Rail Transit Impacts on Residential Land Use

Lessons from the MBTA Red and Orange Line Extensions

Paul Lillehaugen

Rail Transit Impacts on Residential Land Use

Lessons from the MBTA Red and Orange Line Extensions

Paul Lillehaugen

Acknowledgements

A research project of any appreciable scale is always the work of a village. Throughout the course of this thesis, I have been lucky to have the support of a remarkable group of mentors, colleagues, and friends – your advice and camaraderie has been invaluable. Any mistakes are wholly my own.

First and foremost, I must thank my advisor, Professor Tony Gómez-Ibáñez, for his tireless guidance and his patience in traveling this path with me for the past year. Any meeting to discuss my thesis was sure to include insightful wisdom and advice on the next steps needed, but was just as certain to involve the calm, warm vote of confidence needed to talk me back off the newest existential cliff or to stop me from running down the next week-long rabbit hole to nowhere. My work owes much to him and this would not have been completed without his mentorship.

I also owe much to the GSD Urban Planning & Design thesis team. Michael Hooper led a remarkable thesis preparation course and pushed me to levels of preparation months ahead of where I would have been otherwise. Since I can to the GSD, he has been an enthusiastic advocate for in-depth individual scholarship and has provided encouragement nonpareil. In conjunction, similar thanks must be extended to Julia Smachylo, our fantastic and insightful Teaching Fellow, for her input and for her shepherding of the thesis cohort all year.

Manisha Bewtra, Jessie Partridge, and Leah Hendey from MAPC were invaluable in helping me find the data I needed, as was John Baldisserotto at Lamont Library. Thanks are owed to Adam Tanaka for continued advice throughout this process and to Lyndsey Rolheiser for invaluable help on the statistics herein. Scott Walker of the Harvard Map Collection deserves a special thank you for the time he spent walking me through the intricacies of the Neighborhood Change Database and for his willingness to field my continual questions.

I have also gotten much valuable advice from many other professors and mentors throughout this process. Thank you to Kathy Spiegelman, Kathryn Madden, and Jim Kostaras for the willingness to chat and for serving as sounding boards in the early days of this effort. Thank you to David Luberoff and to Chris Zegras for your involvement throughout, your recommendations for further resources, and your willingness to lend the wisdom of your years of transportation knowledge and Boston expertise to my efforts. And a thanks to all of the outside reviewers who have come in throughout the year to lend their ear and their thoughts to my work.

Thank you also to the support of friends and family – in particular, the love of my parents – for everything that you've done throughout the years. My academic career has been founded on your hard work and commitment to learning and I hope this work reflects well on your time and effort.

Thank you to everyone who has taken the time to read this paper in its various stages and formats and who have offered their thoughts and comments over endless conversations as I have labored to bring my thoughts to the place they are today – thank you especially to Rachel Field for your continued patience and input along the way.

And finally, as much as to anyone else, I owe an enormous thank you to the classmates I have had and friends I have made here at the Graduate School of Design. In particular, my thesis classmates have been an invaluable sounding board, both last fall and this spring, and your insight and commiseration, on Friday mornings in thesis prep and on Wednesday evenings over a beer, have not only made this effort possible, but have also made it worthwhile. Thank you to Andres, Annie, Cara, Courtney, Faisal, John, Lucy, Nathalie, Paco, Rebecca, and Tamara for everything – this is for you.

Paul Lillehaugen
May 16, 2016

Abstract

While the importance of rail transit in creating dense, livable places may seem self-evident to many urban planners, there is actually a great discrepancy between two schools of thought. There are those who advocate transit oriented development and the expansion of rail transit systems as a solution to a variety of urban ills, including housing issues. Conversely, there are those who remain skeptical, recognizing that there are benefits from having an existing system, but rarely recommending the construction of new rail transit systems. This thesis examines the impacts of the extensions of the MBTA Red and Orange Lines in Boston during the 1970s and 1980s to add to this conversation by analyzing the changes in the residential nature of neighborhoods around new transit stations in the decades after they were built.

Boston is a particularly relevant place for this inquiry for a number of reasons. Its rail transit system has undergone several phases of development, including the opening of the first underground

subway line in the United States in 1897. The most recent major phase of development was the realignment of the northern and southern stretches Orange Line and extension of the Red Line to Alewife and to Braintree, all of which occurred as a part of a nationwide wave of transit construction in the latter half of the twentieth century. Today, Boston is engaged in a debate around a potential future phase of rail transit expansion, making this an opportune time to assess the lessons that can be learned from past efforts. In this context, there is evidence that improved access to rail transit does indeed generate some increased residential density, particularly with respect to the physical housing stock and especially when considered over a long time frame (twenty years and more). By examining the evidence, we can help further situate the discussion around transit in Boston and beyond.

Contents

1. 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[1] and is now in the planning phase of what would potentially be the first extension in over 30 years,[2] the extension of the Green Line from Lechmere, through the city of Somerville to a new terminus in Medford.

1 Jonathan Belcher, "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.

2 Note: Assembly station was opened in Somerville in 2014 as an infill station on the Orange Line, but did not involve an extension of the track.

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"[3] 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."[4] 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

3 Nathaniel Baum-Snow and Matthew E. Kahn, "Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970-2000," *Brookings-Wharton Papers on Urban Affairs 2005*, ed. Gary Burtless and Janet Rathenberg Pack (Brookings Institution Press: Washington, D.C., 2005), 186.

4 Michael Dyett, et al., "Sponsor's Note," in *Land Use and Urban Development Impacts of BART: Final Report* (Washington, D.C.: U.S. Department of Transportation and U.S. Department of Housing and Urban Development, 1979), 2.

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. Katseff's study of market timing in Boston, Portland, and New Jersey confirms this, finding that home prices have largely adjusted for improved transit accessibility even before a rail line has opened.[5] Conversely, investments in infrastructure have physical ramifications for decades, even long after the infrastructure itself has disappeared. Block-Schacter finds that "[c]urrent density and travel behavior patterns are measurably influenced by past access to rail,"[6] 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.

5 Jared Katseff, "Marrying Market Timing with Human-Centered Urban Design: How Investors and Municipalities can Better Realize Transit Oriented Development," Masters in Urban Planning (Harvard University Graduate School of Design, 2015), 116.

6 David Block-Schacter, "Hysteresis and Urban Rail: The Effects of Past Urban Rail on Current Residential and Travel Choices" (PhD diss., Massachusetts Institute of Technology, 2012), 202.

2. Thesis Question

To that end, my thesis question is this:

> What effect has the construction of MBTA stations had on the residential land use surrounding the station locations and to what extent is the change in transit accessibility predictive of changes in residential land use for a specific station?

3. Merits of Question

In *Autos, Transit, and Cities*, John R. Meyer and José A. Gómez-Ibáñez note that "[p]lanners and policy makers have long viewed transportation policy as a potential tool to control broad patterns of urban land use and metropolitan development"[7] and indicate that improved transit is frequently suggested as a method for encouraging more desirable patterns of land use.[8] While the importance of rail transit in creating dense, livable places may seem self-evident to many urban planners, the empirical evidence on this particular piece of the land use-transportation interaction is relatively sparse (see more in the Frontier of Knowledge below) and the question is relevant because of the discrepancy in opinion between two groups of urbanists with very different perspectives on the value of transit. One group tends

7 John R. Meyer and José A. Gómez-Ibáñez, *Autos, Transit, and Cities* (Cambridge, MA: Harvard University Press, 1981), 104.

8 Ibid.

to see the benefits of rail transit and transit oriented development as almost a given, while others remain deeply skeptical, recognizing some benefits that come with having an existing rail transit system, but rarely recommending the construction of new systems. Critical observers note escalating costs and limited ability to draw ridership from automobiles[9] and limited evidence of impact of agglomeration.[10] They frequently see rail transit infrastructure as a poor use of money and an ineffective approach to fostering urbanity. For example, in a 2005 study of sixteen rail transit systems in the United States, Baum-Snow and Kahn note that it is "[a] common refrain among leading transportation scholars that we overinvest in rail relative to buses"[11] and continue that, "[d]espite the pessimistic evidence we have presented about the likely success of new rail lines [as measured by increased transit ridership, among other things], they are being built at historically high rates."[12] For comparison, the Urban Land Institute's 2003 manual on *Ten Principles for Successful Development Around Transit* is one of many such planning industry documents which seem to operate from an assumption that transit ought to be encouraged and work from that point to recommend how to do it well.[13]

9 Alan Altshuler and David Luberoff, *Mega-Projects: The Changing Politics of Urban Public Investment* (Washington, D.C.: Brookings Institution Press, 2003), 194.

10 Daniel G. Chatman and Robert B. Noland, "Transit Service, Physical Agglomeration and Productivity in US Metropolitan Areas," *Urban Studies* 51.5 (2014): 918.

11 Baum-Snow and Kahn, "Effects of Urban Rail Transit Expansions," 192.

12 Ibid., 195.

13 Robert Dunphy, Deborah Myerson, and Michael Pawlukiewicz, *Ten Principles for Successful Development Around Transit* (Washington, D.C.: Urban Land Institute, 2003).

Clearly, there is a discrepancy between the two views, which provides an impetus to seek further empirical understanding on whether or not rail transit has merit as a tool for urban development. By studying the impact that rail transit infrastructure has on its surroundings, particularly on the intensity of housing development nearby, I hope to enhance shared knowledge which can serve as a launching point for continued conversation, seeking to bring the two sides – and the broader public – closer to a common understanding. I chose to study residential development around stations because of the breadth of planning discussion of the value of walkable, accessible neighborhoods – from Jane Jacobs[14] to the New Urbanists[15] – and the suggestions that transit enables these types of neighborhoods. In *Transit Villages in the 21st Century*, Michael Bernick and Robert Cervero argue that transit villages – their name for transit oriented development – offer "enhanced mobility, environmental quality, [and] pedestrian friendliness"[16] among other things. In *Sustainability and Cities*, Peter Newman and Jeffrey Kenworthy argue that extending transit systems and concentrating development around the newly created nodes is key to creating more sustainable cities for the future.[17] They echo this same

14 For example, see: Jane Jacobs, "The need for primary mixed uses," in *The Death and Life of Great American Cities* (New York: Random House, 1961; New York: Vintage, 1992), 152-77. Citations refer to the Vintage edition.

15 For example, see: Andres Duany, Elizabeth Plater-Zyberk, and Jeff Speck, "How to Make a Town," in *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream* (New York: North Point Press, 2000), 183-214.
See also: Andres Duany, Jeff Speck, with Mike Lydon, *The Smart Growth Manual* (New York: McGraw Hill, 2010), chapter 5.

16 Michael Bernick and Robert Cervero, *Transit Villages in the 21st Century* (New York: McGraw-Hill, 1997), 7.

17 Peter Newman and Jeffrey Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence* (Washington, D.C.: Island Press, 1999), 188-9.

view years later in *The End of Automobile Dependence*, promoting rail transit and development around its nodes as an important part of an effort to dramatically reduce automobile use worldwide.[18] It is worth noting that many of these studies are more prescriptive than descriptive and assume a quite particular normative viewpoint.

