RAIL TRANSIT

9109849

RESIDENTIAL LAND USE IMPACTS

Paul Lillehaugen | 100 Resilient Cities | paul.lillehaugen@gmail.com

ABSTRACT

When evaluating rail transit's potential to create dense, livable places, clearly defining the expected outcomes and examining appropriate timeframes are important considerations. Boston's rail transit extensions in the 1970s and 1980s show evidence that improved access to rail transit is associated with increased density of housing stock. However, the effects take decades to be reflected, an important consideration for project assessment.

KEY POINTS

- According to analysis of data from the Boston metro area between 1960 and 2000, improved access to rail transit is correlated with increased density of both population and housing stock
- Locations within the immediate vicinity of a new rail station (within 1,000 meters) do not exhibit any significant increase in population when compared with areas further from the new stations, but they do show some evidence of increased density of housing stock
- This relationship only appears in the third census period (between twenty and thirty years) after construction of a new rail transit station
- There is wide variation between the results in individual station catchment areas
- The timeframe required to see results approaches or exceeds the typical depreciated lifespan of a fixed asset and the length of a traditional mortgage – while the impacts are real, their realization requires a far longer view than most investors take

> ***Planners and policy makers have long viewed transportation policy as a potential tool to control broad patterns of urban land use and metropolitan development. Expanded or improved mass transit in cities is often alleged to lead to more compact residential and commercial development.***
>
> – John R. Meyer and José A. Gómez-Ibáñez
> *Autos, Transit, and Cities*

QUESTION: Does the evidence support this view?

CONTEXT

Boston has one of the oldest urban rail transit systems in the United States, including the first underground subway system. Under various guises, it developed throughout the late 19th and early 20th centuries into one of the nation's largest and most comprehensive systems. While it saw a lull in expansion throughout the middle of the century, the system, now under the auspices of the Massachusetts Bay Transportation Authority (MBTA), had a second phase of construction from the 1970s to the 1980s and has now begun construction on what will be the first extension in over 30 years, the extension of the Green Line from Lechmere, through the city of Somerville to a new terminus in Medford.

Previous stations have been placed in locations with a wide variety of preliminary characteristics and have seen great variance in their subsequent levels of development. These differences in both initial conditions and post-transit growth have, in combination, resulted in markedly different places today, from vibrant neighborhoods to remote park-and-ride facilities and rail yards. In this context, it is worth examining the experiences of the most recent construction period to determine what lessons can be learned to improve understanding of the likely outcomes at the proposed Green Line stations, as well as any lessons that can be learned which could be used to ensure that new station developments perform as hoped and intended.

Boston is also an appropriate place for this study because a long-range timeframe is essential to studying the physical land use impacts of transit development. While Nathaniel Baum-Snow and Matthew E. Kahn indicate that "it appears that less than ten years is ample time for the new commuting equilibria to be achieved" in the movement of people when new rail transit is built, the 1979 BART Land Use Impact Report from the U.S. Department of Transportation concedes that, as most of its studies were done within the first four years after BART was opened, "some of its impacts, particularly those relating to urban development, will require more time to mature." Hence, Boston provides an ideal location to study the land use effects of rail transit development as it has a variety of stations built within an adequate timeframe. The 1970s and 1980s are recent enough for relatively fine-grained data on socioeconomic and physical characteristics of an area to be available, yet distant enough to allow residential land use changes, if they are to happen, to have taken hold.

Indeed, timescale is of the utmost importance in this instance. One would expect that, given an efficiently-functioning housing market, home prices ought to adjust to changes in transit accessibility relatively rapidly, perhaps nearly instantaneously. Conversely, investments in infrastructure have physical ramifications for decades, even long after the infrastructure itself has disappeared. David Block-Schacter finds that "[c]urrent density and travel behavior patterns are measurably influenced by past access to rail," regardless of whether the rail itself remains in place today. In a similar manner, the housing stock of a neighborhood does not simply reshape itself to the whims of a new marketplace. As with any physical asset, homes are "sticky" and require some time to accommodate the new reality engendered by the opening of a nearby rail transit station. As such, taking a long-term assessment of the impact that improved rail transit access has on housing may reveal impacts that would not be seen in studies conducted shortly after the opening of the new rail expansion.

ACKNOWLEDGMENTS

This poster is the result of research conducted for my thesis as a part of the Masters in Urban Planning program at the Harvard University Graduate School of Design. It was presented there in various formats in the spring of 2016. As such, a heartfelt thank you goes to my thesis advisor, Professor Tony Gómez-Ibáñez. This work owes much to him and would not have been completed without his mentorship.

