RESPONSE OF RESIDENTIAL PROPERTY VALUES TO THE REPLACEMENT OF LIMITED-STOP BUS SERVICE WITH BUS RAPID TRANSIT
AN ANALYSIS OF NEW YORK CITY'S BX12 SELECT BUS SERVICE

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by

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Michael Curley, "Response of Residential Property Values to the Replacement of Limited-Stop Bus Service with Bus Rapid Transit: An Analysis of New York City's Bx12 Select Bus Service." Submitted May 2012. Advisor: Dr. Lance Freeman.

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Michael Curley has conducted this study in partial fulfillment of the requirements for the degree Master of Science in Urban Planning from Columbia University's Graduate School of Architecture, Planning, and Preservation in New York, NY.

Despite the United States' legacy of innovative urban infrastructure and bold capital works projects, public transportation in contemporary America is unequipped to accommodate the needs of current and future generations. According to the National Surface Transportation Policy and Revenue Study Commission, the United States must invest $225 billion per year, an increase of 40% annually, over the next 50 years in order to maintain and adequately enhance its surface transportation systems (2007). In the face of scarce financial resources, the time is ripe for the United States to once again pursue innovative solutions to meet changing transportation needs. As a highly flexible and cost effective alternative, bus rapid transit (BRT) has become an increasingly popular choice over the past decade.

Since 2004, at least six U.S. cities have opened new BRT lines with dozens more currently under construction or in the planning stages (Institute for Transportation and Development Policy [ITDP], 2011). However, recent empirical studies have not kept pace with BRT's growing presence and the full impact of these transportation investments on surrounding properties remains largely unknown. While recent studies suggest that BRT investments generally result in property value increases, the majority of research has been conducted in Bogotá – a planning context that differs noticeably in its approach towards BRT implementation. Whereas Bogotá has taken special pains to accommodate expansive BRT networks as the city's primary form of transit, U.S. cities have pursued BRT on a smaller scale, upgrading single bus routes from local or limited-stop service to BRT, generally as a complement to an already existing transit system (ITDP, 2011). In order to arm planners and policymakers with more relevant data, the impact of BRT investment needs to be further researched within the specific context of U.S. cities.

This study uses a before and after difference-in-differences approach to estimate the response of residential property values to the replacement of limited-stop bus service with BRT. The introduction of BRT, a higher quality service, is expected to have a greater effect on property values than a lower quality service such as limited-stop buses. The Bx12 Select Bus Service (SBS) in the Bronx, New York will serve as the basis for this analysis. Opened in 2008, the Bx12 SBS replaced Bx12 limited-stop (Ltd.) service along Fordham Road/Pelham Parkway. Despite its recent opening, the Bx12 SBS is the longest operating BRT line in New York City. Thus, it is expected that if BRT investments influence property values, it will be most readily apparent in areas surrounding the Bx12 SBS.

Evolution of Public Transportation in New York City

At the turn of the nineteenth century, New York was a small mercantile town situated at the southern tip of Manhattan. Years of unplanned growth and development had left its mark, as jumbled networks of streets and alleys, irregular building lots, and hilly topography characterized the city's built form. In an attempt to "unite regularity and order" and "promote the health of the city," in 1811 the New York State Legislature approved a street grid plan for the city's future development (Burrows and Wallace, 1998). The key provisions of the grid plan included twelve one-hundred foot wide avenues running north-south intersected by narrower cross-streets running east-west. Carving Manhattan into long, narrow blocks, the plan opened thousands of acres to new development and generated a demand for city services such as water, sanitation, and public transportation (Atack and Margo, 1998).

As the city's wealthy and middle class residents moved northward, fleeing the more densely populated neighborhoods of Lower Manhattan, horse-drawn omnibuses responded to the need for public transportation. By the 1850s, streets were overcrowded with omnibus carriages and pedestrian traffic, inflicting devastating economic and social harm upon the city (Cunningham and DeHart, 1993; Atack and Margo, 1998). In an attempt to alleviate overcrowding, an amendment was made to New York state laws in 1866 permitting construction of the city's first form of rapid transit: an elevated railway high above the avenues of Manhattan.

Within fifteen years, a network of elevated trains was transporting 75.6 million passengers annually and pushing the city's border farther and farther north (Burrows and Wallace, 1998). As Manhattan struggled to accommodate growth, developers set their sights on expanding rail service across the Harlem River to unbuilt areas of the Bronx. With the help of extensions to 177th Street in the Bronx, annual ridership ballooned to 196.7 million by 1892 (Burrows and Wallace, 1998). The popularity of the elevated rail network was short lived however, as contracts for the city's first subway were signed in 1900 and construction began shortly thereafter (Cunningham and DeHart, 1993).

In many respects, the evolution of the city's subterranean railways followed the framework established by their elevated counterparts. For the first thirty-two years of the twentieth century, subway lines were built and operated by private, competing enterprises. Early subway lines followed the street grid, paralleling established routes of the elevated railways and providing service to similar neighborhoods. Furthermore, service routes that provided direct connections from the residential neighborhoods of Upper Manhattan and the outer boroughs to downtown business districts were prioritized. The first subway lines for instance, stretched north-south along Broadway between Upper Manhattan and northern Brooklyn, providing convenient access to the factories, offices, and shipyards of Lower Manhattan. As later expansion projects to the Bronx and Queens followed suit, the Manhattan-centric form that characterizes the present-day subway system gradually emerged.

The introduction and expansion of motor buses for public transit usage coincided with the subway's rapid growth. As early as 1907, private companies began operating the nation's first motor bus lines, transporting passengers between Washington Square and 90th Street with open-top double-decker buses (MTA, 2012). Over the next thirty years, private bus companies were slowly acquired by the city and service was expanded. Then as now, buses played an important role in filling the gaps left behind by the elevated railways and subways. Today, a fleet of nearly 5,000 buses covers approximately 3,000 route miles and helps meet the city's demand for public transportation services, especially in the outer boroughs were subway access is more limited (New York Transit Museum, 2012). In recent years, an effort to improve the quality of bus service for its 2.6 million daily riders has resulted in the city's current Select Bus Service program.

Select Bus Service and the Bx12 SBS

Select Bus Service (SBS) is New York City's version of BRT. In 2005, five existing bus corridors were identified for future SBS pilot projects. The first corridor slated for conversion to SBS was the Fordham Road/Pelham Parkway Bx12 bus route in the Bronx, one of the city's busiest bus corridors with annual ridership in excess of 13 million (MTA, 2010).