By looking at the way transit physically shapes a city, we can perhaps reframe the discussion away from both dogmatic visions of a utopian future and financial assessments of a myopic scope, as it is so often presented today, and take an approach suggested by Wharton economist Richard Voith in his laudatory yet measured response published with the 2005 study by Baum-Snow and Kahn, in which he concludes, "I would conjecture that evaluating the impact of very large transit investments like the Washington Metro by using marginal analysis is nearly impossible. The high levels of use have resulted in a city that otherwise could not evolve in a similar manner."[19] To consider the way in which cities evolve due to transit, rather than just the operational aspects of their transit system, encourages us to examine land use and development more broadly. Because residents form the foundation upon which a city is built – from its tax base to its civic life – the residential land use impacts seem and appropriate place to start.

18 Peter Newman and Jeffrey Kenworthy, *The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning* (Washington, D.C.: Island Press, 2015), 234-6.

19 Richard Voith, "Comment," in "Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970-2000," Nathaniel Baum-Snow and Matthew E. Kahn, *Brookings-Wharton Papers on Urban Affairs 2005*, ed. Gary Burtless and Janet Rathenberg Pack (Brookings Institution Press: Washington, D.C., 2005), 204.

4. Literature Review

When examining land use and development around transit stations, there are several categories of literature to review. These include past papers on similar topics in economic and real estate journals as well as studies and recommendations from the field of planning. There are also a variety of variety of methodological sources to consult in order to structure the approach to regression analysis, as well as general background information on transit and transit oriented development. As such, I have begun my literature review with historical and informational background sources, followed by quantitative and qualitative methodological precedents looking at explanatory case studies and encompassing the varied perspectives on the topic of transit and land use.

a. Historical & Topical Precedents

A starting point for any discussion of the interaction between land use and transportation is with the work on the Monocentric City model developed from the work of William Alonso[20] and Richard Muth[21] in the 1960s. In a theoretical city where all employment occurs at the center and residential districts extend out in rings, transportation demand is driven by the need for workers from the outer parts of the city to access employment at the center. Throughout the years, updates and modifications to the model have tried to more accurately explain the evolving form of cities which have spread beyond the traditional form of historic cities. These models serve as much of the basis for transportation demand models today. Furthermore, historical studies indicate that "dramatic urban transportation innovations [such as streetcars and freeways]… greatly modified urban development patterns [and]… brought new lands into development."[22] However, "most public transit improvements proposed since 1960, particularly new rail transit systems, have largely been for the benefit of established urban areas."[23] While the theoretical and historical connection between land use and transportation is well-documented, the more recent connection is less straightforward, as discussed below.

Topical precedents fall into two categories. On one hand, academic and governmental studies, provide a theoretical and contextual grounding for my work. On the other hand, industry publications provide excellent examples of what is being used in the field today and what planners have historically made use of in their work to shape the future of transit oriented neighborhoods. A couple

20 William Alonso, *Location and Land Use: Toward a General Theory of Land Rent* (Cambridge, MA: Harvard University Press, 1964).

21 Richard F. Muth, Cities and Housing: The Spatial Pattern of Urban Residential Land Use (Chicago: The University of Chicago Press, 1969).

22 Meyer and Gómez-Ibáñez, *Autos, Transit, and Cities*, 105.

23 Ibid.

interesting pieces in the latter category are the Davis Square Action Plan[24] and the Urban Land Institute's *Ten Principles for Successful Development Around Transit*,[25] which give a good insight into the past and present of development around rail transit stations and the way in which recommendations have evolved over time.

Within the realm of academic research, perhaps the seminal study in the field – a Department of Transportation report by Robert L. Knight and Lisa L. Trygg – came out in 1977. Employing a nationwide review of eighteen transit systems of a variety of modes (heavy rail, light rail, commuter rail, and dedicated busways) in twelve metropolitan areas,[26] it held that the potential for land use impact of transit is as a part of a "coordinated package,"[27] rather than as a sole or even primary contributing factor. Among other impacts, they do find evidence that, under certain conditions, "[t]ransit improvements can help in intensification of land uses around outlying stations."[28] More recent studies, summarized in surveys by Giuliano[29] and Handy,[30] reaffirm that transit can encourage concentration of development, but

24 Office of Planning & Community Development, *Davis Square Action Plan* (Somerville, MA: Office of Planning & Community Development, 1984).

25 Dunphy, Myerson, and Pawlukiewicz, *Ten Principles*.

26 Robert L. Knight and Lisa L. Trygg, *Land Use Impacts of Rapid Transit: Implications of Recent Experience: Executive Summary* (Washington, D.C.: U.S. Department of Transportation, 1977), 4.

27 Ibid., 2.

28 Ibid., 9.

29 Genevieve Giuliano, "Land Use Impacts of Transportation Investments," in *The Geography of Urban Transportation*, ed. Susan Hanson and Genevieve Giuliano (New York: Guilford, 2004), 268.

30 Susan Handy, "Smart Growth and the Transportation–Land Use Connection: What Does the Research Tell Us?," *International Regional Science Review* 28, 2 (2005): 159.

only under the right circumstances. In a study that primarily examines heavy rail systems built in the latter half of the twentieth century, Giuliano finds that rail transit may impact land use where there "is a significant impact on accessibility"[31] and that routes that simply replace existing bus service may have a limited impact.[32] She also notes that "[i]mpacts are highly localized and tend to occur in fast-growing, heavily-congested core areas"[33] where there are "complementary zoning, parking, and traffic policy, and especially… development subsidies."[34] Focusing on light rail transit, Handy's survey concludes that transit can indeed increase density,[35] if it is accompanied by a growing economy,[36] supportive government policies,[37] and significant improvements in accessibility.[38]

Building from that point, there are several city-specific studies that are relevant to my work in Boston. Among the most well-studied is the BART system in San Francisco. Badoe and Miller make note of studies – by Webber 1976 and Giuliano in 1995 – which looked at the impacts of BART in San Francisco at one and five years after construction, noting little impact.[39] It was not until Cervero and

31 Giuliano, "Land Use Impacts," 268.

32 Ibid., 264.

33 Ibid., 268.

34 Ibid.

35 Handy, "Smart Growth," 159.

36 Ibid., 157.

37 Ibid., 158.

38 Ibid.

39 Daniel A. Badoe and Eric J. Miller, "Transportation–land-use interaction: empirical findings in North America, and their implications for modeling," *Transportation Research Part D* 5 (2000): 244-5.

Landis examined twenty years of data on BART that they found any notable impact. Using matched-pair assessments of BART station locations and corresponding highway interchanges, they found that transit accessibility provided minimal increase in single-family residential and non-residential density, though it did appear associated with a marked increase in multi-family residential density.[40] Even then, their conclusions indicated that BART was a contributor to, rather than a driver of, residential development.[41] Writing at about the time that many of these late-twentieth-century rail projects are beginning service, Meyer and Gómez-Ibáñez offer a compelling explanation for this lag. "The impact of transportation on urban development is also slowed or limited in the short run by the durability of existing houses or commercial structures… the cost of moving or replacing the present stock of buildings is such that it might take many years before substantial changes in location were observable,"[42] an explanation that seems to have been borne out by subsequent studies. In addition, I would speculate that this long lag time (twenty years) to see results is the reason why financial studies appear to be more common – it seems plausible that land values could reflect transit benefits much more quickly than patterns of physical development could do so.

b. Assessing Land Use as a Function of Transportation

For methodological precedents, I look to a few different guides. One segment is on the structure of my inquiry, while the other regards the techniques of analysis to be used. From a structural

40 Robert Cervero and John Landis, "Twenty Years of the Bay Area Rapid Transit System: Land Use and Development Impacts," *Transportation Research Part A* 31 (1997): 321.

41 Ibid., 331-332.

42 Meyer and Gómez-Ibáñez, *Autos, Transit, and Cities*, 105.

standpoint, David Luberoff's case study on the proposed Green Line[43] extension provides a contextually-situated guide for thinking about socioeconomic and policy-based drivers of change (or lack thereof) in a neighborhood. It also provides some examples of ways in which data can be organized and analyzed, though the case stops short of drawing any conclusions itself.

For techniques, one good resource is a hedonic assessment of rail impacts by Bowes and Ihlanfeldt. While I am not doing a hedonic model, their methodological discussion[44] and table of regression variables (including distance to highway, distance to Central Business District, and distance to transit stops)[45] is helpful in my own formulation. Likewise, Cohen's discussion of spatial autocorrelation and spatial lag[46] provides helpful insights for considering the way different station locations interact with one another as I approach my regression analysis, though the complexity of his methodology is beyond the scope of this paper.

To explore the impacts of land use as a function of transportation, attention has been paid to both the financial impacts, embodied in hedonic pricing models, and the locational impacts, as captured in measures of local land use and transportation decisions.

---

43 David Luberoff, "Extending the Green Line to Somerville (Abridged)," Case Number 1983.3 (Cambridge, MA: Harvard University John F. Kennedy School of Government, 2013).

44 David R. Bowes and Keith R. Ihlanfeldt, "Identifying the Impacts of Rail Transit Stations on Residential Property Values," *Journal of Urban Economics* 50, no. 1 (2001): 7-11.

45 Ibid., 8.

46 Jeffrey P. Cohen, "The Broader Effects of Transportation Infrastructure: Spatial Econometrics and Productivity Approaches," *Transportation Research Part E: Logistics and Transportation Review* 46, no. 3 (May 2010): 318.

i. Hedonic Pricing Effects of Transportation

Using sprawl as a proxy for the relative access or lack of access to transportation networks, an interesting working paper by Patrick Bajari and Matthew Kahn exemplifies the understanding that can be derived from hedonic modeling. Looking at Los Angeles County, they find (unsurprisingly) that houses and lots are larger in sprawling neighborhoods.[47] However, they find little willingness on the part of homeowners to pay for the larger lots (thought plenty of willingness to pay for a larger house) and speculate that residents would be willing to encourage smaller lot sizes and higher density in order to gain more by reducing commuting time.[48] Overall, they can provide their perspective on possibilities, but lack a large amount of predictive power in their findings so far.

Within the specific realm of transit, there have been a variety of studies which have used a hedonic pricing model to look at property values around transit stations. In one interesting paper, Lewis-Workman and Brod looked at BART stations in San Francisco, MTA stations in New York, and MAX stations in Portland, Oregon. They found strong evidence of price bonuses for transit proximity in San Francisco and New York, but less compelling results in Portland.[49] This highlights again the ambiguities at work in the field; it is difficult to account for the abundance of external factors in a city and even the most sophisticated models struggle to find results that are broadly applicable. For example, New York City and San Francisco are two of the densest cities in the

47 Patrick Bajari and Matthew Kahn, "Estimating Hedonic Models of Consumer Demand with an Application to Urban Sprawl" (Working Paper, 2007), 13.

48 Ibid., 20.

49 Steven Lewis-Workman and Daniel Brod, "Measuring the Neighborhood Benefits of Rail Transit Accessibility," *Transportation Research Record* 1576 (1997): 153.

country, with two of the most comprehensive rail transit systems, while Portland is not; it is plausible that the increasing returns to scale of transit may be a factor in its effect.

ii. Locational Effects of Transportation

When looking at locational effects, several studies are of particular interest. For one, in an empirical study of much of the second half of the twentieth century, Baum-Snow found that "one new highway passing through a central city reduces its population by about 18 percent,"[50] a trend that encourages suburbanization. In a more typological approach, Newman and Kenworthy identify three models of cities that occur based on their transportation system: the walking city, the transit city, and the automobile city. The indicate that the automobile has often been seen by transportation planners as the solution to urban mobility problems, when in fact its capacity is always absorbed quickly, while the environmental, economic, and social issues of automobile dependence remain.[51] Both studies point to the adverse and anti-urban impacts of automobile orientation in cities, thus providing the impetus to look at transit and determine if it can provide an opportunity to create a more successful and sustainable urban form.