Additional thanks are due to Professor Michael Hooper, who tirelessly coached my thesis cohort through the process of developing and honing our ideas, as well as to Julia Smachylo, our patient and insightful Teaching Fellow.

Finally, thank you to the team at the Harvard Map Collection for their invaluable help in navigating the Neighborhood Change Database.

Image 1: Housing development near the Malden Center MBTA Station [author's photo]

METHODS

My approach to the study of the residential impacts of urban rail transit stations in Boston consists of two main pieces of analysis:

1. Regression analysis of past and current land use around the selected stations on the MBTA Red Line and Orange Line extensions to determine the extent to which improvements in transit accessibility can predict the future pattern of development at the site, including consideration of differences in initial and current conditions at various station sites
2. Comparative statistical analysis of residential changes for a select group of example stations which saw the most marked increase in transit accessibility during this time

Data Acquisition and Cleaning

In order to analyze the impact that a new transit station has on the nearby residential environment, historical demographic and social data was obtained from the Neighborhood Change Database (NCDB). As a part of NCDB, census data for the years 1970 to 2010 are standardized into consistent 2010 census tracts, allowing for comparisons to be made across time. For the purposes of this study, the Census Tracts considered are those which are a part of the portion of the *Boston-Cambridge-Newton, MA-NH Metropolitan Statistical Area* Core Based Statistical Area (CBSA) and are located in the Commonwealth of Massachusetts. The area studied includes 914 census tracts (n=914) as defined by 2010 boundaries.

However, while the 2010 data is the most accurate, it is the least consistent with the other years' data. Several tracts – including ones in South Boston and East Boston, as well as farther afield – appear to have been awkwardly weighted by the NCDB formula and exhibit strange jumps in population, seeing as much as 99% of their population disappear in ten years or, conversely, seeing population gains of more than 1000% over ten years. In each case, it appears that large amounts of housing from one census tract has been inappropriately attributed to a nearby (and lightly-populated) census tract in some years. The majority of major discontinuities between years occur between 2000 and 2010. Because of the difficulties in determining how much change between 2000 and 2010 is due to actual measurable changes in residential patterns and how much is due to inaccuracies embedded in NCDB, this analysis has involved only 1970 to 2000 data.

Station Location Classification

In order to relate historical census information to the changes in MBTA rail transit during the 1970s and 1980s, GIS data of the location of current MBTA stations had to be augmented with information about the dates when stations opened since 1970 (so that they could be removed from analysis of earlier dates), and locations of former stations that have closed since 1970, so they could be added to analysis prior to their closure. By calculating the centroid proximity of each of the census tracts in the dataset (n=914), a matrix of dates and distances was created.