Opened in 2008, the Bx12 SBS runs 7.8 miles along Fordham Road/Pelham Parkway, the Bronx's major east-west thoroughfare, connecting Bay Plaza Terminal in the Bronx to Broadway/ 207th Street in Manhattan (Map 1.1). The Bx12 SBS operates simultaneously with Bx12 local service and has replaced all Bx12 Ltd. service along Fordham Road/Pelham Parkway. In the absence of east-west subway service, the Bx12 SBS and Bx12 play critical roles in connecting two sides of the Bronx (Map 1.2). In addition to serving as a link between a number of residential neighborhoods in the Bronx, the bus route provides access to 8 different subway lines and 3 Metro-North commuter railroad lines (A, B, D, 1, 2, 4, 5, 6, Hudson Line, Harlem Line, New Haven Line) as well as numerous city institutions and regional attractions, including Fordham University, the Bronx Zoo, the New York Botanical Gardens, and the Bay Plaza Shopping Center. Outfitting of the Fordham Road/Pelham Parkway bus corridor to accommodate for SBS came at a price tag of $10.5 million or $1.35 million per mile. Improvements to the route included off-board fare payment machines, enhanced bus stations, transit signal priority (25 of 30 intersections), articulated buses, and painted bus lanes (ITDP, 2011; MTA New York City Transit and NYC DOT, 2010). Bus lanes cover approximately 3.5 miles of the 7.8 mile route and are not physically separated, operating in mixed traffic for the remaining 4.3 miles. With the exception of 7 AM – 7 PM on weekdays, parking and traveling in the bus lane is permitted. All businesses with frontage along a bus lane are required to schedule deliveries from 10 AM – 2 PM. Bus lanes may also be used at all times for right-hand turns and pick up/drop off.

In terms of accessibility and service quality, the Bx12 SBS offers only slightly faster and more frequent service than the Bx12 Ltd. it replaced (Table 1.1). Hours of service have expanded to 5 AM through 11 PM. Level of service during peak periods has increased from 6-8 minutes to 5-6 minutes, while non-peak headways for both bus services are comparable. Average bus speeds have increased about 20%, cutting end-to-end travel times from 58 to 47 minutes. Off-board fare payment is responsible for about 50% of time travel reductions, shaving end-to-end dwell time at bus stops from nearly 15 minutes to 9.5 minutes (MTA New York City Transit and NYC DOT, 2010).

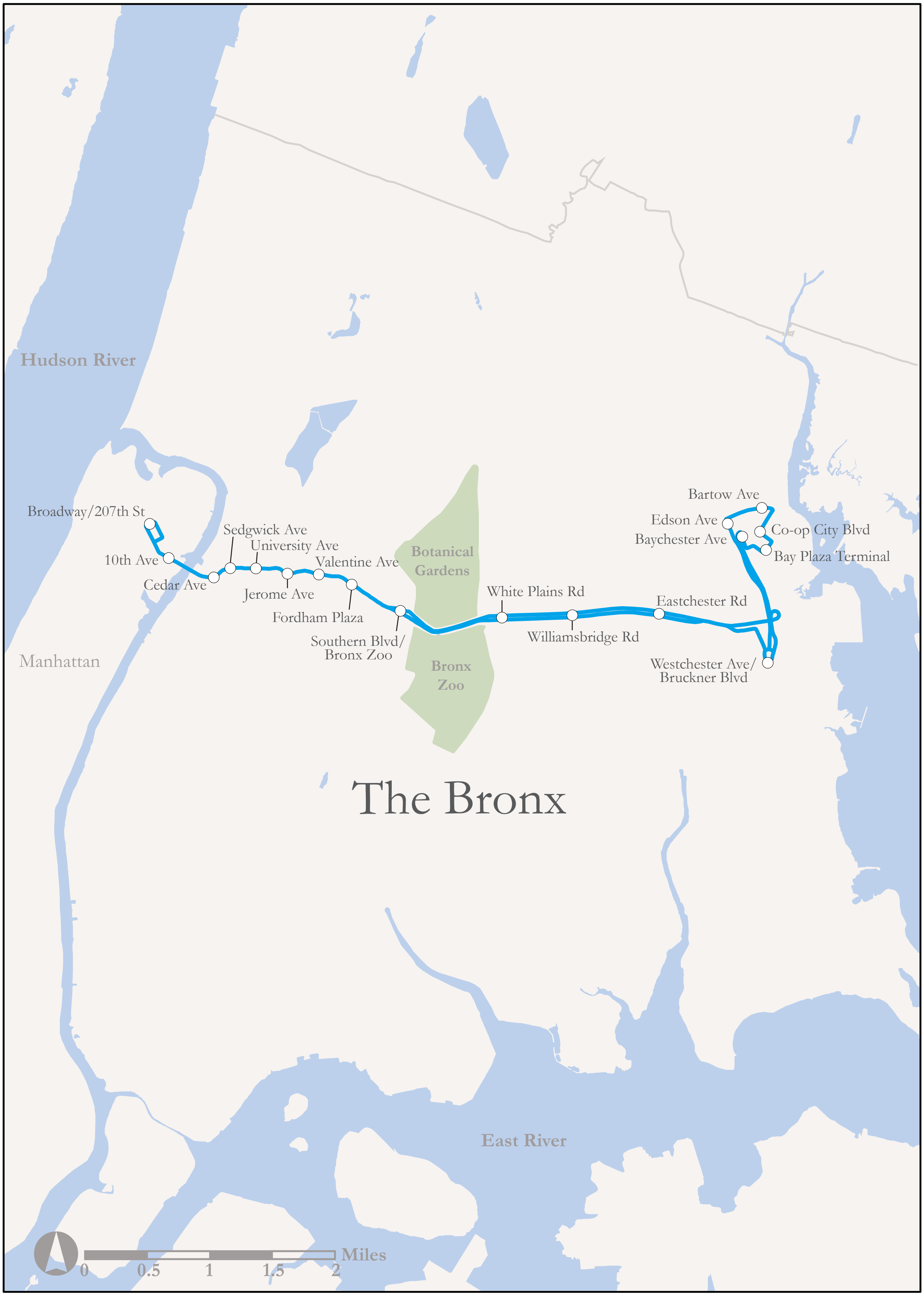
Table 1.1: Level of Service and Ridership Comparisons between Bx12 Ltd. and Bx12 SBS

		Frequency of Service (min)				
Bus Line	Hours of Service*	Peak	Off Peak	Avg. Vehicle Speed (mph)	End-to-End Length (min)	Avg. Daily Ridership**
Bx12 Ltd.	6 AM – 8:30 PM	6-8	7-10	8.0	57:54	42,219
Bx12 SBS	5 AM – 11:30 PM	5-6	7-8	9.4	46:44	45,495

* Approximate weekday, non-holiday service hours. Weekend service for Bx12 Ltd.: 10 AM – 7:30 PM on Saturday, no Sunday service. Bx12 SBS: 6 AM – 11:30 PM on both Saturday and Sunday.
**Average daily ridership figures represent the average for an entire year and include all Bx12 local bus service. Years of comparison were 2007 (Bx12 Ltd.) and 2009 (Bx12 SBS)

Sources: MTA New York City Transit, 2008; MTA New York City Transit and NYC DOT, 2010

Map 1.1: Fordham Road/Pelham Parkway Bx12 SBS Route



Map 1.2: Subway Connections to Manhattan

Idling Bx12 SBS bus at the Broadway/207th Street Station terminus in Manhattan

Passengers boarding at Broadway/207th Street Station

Off-board fare payment

Analyzed from a different perspective, the Bx12 SBS has reduced travel times on average by 22 seconds per stop. For many people riding the bus only a short distance (ex. home to subway), these time savings could be negligible.