In considering the effects that rail transit, in particular, has on locational measures, the aforementioned 1977 Department of Transportation study by Knight and Trygg retains its importance today. In assessing the impact of major heavy rail expansions, for instance, the authors surveyed the impacts of six transit systems in the U.S.

---

50 Nathaniel Baum-Snow, "Did Highways Cause Suburbanization?" *The Quarterly Journal of Economics* 122, no. 2 (May 2007): 775.

51 Peter W. G. Newman and Jeffrey R. Kenworthy, "The land use–transportation connection: An overview," *Land Use Policy* 13, no. 1 (1996): 2-6.

and Canada, finding strong evidence in some places that transit had influenced commercial and residential development, while in others there was no noticeable impact; they saw evidence of development at specific sites in Boston, Philadelphia, and Toronto, but little impact in Montreal, Cleveland, or Chicago.[52] Additionally, much of the development has been found to be constrained to the Central Business District, with little suburban or regional impact.[53] As mentioned, studies have come to the general conclusion (which makes sense from an instinctive point of view), that any impacts of transit development take a long time to be reflected in land use patterns.[54, 55]

A couple of additional key resources in this area are a pair of papers by Nathaniel Baum-Snow and Matthew E. Khan on urban rail transit.[56, 57] The work of Baum-Snow and Kahn provides some direction and foundation for format and methodology, and provided part of the rationale for choosing Boston as a city of interest for study. In their look at ridership increases accompanying rail transit development, they found statistically significant, sustained increases in ridership over timeframes of up to thirty years – at least at some types of stations – in Atlanta, Baltimore, Boston, San Diego, San Francisco, and Washington D.C.[58] If we are to look at what impact rail transit stations have on the

52 Knight and Trygg, *Land Use Impacts of Rapid Transit*, 8.

53 Ibid. 8-10.

54 Ibid., 2.

55 Dyett, et al., "Sponsor's Note," 2.

56 Nathaniel Baum-Snow and Matthew E. Kahn, "The effects of new public projects to expand urban rail transit," *Journal of Public Economics* 77, 2 (2000): 241-63.

57 Baum-Snow and Kahn, "Effects of Urban Rail Transit Expansions," 147-206.

58 Ibid., 180-3.

use of land around them, it seems prudent to look, at least initially, at stations in cities that have shown sustained success at attracting riders to transit. If there is to be an effect under any circumstances, we would expect that effect to be most likely to occur where transit ridership has been stimulated as well, signaling a successful rail transit system.

The longer of Baum-Snow and Kahn's two joint papers is representative of the leading edge in the field of study today and is a key resource in the study of the impact of transportation on land use. They look at cities with old and new rail systems and compare the effect the systems have on variables such as population density and transit mode share. They also examine a variety of factors to try to explain the location in which transit stops are built. They find that the effects of rail transit are quite specific to the metropolitan area, with some systems (including Boston) seeing success in increasing ridership, while others have not.[59] They indicate that, "[b]ased on this evidence, it appears that less than ten years is ample time for the new commuting equilibrium to be achieved in most cases"[60] though, notably, they make no mention of spatial equilibrium (which they were not directly assessing), something that ought to take longer to be reflected. To a similar point, they state that "[w]hile we find scant evidence that rail lines have reduced pollution and congestion externalities, we do find potentially large commuting time savings associated with new rail infrastructure."[61] There are some things that rail transit appears to do well and other things that it does not. If we want to seek to understand the impact that rail transit has on the built environment and on residential development, it is helpful to build upon their work,

59 Ibid., 177.

60 Ibid., 186.

61 Ibid., 192.

assessing a city whose transit system has been found to have at least some measure of impact on its surroundings. If the MBTA extensions have indeed led to increased ridership, they are a better place to look for evidence of physical changes than a system which has had no such behavioral impacts.

To this point, nearly as helpful as the analysis in the paper is the perspective it provides in helping to identify further lines of inquiry, particularly since it is appended by commentary from Wharton professor Richard Voith, who explicitly defines some areas that need further study.[62] Gaps in the Baum-Snow and Kahn model are particularly notable in the physical (rather than behavioral) impact that transit has on its surroundings – something I hope to advance – and in controlling for the investment in roads. Controlling for the cost of roads is beyond the scope of my research, but have included access to highways as a part of my study.

62 Voith, "Comment," 199.

5. Methodology & Results

My approach to the study of the residential impacts of urban rail transit stations in Boston consists of three overarching pieces of analysis.

1. First, I conducted statistical analysis of past and current land use around the selected stations on the MBTA Red Line and Orange Line extensions, including a time-series regression analysis 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. Second, I selected a group of example stations which saw the most marked increase in transit accessibility during this time, conducting further statistical and qualitative analysis of residential changes at the location.

3. Finally, I offer some thoughts on the residential development potential of the station locations of the proposed Green Line, based on the results of my quantitative and qualitative analysis of the Red Line and Orange Line stations.

a. Regression Analysis

i. 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).[63] As a part of NCDB, census data for the years 1970 to 2010 and 5-year American Community Survey (ACS) estimates based on data collected from 2006 to 2010 are standardized into consistent 2010 census tracts, allowing for comparisons to be made across time. ACS data is used in cases for which there is not data available in the 2010 census files which corresponds to earlier census data. For example, the 2010 census data in NCDB omits much of the detailed housing data found previously, but this information is instead contained within the ACS tables.

For the purposes of this study, the Census Tracts 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. For simplicity's sake, and because they are quite far from the Boston MBTA rapid transit system, census tracts in New Hampshire that are a part of the

63 Source: 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).

CBSA have been excluded from the analysis. The area studied includes 914 census tracts (*n*=914) as defined by 2010 boundaries.

However, there are some concerns with the data, some of which stem from the Census data itself and some of which are artifacts of the NCDB method of weighting and apportioning population and other units from historical census tracts:

- The country had not yet been fully divided into census tracts in 1970 and several areas in the CBSA had not yet been tracted at this point. Because the lack of 1970 data precludes these tracts from before-and-after analysis with respect to the impact of transit expansions in the 1970s, they have been excluded from the analysis. All of these tracts are located relatively far from the center of Boston and well outside of the boundaries of the area served by MBTA rapid transit.
- Several tracts lack data on many of the variables measured, particularly in the 2010 census (or, more frequently, in the 2006-2010 American Community Survey). A survey of these tracts in GIS indicates that they are primarily recreational areas (large parks, golf courses, etc.) that can reasonably be expected to have little population. There is also one primarily industrial area in the Boston port that shows similar behavior. These tracts exhibit inconsistent data and outliers between various years and, because of their primarily non-residential nature and their data eccentricities, have been excluded from analysis.
- 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. These jarring changes occur most frequently between the 2000 census (which is the last one being artificially manipulated) and the 2010 census, which was actually surveyed using the current tract boundaries. The most egregious of these discontinuities have been removed from the data analysis.

- While the 2010 data is the most accurate, it is the least consistent with the other years' data. The majority of major discontinuities between years (other than ones caused by the lack of 1970 data in untracted areas) occur between 2000 and 2010. As noted above, the most extreme outliers have been excluded from analysis. However, at this point, it is impossible to gauge the true extent of the issue and, in many places, impossible to determine 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. With that in mind, regression analysis has involved only 1970 to 2000 data. While 2010 is the most accurate, it is the least precise with regards to the rest of the data (where accuracy refers

> to "getting the right answer", while precision refers to "getting the same answer consistently"). Because the inaccurate census tracts in 1970 to 2000 appear to lie directly next to the ones which should have their data, and because the difference in the distance to various geographic points for the sake of analysis of adjacent census tracts in not that great, the overall picture should be illuminating, if far from ideal.

With these changes accounted for, analysis is conducted in 831 census tracts (*n=831*) across four decades.

ii. 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[64] had to be augmented with information about the dates when stations opened since 1970[65] (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.[66] By assembling the three types of stations – those that have been open since before 1970, those that opened between 1970 and 2010, and those that closed between 1970 and 2010 – into a single GIS layer (*n=149*) with date information and

---

64 Source: "MBTA_NODE," GIS datalayer, Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT, http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/mbta.html.

65 Belcher, "Changes to Transit Service," 310-318.

66 Source: Coordinates from Wikipedia and GeoHack, https://tools.wmflabs.org/geohack/.

calculating the centroid proximity of each of the census tracts in the dataset (*n=914*), a matrix of dates and distances was created.[67]

Using that matrix, census tracts were assigned a nearest station proximity for each decade from 1970 to 2010. For each decade after 1970, and a dummy variable *is_new* (1 for true, 0 for false) indicated whether the nearest transit station had been opened since 1970. If true, the date of the opening was recorded, the number of years since that date was calculated, and the decrease in distance to the nearest transit station was calculated.[68] Conversely, if the nearest station to a census tract closed, as happened along several Green Line corridors, in addition to the realignment of the Orange Line, the increase in distance to the nearest station was calculated. No value was recorded for *is_new* or for the year or age of the associated station unless that newly-nearest station also happened to be one of the newly-opened stations.

For each decade after 1970, census tracts which had been identified as being nearest to a new transit station and were calculated to be within 1,000 meters of that station were also assigned dummy variables (*new_1000_1per*, *new_1000_2per*, and *new_1000_3per*) according to whether the station had been open for one, two, or three census periods. For example, a 1980 record that is nearest to a transit station opened in 1975 would be considered to have had access for

67 For geographic map of stations today, see Appendix D. Geographic MBTA System Map: Current
For geographic map of stations prior to 1970, see Appendix E. Geographic MBTA System Map: Pre-1970

68 Note: There are stations that opened during the year in 1980. For the purposes of determining whether or not a station was "open" prior to that year's census data being collected, it was determined that the station had to be open before the beginning of the year, rather than before the end of the year. Hence, 1980 census data is not calculated as being near stations that opened that year. Rather, those stations are introduced in the 1990 analysis with an age of 10 years.

one period, while the same census tract near the same station in 2000 would have had access for three periods. This designation allows for the identification of census tracts which are most proximate to new transit stations and for the assessment of the impacts these stations might have over time.

iii. Regression Analysis Approach

Using the panel data assembled above, statistical and econometric 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 is 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. 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.[69] The variables considered are listed below.

69 As in the 2000 paper "The effects of new public projects to expand urban rail transit" by Baum-Snow and Kahn, analysis is limited to census tracts within a 25 kilometer radius of the central business district (*n=543*), as approximated by the location of the Downtown Crossing MBTA station. This limits the assessment to portions of the metropolitan area that might reasonably be served by rail transit and prevents analysis from being skewed by the effects of far-flung locations which are either not served by rail transit or are only a part of the much more infrequent commuter rail network.

