Economic Impacts of Transit Investments, Social Challenges and Strategies for Sustaining High Ridership – Part II

NCDOT Project 2020-37
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Jean-Claude Thill, Ph.D.
Knight Distinguished Professor
Department of Geography & Earch Sciences
University of North Carolina Charlotte

UNIVERSITY OF NORTH CAROLINA CHARLOTTE

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16. Abstract

This study examines three facets of the socioeconomic impacts of public investment in urban light-rail infrastructure: (i) the impact on land and building development; (ii) the impacts on population mobility and displacement; and (iii) the impact on light-duty vehicle ownership and use. We study the LYNX light rail transit (LRT) system in Charlotte, NC, which includes an original line and its extension. The analyses are spatio-temporal to account for the degree of proximity to the LRT stations and for the timing with respect to the different phases of the progress toward opening of rail service on the two corridors (including the announcement of alignment, construction, and start of the service). Microlevel datasets include administration building permits sourced from the Mecklenburg County Permitting office, rezoning petitions, subdivision application, tax parcel data, single-family home sales, a proprietary historical population database, and North Carolina DMV vehicle registration datasets. All data span about two decades. Our results find some evidence that land and building development is impacted by proximity and timing of LRT, by contrast to control areas. However, the magnitude of effects varies over time and by type of capital investment in real estate (residential vs commercial, new vs renovation, demolitions). We also find that proximity to Uptown Charlotte is an overwhelmingly powerful factor. WE also find that the capital invested shows a stronger response to LRT development than the number of parcels developed/redeveloped. We propose the concept of Unit of Development Decision (UDD) as better suited than individual building permits. Using building permits as evidence of land development is shown to be feasible, rich in detail, but highly dependent of the quality and consistency of the municipality's data management and handling processes. Regarding vehicle ownership, the analysis concludes that LRT service is a factor, but the effect is rather small and not always consistent bot spatially and longitudinally. Finally, LRT service affects the magnitude of population relocation and displacement; displacement is also linked to the intensity of land redevelopment and rezoning applications. Populations that move close to LRT stations have different socioeconomic profiles (age, family status and income) than those that move away.

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Report for RP 2020-37:

Economic Impacts of Transit Investments, Social Challenges and Strategies for Sustaining High Ridership

Part II

Jean-Claude Thill

Knight Distinguished Professor of Public Policy

UNC Charlotte

{Jean-Claude.Thill@charlotte.edu}

Research Assistants

Faizeh Hatami, graduate student, UNC Charlotte

Zurikanen Iddrisu, graduate student, UNC Charlotte

Paul Jung, graduate assistant, UNC Charlotte

Erfan Kefayat, graduate student, UNC Charlotte

Eric Meyer, graduate student, UNC Charlotte

Behnam Nikparvar, graduate student, UNC Charlotte

UNIVERSITY OF NORTH CAROLINA CHARLOTTE

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A. Overall Introduction

This document contains a synopsis of the research conducted at UNC Charlotte as part of this NCDOT funded project. It encompasses three parts dedicated to the three facets of the work spearheaded by the Charlotte part of the team. The first part is devoted to the understanding of land and building development in Mecklenburg County as these activities correlate with the building and operation of the LYNX Light Rail Transit system of CATS. The second part focuses on light vehicle ownership and use in Mecklenburg County. The third and last part investigates population relocation and displacement in Mecklenburg County as these transfers may be associated with rail transit infrastructure investment.

B. Land and Building Development

1. Introduction

Cities are eminently dynamic spaces in the sense that changes are engrained in the makeup of these environments. They are systems that evolve within the setting of broader contexts that supports, enables, sustains and constraints their own trajectories. Transportation infrastructure is vital for the existence of an urban system. Its effects of the socio-economic spheres of the urban systems is often approached from the angle of the economy value created by proximity to transportation infrastructure and captured by the value of real estate assets through market mechanisms. Other perspectives focus on job creation or business creation and death. In this section, the objective was to study the investment made in land through "improvements" made by land and building owners. Specifically, we looked at the intensity of investment made through these improvements, their nature (commercial versus residential, for instance, but also new structures vs reinvestment), as they relate to the establishment of a new light rail line, such as the LYNX system in Charlotte, NC. The approach is spatio-temporal as it seeks to underscore the influence of the geographic proximity to points of access to the rail system (accessibility to rail) as well as concordance with the major events and decision points that punctuate the LRT investment (esp. announcement of the system's alignment, construction, and opening). A critical point of departure of this work with respect to many others is the heavy reliance on institutional databases, particularly building permits, subdivision applications, rezoning applications, real property tax records. An important goal of this project is to determine the opportunities to scale this research approach in other cities, as well as the challenges, both for academic research and for use by planning and implementation agencies.