Average daily ridership has responded to the SBS improvements, posting solid increases of 4.29% (2007-2008) and 7.75% (2007-2009) during a time when citywide bus ridership levels held stagnant (MTA New York City Transit and NYC DOT, 2010). Higher ridership figures are not necessarily the result of SBS attracting more people to bus travel, but rather could reflect the Bx12 SBS's extended hours of service and more frequent headways. Nevertheless, the response from riders has been overwhelmingly positive. Based on survey responses collected in August 2008, shortly after the beginning of service, 98% of SBS riders stated they were "satisfied" or "very satisfied" with the new service. A substantial majority (89%) felt that SBS service was better than the Bx12 Ltd. service it replaced (MTA New York City Transit and NYC DOT, 2010).

Based on the reductions in average travel times and rider survey responses, it is clear that the Bx12 SBS has improved accessibility and the quality of service along Fordham Road/Pelham Parkway, even if only marginally. Given these conditions and holding all else constant, it is expected that a person would be more willing to pay for proximity to SBS than a Ltd. service.

THEORETICAL FRAMEWORK & LITERATURE REVIEW

Early scholarly work on the relationship between transportation investments and land values ignored the questions posed by urban areas, choosing instead to theorize about the natural laws that governed land uses in an agricultural context. During the nineteenth century, economists sought to understand the pattern that agricultural land uses took and how rents were determined. David Ricardo (1817) and Johann Heinrich von Thünen (1826) revealed that the cost of transportation increased with distance from the market and that land rent is dependent on multiple factors, including the fertility of the land and location relative to the market. Having laid the theoretical foundations of land valuation, scholars at the turn of the twentieth century shifted their attention to its applications within an urban context.

Seminal urban land rent theories closely resembled those for agriculture, reiterating and advancing the notions that value is dependent on proximity and land goes to the highest bidder. While these studies opened the discussion on urban land rents, they did not extend to residential property or address the influence of land size on value (Alonso, 1964). Consequently, it was not until a more formal model emerged that urban land rent theory could be further developed.

The monocentric city model advanced by Alonso (1964), Mills (1967), and Muth (1969) stipulates that all employment occurs in a central business district (CBD), and that workers are faced with a tradeoff between the increasing costs of commuting and the decreasing prices of land associated with living farther away from the CBD. In recent decades, this basic concept has served as the theoretical premise for all transit capitalization studies. With accessibility to the CBD as a primary determinant of a household's willingness to pay, empirical studies have generally expected to find that transportation investments have some measurable impact on land and property values.

Empirical Studies of Railway Capitalization

Studies exploring the relationship between land or property values and transportation investments have typically focused on rail-based modes of transit. A form of hedonic price analysis is the most common method for evaluating the significance of the relationship. Common wisdom suggests that there is generally a positive, although modest relationship between the two, and that effects are greatest within immediate proximity of rail stations (Landis et al., 1995). For example, in a study of single-family home prices in San Francisco, Landis et al. (1995) found that home prices decreased up to $2.39 per meter distance from BART stations. More recent studies have revealed similar findings. Cervero and Duncan (2002a) found that multi-family units near light rail transit in San Diego demanded a premium of 2 – 6%. McMillen and McDonald (2004) confirmed earlier results by McDonald and Osuji (1995), finding a premium of

3% for every .25 mile distance closer to Chicago's Midway Line.

In a small handful of cases, researchers have reported that land and property values are negatively associated with proximity to mass transit (Landis et al., 1995; Forrest et al., 1996). In both of these studies, researchers attribute their results to the potential negative qualities associated with the transit service itself, such as limited service hours, slow operating speeds, and noise. Some have suggested that discrepancies in data and results between studies can be attributed to the importance of omitted variables, the specificity of results, the limitations of the methods used, or a combination of all three (Martinez and Viegas, 2008; Landis et al., 1995).

Empirical Studies of BRT Capitalization

Unlike rail service, BRT is still a nascent form of transit in the U.S. and there remains much to be learned. Table 2.1 provides a summary of recent research on the capitalization effects of BRT. The majority of studies have utilized a hedonic price analysis with distance from the nearest BRT station serving as an independent variable. One of the earliest empirical studies of BRT capitalization in the U.S. was undertaken by Cervero and Duncan (2002b). Relying on a hedonic price analysis that used .25 and .5-mile walking distances, results showed that residential properties in close proximity to BRT stations in Los Angeles generally sold for less while commercial properties sold for more. These results stand in contrast to more recent

Table 2.1: Summary of Selected BRT Capitalization Studies

Researchers	Intervention Area	Property Type	Comparison Method	Accessibility Measure	Results
Cervero & Duncan (2002b)	Los Angeles, CA	Residential & Commercial	Sales records; Hedonic	Walk distance; Straight-line & Along streets	Residential sells for less, but commercial sells for more near BRT stations
Rodriguez & Targa (2004)	Bogotá, Colombia	Multi-family	Sales listings; Hedonic	Walk time	Premium of 6.8-9.3% for every 5 minute walk closer to BRT station
Perdomo et al. (2007)	Bogotá, Colombia	Residential & Commercial	Sales listings; Propensity Score		Most comparisons found no BRT effect
Mendieta & Perdomo (2007)	Bogotá, Colombia	Residential & Commercial	Assessed value; Hedonic	Walk time; Straight-line	Price increase of .12-.38% for every 5 minute walk closer to BRT station
Rodriguez & Mojica (2009)	Bogotá, Colombia	Residential	Sales listings; Before/After	Walk distance; Straight-line	Price increase of 13-14% identified for target areas relative to control areas
Munoz-Raskin (2010)	Bogotá, Colombia	Residential	Sales listings; Hedonic	Walk time; Straight-line	Premium on properties in immediate walk of BRT feeder lines
Perk et al. (2010)	Pittsburgh, PA	Single-family	Hedonic	Walk distance	Property values increase with proximity to BRT.
Cervero & Kang (2011)	Seoul, Korea	Residential	Assessed value; Hedonic	Walk distance; Straight-line	Premium up to 10% for residential within 300 m; 25% for retail and non-residential within 150 m

studies that have used similar methodologies. Looking at the East Busway in Pittsburgh, Perk et al. (2010) used a hedonic model to find that single-family homes closer to BRT stations demanded higher premiums than those farther away. Comparable trends were uncovered by Cervero and Kang (2011), who used assessed values to estimate land price premiums of up to 10% for residences within 300 meters of Seoul's BRT stations. Even higher premiums (25%) were detected for retail and other non-residential uses within 150 meters.