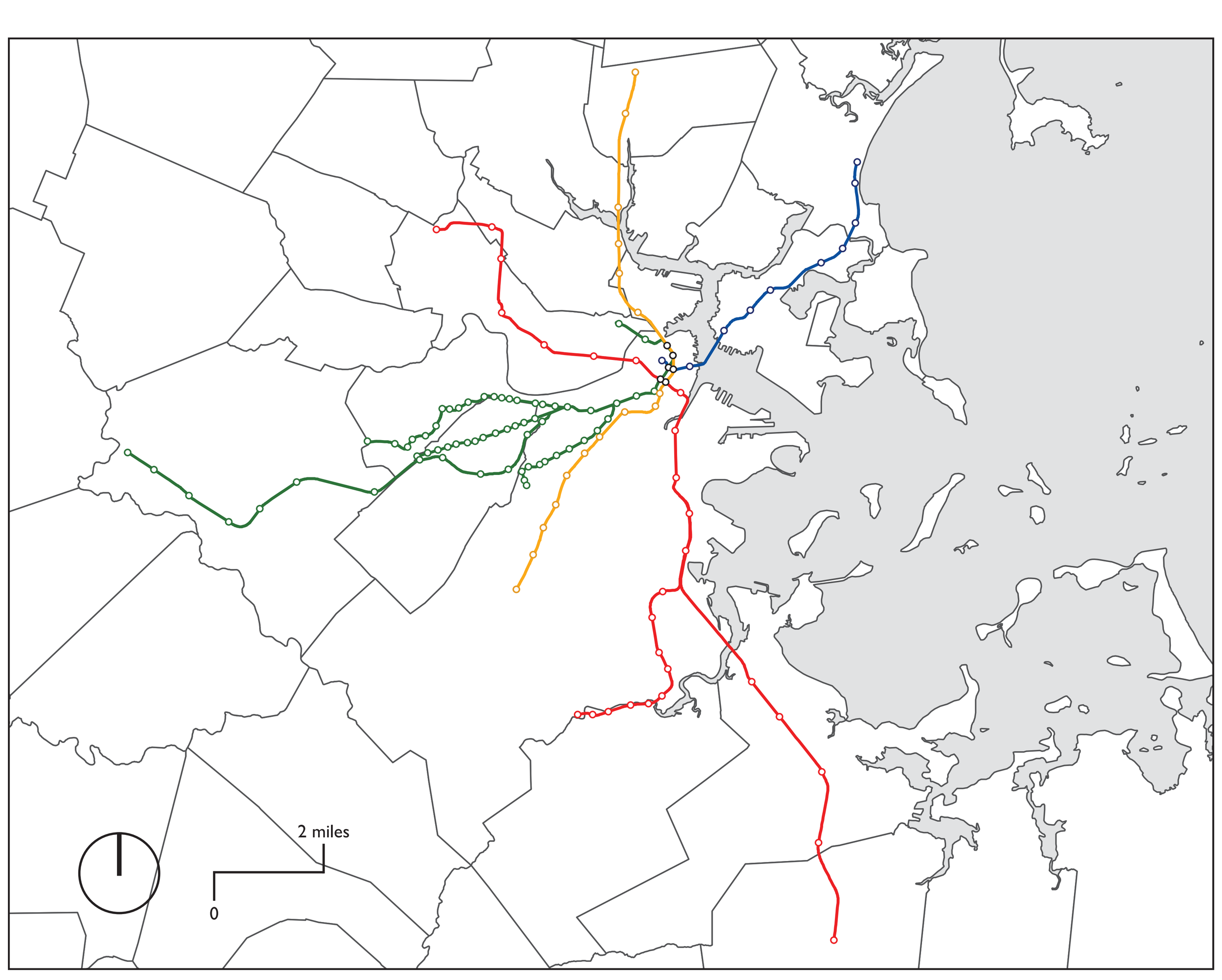

Image 2: Current MBTA rail transit map [MassGIS, Esri]