2. State of the Art

There is a substantial body of literature on urban change or neighborhood change, which often narrows the focus of investigation on gentrification. Models range from sociological models of invasion and succession (Park, 1952), filtering models (Sweeney, 1974), life cycle models (Hoover and Vernon, 1959), and others. Literature points out two major explanations for change, namely, the effect of amenities (including schools, parks and other green spaces) (Brueckner et at., 1999), and access to public transit systems (LeRoy and Sonstelie, 1983). The emphasis of the land or building development/redevelopment process as a core component of urban change tends to be favored by economists and business scholars.

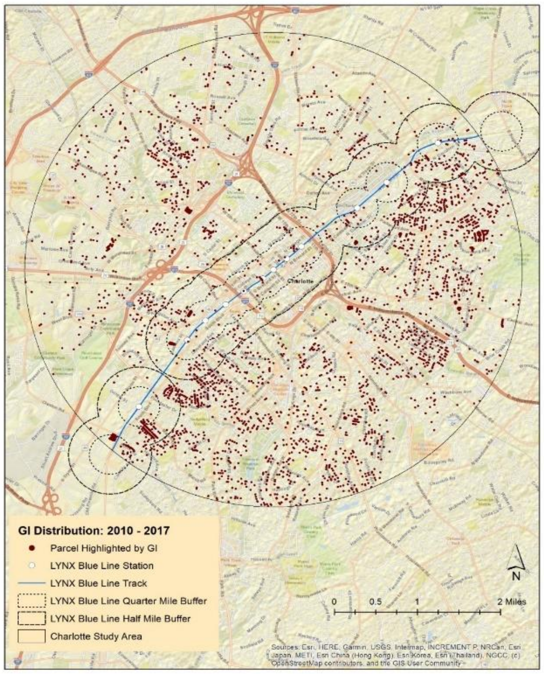
Financial considerations are central to this approach with attention paid to the efficiency of the capital investment, the return on investment, and prospects on future return on the investment given what the opportunity cost of capital may be. An intersecting lane of research looks at the role played by government and community entities and not-for-profit organizations in regulating development through zoning and ordinance, covenants, easements, and other legal arrangements (like land trusts, historic districts).

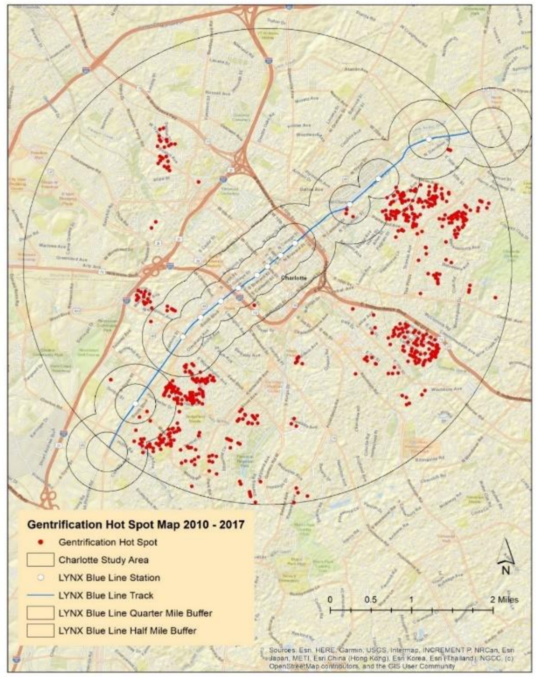
Building permits and other institutional databases are a relatively untapped source of information regarding the physical state of neighborhoods and how they change, which can expand this knowledge base to more precisely measure how neighborhoods change. Furthermore, building permits can also be used in conjunction with other theories of urban and neighborhood change outside of gentrification.

There have been limited applications for building permits to analyze neighborhood change, and of these studies, the vast majority are limited to a single type of permit (construction, renovation, or demolition, and then residential or commercial) or small temporal scale. For example, Helms (2003) employed building permits for renovations to determine the characteristics of houses and neighborhoods most likely to undergo renovation in the Chicago area. Ploegmakers et al. (2018) studied investment into industrial sites building in the Netherlands by examining industrial permits. Hawkins et al. (2022) utilized a count of building permits among other variables in quantifying gentrifying neighborhoods in the Greater Toronto area.

