

ESTIMATES OF PROPERTY VALUE INCREASE DUE TO THE WS BART STATION

Since the regression models show statistically significant and consistent price increases for single-family houses, only this housing type is considered in order to estimate mean property value increase due to the WS BART Station. The researcher used the following steps to calculate this value increase:

1. Calculate the average house price increase: First, the coefficients of the interaction terms for houses within 2 miles of WS BART Station and the various sub-periods were used to identify the average value increase during the various sub-periods (see Table 12, Column C). Next, the study dataset was used to calculate the average sale price during each sub-period (see Table 12, Column D). Then, using the data in Columns C and D, the percent increase in house prices during each sub-period was calculated (see Table 12, Column E), finding an average house price increase of 9% to 15%.

2. Calculate the total property value increase in the study area: The 10.25% property increase in the post-operations period of March 2017–April 2018 [this also fell toward the lower end of the 9%–15% range identified in the step 1) above] was applied to the average price of houses sold during this period, $1,530,960, to calculate the average station-induced price increase at $156,900 per house (see Table 13, Row 4). Next, using the County Tax Assessors' files, the total number of single-family houses located within 2 miles of the WS BART Station (see Table 13, Row 1) were calculated. Finally, Rows 1 and 4 were multiplied to calculate the total property value increase within the 2-mile area around the WS BART Station at $1.69 billion (see Table 13, Row 5).

3. Calculate the inflation- and property-tax-adjusted 30-year appreciation on the station-induced property value increase: Not only did property owners receive a one-time windfall gain from the WS BART Station: they will continue to benefit from the home value appreciation on this initial gain. To calculate this value appreciation, first data from the US Census and the Alameda County, CA, Consolidated Plan: Executive Summary[102] were used to calculate the average annual property value increase. The data showed that during the period 1980–2010, median home value in Alameda County increased from $85,300 to $497,200—a 6.05% annual increase (see Table 14, Row 1). Notably, the 6.05% increase is a conservative estimate, because it includes all owner-occupied properties, not just single-family houses, which typically increase in value at a higher rate than the rest of the housing types. Next, the 6.05% increase was inflation-adjusted by subtracting the average increase in the non-housing CPI for the San Francisco-Oakland-Hayward region. The BLS data show a 293% increase in non-housing CPI during the 1980–2018 period, representing a 2.87% annual increase. Therefore, the inflation-adjusted increase is 3.18% (6.05% minus 2.87%). Please refer to Table 14, Row 2. Finally, 1.5% was deducted from this, 3.18%, to account for the property taxes payable on the station-induced property value gain. After the property tax discount, the annual gain equals 1.68% (3.18% minus 1.5%). Please see Table 14, Row 3. Notably, 1.5% is a very

generous property tax discount, because residential properties in the San Francisco Bay Area typically only pay between 1% to 1.3% property tax. For example, the tax rate is 1.17% for the City of Fremont. Furthermore, the property owners will only pay this increased tax when they buy a new property. Finally, the inflation- and property-tax-adjusted 1.68% annual gain are used to calculate the 30-year gain on the total $1.69-billion property value increase, which is found to equal $2.79 billion (see Table 13, Row 6). A 30-year period was chosen as a reasonable time-span during which the WS BART Station would continuously serve the local community.

4. Calculate the total property value increase: The initial property value gain of $1.69 billion was added to the 30-year gain of $2.79 billion to calculate the total gain of $4.48 billion (see Table 13, Row 7).

5. Calculate the total WSX Project cost: As per a 2015 BART Status Project Report,[103] the WSX Project cost equaled $767 million in 2014 dollars (or $802 million in 2018 dollars when inflation-adjusted using the non-housing CPI), which increased 4.5% between 2014 and 2018. Therefore, $767 million was multiplied by 1.045 to arrive at the $802 million project cost.

6. Calculate the percent value increase to be shared by property owners: Assuming that the property owners only share the proportion of property value increment sufficient to fund the WSX Project cost, the WSX Project cost (Table 13, Row 8) was divided by the total value increment (Table 13, Row 7)—and multiplied by 100%—to arrive at 17.9%.

In summary, properties owners need to only share less than one-fifth of the total property increment to fund the entire WSX Project. This percentage is likely to be even smaller if the owners of the other property types also share property value increments, such as the owners of apartment, office and commercial buildings.