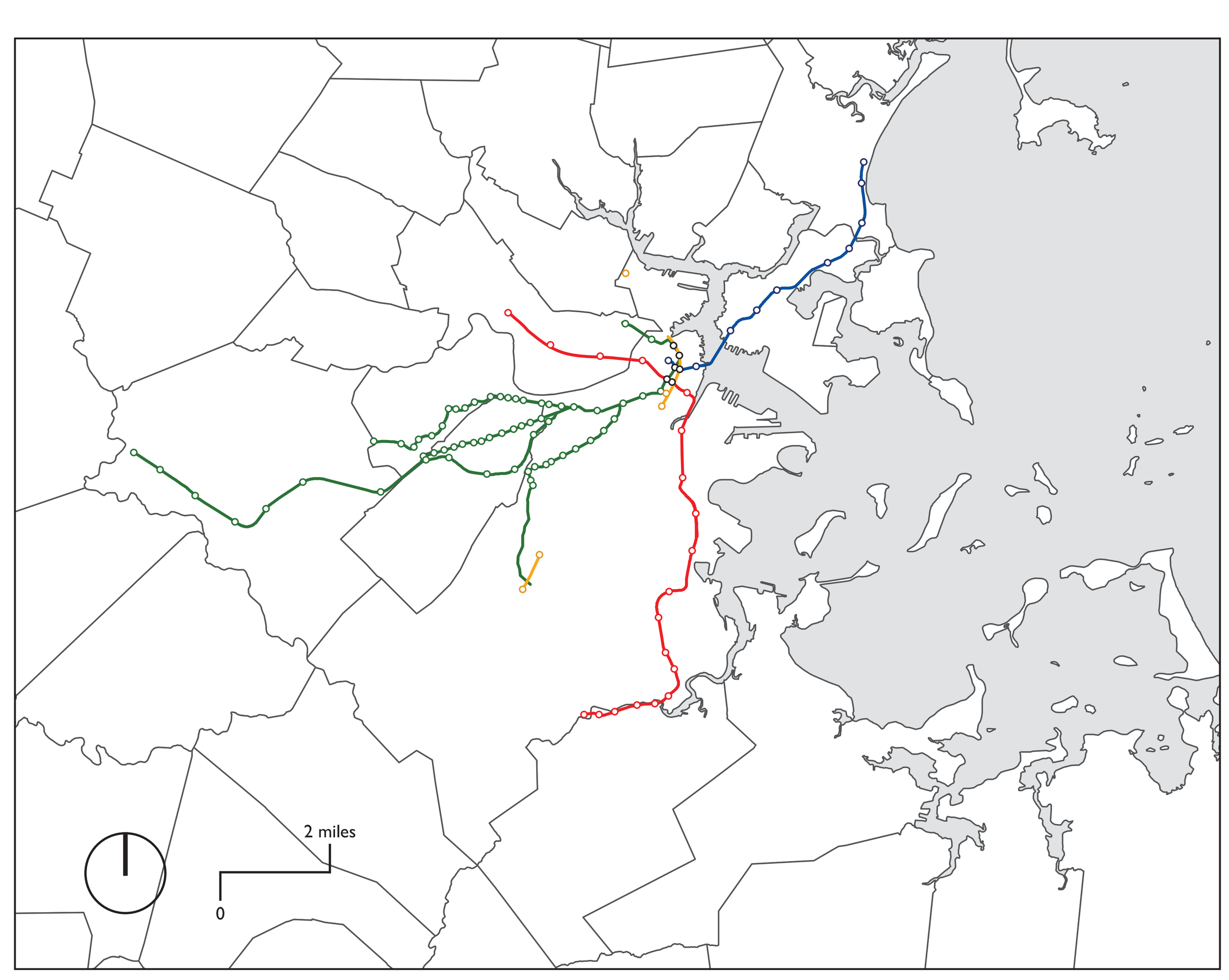

Image 3: MBTA system without post-1970 additions [MassGIS, Esri]

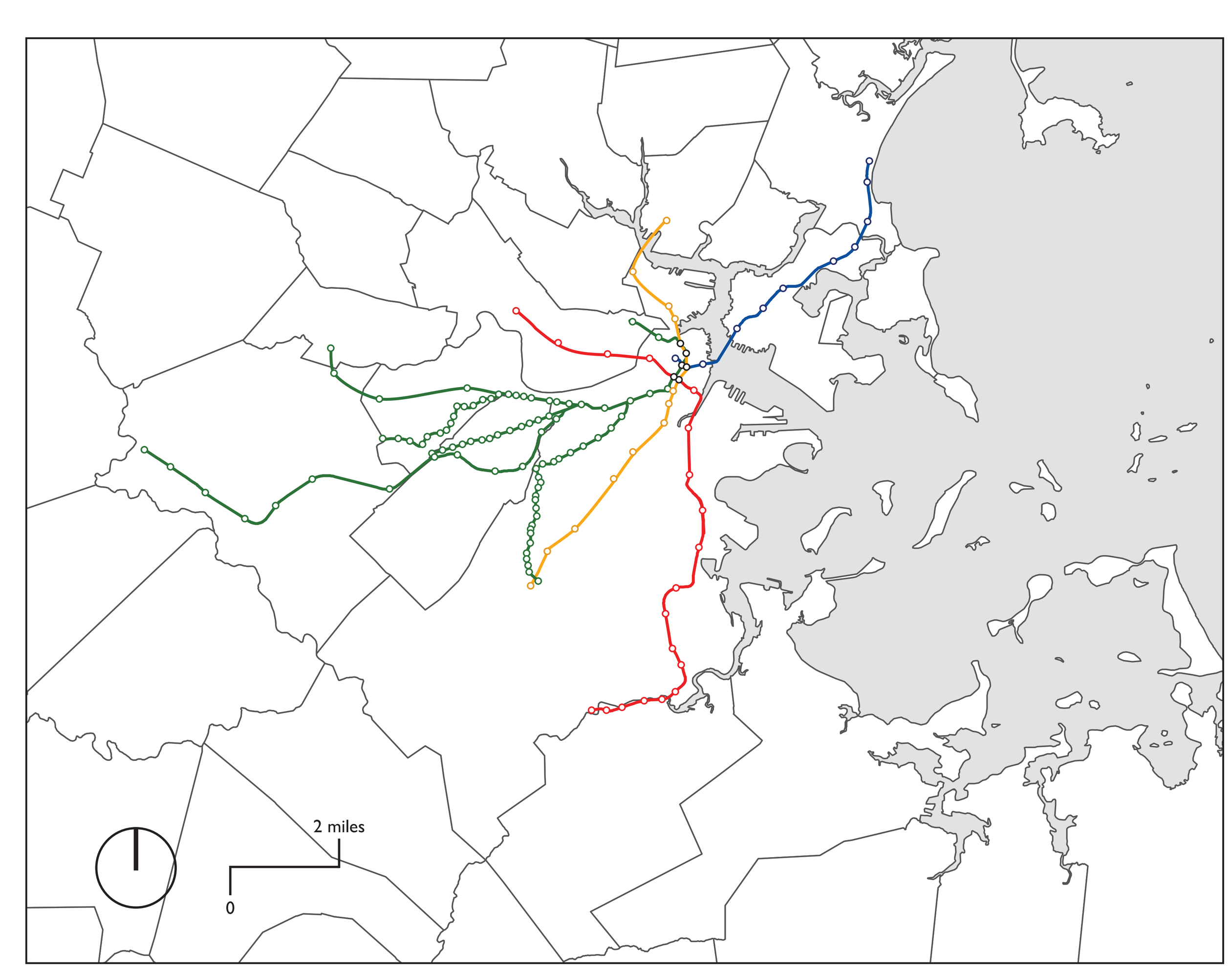

Image 4: 1970 MBTA rail transit map [MassGIS, Esri]