Table 1. List of Regression Variables

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

* Source: Massachusetts Bay Transportation Authority, *Ridership and Service Statistics ("The Blue Book")*, 14th ed., (Boston: Massachusetts Bay Transportation Authority, 2014), 103 (Ch. 08, p. 2).

iv. Regression Results: Impact on Population

The first test (see Table 2) is a simple assessment of whether a new transit stop, indicated by a "yes" (dummy value of 1) for the is_new variable, has an impact on population in a census tract. As shown in the table above, it is right on the cusp of statistical significance ($P \leq 0.05$), thus showing some evidence of an impact on population. While several of the supporting variables appear to be insignificant, the overall model predicts about 24% of the variance in population, which seems reasonable, given the wide variety of complicating factors in a city.

To build upon the results of simply having a new transit station nearest to a census tract, assessing the impact of the relative scale of changes in accessibility is a natural next step. By calculating the change in distance to the nearest station, we can see that there is a statistically significant effect of being nearer the station (see Table 3). As the measure of dist¬_change is negative, a negative coefficient means that the more distance you remove, the greater the positive change in population and, conversely, if a census tract saw an increase in distance from transit (as a few did), that would be associated with a reduction in population, all else equal.

Finally, in order to further understand the impact of close proximity to a new rail transit station – within the area which might be considered a walkable distance from the station, and hence, the area where we might expect to see the biggest impact if there is an impact of being near transit – we can look at the impact of getting a station in the immediate vicinity at three different timeframes.

When looking at the first census period (see Table 4) after a station was built (which in our data could occur as little as three years after opening or as many as ten years after, if the station opened during the course of a year in which a census was taken), we see no impact of proximity to transit on population. This similar lack of statistical significance (where $P > 0.05$), continues at two (see Table 5) and three (see Table 6) census periods after a transit station is built, indicating that there doesn't seem to be a link between new transit proximity and population change over the observed timeframe.

In total, we see some evidence that improved transit accessibility may be associated with an increase in population, but there doesn't appear to be a strong connection between immediate proximity to new transit and population change.

Table 2. Effect of New Transit Stop on Population

Source	SS	df	MS
Model	204,478,229	9	22,719,803.2
Residual	642,312,202	1,619	396,733.911
Total	846,790,430	1,628	520,141.542

Number of obs	=	1,629
F(9, 1619)	=	57.27
Prob > F	=	0.0000
R-squared	=	0.2415
Adj R-squared	=	0.2373
Root MSE	=	629.87

	cum_pop_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	is_new*	79.3863	40.5291	1.96	0.0500	-0.1086	158.8813
Historical Predictors	dist_transit_1970	0.0136	0.0082	1.67	0.0950	-0.0024	0.0296
	single_fam_1970	0.0854	0.0565	1.51	0.1310	-0.0255	0.1963
	tract_pop_1970**	-0.2008	0.0115	-17.48	0.0000	-0.2234	-0.1783
	per_transit_work_1970**	-1,052.4230	200.2065	-5.26	0.0000	-1,445.1140	-659.7322
	per_white_1970	103.5169	105.9496	0.98	0.3290	-104.2959	311.3298

Contemporary Physical Attributes	dist_dtc	0.0005	0.0070	0.07	0.9420	-0.0132	0.0142
	dist_highway*	-0.0191	0.0089	-2.15	0.0320	-0.0365	-0.0017
	pnr_over1000**	-114.7355	43.0759	-2.66	0.0080	-199.2258	-30.2452

* Significant at a 95% confidence level ($P \le 0.05$)

** Significant at a 99% confidence level ($P \le 0.01$)

Table 3. Effect of Change in Distance to Transit on Population

Source	SS	df	MS
Model	205,492,972	9	22,832,552.5
Residual	641,297,458	1,619	396,107.139
Total	846,790,430	1,628	520,141.542

Number of obs	=	1,629
F(9, 1619)	=	57.64
Prob > F	=	0.0000
R-squared	=	0.2427
Adj R-squared	=	0.2385
Root MSE	=	629.37

	cum_pop_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	dist_change*	-0.0283	0.0112	-2.53	0.0110	-0.0502	-0.0064
Historical Predictors	dist_transit_1970	0.0114	0.0082	1.40	0.1620	-0.0046	0.0275
	single_fam_1970	0.0835	0.0563	1.48	0.1380	-0.0270	0.1939
	tract_pop_1970**	-0.2001	0.0115	-17.45	0.0000	-0.2226	-0.1776
	per_transit_work_1970**	-1,040.2000	200.1809	-5.20	0.0000	-1,432.8410	-647.5594
	per_white_1970	69.5329	105.2274	0.66	0.5090	-136.8633	275.9291

Contemporary Physical Attributes	dist_dtc	0.0001	0.0067	0.02	0.9830	-0.0131	0.0133
	dist_highway*	-0.0184	0.0089	-2.08	0.0380	-0.0358	-0.0010
	pnr_over1000*	-106.2787	42.4148	-2.51	0.0120	-189.4724	-23.0850

* Significant at a 95% confidence level ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 4. Effect of New Transit Stop on Population after One Census Period

Source	SS	df	MS
Model	203,094,239	9	22,566,026.6
Residual	643,696,191	1,619	397,588.753
Total	846,790,430	1,628	520,141.542

Number of obs	=	1,629
F(9, 1619)	=	56.76
Prob > F	=	0.0000
R-squared	=	0.2398
Adj R-squared	=	0.2356
Root MSE	=	630.55

	cum_pop_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	new_1000_1per	-70.3018	119.2589	-0.59	0.5560	-304.2198	163.6162
Historical Predictors	dist_transit_1970**	0.0208	0.0073	2.86	0.0040	0.0065	0.0351
	single_fam_1970	0.1014	0.0560	1.81	0.0700	-0.0083	0.2112
	tract_pop_1970**	-0.1994	0.0115	-17.33	0.0000	-0.2220	-0.1768
	per_transit_work_1970**	-1,084.5410	200.3219	-5.41	0.0000	-1,477.4590	-691.6238
	per_white_1970	81.0318	105.3829	0.77	0.4420	-125.6694	287.7331

Contemporary Physical Attributes	dist_dtc	-0.0048	0.0065	-0.74	0.4620	-0.0174	0.0079
	dist_highway*	-0.0215	0.0088	-2.43	0.0150	-0.0388	-0.0042
	pnr_over1000*	-98.0259	42.4755	-2.31	0.0210	-181.3386	-14.7132

* Significant at a 95% confidence level ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 5. Effect of New Transit Stop on Population after Two Census Periods

Source	SS	df	MS
Model	203,101,792	9	22,566,865.8
Residual	643,688,638	1,619	397,584.088
Total	846,790,430	1,628	520,141.542

Number of obs	=	1,629
F(9, 1619)	=	56.76
Prob > F	=	0.0000
R-squared	=	0.2398
Adj R-squared	=	0.2356
Root MSE	=	630.54

	cum_pop_change	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Variable of Interest	new_1000_2per	-72.1978	119.2582	-0.61	0.5450	-306.1144	161.7189
Historical Predictors	dist_transit_1970**	0.0208	0.0073	2.86	0.0040	0.0065	0.0351
	single_fam_1970	0.1014	0.0560	1.81	0.0700	-0.0083	0.2111
	tract_pop_1970**	-0.1994	0.0115	-17.33	0.0000	-0.2220	-0.1768
	per_transit_work_1970**	-1,084.7220	200.3208	-5.41	0.0000	-1,477.6370	-691.8065
	per_white_1970	81.0735	105.3823	0.77	0.4420	-125.6265	287.7735

Contemporary Physical Attributes	dist_dtc	-0.0048	0.0065	-0.74	0.4620	-0.0175	0.0079
	dist_highway*	-0.0215	0.0088	-2.43	0.0150	-0.0388	-0.0042
	pnr_over1000*	-97.9878	42.4752	-2.31	0.0210	-181.3000	-14.6756

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

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

Table 6. Effect of New Transit Stop on Population after Three Census Periods

Source	**SS**	**df**	**MS**
Model	203,810,008	9	22,645,556.4
Residual	642,980,422	1,619	397,146.648
Total	846,790,430	1,628	520,141.542

Number of obs	=	1,629
F(9, 1619)	=	57.02
Prob > F	=	0.0000
R-squared	=	0.2407
Adj R-squared	=	0.2365
Root MSE	=	630.20

	cum_pop_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	new_1000_3per	240.9764	164.3384	1.47	0.1430	-81.3619	563.3147
Historical Predictors	dist_transit_1970**	0.0211	0.0073	2.89	0.0040	0.0068	0.0354
	single_fam_1970	0.1041	0.0558	1.86	0.0620	-0.0054	0.2136
	tract_pop_1970**	-0.2005	0.0115	-17.44	0.0000	-0.2230	-0.1779
	per_transit_work_1970**	-1,060.8990	200.2231	-5.30	0.0000	-1,453.6230	-668.1758
	per_white_1970	77.0895	105.3045	0.73	0.4640	-129.4578	283.6369

Contemporary Physical Attributes	dist_dtc	-0.0043	0.0065	-0.67	0.5040	-0.0170	0.0084
	dist_highway*	-0.0210	0.0088	-2.38	0.0170	-0.0382	-0.0037
	pnr_over1000*	-101.5285	42.4081	-2.39	0.0170	-184.7090	-18.3480

* Significant at a 95% confidence level ($P \leq 0.05$)
** Significant at a 99% confidence level ($P \leq 0.01$)

v. Regression Results: Impact on Housing Stock

To further elaborate the study, it is interesting to look at the impacts on residential housing as measured by housing units in a census tract. While the change in housing units may not simply reflect new construction or tear-down (for example, subdivision of houses and conversion of industrial buildings can provide new units) and hence doesn't necessarily provide much insight into the physical attributes of housing in a census tract, it provides a relatively good snapshot of the physical presence (and changes therein) of the housing stock in a tract.

Applying the same measures as before (see Table 7), we see a somewhat stronger connection between getting a new transit station and the change in housing stock that we did with population. In addition, more of the supporting variables seem relevant, though the overall prediction of variance is somewhat lower.

Applying the same measures to the change in distance to transit (see Table 8), we see strong, statistically significant evidence that a greater reduction in distance to transit is associated with a greater increase in housing stock (again, the values are inverted).

Finally, when looking at the impacts of close proximity to a new rail transit station on housing stock, we actually see a divergence from the pattern we saw with population. While the effects at one (see Table 9) and two (see Table 10) census periods are still ambiguous and statistically insignificant, we do see a significant impact after three census periods have elapsed (see Table 11).