The majority of capitalization research has focused on Bogotá, Colombia's TransMilenio. Opened in late 2000, the TransMilenio system has rapidly become one of the world's largest and is considered to be the premier example of BRT. Shortly after opening, Rodriguez and Targa (2004) used a hedonic price model to determine that for every 5 minutes of additional walking time to a BRT station, the rental price of a property decreased anywhere from 6.8 – 9.3%. Using assessed property values, Mendieta and Perdomo (2007) also found property values to increase with proximity to BRT stations. Price increases of .12-.38% for every 5 minute walk closer to a BRT station were observed. These results were later supported by Munoz-Raskin (2010), who found that the housing market places value premiums on properties within immediate walking proximity of feeder lines.

BRT studies conducted without the use of hedonic price analysis have also achieved some success. Rodriguez and Mojica (2009) used a before and after model based on McDonald and Osuji (1995) to assess the impact of TransMilenio's 2003 extension on the asking prices of residential properties. The study identified price increases of 13 – 14% for intervention areas relative to control areas unaffected by the extension. Evidence of anticipation effects in the real estate market for the year before the extension was also found.

Need for Further Research

While there is growing evidence that BRT is positively correlated with property values, the majority of research has taken place in Bogotá – a planning context that differs noticeably in its approach towards BRT implementation. Emerging in response to the city's pressing need for public transportation, the TransMilenio system received significant levels of municipal funding and was given special priority with the intention of creating a sophisticated network of high-speed bus routes. With over 385 route miles and 1.5 million daily riders, the TransMilenio has firmly established itself as the city's primary form of transit and played a significant role in shaping the city's built form and land use patterns (Rodriguez and Mojica, 2009; Munoz-Raskin, 2010). BRT in the U.S. has followed a different path, typically serving as a complement to already established systems rather than as a primary means of transit (ITDP, 2011). Furthermore, a perceived lack of need for transit improvements in addition to a shortage of municipal and federal funding has diminished the scale and ambition of BRT projects, leading to local and limited-stop routes being upgraded to BRT instead of the construction of fully built-out networks (ITDP, 2011). The consequences of these contextual differences for property values are certainly significant and serve to illustrate the multifaceted nature of BRT.

METHODOLOGY

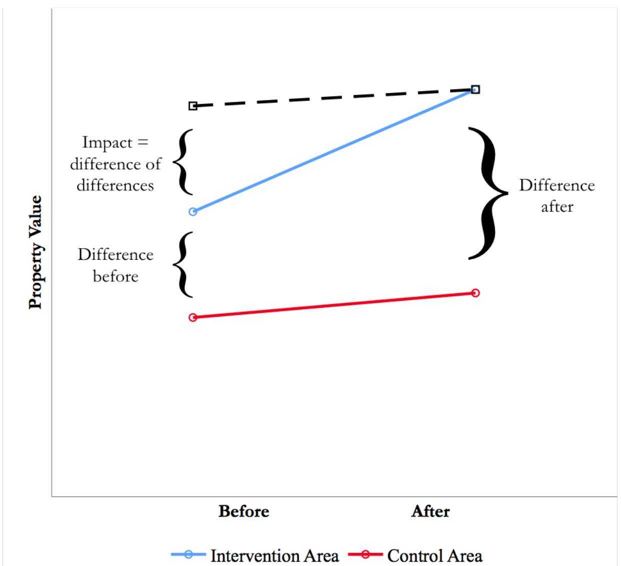
A before and after difference-in-differences (DID) approach is used to test whether or not the improvements to accessibility and quality of service resulting from the implementation of the Bx12 SBS have been reflected in residential property values. The DID model estimates the impact of the Bx12 SBS by comparing differences between time periods (before and after) and across research areas (intervention and control areas). As illustrated in Figure 3.1, the before period difference is subtracted from the after period difference, leaving behind the double difference, or estimated impact.

Drawing on the research of McDonald and Osuji (1995) and Rodriguez and Mojica (2009), the basic DID regression equation used for calculating the effect of the Bx12 SBS on residential property values is:

$$V_{i,t} = \alpha + \beta\Gamma_i + \gamma P_t + \delta\Gamma_i * P_t + \varepsilon_{i,t}$$

where $V_{i,t}$ is the change in value for property i in year t, Γ_i is a binary variable indicating location (=1 if property is within intervention area, =0 if property is within control area), P_t is a binary variable indicating time (=1 indicating an "after" year, =0 if indicating a "before" year), $\Gamma_i * P_t$ is an interaction term of location and time (=1 only in the "after" period if property i falls within the intervention area), $\varepsilon_{i,t}$ is a normally distributed error term with constant variance, and α, β, γ, and δ are the coefficients to be estimated through the regression. For the purposes of this study, the interaction term $\Gamma_i * P_t$ is of greatest importance and is used to evaluate the statistical significance of the combined effect of location and time on property values.

Figure 3.1: Difference-in-Differences (DID)



Using the DID approach, the impact of two separate events on residential property values will be estimated. The effect of the first event, the 2006 announcement of future SBS service along Fordham Road/Pelham Parkway, will be estimated by comparing changes between 2005 and 2007 across intervention and control areas. It is reasoned that with the expectation of future SBS service along the bus corridor, the 2006 announcement could have triggered a response in intervention area property values. Of more central focus to this study is the second time period, which will test how residential properties that had access to local and limited-stop service have responded to the benefits of BRT since the beginning of service in 2008. The impact of the 2008 opening will be estimated by analyzing the changes between 2007 and 2009 across intervention and control areas.

The basic DID model can be extended to include additional variables that influence property values. Previous BRT capitalization studies have included measures of a property's structural quality, neighborhood characteristics, transportation accessibility, and quality of local services. Due to data constraints, this investigation is limited to the following four housing characteristics:

1. *Square footage of residential area* (*RESAREA*): *RESAREA* is an estimate of the portion of the property allocated for residential use. The price of the property is expected to increase with residential area. Thus, the larger the property the more expensive it is likely to be. Previous capitalization studies have found this to be the single best predictor of home prices (Landis et al., 1995).
2. *Year of construction* (*YEARBUILT*): The value placed on this variable is highly dependent on the city and neighborhood in which the property is located. Whereas older homes may be associated with architectural and historical character in some areas, they may be a sign of obsolescence in others. Thus, the value of property is highly dependent on this interpretation.
3. *Current floor-area-ratio* (*BUILTFAR*): Local zoning regulations can have a tremendous influence on property values. For this reason, *BUILTFAR* is used as a determinant of residential property type, where multifamily units are only permitted in areas with an FAR greater than or equal to 2. All else being equal, properties with higher existing FAR should generally be more valuable.
4. *Maximum allowed floor-area-ratio* (*MAXFAR*): All else being equal, it is expected that properties with higher maximum permitted FAR are more highly valued. During the time frame analyzed within this study, multiple rezonings took place in Bronx County that could have had some impact on property values.