REGRESSION ANALYSIS

Using the assembled panel data, time-series regression analysis was used to seek evidence of a connection between changes in the transit accessibility of a location and changes in the residential patterns of the census tract, both demographic and physical. Using historical census data that has been regularized to consistent census geographies and spatially associated to current and former MBTA station locations, it is possible to assess the impact that changes in transit proximity have had on population and housing stock in a census tract. The regression analysis incorporated a number of variables measuring changes in transit accessibility, historical demographics and transportation patterns, and spatial characteristics within the metropolitan area (see Table 1 at right). A series of regressions were run for both changes in population and changes in housing stock, changing the variable of interest to examine how different measures of accessibility change impacted residential changes.

While not all of the regression outputs can be included here, a summary of results is as follows:

- When the nearest rail transit stop to a census tract is a new station, it is associated with a modest increase in population and housing stock
- A reduction in linear distance to transit is associated with an increase in both population and housing stock
- However, specifically being in close proximity to a station – defined as within 1,000 meters – is not associated with an increase in population at either one, two, or three census periods after the construction of the new station

The most interesting results come when assessing the impact that a new rail transit station in the immediate proximity has on housing stock. As with the impact on population, the effects at one and two census periods are ambiguous and statistically insignificant (see Tables 2 & 3 below). However, when looking three census periods after a new transit station is built, we do indeed see a statistically significant increase in the housing stock in census tracts within a 1,000 meter radius of the station (see Table 4 below). This lends credence to the idea that transit is in fact associated with an increase in the residential built fabric nearby while also reinforcing the understanding that these physical changes take a long time to materialize.

Table 1. Dependent and Independent Variables for Regression Analysis

Dependent Variables	
cum_pop_change	Aggregate change in population since 1970
cum_hous_change	Aggregate change in housing stock (number of units) since 1970
Variables of Interest	
is_new	Dummy variable (1/0) indicating whether the nearest station to a census tract is new since 1970
dist_change	Calculated continuous variable measuring the change in transit accessibility, where a negative number indicates that the nearest station is closer than it used to be
new_1000_1per	Dummy variable (1/0) indicating that there is a new station within 1,000 meters that has been open for one census period
new_1000_2per	Dummy variable (1/0) indicating that there is a new station within 1,000 meters that has been open for two census periods
new 1000_3per	Dummy variable (1/0) indicating that there is a new station within 1,000 meters that has been open for three census periods
Historical Predictors	
dist_transit_1970	Calculated continuous variable measuring distance to nearest transit station in 1970. Intended to capture relative transit accessibility historically
single_fam_1970	Number of single family homes in census tract in 1970. Intended to capture historic neighborhood character
tract_pop_1970	Population in census tract in 1970. Intended to capture the relative intensity of residential use at the time
per_transit_work_1970	Percent of commuters taking transit to work in 1970. Intended to capture relative transit use (and hence potential predisposition for adoption of future transit enhancements)
per_white_1970	Percent of residents in census tract who were white in 1970. Intended to roughly capture potential racial considerations which have sometimes accompanied transit expansions
Contemporary Physical Attributes	
dist_dtc	Calculated linear distance to Downtown Crossing MBTA station. Intended to account for relative centrality of a census tract
dist_highway	Calculated distance to nearest highway entrance. Intended to account for relative access to alternative transportation mode
pnr_over1000	Dummy variable (1/0) indicating whether the transit station has more than 1,000 park & ride spots. Intended to roughly capture a station's physical nature and connection to surroundings

Table 2. Effect of New Transit Stop on Housing Stock after One Census Period

Source	SS	df	MS
Model	28,868,219.6	9	3,207,580.0
Residual	133,863,900	1,619	82,683.076
Total	162,732,119	1,628	99,958.304