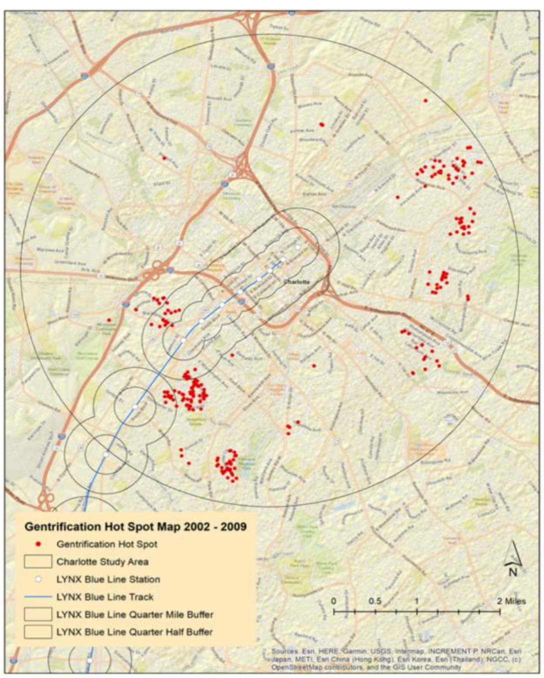
In other bodies of literature, Steenberg et al. (2017) used building permit data to explain differences in urban forest structure, tree planting, and mortality in Chicago. Lewis (2012) looked at the probability of parcels containing a renovation building permit in Baltimore County, Maryland. Jones (2015) studied TOD and gentrification in Vancouver's SkyTrain corridor, looking at demolition permits as part of the study. Stevenson et al. (2010) analyzed disaster recovery patterns in Louisiana post-Hurricane Katrina by compiling and examining construction building permits.

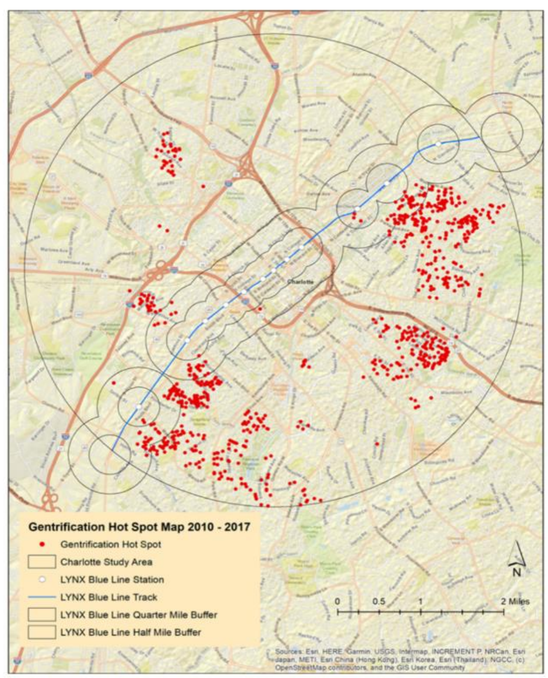
In Charlotte, Yonto (2021) used building permit data to study the spatial-temporal patterns of residential gentrification within a three-mail radius of the city center (Uptown). This study was limited geographically, but also limited in time (2002-2017). Also, it relied extensively on non-automated process to assemble the dataset. This study served as a pilot for this project, which was considerably scaled up over space and time, expanded to include all building uses, assembled with other datasets, and was designed for higher degree of automation. The maps below show maps of the extent of gentrification identified in this study.





Yonto's (2021) analysis encompassed a statistical analysis to identify geographic zones where an elevated concentration of instances of residential gentrification could be observed over different time periods. These areas are shown below for 2002-2009 and 2010-2017.





Also, Yonto's work includes a multivariate model of occurrences of gentrification over the 2002-2017 period in the study area mentioned above. Using a survival analysis model, various factors were tested, including proximity to retail and service amenities, proximity to employment, school performance, proximity to park, and proximity to LRT stations. Of relevance to this project, it should be reported that this earlier pilot analysis did not find proximity to access points to the LRT a significant factor of gentrification.

Finally, another local study of relevance to this project is in Delmelle et al. (2014). This study leveraged the availability of extensive multi-year real property tax records in Mecklenburg Co. to trace space and temporally the trends of development through densification in the county.

3. Data

The primary dataset for our study has been acquired from the Mecklenburg County Open Mapping website (http://maps.co.mecklenburg.nc.us/openmapping/data.html?search=) and through queries of the Mecklenburg County building permit data warehouse; it includes 413,122 building permits from the years 1990 to 2020 as point-level geometry, covering the whole of Mecklenburg County, North Carolina: Charlotte, Mint Hill, Davidson, Cornelius, Matthews, Huntersville, Pineville, and unincorporated land. Each building permit records a large number of relevant items, including over 200 attributes such as construction cost, contractor name, address, and license number, USDC code, neighborhood, issue and completion dates, inspection status, and developer, among others. In Mecklenburg County, permits are required for most construction, renovation, or demolition, providing us with a record of physical infrastructure changes over the past three decades. We assumed the record of building permits is an accurate representation of this changing physical infrastructure, and that the changes from projects in which obtaining a permit may not be required are minimal (in Mecklenburg County, projects on one- and two-family dwellings with a cost of $15,000 or less often do not require a permit) (Permitting 2021). The permits additionally cover residential, industrial, and commercial developments, indicated the by building permit USDC code. Other construction types, such as parking lots, retaining walls, storage sheds, cell towers, and in-ground pools are also included. Electrical, mechanical, and plumbing permits are considered "sub-permits" and are not included in the dataset, although the costs associated are included in the cost calculations.