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. 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 7. Effect of New Transit Stop on Housing Stock

Source	SS	df	MS
Model	31,680,745.9	9	3,520,082.9
Residual	131,051,373	1,619	80,945.876
Total	162,732,119	1,628	99,958.304

Number of obs	=	1,629
F(9, 1619)	=	43.49
Prob > F	=	0.0000
R-squared	=	0.1947
Adj R-squared	=	0.1902
Root MSE	=	284.51

	cum_hous_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	is_new**	109.1860	18.3069	5.96	0.0000	73.2784	145.0937
Historical Predictors	dist_transit_1970*	0.0086	0.0037	2.33	0.0200	0.0014	0.0158
	single_fam_1970**	0.0807	0.0255	3.16	0.0020	0.0306	0.1308
	tract_pop_1970**	-0.0205	0.0052	-3.95	0.0000	-0.0307	-0.0103
	per_transit_work_1970**	-308.0627	90.4328	-3.41	0.0010	-485.4403	-130.6851
	per_white_1970**	189.8779	47.8572	3.97	0.0000	96.0093	283.7464

Contemporary Physical Attributes	dist_dtc	-0.0005	0.0032	-0.17	0.8660	-0.0067	0.0057
	dist_highway**	-0.0122	0.0040	-3.04	0.0020	-0.0201	-0.0043
	pnr_over1000	12.0147	19.4573	0.62	0.5370	-26.1494	50.1787

* Significant at a 95% confidence level ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 8. Effect of Change in Distance to Transit on Housing Stock

Source	SS	df	MS
Model	30,797,652.4	9	3,421,961.4
Residual	131,934,467	1,619	81,491.332
Total	162,732,119	1,628	99,958.304

Number of obs	=	1,629
F(9, 1619)	=	41.99
Prob > F	=	0.0000
R-squared	=	0.1893
Adj R-squared	=	0.1847
Root MSE	=	285.47

	cum_hous_change	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
Variable of Interest	dist_change**	-0.0251	0.0051	-4.95	0.0000	-0.0350	-0.0151
Historical Predictors	dist_transit_1970**	0.0102	0.0037	2.75	0.0060	0.0029	0.0175
	single_fam_1970**	0.0877	0.0255	3.43	0.0010	0.0376	0.1378
	tract_pop_1970**	-0.0193	0.0052	-3.71	0.0000	-0.0295	-0.0091
	per_transit_work_1970**	-309.6368	90.7971	-3.41	0.0010	-487.7290	-131.5445
	per_white_1970**	147.9979	47.7286	3.10	0.0020	54.3817	241.6142

Contemporary Physical Attributes	dist_dtc	-0.0034	0.0031	-1.11	0.2680	-0.0094	0.0026
	dist_highway**	-0.0127	0.0040	-3.15	0.0020	-0.0205	-0.0048
	pnr_over1000	26.9854	19.2383	1.40	0.1610	-10.7492	64.7200

* Significant at a 95% confidence level ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 9. 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 ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 10. 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 ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

Table 11. 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 ($P \leq 0.05$)

** Significant at a 99% confidence level ($P \leq 0.01$)

b. Station Experiences

As shown in the regression analysis above, there does appear to be a connection between increased transit accessibility and an increase in population and housing stock. If transit is indeed to be a part of the effort to create denser, more (theoretically) walkable communities, those impacts ought to be reflected in the structure of the neighborhood. However, a cursory glance at the physical experience on the ground at the stations in Table 1 (below) make it clear that a variety of outcomes have been seen in the recent history of Boston rail transit station development – from contextual neighborhood stations to large park and ride facilities separated from the surrounding communities. Thus, by taking a closer look at stations which reflect both the typical and extraordinary experiences of transit development in Boston can shed further illumination on the likely land use outcomes of development, particularly since such development does not occur in a political vacuum.

For example, at the time the Red Line was being extended to Alewife, the residents around Davis Square were concerned about changes is the neighborhood. As part of a community-oriented planning process in the city of Somerville, the Davis Square Task Force indicated that "[o]ne of the major goals of the Davis Square Action Plan [was] to preserve the character and quality of life in the residential neighborhoods which surround the commercial core"[70] and advocated for the preservation of existing height limits in the area.[71] This would serve to resist physical changes that might come along with rail transit development and ensured the medium-density, walkable character of the neighborhood was preserved. However, in his study

70 Office of Planning, *Davis Square Action Plan*, 11.

71 Ibid., 5.

of the gentrification effects of transit-oriented development, Kahn notes that, "In Boston, the average tract treated with a 'Park and Ride' station experienced a 5% decline in home prices, while the average tract treated with a 'Walk and Ride' station experienced a 7% increase in home prices."[72] An area like Davis Square would likely have seen greater vertical development if restrictions were not in place. Thus, though this is but one example, it is clear that additional lessons can be learned by considering the specific experience and particular stations.

i. Comparative Statistics

To begin the case study analysis of individual stations, I selected a subset comprised of three groups of the stations located on the MBTA Red Line and Orange Line which were built in the 1970s and 1980s and which are not near the site of previous rapid transit stations (and which thus would function as replacements, rather than as new service). The stations that will be a part of my analysis are presented in Table 2. A map is available in Appendix B.[73]

72 Matthew E. Kahn, "Gentrification Trends in New Transit-Oriented Communities: Evidence from 14 Cities that Expanded and Built Rail Transit Systems," *Real Estate Economics* 35, no. 2 (2007): 173.

73 Excluded from this analysis are the Orange Line stations at Community College and between Tufts Medical Center and Green Street because, while there were opened in the 1970s and 1980s, they are either located in areas that were already relatively close to other rapid transit services or they are proximate replacements of either the Charlestown Elevated or the Washington Street Elevated, which were torn down in the construction of the new Orange Line alignment. Assembly, which opened as an infill station on the Orange Line in 2014, is also excluded. While Assembly has seen rapid growth around it in a previously transit-scarce location (part of a unique political and development strategy), no census has been taken since the opening of the stations and it is simply too early to say anything definitive about the experience there, or to draw conclusions that might be applied elsewhere.

Table 12. Stations for Analysis [74]

Red Line (North)	**Red Line (South)**	**Orange Line (North)**
Alewife (1985)	North Quincy (1971)	Oak Grove (1977)
Davis (1984)	Wollaston (1971)	Malden Center (1975)
Porter (1984)	Quincy Center (1971)	Wellington (1975)
	Quincy Adams (1983)	
	Braintree (1980)	

For this subset of stations, I identified census tracts whose centroid was located within a 1,000 meter radius of a station to roughly approximate the walkshed of the station and to assess the residential changes in the area from before the new station opened (1970 or 1980 census data) to the year 2000. A map highlighting these census tracts is available in Appendix F. Note that there are no census tracts whose centroid is within 1,000 meters of Braintree station, so no assessment of its impact has been included. The results of the analysis are presented in Tables 13 – 18 below.

After conducting the comparative statistical analysis of the selected stations, a few patterns emerge. First, it is evident that nearly all station areas examined lost population in the time period between the last census prior to the opening of the new transit station and the year 2000. However, in most cases, it appears that the majority of population loss occurred early in the timeframe studied and actually rebounded in the latter years, indicating that perhaps there is a broader structural movement at work in the metropolitan area at this time. Second, in a turn that is a bit surprising, given the universal loss of population, the stations have all gained in housing units since the arrival of transit. Third, there is great variance in the magnitude of these changes and, especially in the case of housing stock changes, these

74 Dates from Belcher, "Changes to Transit Service," 310-8.

appear to be strongly correlated with the corridor in which the station is located, indicating some strong spatial differences between the three.

Table 13. Population Impacts –Red Line (North)

Station	Year Opened	Census Tract	Pop. Change 1970 – 1980	Pop. Change 1980 – 1990		Pop. Change 1990 – 2000		Pop. Change Pre-Transit – 2000	
Alewife	1985	25017354600		-123	-2.95%	372	9.20%	*249*	*5.98%*
		25017354900		5	0.10%	112	2.17%	*117*	*2.27%*
		25017355000*		-453	-16.32%	344	14.81%	*-109*	*-3.93%*
		25017356100		-324	-8.90%	-209	-6.30%	*-533*	*-14.64%*
				-895	*-5.69%*	*619*	*4.17%*	***-276***	***-1.75%***
Davis	1984	25017350400		-132	-2.13%	-224	-3.69%	*-356*	*-5.73%*
		25017350500		5	0.28%	-174	-9.58%	*-169*	*-9.33%*
		25017350600		-179	-3.96%	321	7.39%	*142*	*3.14%*
		25017350800		-121	-6.05%	-144	-7.67%	*-265*	*-13.26%*
		25017350900**		-98	-2.80%	-197	-5.80%	*-295*	*-8.44%*
		25017354700**		70	3.35%	275	12.74%	*345*	*16.52%*
		25017354800**		24	1.22%	30	1.51%	*54*	*2.75%*
		25017355000*		-453	-16.32%	344	14.81%	*-109*	*-3.93%*
				-884	*-3.56%*	*231*	*0.96%*	***-653***	***-2.63%***

Porter	1984	25017350900**	-98	-2.80%	-197	-5.80%	*-295*	*-8.44%*
		25017351000	-113	-1.62%	-434	-6.34%	*-547*	*-7.86%*
		25017353600	-156	-3.24%	-31	-0.67%	*-187*	*-3.88%*
		25017354000	315	7.64%	175	3.94%	*490*	*11.89%*
		25017354500	-72	-2.89%	-68	-2.81%	*-140*	*-5.62%*
		25017354700**	70	3.35%	275	12.74%	*345*	*16.52%*
		25017354800**	24	1.22%	30	1.51%	*54*	*2.75%*
			-30	*-0.12%*	*-250*	*-0.96%*	***-280***	***-1.08%***
			-1,352	**-2.41%**	**148**	**0.27%**	**-1,204**	**-2.14%**

* 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 14. Population Impacts –Red Line (South)

Station	Year Opened	Census Tract	Pop. Change 1970 – 1980		Pop. Change 1980 – 1990		Pop. Change 1990 – 2000		Pop. Change Pre-Transit – 2000	
North Quincy	1971	25021417200	-121	-1.58%	-192	-2.55%	281	3.83%	*-32*	*-0.42%*
		25021417501	-230	-4.13%	-258	-4.83%	-150	-2.95%	*-638*	*-11.46%*
		25021417502	-197	-4.13%	-221	-4.84%	189	4.35%	*-229*	*-4.80%*
			-548	*-3.05%*	*-671*	*-3.85%*	*320*	*1.91%*	***-899***	***-5.00%***
Wollaston	1971	25021417100	-326	-6.57%	-300	-6.47%	-162	-3.73%	*-788*	*-15.87%*
		25021417601	-23	-0.42%	71	1.30%	-165	-2.97%	*-117*	*-2.13%*
			-349	*-3.33%*	*-229*	*-2.26%*	*-327*	*-3.31%*	***-905***	***-8.65%***
Quincy Center	1971	25021417701	-177	-5.53%	40	1.32%	614	20.04%	*477*	*14.90%*
		25021418101	-138	-2.98%	202	4.50%	308	6.56%	*372*	*8.03%*
			-315	*-4.02%*	*242*	*3.22%*	*922*	*11.88%*	***849***	***10.84%***
Quincy Adams	1983	25021418004			*5*	*0.20%*	*448*	*18.23%*	***453***	***18.47%***
Braintree	1980	–	*No Census Tracts have a centroid within 1,000 meters of Braintree station*							
			-1,212	**-3.34%**	**-653**	**-1.74%**	**1,363**	**3.70%**	**-502**	**-1.30%**

Table 15. Population Impacts – Orange Line (North)