Number of obs	=	1,629
F(9, 1619)	=	38.79
Prob > F	=	0.0000
R-squared	=	0.1774
Adj R-squared	=	0.1728
Root MSE	=	287.55

	cum_hous_change	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Variable of Interest	new_1000_1per	-48.9059	54.3854	-0.90	0.3690	-155.5790	57.7672
Historical Predictors	dist_transit_1970**	0.0185	0.0033	5.57	0.0000	0.0120	0.0250
	single_fam_1970**	0.1040	0.0255	4.08	0.0000	0.0539	0.1540
	tract_pop_1970**	-0.0188	0.0052	-3.58	0.0000	-0.0291	-0.0085
	per_transit_work_1970**	-347.6902	91.3524	-3.81	0.0000	-526.8715	-168.5089
	per_white_1970**	157.9028	48.0575	3.29	0.0010	63.6413	252.1643
Contemporary Physical Attributes	dist_dtc**	-0.0077	0.0030	-2.61	0.0090	-0.0135	-0.0019
	dist_highway**	-0.0153	0.0040	-3.80	0.0000	-0.0232	-0.0074
	pnr_over1000	34.0357	19.3700	1.76	0.0790	-3.9572	72.0286

* Significant at a 95% confidence level (P ≤ 0.05)
** Significant at a 99% confidence level (P ≤ 0.01)

Table 3. Effect of New Transit Stop on Housing Stock after Two Census Periods

Source	SS	df	MS
Model	28,951,817.6	9	3,216,868.6
Residual	133,780,302	1,619	82,631.440
Total	162,732,119	1,628	99,958.304

Number of obs	=	1,629
F(9, 1619)	=	38.93
Prob > F	=	0.0000
R-squared	=	0.1779
Adj R-squared	=	0.1733
Root MSE	=	287.46

	cum_hous_change	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Variable of Interest	new_1000_2per	73.3640	54.3684	1.35	0.1770	-33.2758	180.0038
Historical Predictors	dist_transit_1970**	0.0186	0.0033	5.61	0.0000	0.0121	0.0252
	single_fam_1970**	0.1073	0.0255	4.21	0.0000	0.0573	0.1574
	tract_pop_1970**	-0.0195	0.0052	-3.71	0.0000	-0.0298	-0.0092
	per_transit_work_1970**	-336.0558	91.3238	-3.68	0.0000	-515.1812	-156.9305
	per_white_1970**	155.2170	48.0425	3.23	0.0010	60.9849	249.4491
Contemporary Physical Attributes	dist_dtc*	-0.0075	0.0029	-2.56	0.0110	-0.0133	-0.0018
	dist_highway**	-0.0148	0.0040	-3.68	0.0000	-0.0227	-0.0069
	pnr_over1000	31.5770	19.3640	1.63	0.1030	-6.4041	69.5580

* Significant at a 95% confidence level (P ≤ 0.05)
** Significant at a 99% confidence level (P ≤ 0.01)

Table 4. Effect of New Transit Stop on Housing Stock after Three Census Periods

Source	SS	df	MS
Model	29,235,005.4	9	3,248,333.9
Residual	133,497,114	1,619	82,456.525
Total	162,732,119	1,628	99,958.304

Number of obs	=	1,629
F(9, 1619)	=	39.39
Prob > F	=	0.0000
R-squared	=	0.1797
Adj R-squared	=	0.1751
Root MSE	=	287.15

	cum_hous_change	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Variable of Interest	new_1000_3per*	171.7243	74.8818	2.29	0.0220	24.8489	318.5997
Historical Predictors	dist_transit_1970**	0.0187	0.0033	5.64	0.0000	0.0122	0.0252
	single_fam_1970**	0.1059	0.0254	4.16	0.0000	0.0560	0.1557
	tract_pop_1970**	-0.0196	0.0052	-3.73	0.0000	-0.0298	-0.0093
	per_transit_work_1970**	-330.9560	91.2329	-3.63	0.0000	-509.9029	-152.0091
	per_white_1970**	155.1196	47.9826	3.23	0.0010	61.0051	249.2341
Contemporary Physical Attributes	dist_dtc*	-0.0074	0.0029	-2.51	0.0120	-0.0132	-0.0016
	dist_highway**	-0.0149	0.0040	-3.72	0.0000	-0.0228	-0.0071
	pnr_over1000	31.5637	19.3235	1.63	0.1030	-6.3380	69.4653

* Significant at a 95% confidence level (P ≤ 0.05)
** Significant at a 99% confidence level (P ≤ 0.01)