The inclusion of these additional variables allows for changes between the before and after period to be accounted for, helping to better explain the estimated impact of the Bx12 SBS on residential property values. Table 3.1 provides mean values for each of these variables.

One limitation of the DID approach is that the effect of inflation and other secular influences on the residential property market such as the 2008 economic recession cannot be isolated from the impact of replacing Ltd. service with SBS. Thus, it is possible that price increases or decreases could be a reflection of overall trends in the property market, and not simply the result of SBS (Rodriguez and Mojica, 2009). To help correct this problem, control area properties that were unaffected by the replacement of Ltd. service with SBS are included in the analysis.

Table 3.1: Mean Values of Property Characteristics by Area and Time Period

			Intervention Area		Control Area	
			Walking Time in Minutes		Walking Time in Minutes	
Variable	Units	Data Source	0-5	5-10	0-5	5-10
2005						
Assessed Value	2005$	PLUTO	$165,462	$124,654	$109,570	$99,150
Residential Area (RESAREA)	sqft	PLUTO	13,902	11,491	9,227	7,685
Year of Construction (YEARBUILT)	year	PLUTO	1928	1934	1919	1928
Current FAR ≥ 2 (Dummy: BUILTFAR)		PLUTO	0.33	0.19	0.20	0.16
Maximum Allowed FAR ≥ 2 (Dummy: MAXFAR)		PLUTO	0.63	0.44	0.72	0.59
Observations			1,809	4,975	3,091	3,893
2007						
Assessed Value	2007$	PLUTO	$174,590	$136,487	$120,752	$107,475
Residential Area (RESAREA)	sqft	PLUTO	13,802	11,410	9,402	7,697
Year of Construction (YEARBUILT)	year	PLUTO	1930	1935	1923	1929
Current FAR ≥ 2 (Dummy: BUILTFAR)		PLUTO	0.33	0.19	0.21	0.16
Maximum Allowed FAR ≥ 2 (Dummy: MAXFAR)		PLUTO	0.63	0.44	0.67	0.52
Observations			1,835	5,072	3,175	3,931
2009						
Assessed Value	2009$	PLUTO	$206,560	$154,301	$131,482	$118,418
Residential Area (RESAREA)	sqft	PLUTO	13,671	11,291	9,380	7,691
Year of Construction (YEARBUILT)	year	PLUTO	1930	1936	1932	1932
Current FAR ≥ 2 (Dummy: BUILTFAR)		PLUTO	0.34	0.20	0.23	0.17
Maximum Allowed FAR ≥ 2 (Dummy: MAXFAR)		PLUTO	0.62	0.44	0.62	0.51
Observations			1,868	5,175	3,308	4,011

Selection of Intervention and Control Areas

Two intervention areas, one representing all properties within a 0-5 minute walk and the other representing all properties within a 5-10 minute walk, were used to compare how proximity to SBS influences the size of the capitalization effect. Intervals of 0-5 and 5-10 minutes are generally considered to be acceptable walking times to transit and have been used throughout the BRT literature (Rodriguez and Targa, 2004; Mendieta and Perdomo, 2007; Munoz-Raskin, 2010). All properties within the designated walking times were identified using the network analyst tool in ArcGIS. Assuming an average pedestrian walking speed of 3 mph and that all travel takes place on sidewalks, network analyst was used to generate 0-5 and 5-10 minute walking areas from all SBS stations (Map 3.1). This stands in contrast to the vast majority of studies, which have used a simpler and less accurate "as-the-crow-flies" buffer distance, ignoring how pedestrians actually move through space.

In order for meaningful insight to be drawn from the investigated properties, comparisons had to be made with properties that did not benefit from the replacement of local or Ltd. service with SBS. The Bx40 and Bx42, which provide simultaneous local bus service along Tremont Avenue in the Bronx, were identified as appropriate for determining control areas. Lying just south of Fordham Road/Pelham Parkway, Tremont Avenue was chosen because it is a similar east-west thoroughfare that connects both high and low density residential and commercial areas to numerous subway and commuter rail lines. Similar to intervention areas, specific control areas and the residential properties within them were identified based on 0-5 and 5-10 minute walking times using the ArcGIS network analyst tool (Map 3.2). Since the Bx40 and Bx42 service a larger area than the Bx12 SBS, only a selected portion of the bus route was included in the control area. As seen in Table 3.1, this allowed for comparison of an approximately equal number of properties between intervention and control areas.