Station	Year Opened	Census Tract	Pop. Change 1970 – 1980		Pop. Change 1980 – 1990		Pop. Change 1990 – 2000		Pop. Change Pre-Transit – 2000	
Oak Grove	1977	25017336401	-462	-9.89%	-207	-4.92%	-99	-2.47%	*-768*	*-16.45%*
		25017341101	-329	-6.98%	57	1.30%	225	5.06%	*-47*	*-1.00%*
		25017341600	-95	-1.45%	-414	-6.39%	488	8.05%	*-21*	*-0.32%*
			-886	*-5.55%*	*-564*	*-3.74%*	*614*	*4.23%*	***-836***	***-5.24%***
Malden Center	1975	25017341102	-268	-7.09%	44	1.25%	177	4.98%	*-47*	*-1.24%*
		25017341200	-868	-11.66%	-22	-0.33%	30	0.46%	*-860*	*-11.55%*
		25017341300	-609	-15.50%	833	25.09%	573	13.80%	*797*	*20.29%*
			-1,745	*-11.52%*	*855*	*6.38%*	*780*	*5.47%*	***-110***	***-0.73%***
Wellington	1975	25017339801	-12	-0.47%	263	10.40%	4	0.14%	*255*	*10.04%*
		25017350103	-743	-14.02%	-401	-8.80%	731	17.59%	*-413*	*-7.79%*
			-755	*-9.63%*	*-138*	*-1.95%*	*735*	*10.58%*	***-158***	***-2.02%***
			-3,386	**-8.69%**	**153**	**0.43%**	**2,129**	**5.96%**	**-1,104**	**-2.83%**

Table 16. 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 17. 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 18. 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%**

ii. Municipal Context

In order to illuminate potential outliers in the data above, it is worthwhile to examine the broader experiences in the cities in which these stations were constructed. By looking at the experience in the average tract in these cities, it is possible to determine whether the residential changes around the station are basically in line in direction and magnitude with changes around the city, or if they are in some way different from the patterns elsewhere.[75] For comparison, here are the average changes across the cities containing the new stations:

Table 19. Average Municipal Changes, 1970 – 2000

City	Stations	Average Tract Population Change	Average Tract Housing Stock Change
Braintree	*Braintree*	-150.4	408.4
Cambridge	*Alewife, Porter*	12.2	228.6
Malden	*Oak Grove, Malden Center*	14.0	392.7
Medford	*Wellington*	-719.0	235.3
Quincy	*North Quincy, Wollaston, Quincy Center, Quincy Adams*	1.6	550.6
Somerville	*Davis*	-622.9	155.1

Here we can see that Cambridge, Malden, and Quincy had roughly no net population gain or loss (in fact, a marginal gain, on average), making the relatively large population losses around North Quincy, Wollaston, and Oak Grove stand out, as well as the relatively large population gains at Quincy Center and Quincy Adams.

75 Note that this has been analyzed based on the municipal location of the station, not of the individual census tracts. While in most cases there will not be a difference, a few census tracts will lie over the border in another city, especially along the northern stretch of the Red Line on the Cambridge/Somerville border. Again, we have no comparative data for Braintree because there are no census tracts with their centroid within a 1,000 meter radius of the Braintree station. However, the municipal averages are included for context.

Wellington also seems to have lost relatively little population, given the steep declines in the city of Medford as a whole. This indicates that, in some instances, population growth in the city seems to have concentrated itself away from new transit stations, rather than near it, though in the case of the four Quincy stations, there appears to have been more of a shift in residential patterns along the Red Line extension, rather than either a major attraction or repulsion.

Meanwhile, housing stock changes seem mostly in-line with the municipal trends, though Quincy Center seems notable once again for its remarkably high rate of growth. This suggests that perhaps growth in housing stock around stations is as much an artefact of general levels of development in the city as it is a phenomenon driven by new transit stations. Quincy was noted for its condominium development in the 1980s,[76] but then saw many units sit vacant[77] or sell at reduced prices[78] when the market fell in 1990. The location of these developments may have been partially driven by access to transit, but the boom was evidently occurring across the city.

Looking elsewhere, Wellington is an interesting case not because it avoided the large cumulative population loss that occurred in Medford at this time, but because it actually experienced such a loss in the 1970s and 1980s before reversing that trend dramatically in the 1990s. While its increase in housing stock is more evenly spread, Wellington provides a good reminder that it can take decades for residential changes to take root around a new transit development.

76 Patrick Ronan, "Boston's real estate boom spills south into Quincy," *The Patriot Ledger*, January 8, 2015, accessed May 11, 2016, http://www.patriotledger.com/article/20150608/NEWS/150606443/?Start=1.

77 Ibid.

78 Susan Diesenhouse, "Quincy, Mass.: Lower Prices Move Condos," Northeast Notebook, *The New York Times*, Sunday, July 8, 1990, ProQuest.

Designed as a new repair shop for the Orange Line,[79] Wellington has always faced the structural challenges to development of being sited at a rail yards. However, plans to redevelop the area for housing and other uses go almost as far back as the station itself, which opened in 1975. For example, there was a $100 million mixed-use proposal for the site in the planning phase in 1979.[80] However, it wasn't until the late 1990s and early 2000s (which extends beyond the timeframe of our statistical analysis) that the station area really started to see more development (see historic and contemporary aerial photographs in Appendices G and H – note the large increase in development to the west of the station). This lends further credence to the idea that successful residential development around transit can take a long time, a repeated lesson that ought to be heeded.

c. Applications to Green Line Extension

Finally, we ought to ask whether the lessons learned from the Red Line and Orange Line extensions in the 1970s and 1980s can teach us anything for the proposed Green Line extension in Somerville and Medford. I believe the lessons learned can provide some insight into what may happen in the neighborhoods surrounding the Green Line extension once it is built and into the steps and choices the city might take to promote one outcome or another at the various station locations. A map of the proposed route and stations can be found in Appendix C.

A cursory examination of the route shows that the proposed station locations seem to have much more in common with established,

79 A.S. Plotkin, "It took too long, cost too much, but new Orange Line almost done," *The Boston Globe*, March 23, 1975, ProQuest.

80 Anthony J. Yudis, "Medford takes first step in $100 million project," Lots and Blocks, *The Boston Globe*, March 18, 1979, ProQuest.

small-scale residential neighborhoods like Davis Square and Wollaston than they do with a historical commercial downtown like Quincy Center or a *tabula rasa* development site like Wellington. Davis and Wollaston are locations which haven't seen as much of a turnaround in population growth as many of the other transit station areas did in the 1990s, and Wollaston has also begun to lose housing stock. Additionally, Medford and Somerville as a whole are the two cities which have seen the largest overall reduction in population in our study. Both cities are concerned about the state of their housing (see, for example, Somerville's recent mandatory 20% inclusionary zoning ordinance[81] and Medford's recent consolidated housing plan[82]), so it is possible that they will take a more intentional approach to housing around the Green Line – if it arrives – than was taken in the past. However, this indicates much more of a policy decision and the importance of support than it does any suggestion that building the Green Line will, on its own, make a remarkable difference in residential makeup and development in either city, something that is also supported by the findings from studies in other cities discussed earlier.

And, finally, cites and residents shouldn't expect an immediate change. The example of Assembly notwithstanding (and the rapid development there is, again, an example of a variety of policies working in concert, of which the creation of a new transit stop is only one), evidence points to gradual, long-term increases in housing as a result of new access to transit. Given that the cities are already much closer

81 "Newstalk – May 11th," *The Somerville Times*, May 11, 2016, accessed May 11, 2016, http://www.thesomervilletimes.com/archives/67310.

82 Medford Office of Community Development, *DRAFT Five Year Consolidated Plan (2015-2020) and Annual Action Plan (2015-2016)* (Medford, MA: City of Medford Office of Community Development, 2015), http://www.medfordma.org/wp-content/uploads/2012/12/Updated-Draft-Con-Plan_4.28.15_Optimized.pdf.

to rail transit than, say, Quincy was prior to the Red Line extension, it is hard to expect that the impacts will be markedly greater than average, especially if we recall Giuliano's finding that new transit is most likely to drive land use change when it has "a significant impact on accessibility."[83]

83 Giuliano, "Land Use Impacts," 268.

6. Conclusions & Next Steps

This paper sought to elucidate the effect that the construction of new MBTA stations in the 1970s and 1980s had on the residential land use surrounding the station locations and to illuminate the extent to which a change in transit accessibility is predictive of changes in residential land use for a specific station. To that end, evidence from a variety of sources indicates that improved access to transit can indeed be a contributor to increased residential density, especially increased units of housing stock. However, this development is not uniform, is subject to the peculiarities of a particular location, and frequently takes decades to occur – much longer than the typical electoral-cycle timeframe considered by a political leader who might be contemplating advocating for a project. From the evidence of previous studies, it is also beyond the timeframe of assessment and review that many projects undergo, possibly resulting in the failure to capture evidence of such changes as a result of transit expansion. Ultimately, this work provides modest but promising evidence for the efficacy of transit and offers several further avenues for study, both in the refinement of the study methodology and in the extension of analysis to other sectors and locations.

First, as acknowledged above, there are some concerns with the data from the Neighborhood Change Database (NCDB) and further work ought to be done to resolve issues around geographic inconsistencies, allowing analysis to be continued to 2010 (and, subsequently, beyond), which might reveal some interesting trends, as the Boston real estate market has been quite hot recently. Alternatively, census data with consistent geographies can be accessed through the National Historic Geographic Information System (NHGIS),[84] which may offer more geographic accuracy and consistency than the NCDB. However, regularizing the NHGIS data requires using a computer coding model to create weighted historical assignments specifically for this project, something that is beyond the scope of this thesis.

Second, there is potential for the use of more advanced statistical processing methods to more fully account for outside factors and attempt to isolate the effects of transit. One intriguing method is Propensity Score Matching, which would essentially group the census tracts by scores assigned based on their various characteristics (locational, demographic, etc.) allowing the researcher to hold those values constant while varying the input of a new transit station. This would allow for the removal of some of the complicating factors which can make it difficult to determine just how much impact the change in transit accessibility itself is having on residential (or other) development.

---

84 See: Minnesota Population Center, *National Historical Geographic Information System: Version 2.0* (Minneapolis, MN: University of Minnesota, 2011), https://www.nhgis.org/.

To that point, there is an opportunity to expand the scope of study beyond just residential land use. Business data is much more difficult to come by than census data (much of the data is either proprietary, incomplete, or both), and it is harder to find historical data, but one potential source of information on changes to the physical fabric in both the residential and commercial realms is in building permit or assessor's information in the cities of interest, which could include built square footage and use at various points in time. The effort required to assemble that data would be substantial, as much of it may exist in analog format only in various municipal buildings, but it could provide a broader picture of the nature of historical physical development.

Finally, this analysis can be extended to other metropolitan areas, particularly to ones that developed new systems or extended old ones around the same time that Boston did. Due to the availability of tract-level census data back to 1970 in much of the country, the transit construction boom at the end of the twentieth century provides a great opportunity to study its efficacy and localized effects in a way that hasn't been possible before. By better understanding our cities and the way they have been affected by transit systems historically, we can have a more effective and informed dialogue around the true impacts that rail transit has and can have in our communities.

Appendices

Appendix A. Bibliography

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

Altshuler, Alan and David Luberoff, *Mega-Projects: The Changing Politics of Urban Public Investment*. Washington, D.C.: Brookings Institution Press, 2003.

Badoe, Daniel A. and Eric J. Miller. "Transportation–land-use interaction: empirical findings in North America, and their implications for modeling." *Transportation Research Part D: Transport and Environment* 5, no. 4 (July 2000): 235-63.

Bajari, Patrick and Matthew Kahn. "Estimating Hedonic Models of Consumer Demand with an Application to Urban Sprawl." Working Paper, 2007.

Baum-Snow, Nathaniel. "Did Highways Cause Suburbanization?" *The Quarterly Journal of Economics* 122, no. 2 (May 2007): 775-805.