COMPARATIVE STATISTICS

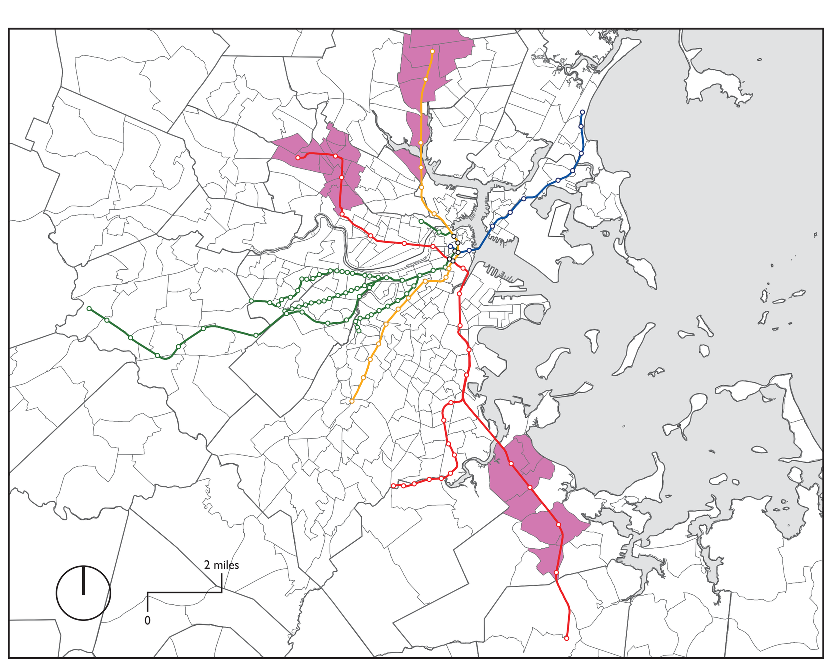

Image 5: Census Tracts within 1,000m of new station [MassGIS, Esri]

Echoing the results of the regression analysis, an examination of the individual census tracts around the new stations (tracts shown in pink in the map in Image 5 above) shows wide variance over time across different tracts, but shows that in the long run, census tracts that are near a new rail transit station have seen an increase in housing nearby. While this doesn't control for larger trends in the Boston metro area, it lends additional support to the association between new rail transit stations and long-term increases in nearby housing stock.

Table 5. Housing Stock Impacts – Red Line (North)

Station	Year Opened	Census Tract	Housing Change 1970 – 1980		Housing Change 1980 – 1990		Housing Change 1990 – 2000		Housing Change Pre-Transit – 2000	
Alewife	1985	25017354600			42	2.26%	175	9.22%	*217*	*11.69%*
		25017354900			-41	-1.90%	35	1.66%	*-6*	*-0.28%*
		25017355000*			-80	-6.27%	139	11.63%	*59*	*4.63%*
		25017356100			-12	-0.84%	12	0.85%	*0*	*0.00%*
					-91	*-1.36%*	*361*	*5.45%*	***270***	***4.02%***
Davis	1984	25017350400			85	3.67%	138	5.74%	*223*	*9.62%*
		25017350500			-135	-15.86%	43	6.01%	*-92*	*-10.81%*
		25017350600			109	10.69%	-16	-1.42%	*93*	*9.12%*
		25017350800			-5	-0.64%	2	0.26%	*-3*	*-0.38%*
		25017350900**			64	4.19%	18	1.13%	*82*	*5.37%*
		25017354700**			68	6.83%	155	14.58%	*223*	*22.41%*
		25017354800**			93	10.36%	-16	-1.61%	*77*	*8.57%*
		25017355000*			-80	-6.27%	139	11.63%	*59*	*4.63%*
					199	*2.06%*	*463*	*4.69%*	***662***	***6.85%***
Porter	1984	25017350900**			64	4.19%	18	1.13%	*82*	*5.37%*
		25017351000			112	3.81%	26	0.85%	*138*	*4.69%*
		25017353600			-21	-1.23%	59	3.49%	*38*	*2.22%*
		25017354000			14	0.66%	16	0.75%	*30*	*1.42%*
		25017354500			-124	-8.90%	71	5.59%	*-53*	*-3.80%*
		25017354700**			68	6.83%	155	14.58%	*223*	*22.41%*
		25017354800**			93	10.36%	-16	-1.61%	*77*	*8.57%*
					206	*1.78%*	*329*	*2.79%*	***535***	***4.62%***
					169	**0.73%**	**857**	**3.66%**	**1,026**	**4.41%**

* Stations within 1,000 meters of both Alewife and Davis stations; have only been counted once in totals
** Stations within 1,000 meters of both Davis and Porter stations; have only been counted once in totals

Table 6. Housing Stock Impacts – Red Line (South)