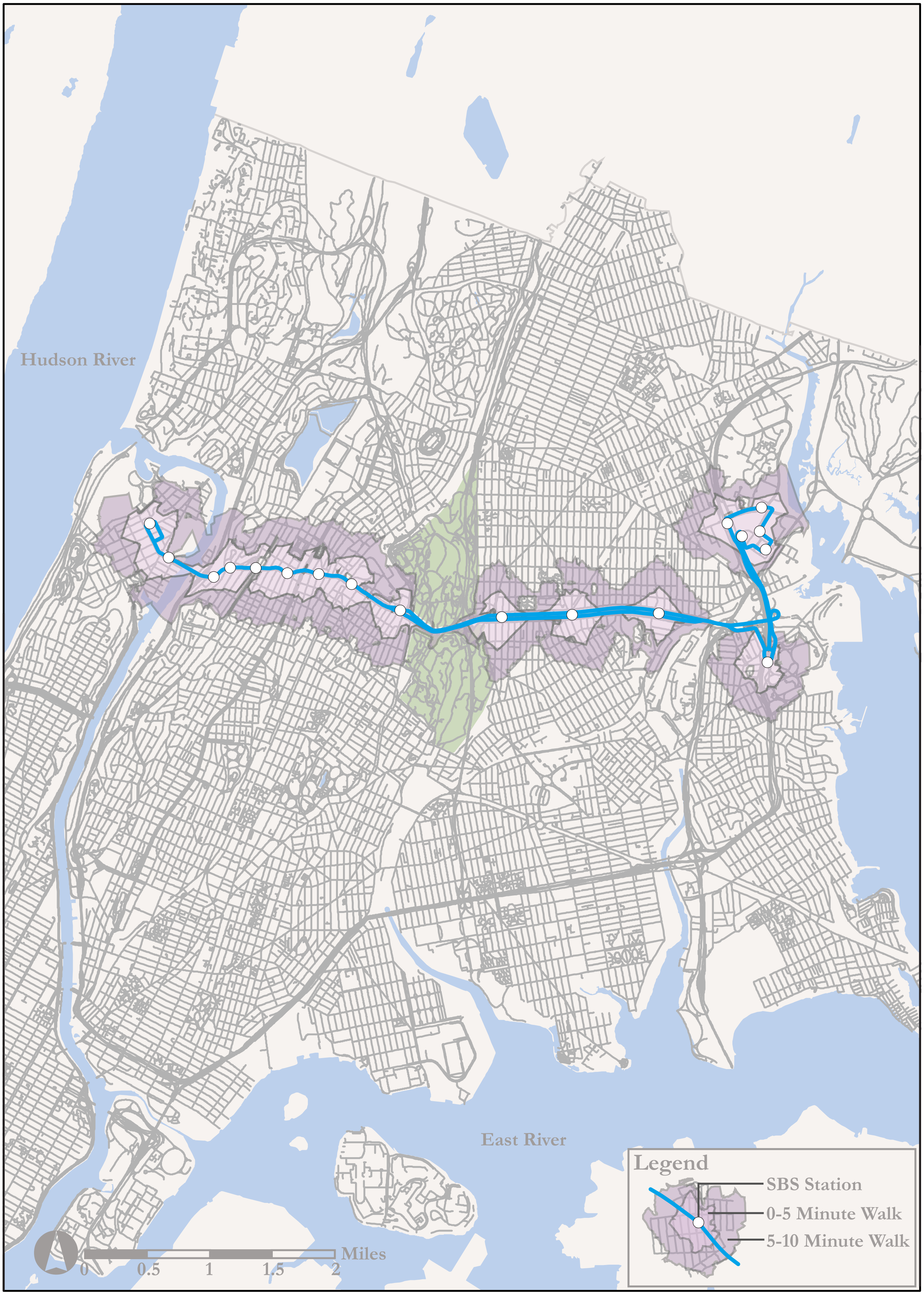
Data Sources

All property data within this study were compiled by the New York City Department of Finance and provided through the New York City Department of City Planning in the form of Primary Land Use Tax Lot Output (PLUTO) data. PLUTO is released bi-annually and contains over seventy fields of extensive land use and geographic data at the tax lot level. In order to estimate the impact of the 2006 announcement of future SBS service and the 2008 opening of Bx12 SBS service, data were collected for the years before (2005, 2007) and after (2007, 2009) each event.

This study uses actual assessed value, herein referred to as "assessed value" or "property value," as a measure of property value. Assessed values are calculated by the New York City Department of Finance by multiplying the tax lot's estimated full market value by a uniform "level of assessment" for the property's tax class. This value is then compared to calculations made using New York State laws to limit how much the assessed value can increase from year to year. The lower amount between the two is considered the assessed value (New York City Department of City Planning, 2008; New York City Department of Finance, 2012).

While a property's historical selling price may be perceived as a more precise reflection of property value, there is ample precedent (Mendieta and Perdomo, 2007; Cervero and Kang, 2011) and justification for the use of assessed values. Unlike sales transaction data, assessed values are updated annually and serve as a relatively complete data source. Furthermore, assessed values provide systematic and generally conservative estimates, whereas market transaction data can often be inflated or reflect seasonal variations in demand or local economic conditions (Armstrong and Rodriguez, 2006). However, it should be noted that assessed property values are not entirely indicative of market values and that many assessments take several years to catch up with market value growth or decline (Spengler, 1930; New York City Department of Finance, 2012).

Map 3.1: Intervention Area - Network Analysis Polygons



Map 3.2: Intervention and Control Area Properties

FINDINGS

Analysis of the capitalization effects of the Bx12 SBS is divided into two sections. The first section discusses results of the basic DID model while results of the extended model are presented in the second.

Basic DID Model

The results of the first four regressions have been compiled in Table 4.1 and 4.2. Results were obtained using a robust model after all regression equations were found to exhibit heteroskedasticity. Indication of a statistically significant relationship between property values and the independent variables occurs at the 5% level when P>|t| is less than 0.05. During both time periods, the intervention area (IA) coefficient for properties within a 0-5 minute walk is statistically significant. Similarly, regression models for a 0-5 minute walk over both time periods were significant as a whole with P-values of less than 0.05. All models exhibited low R-square values, suggesting the model parameters fit the data poorly.

In 2005, before the announcement of future SBS service along Fordham Road/Pelham Parkway, residential properties falling within the intervention area (IA) of 0-5 minutes were valued at a premium of $55,892.64. Based on the value of the CONSTANT coefficient, the representative value of properties outside of the intervention area and before the announcement was $109,570.20. Thus, residential properties within the 0-5 minute intervention area were valued at a total of $165,462.84 in 2005. The interaction term

Table 4.1: Capitalization Effects 2005-2007

	0-5 Minute Walk (2005-2007)				5-10 Minute Walk (2005-2007)			
	Coefficient	Std. Error	t-value	P>|t|	Coefficient	Std. Error	t-value	P>|t|
IA	55,892.64	16,006.70	3.49	0.000	25,504.73	23,942.18	1.07	0.287
YEAR	11,182.08	18,170.42	0.62	0.538	8,325.64	20,001.76	0.42	0.677
IA_YEAR	-2,053.92	23,869.18	-0.09	0.931	3,507.60	36,931.93	0.09	0.924
CONSTANT	109,570.20	12,017.11	9.12	0.000	99,149.67	13,718.86	7.23	0.000
Prob > F		0.0001				0.4916		
R-Squared		0.0018				0.0001		
Observations		9,910				17,871		

Table 4.2: Capitalization Effects 2007-2009

	0-5 Minute Walk (2007-2009)				5-10 Minute Walk (2007-2009)			
	Coefficient	Std. Error	t-value	P>|t|	Coefficient	Std. Error	t-value	P>|t|
IA	53,838.71	17,706.50	3.04	0.002	29,012.33	28,120.03	1.03	0.302
YEAR	10,729.90	21,343.53	0.50	0.615	10,942.66	23,009.89	0.48	0.634
IA_YEAR	21,239.66	26,981.99	0.79	0.431	6,871.13	44,454.49	0.15	0.877
CONSTANT	120,752.20	13,629.06	8.86	0.000	107,475.30	14,555.49	7.38	0.000
Prob > F		0.0000				0.4624		
R-Squared		0.0019				0.0001		
Observations		10,186				18,189		

(IA_YEAR) was not significant based on a P-value of 0.931 within a 0-5 minute walk and 0.924 within a 5-10 minute walk. These results do not necessarily mean that properties within an intervention area after the announcement and opening of SBS are not more highly valued. It does mean there is only a 6.9% and 7.6% probability that location within the IA has an impact on property values.