Baum-Snow, Nathaniel and Matthew E. Kahn. "The Effects of New Public Projects to Expand Urban Rail Transit." *Journal of Public Economics* 77, no. 2 (2000): 241-63.

———. "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.

Bernick, Michael and Robert Cervero. *Transit Villages in the 21st Century*. New York: McGraw-Hill, 1997.

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.

Bowes, David R. and Keith R. Ihlanfeldt. "Identifying the Impacts of Rail Transit Stations on Residential Property Values." *Journal of Urban Economics* 50, no. 1 (2001): 1-25.

Burtless, Gary and Janet Rothenberg Pack, eds. *Brookings-Wharton Papers on Urban Affairs 2005*. Washington, D.C.: Brookings Institution Press, 2005.

Cervero, Robert and John Landis. "Twenty Years of the Bay Area Rapid Transit System: Land use and Development Impacts." *Transportation Research Part A: Policy and Practice* 31, no. 4 (1997): 309-33.

Chatman, Daniel G. and Robert B. Noland. "Transit Service, Physical Agglomeration and Productivity in US Metropolitan Areas." *Urban Studies* 51.5 (2014): 917-37.

Cohen, Jeffrey P. "The Broader Effects of Transportation Infrastructure: Spatial Econometrics and Productivity Approaches." *Transportation Research Part E: Logistics and Transportation Review* 46, no. 3 (May 2010): 317-26.

Diesenhouse, Susan. "Quincy, Mass.: Lower Prices Move Condos." Northeast Notebook. *The New York Times*, Sunday, July 8, 1990. ProQuest.

Duany, Andres, Elizabeth Plater-Zyberk, and Jeff Speck. "How to Make a Town." In *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream*, 183-214. New York: North Point Press, 2000.

Duany, Andres, Jeff Speck, with Mike Lydon. *The Smart Growth Manual*. New York: McGraw Hill, 2010.

Dunphy, Robert, Deborah Myerson, and Michael Pawlukiewicz. *Ten Principles for Successful Development Around Transit*. Washington, D.C.: Urban Land Institute, 2003.

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.

Giuliano, Genevieve. "Land use Impacts of Transportation Investments: Highway and Transit." In *The Geography of Urban Transportation*, edited by Susan Hanson and Genevieve Giuliano. Third ed., 237-73. New York: The Guilford Press, 2004.

Handy, Susan. "Smart Growth and the Transportation–Land use Connection: What does the Research Tell Us?" *International Regional Science Review* 28, no. 2 (2005): 146-67.

Hanson, Susan and Genevieve Giuliano, eds. *The Geography of Urban Transportation*. Third ed. New York: The Guildford Press, 2004.

Jacobs, Jane. "The need for primary mixed uses." In *The Death and Life of Great American Cities*, 152-77. New York: Random House, 1961. Reprint, New York: Vintage, 1992. Citations refer to the Vintage edition.

Kahn, Matthew E. "Gentrification Trends in New Transit-Oriented Communities: Evidence from 14 Cities that Expanded and Built Rail Transit Systems." *Real Estate Economics* 35, no. 2 (2007): 155-82.

Katseff, Jared. "Marrying Market Timing with Human-Centered Urban Design: How Investors and Municipalities can Better Realize Transit Oriented Development." Masters in Urban Planning, Harvard University Graduate School of Design, 2015.

Knight, Robert L. and Lisa L. Trygg. *Land Use Impacts of Rapid Transit: Implications of Recent Experience: Executive Summary*. Washington, D.C.: U.S. Department of Transportation, 1977.

Lewis-Workman, Steven and Daniel Brod. "Measuring the Neighborhood Benefits of Rail Transit Accessibility." *Transportation Research Record: Journal of the Transportation Research Board* 1576, no. 1 (1997): 147-53.

Luberoff, David. "Extending the Green Line to Somerville (Abridged)." Case Number 1983.3. Cambridge, MA: Harvard University John F. Kennedy School of Government, 2013.

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

Medford Office of Community Development. *DRAFT Five Year Consolidated Plan (2015-2020) and Annual Action Plan (2015-2016)*. Medford, MA: City of Medford Office of Community Development, 2015. http://www.medfordma.org/wp-content/uploads/2012/12/Updated-Draft-Con-Plan_4.28.15_Optimized.pdf.

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

Muth, Richard F. *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Chicago: The University of Chicago Press, 1969.

Newman, Peter W. G. and Jeffrey Kenworthy. *The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning*. Washington, D.C.: Island Press, 2015.

———. "The land use–transportation connection: An overview." *Land Use Policy* 13, no. 1 (1996): 1-22.

———. *Sustainability and Cities: Overcoming Automobile Dependence*. Washington, D.C.: Island Press, 1999.

"Newstalk – May 11th." *The Somerville Times*, May 11, 2016. Accessed May 11, 2016, http://www.thesomervilletimes.com/archives/67310.

Plotkin, A.S. "It took too long, cost too much, but new Orange Line almost done." *The Boston Globe*, March 23, 1975. ProQuest.

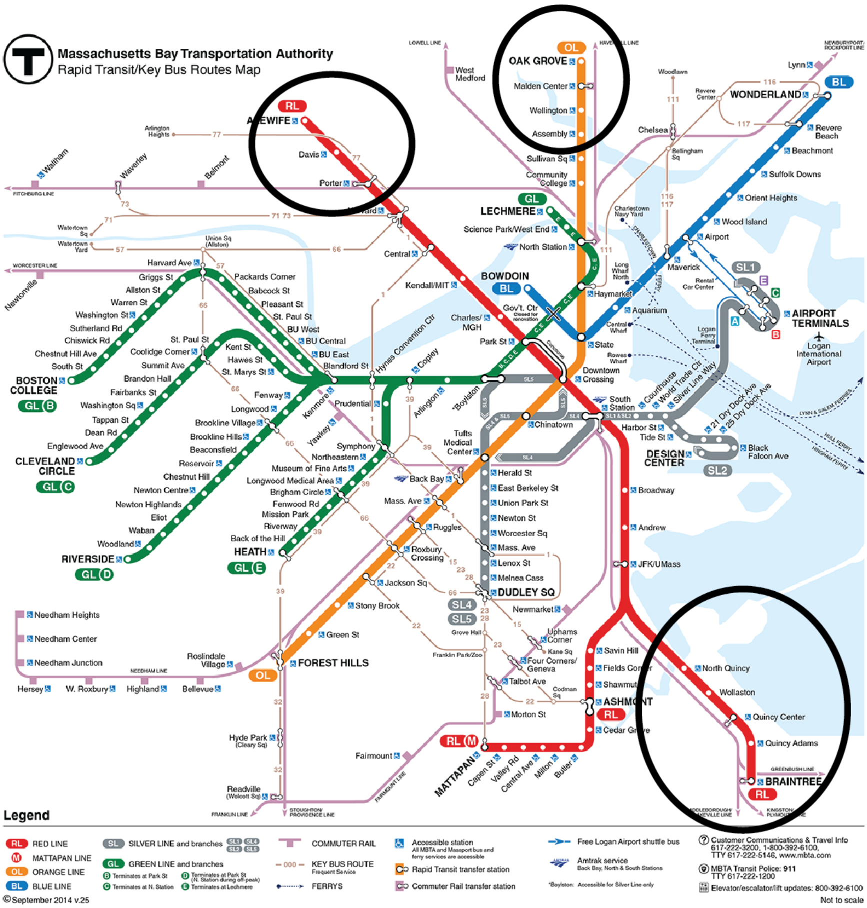
Office of Planning & Community Development. *Davis Square Action Plan*. Somerville, MA: Office of Planning & Community Development, 1984.

Ronan, Patrick. "Boston's real estate boom spills south into Quincy." *The Patriot Ledger*, January 8, 2015. Accessed May 11, 2016 http://www.patriotledger.com/article/20150608/NEWS/150606443/?Start=1.

Voith, Richard. "Comment." In "Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970-2000," by Nathaniel Baum-Snow and Matthew E. Kahn. In *Brookings-Wharton Papers on Urban Affairs 2005*, edited by Gary Burtless and Janet Rothenberg Pack, 198-204. Washington, D.C.: Brookings Institution Press, 2005.

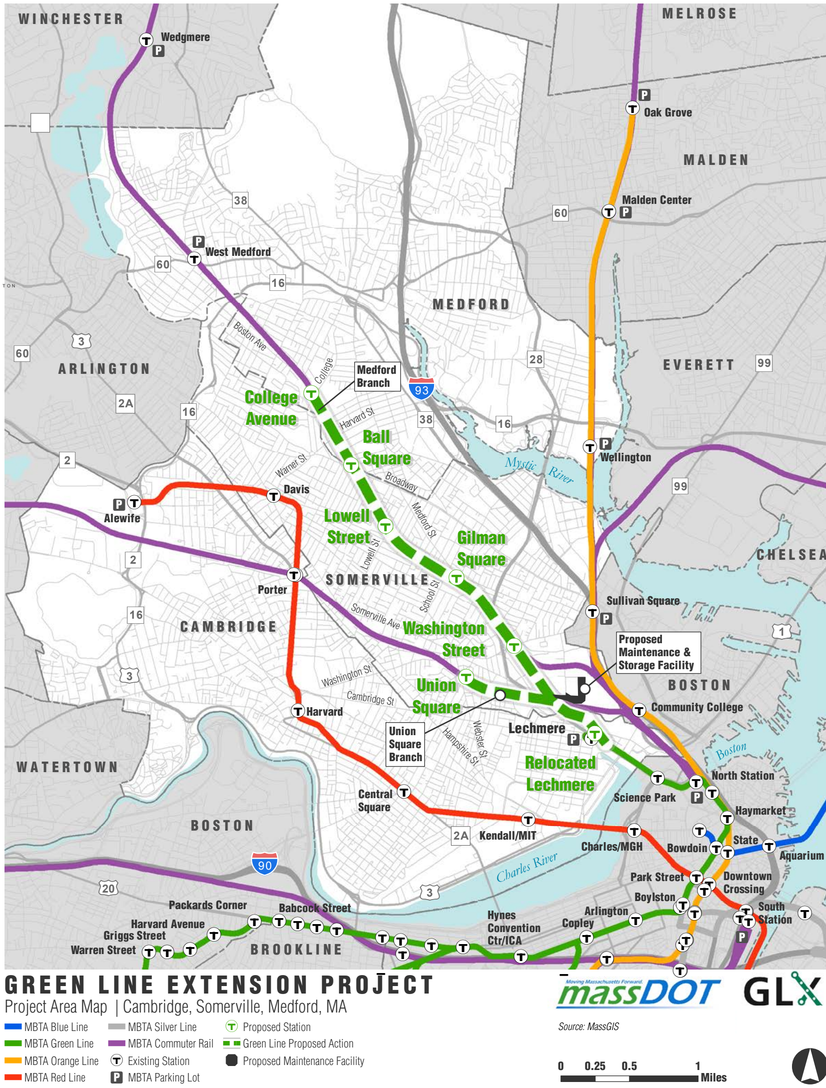
Yudis, Anthony J. "Medford takes first step in $100 million project." Lots and Blocks. *The Boston Globe*, March 18, 1979. ProQuest.