Station	Year Opened	Census Tract	Housing Change 1970 – 1980		Housing Change 1980 – 1990		Housing Change 1990 – 2000		Housing Change Pre-Transit – 2000	
North Quincy	1971	25021417200	526	21.65%	147	4.97%	-3	-0.10%	*670*	*27.57%*
		25021417501	258	14.13%	-116	-5.57%	27	1.37%	*169*	*9.26%*
		25021417502	220	14.07%	93	5.21%	66	3.52%	*379*	*24.23%*
			1,004	*17.25%*	*124*	*1.82%*	*90*	*1.30%*	***1,218***	***20.93%***
Wollaston	1971	25021417100	152	9.85%	39	2.30%	-22	-1.27%	*169*	*10.95%*
		25021417601	324	17.96%	199	9.35%	-184	-7.91%	*339*	*18.79%*
			476	*14.22%*	*238*	*6.23%*	*-206*	*-5.07%*	***508***	***15.18%***
Quincy Center	1971	25021417701	102	8.63%	157	12.23%	496	34.42%	*755*	*63.87%*
		25021418101	229	14.10%	379	20.45%	130	5.82%	*738*	*45.44%*
			331	*11.80%*	*536*	*17.09%*	*626*	*17.04%*	***1,493***	***53.21%***
Quincy Adams	1983	25021418004			*3*	*0.28%*	*335*	*30.73%*	***338***	***31.09%***
Braintree	1980	–	*No Census Tracts have a centroid within 1,000 meters of Braintree station*							
			1,811	**15.13%**	**901**	**6.06%**	**845**	**5.36%**	**3,557**	**27.24%**

Table 7. Housing Stock Impacts – Orange Line (North)

Station	Year Opened	Census Tract	Housing Change 1970 – 1980		Housing Change 1980 – 1990		Housing Change 1990 – 2000		Housing Change Pre-Transit – 2000	
Oak Grove	1977	25017336401	137	8.48%	65	3.71%	56	3.08%	*258*	*15.98%*
		25017341101	166	9.78%	159	8.53%	46	2.27%	*371*	*21.85%*
		25017341600	193	8.32%	34	1.35%	135	5.30%	*362*	*15.60%*
			496	*8.81%*	*258*	*4.21%*	*237*	*3.71%*	***991***	***17.59%***
Malden Center	1975	25017341102	135	9.96%	125	8.39%	36	2.23%	*296*	*21.85%*
		25017341200	113	4.63%	185	7.25%	34	1.24%	*332*	*13.61%*
		25017341300	-32	-1.90%	653	39.60%	-46	-2.00%	*575*	*34.21%*
			216	*3.94%*	*963*	*16.92%*	*24*	*0.36%*	***1,203***	***21.97%***
Wellington	1975	25017339801	168	20.27%	239	23.97%	0	0.00%	*407*	*49.10%*
		25017350103	56	3.18%	-57	-3.14%	111	6.31%	*110*	*6.25%*
			224	*8.65%*	*182*	*6.47%*	*111*	*3.71%*	***517***	***19.97%***
			936	**6.83%**	**1,403**	**9.59%**	**372**	**2.32%**	**2,711**	**19.79%**

REFERENCES

Baum-Snow, Nathaniel and Matthew E. Kahn. "Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970–2000." In *Brookings-Wharton Papers on Urban Affairs 2005*, edited by Gary Burtless and Janet Rothenberg Pack, 147-206. Washington, D.C.: Brookings Institution Press, 2005.

Belcher, Jonathan. "Changes to Transit Service in the MBTA District: 1964-2015." TransitHistory. Updated June 27, 2015. Accessed December 13, 2015. http://www.transithistory.org/roster/MBTARouteHistory.pdf.

Block-Schacter, David. "Hysteresis and Urban Rail: The Effects of Past Urban Rail on Current Residential and Travel Choices." PhD diss., Massachusetts Institute of Technology, 2012.

Dyett, Michael, David Dornbusch, Michael Fajans, Caj Falcke, Victoria Gussman, and James Merchant. *Land Use and Urban Development Impacts of BART: Final Report*. Washington, D.C.: U.S. Department of Transportation, 1979.

GeoLytics, Inc, Urban Institute, and U.S. Census Bureau. Neighborhood Change Database (NCDB) 2010 tract data for 1970-80-90-00-10. East Brunswick, NJ: GeoLytics, 2013.

Massachusetts Bay Transportation Authority. *Ridership and Service Statistics ("The Blue Book")*, 14th ed. Boston: Massachusetts Bay Transportation Authority, 2014.

Meyer, John R. and José A. Gómez-Ibáñez. *Autos, Transit, and Cities.* Cambridge, MA: Harvard University Press, 1981.