Results found for 2007-2009 closely resembled those of 2005-2007. Before the opening of Bx12 SBS service, a premium of $53,838.71 was estimated for all intervention area residential properties within a 0-5 minute walk. The estimated total value of residential properties was $174,590.91, an increase of $9,128.07 from 2005. The IA_YEAR coefficient was again found to be not statistically significant. However, it can be said with 56.9% probability that being located within a 0-5 minute walk after the opening of SBS added $21,239 to property values relative to control area properties located at the same walking interval.

A difference-in-differences proof was used in order to replicate and confirm the estimates produced by the four regressions discussed above. Tables 4.3 through 4.6 show how the double difference can be computed as the difference between time periods (before and after) and across research areas (intervention and control areas). Found in the bottom-right of each table, the DID estimate confirms the coefficient of IA_YEAR for each respective time period. It can also be seen that the before period average assessed value for control area properties matches the CONSTANT coefficient in each case. Based on this proof, it can be certain that the results obtained in Tables 4.1 and 4.2 are not the result of researcher error and that any lack of significant interaction terms could possibly lie in the modeling parameters.

Expanded DID Model

Using all variables from the original regressions, including those that were found statistically insignificant, the DID model was expanded and rerun in an attempt to better inform the relationship between SBS and residential property values. A robust model was again used to correct for heteroskedasticity. The results compiled in Tables 4.7 and 4.8 indicate that the presence of the four additional independent variables changed the original results only slightly.

Beginning with Table 4.7, it is clear the model fits the data better in the presence of the additional variables, explaining 49% of variation in the sample of 0-5 minute walk residential property values and 85% of variation in the sample of 5-10 minute walk residential property values. Given the large sample size and diversity of the samples, these are decent measures of goodness-of-fit. Both models possess an overall P-value of 0.0000, indicating that collectively the independent variables are a reliable predictor of property value.

The value and statistical significance of the coefficients varies by walking time. Residential area (RESAREA) is the most significant variable for both walking times. In a 0-5 minute walk, every additional square foot of residential living area above the mean added $13.50 to the value of a property in 2005. In a 5-10 minute walk, every additional square foot of residential living area added $8.41. The coefficient for the year of construction (YEARBUILT) was also statistically significant and positive for both walking times. This result suggests that newer homes are generally more highly valued in the sample neighborhoods. Properties in a 0-5 minute walk were valued at $19.18 for every additional year above the mean, while newer properties farther away were even more valuable, adding $130.24 for every additional year above the mean. The coefficients measuring location within the intervention area (IA), "after" time period (YEAR), and the combined term of location within the investigation during the "after" time period (IA_YEAR) were not statistically significant in either walking times.

The two variables describing FAR also vary in importance and significance by walking time. In 2005, properties within a 0-5 minute walk did not place greater value on existing FAR of greater than or equal to 2, in contrast to properties within a 5-10 minute walk, which valued existing FAR at a premium of $193,733. This trend could be the result of residential property markets at farther walking distances having fewer high density buildings, allowing those properties that do have FAR greater than or equal to 2 to be more highly valued. Similarly, maximum allowed FAR was valued at a premium of $7,866 within a 0-5 minute walk, but

Table 4.3: DID Estimates of 0-5 Minute Walk (2005-2007)

-	Average Assessed Property Value 2005	2007	Difference between Years	-
Properties in Study Area 0-5 minute walk	$165,462.80	$174,590.90	$9,128.10	
Properties in Control Area 0-5 minute walk	$109,570.20	$120,752.20	$11,182.00	
Difference between areas	$55,892.60	$53,838.70	-$2,053.90	
DID estimate			**-$2,053.90**	

Table 4.4: DID Estimates of 5-10 Minute Walk (2005-2007)

-	Average Assessed Property Value 2005	2007	Difference between Years	-
Properties in Study Area 5-10 minute walk	$124,654.40	$136,487.60	$11,833.20	
Properties in Control Area 5-10 minute walk	$99,149.67	$107,475.30	$8,325.63	
Difference between areas	$25,504.73	$29,012.30	$3,507.57	
DID estimate			**$3,507.57**	

Table 4.5: DID Estimates of 0-5 Minute Walk (2007-2009)

-	Average Assessed Property Value 2007	2009	Difference between Years	-
Properties in Study Area 0-5 minute walk	$174,590.90	$206,560.50	$31,969.60	
Properties in Control Area 0-5 minute walk	$120,752.20	$131,482.10	$10,729.90	
Difference between areas	$53,838.70	$75,078.40	$21,239.70	
DID estimate			**$21,239.70**	

Table 4.6: DID Estimates of 5-10 Minute Walk (2007-2009)

-	Average Assessed Property Value 2007	2009	Difference between Years	-
Properties in Study Area 5-10 minute walk	$136,487.60	$154,301.40	$17,813.80	
Properties in Control Area 5-10 minute walk	$107,475.30	$118,418.00	$10,942.70	
Difference between areas	$29,012.30	$35,883.40	$6,871.10	
DID estimate			**$6,871.10**	

Table 4.7: Capitalization Effects 2005-2007

	0-5 Minute Walk (2005-2007)				5-10 Minute Walk (2005-2007)			
	Coefficient	Std. Error	t-value	P>|t|	Coefficient	Std. Error	t-value	P>|t|
IA	-6,845.90	11,361.03	-0.60	0.547	-13,067.36	11,584.54	-1.13	0.259
YEAR	9,107.77	14,108.13	0.65	0.519	7,190.43	15,259.70	0.47	0.638
IA_YEAR	1,354.85	14,884.85	0.09	0.927	4,613.59	16,349.34	0.28	0.778
RESAREA	13.50	0.56	23.94	0.000	8.41	0.71	11.87	0.000
YEARBUILT	19.18	9.27	2.07	0.039	130.24	34.41	3.78	0.000
BUILTFAR	1,541.48	29,005.99	0.05	0.958	193,733.30	27,587.71	7.02	0.000
MAXFAR	7,866.99	2,049.07	3.84	0.000	2,620.97	1,982.26	1.32	0.186
CONSTANT	-57,818.01	17,284.91	-3.34	0.001	-248,368.30	65,447.41	-3.79	0.000
Prob P > F		0.0000				0.0000		
R-Squared		0.4985				0.8553		
Observations		9,910				17,871		

Table 4.8: Capitalization Effects 2007-2009

	0-5 Minute Walk (2007-2009)				5-10 Minute Walk (2007-2009)			
	Coefficient	Std. Error	t-value	P>|t|	Coefficient	Std. Error	t-value	P>|t|
IA	-10,615.67	13,025.33	-0.82	0.415	-14,948.86	11,691.97	-1.28	0.201
YEAR	10,969.60	18,052.25	0.61	0.543	9,236.49	17,380.09	0.53	0.595
IA_YEAR	22,493.10	18,928.63	1.19	0.235	8,921.40	18,600.34	0.48	0.631
RESAREA	13.64	0.49	27.84	0.000	10.52	0.87	12.14	0.000
YEARBUILT	-0.74	17.70	-0.04	0.967	52.95	33.85	1.56	0.118
BUILTFAR	40,411.44	31,498.27	1.28	0.200	163,947.60	31,379.11	5.22	0.000
MAXFAR	12,912.19	2,924.26	4.42	0.000	2,567.43	2,091.47	1.23	0.220
CONSTANT	-23,202.39	33,523.48	-0.69	0.489	-103,392.60	64,650.20	-1.60	0.110
Prob P > F		0.0000				0.0000		
R-Squared		0.3762				0.8723		
Observations		10,186				18,189		

was not more highly valued at a time of 5-10 minutes. These results confirm the expectation that properties with the potential for higher FAR within close proximity to a major thoroughfare such as Fordham Road/Pelham Parkway are more highly valued.