Table 12. Property Value Increase: Single-Family Houses

Time period (A)	House Type (B)	Average Increase (C)	Average House Price (D)	Average % Increase (E)
2007–2009	Single-family	$98,180	$1,094,211	8.97%
2010–2014	Single-family	$105,100	$1,074,986	9.78%
2015–February 2017	Single-family	$205,900	$1,386,769	14.85%
March 2017–April 2018	Single-family	$156,900	$1,530,960	10.25%

Table 13. Proportion of Property Value Increment Needed to Recoup Project Cost

Row #		
1	Total single-family houses within the study area (2-mile radius around the WS BART Station)	10,775
2	Average sale price (2018 USD)	$1,530,960
3	Average price increase (%)	10.25%
4	Average price increase (2018 USD)	$156,900.00
5	Total home value increase in the study area (2018 $) (Row #1 times Row #4)	$1,690,597,500
6	30-year appreciation on the price increase due to the WS BART Station	$2,786,803,510
7	Total value increase (sum of Rows #5 and #6)	$4,477,401,010
8	Total construction cost (2018 USD)	$801,515,000
9	Percent value increase to be shared by the property owners to recoup project cost (Row #8 divided by Row #9 times 100)	17.90%

Table 14. 30-Year Gain on BART-Induced Property Value Increase

Row #		
1	% annual home value increase, 1980–2010	6.05%
2	% increase controlling for inflation (Row #1 minus 2.87% annual inflation)	3.18%
3	% increase after accounting for property taxes (Row #2 minus 1.5% property tax)	1.68%

V. CONCLUSIONS AND POLICY IMPLICATIONS

This research shows that a suburban heavy-rail-based rapid transit station, the WS BART Station, significantly increased price of single-family houses in a 2-mile radius around the station. The results for condominiums/townhouses also indicate property value increase, although the findings are less conclusive; nonetheless, it is important to note that the station project did not decrease the value of condominiums and townhouses.

This study should help to build a strong consensus that VC tools can be used to fund transit projects. The study findings support advocacy efforts for enhancing transit service in the San Francisco Bay Area specifically. The findings also address the NIMBYs' concerns related to rail transit's negative impact on property values. Furthermore, the estimation of the magnitude of BART-induced property value increase should help advocate for the use of VC tools to fund other BART extension projects, such as the BART extension from Berryessa to downtown San Jose and onward to Santa Clara, and from Dublin/Pleasanton Station to Livermore in the East Bay—after all, the entire WSX Project could have been financed with less than a 20% share of the BART-induced property value increment for single-family houses. Therefore, I urge transit agencies, elected officials, and policy-makers to proactively pursue VC tools to fund transit projects. They should modify their approach to interacting with the community about transit provision—moving from an almost complete focus on alleviating property owner concerns about transit's negative impacts to engaging the community to share the property value increment to fund transit, while taking steps to address community members' genuine concerns (for example, concerns about sound and station area vehicular traffic). Apart from providing much-needed transit funds, such a local share should also help secure state and federal funds that require local commitment and funding.

Finally, some may argue that requiring property owners to share property value increment is akin to taxing them, and that the use of LVC tools runs counter to programs that incentivize density near transit. However, it is important to view LVC tools as ways to *share* the gains that accrue due to public actions, and not as taxes. Taxes do not require a quid pro quo (expectation of a benefit). LVC tools do. Therefore, to the extent that publicly-funded infrastructure projects lead to private gains (e.g., in the form of increases in the value of privately-owned properties), it is reasonable to ask the private property owners to share some of the value increase. In the long run, the private property owners also benefit, because more of the publicly-funded infrastructure can be provided if LVC revenues are available to fiscally-constrained public agencies. Furthermore, LVC tools can be designed to meet other policy objectives—for example, compact developments could share less value increment compared to the sprawling low-density developments.

ABBREVIATIONS AND ACRONYMS

ACTIA	Alameda County Transportation Improvement Authority
AGT	Automated Guideway transit
BART	Bay Area Rapid Transit
BLS	Bureau of Labor Studies
BRTS	Bus Rapid Transit System
CBD	Central Business District
CEQA	California Environmental Quality Act
CPI	Consumer Price Index
GIS	Geographic Information System
EIR	Environmental Impact Report
FAST	Fixing America's Surface Transportation Act
FE	Fixed Effect
GWR	Geographically Weighted Regression
HBLR	Hudson-Bergen Light Rail
HPM	Hedonic Price Modeling
ISTEA	Intermodal Surface Transportation Efficiency Act
LM	Lagrange Multiplier
LVC	Land Value Capture
MAP-21	Moving Ahead for Progress in the 21st Century Act
MARTA	Metropolitan Atlanta Rapid Transit Authority
MPO	Metropolitan Transportation (Planning) Organization
MTC	Metropolitan Transportation Commission
MUNI	San Francisco Municipal Railway
NIMBY	Not in My Backyard
OLS	Ordinary Least Squares
OV	Omitted Variable
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SDM	Spatial Durbin Model
SFO	San Francisco International Airport
SP	Southern Pacific
TIF	Tax Increment Financing
TEA 21	Transportation Equity Act for the 21st Century
TOD	Transit Oriented Development
UP	Union Pacific
UPRR	Union Pacific Railroad
VC	Value Capture
VTA	Santa Clara Valley Transit Authority
WP	Western Pacific
WS	Warm Springs
WSX	Warm Springs BART Extension

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PEER REVIEW

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