Appendix B. Boston Transit Map[85]



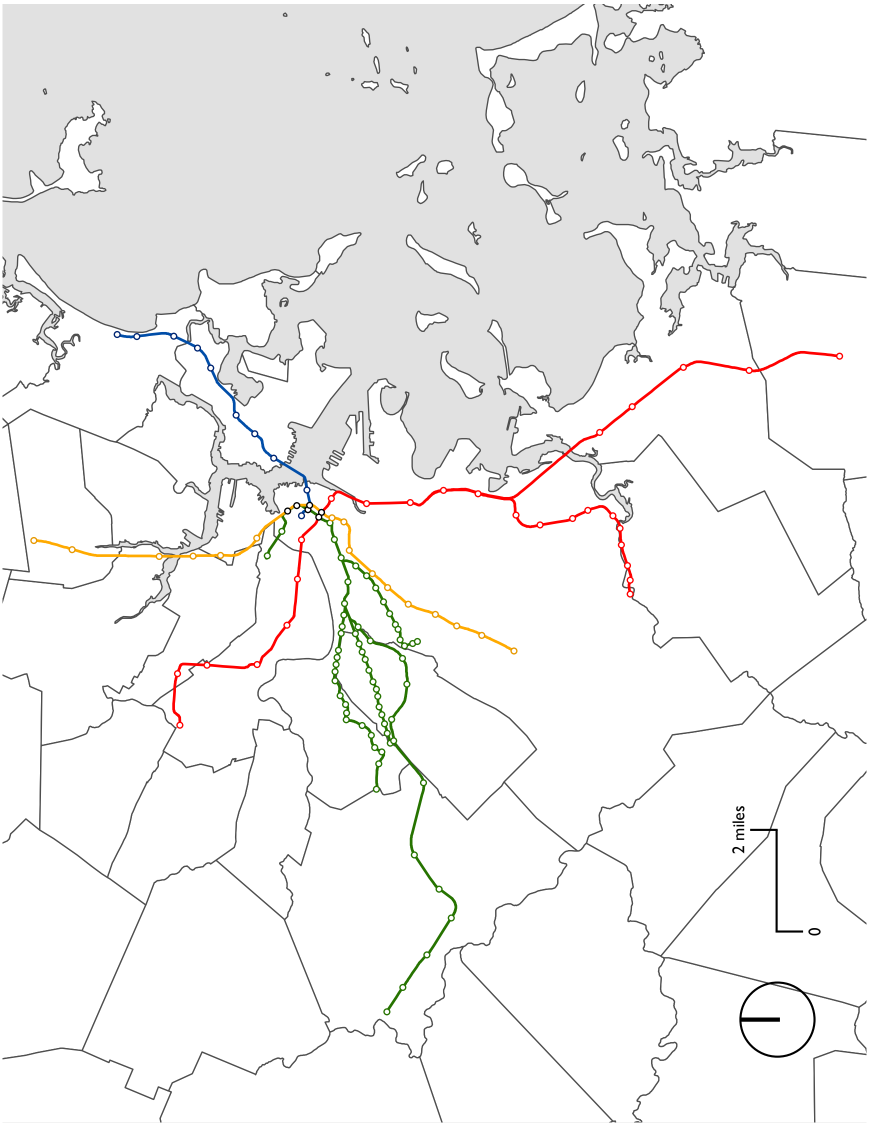
85 Source: Massachusetts Bay Transportation Authority, "Subway Map," *Schedules & Maps*, accessed November 20, 2015, http://www.mbta.com/schedules_and_maps/subway/.

Appendix C. Proposed Green Line Extension[86]



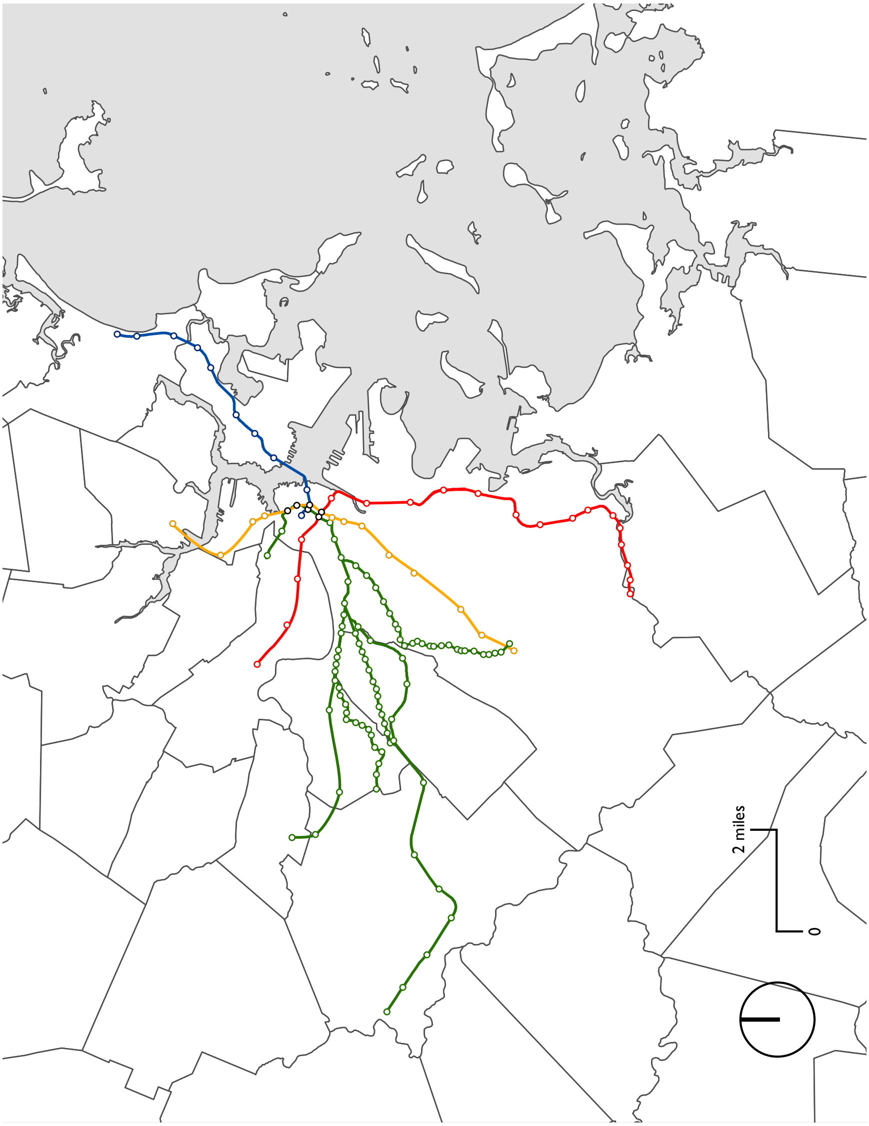
86 Source: Massachusetts Department of Transportation, "Green Line Extension Project: Project Area Map," *GLX: Green Line Extension*, accessed December 13, 2015, http://greenlineextension.eot.state.ma.us/.

Appendix D.
Geographic MBTA System Map: Current[87]



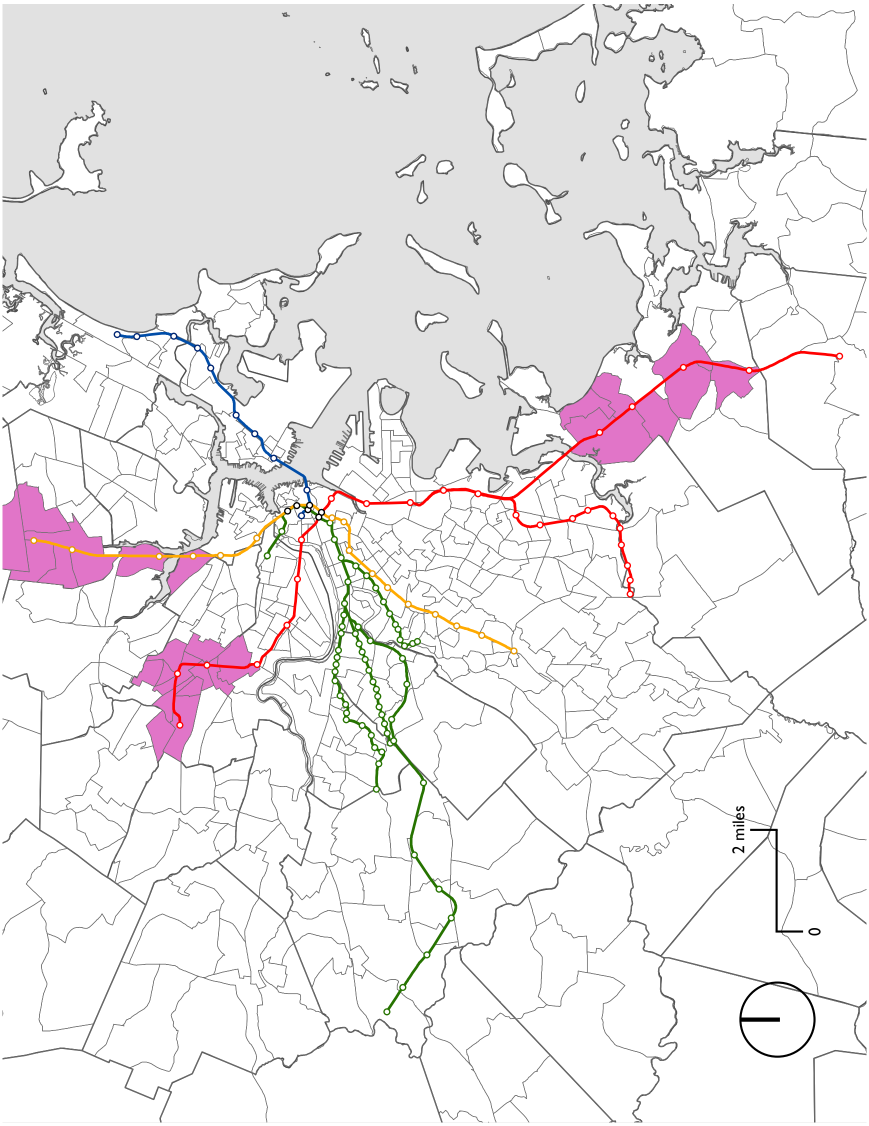
87 Source: MassGIS, ESRI.

Appendix E.
Geographic MBTA System Map: Pre-1970 [88]



88 Source: MassGIS, ESRI.

Appendix F. Station Area Census Tracts [89]



89 Source: MassGIS, ESRI.

Appendix G. Wellington Station Area in 1995 [90]

90 Source: MassGIS, ESRI.

Appendix H. Wellington Station Area in 2014 [91]

91 Source: U.S. Geological Survey, MassGIS, ESRI.

While the importance of rail transit in creating dense, livable places may seem self-evident to many urban planners, there is actually a great discrepancy between two schools of thought. There are those who advocate transit oriented development and the expansion of rail transit systems as a solution to a variety of urban ills, including housing issues. Conversely, there are those who remain skeptical, recognizing that there are benefits from having an existing system, but rarely recommending the construction of new rail transit systems. This thesis examines the impacts of the extensions of the MBTA Red and Orange Lines in Boston during the 1970s and 1980s to add to this conversation by analyzing the changes in the residential nature of neighborhoods around new transit stations in the decades after they were built.

Cover photo taken by the author, 2016