Turning to Table 4.8, it is apparent that the model fits the data rather well given the large sample size. The model explains 37% of variation in the sample of 0-5 minute walk residential property values and 87% of the variation in the sample of 5-10 minute walk residential property values. Both models were found to be statistically significant at the 5% level.

In the 2007-2009 time period, the coefficients of all statistically significant variables closely resembled those from 2005-2007 with the exception of YEARBUILT. In 2007, newer homes were no longer more highly valued within 0-5 and 5-10 minute walk times. RESAREA was the only significant variable within both walking intervals. Every additional square foot of residential living area increased value by $13.64 within a 0-5 minute walk and by $10.52 within a 5-10 minute walk. The coefficients IA, YEAR, and IA_YEAR, were again found to be not statistically significant in either walking interval.

The two variables describing FAR followed a familiar pattern. In 2007, properties within a 0-5 minute walk did not place greater value on existing FAR of greater than or equal to 2, in contrast to properties within a 5-10 minute walk, which valued existing FAR at a premium of $163,947. Similarly, maximum allowed FAR was valued at a premium of $12,912 within a 0-5 minute walk, but was not more highly valued at a time of 5-10 minutes.

Summary of Findings

Both the basic and extended DID models failed to produce a statistically significant interaction term, suggesting that residential properties within immediate proximity to Bx12 SBS stations after the 2006 announcement and 2008 opening were not more highly valued relative to control area properties. While it cannot be said with 95% probability, the possibility that SBS positively influenced residential property values should not be ruled out entirely. It is possible that these models were not able to detect such an effect.

The results of this study stand apart from the established literature on BRT capitalization, with only Perdomo et al. (2007) finding that the opening of the TransMilenio system did not significantly impact residential properties in Bogotá. Given the differences between BRT in these two cities in terms of social context, scale, and quality of service, it was anticipated that the intensity of capitalization would be lower in New York, but still present. The complete absence of significance suggests that the marginal improvements in quality of service that resulted from the replacement of limited-stop bus service with SBS were not enough to positively influence residential property values. One possible interpretation of these results is that the gap between SBS and best-practice examples of BRT internationally is wider than initially thought. Despite possessing some common elements of BRT (off-board fare payment, dedicated bus lanes, transit-signal priority, low floor buses), the Bx12 SBS's inability to significantly improve quality of service distances it from best-practice systems and helps explain why residential property values were not measurably impacted (ITDP, 2011). Alternatively, these results could be a testament to New York's already well-developed and ubiquitous multimodal transit system. While most recent studies have found a positive relationship between BRT and property values, research has taken place in cities that previously lacked transit, making direct comparisons to SBS difficult. In order to produce a measurable impact on property values in New York, it is probable that a more extensive and sizable transit project would be required.

The results presented here, however, are not conclusive, as this research has likely examined the impact of the Bx12 SBS too soon after the 2008 opening. While some studies have taken place shortly after opening (Rodriguez and Targa, 2004), the majority have waited with the expectation that capitalization effects of BRT take years to manifest. Furthermore, in order to get a better picture of SBS's impact over time, the "after" period of the DID model should account for a series of years, not just one (Rodriguez and Mojica, 2009). This was not done because of time and data constraints.

The availability of data also limited the number of additional variables included within the extended DID model. The omission of relevant variables, including measures of public services, socioeconomic status, and neighborhood characteristics could be leading to a bias of unknown direction and magnitude in the coefficients of independent variables (McDonald and Osuji, 1995). This is a chronic issue faced by researchers using both DID and Hedonic models – regardless of the number of explanatory variables included, there will always be some left out.

Further concerns included the inability of the DID models to isolate the effects of inflation and the global economic recession of 2008. While it is assumed that inflation and the recession impacted both study area and control area property values equally, it cannot be said with any certainty. Other studies that have not isolated the impact of inflation have still achieved good results, including Rodriguez and Mojica's 2009 study of the TransMilenio, which identified price increases of 13-14% for intervention areas relative to control areas that were unaffected.

Lastly, the use of assessed values as a measure of property value could have an impact on the results. While a number of recent capitalization studies have used assessed values, including Mendieta and Perdomo (2007) and Cervero and Kang (2011), the approach is not without its faults. The New York City Department of Finance acknowledges that assessed property values are not entirely indicative of market values and that many assessments take several years to catch up and reflect actual market growth or decline. Thus, there is a possibility that some of the assessed values used within this study are delayed and reflect market conditions of previous years.

PLANNING IMPLICATIONS

This study provides planners and policymakers in New York City with a more complete picture of the SBS program and the impact of upgrading from local or Ltd. service to SBS on surrounding properties. Despite the overwhelmingly positive response from riders, the upgrade has only marginally improved the quality of service along Fordham Road/Pelham Parkway and has not increased surrounding residential property values. At a price tag of $10.5 million, are the benefits worth the cost? The answer to this question seems to depend on the future of the SBS program. It remains to be seen whether or not future SBS lines will use the Bx12 SBS pilot project as a strict blueprint or choose to improve and build upon it. In order to provide a higher quality of service, future SBS lines must place greater emphasis on outfitting all intersections with transit-signal priority, banning personal-automobile travel in bus lanes, ensuring that buses do not operate in mixed-traffic, and streamlining the boarding process to more closely resemble subway travel. Incorporating these features into future SBS projects will provide a higher quality of service that will increase the potential for capitalization effects.

Without identifying measurable increases in property values, the potential of SBS as a tool for economic development remains limited. Often, increases in property values are associated with new development and changes in land use patterns. If no increases in property values are identified, the jobs and revenues associated with new development and changes in land use patterns will likely not result. Furthermore, innovative methods of financing public transit will not be applicable. Without measurable increases in property values, there is no potential for a "self-sufficient" transit system through tax increment financing.

It has been the intent of this study to serve as a starting point for further research of BRT in the U.S. and SBS in New York City. It would be beneficial to revisit the results of this study at a later date when the capitalization effects of the SBS are more fully apparent. Given more time and data, future studies may prove more insightful and challenge what has been presented here.

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