Many times, building permits are not isolated events. This is particularly the case when there is large scale redevelopment or development that affect multiple structure and/or multiple land parcels. Hence individual building permits were assembled into what larger entities similar to projects, which we called Units of Development Decision (UDDs). These UDDs exhibit spatial contiguity of the parcels on which they occurred and happened within time frame during which ongoing capital investment was demonstrated to have taken place. The process to create UDDs from building permits and ancillary datasets is discussed hereunder. It is believed that UDDs are more meaningful units of analysis than building permits as they account for the long-term planned nature of real estate capital investment decision and the operational segmentation of short-terms decision within this broader context.

UDDs are collection(s) of building permits that can, with reasonable certainty, be regarded as having been conceived by the land property owner and developer as a part of the same land development project, which is demonstrated by their close proximity in time and space. Projects can encompass a variety of different construction types, but are typically defined as the construction, renovation, or demolition of single or multiple physical structures (buildings) that are part of one development scheme, built at one time or in phases (Council of the District of Columbia, 2018).

Some UDDs are just a single building permit; for example, a family deciding to upgrade their kitchen to modern standards. On the other hand, others may include numerous permits, such as the construction of a condominium or townhomes complex with each unit having its own building permit. UDDs are valuable concepts because the county's groupings of permits into projects are often inconsistent, reflecting the operational matters on the construction process rather than planning considerations. They refit the building permits away from the county's mission to ensure buildings are safe and compliant with North Carolina Building Codes (Code Enforcement 2022), and towards our own desire to build a dataset of development decisions. While building permits themselves can be used to chart development on a small scale, UDDs allow for greater contextualization of building permit projects. By examining the number of UDDs and the cost per UDD in a particular area, there is potential to identify areas of significant centralized development (many permits per UDD) as well as more decentralized development (few permits per UDD).

As part of this research project, we cleaned our building permit data using various tools and functionalities in ArcGIS Pro, Python and R Scripts. The most important attribute that was cleaned was the USDC code, a representation of the type of construction for the building permit and the land use of the building permit parcel. These codes, adapted from the US Department of Commerce, are used by the Mecklenburg County Permitting Office. For many building permits, the USDC code was found not to be consistent with the permit description. Earlier on, building permit applications were keyed in by staff at the County Permitting Office, while more recently, applications have been submitted directly on-line by the applicant (usually a contractor or representative thereof). No further control of the quality of the information entered is done after the original entry, which may explain some inconsistencies found in the data. Also, over time, the meaning of certain USDC codes has changed. To resolve these inconsistencies, a manual validation process was employed to edit the building permit data, ensuring the USDC code was in line with both the description for that permit as well as the land-use type as identified by the tax parcel data, or verified on Google Street View and/or the on-line Polaris 3G property records portal of Mecklenburg County. The table below summarizes the USDC coding system.

Classification	Code	Explanation
New Residential (Housekeeping)	101	Single-family houses, detached
	102	Single-family houses, attached
	103	Two-family buildings
	104	Three and four family buildings
	105	Five or more family buildings
	112	Mobile homes
	114	Three and four family condos (no land for sale with unit
	115	Five or more family condos (no land for sale with unit)
New Residential (non-Housekeeping)	213	Hotels, motels and tourist cabins
	214	Rooming, boarding, fraternity, sorority
New Nonresidential Buildings	318	Amusement, social, recreational
	319	Churches/other religious buildings
	320	Industrial, factories, manufacturing, and printing plants
	321	Parking garages
	322	Services stations and repair garages
	323	Hospitals, clinics, rest and convalescent homes
	324	Offices, banks, medical offices
	325	Public works, utilities, sewage disposal, water supply
	326	Schools, libraries, universities, museums
	327	Stores, restaurants, malls, markets, beauty shops
	328	Other nonresidential (sheds, barns, post offices, jails)
	329	Parks, outdoor stadiums, marinas
Additions, Alterations, Conversions	434	Residential
	437	Nonresidential
	438	Additions of residential garages and carports
	540	Non-housekeeping to housekeeping
	541	Housekeeping to non-houskeeping
Demolitions	645	Residential
	647	
	648	
	649	Nonresidential
Source: https://www.mecknc.gov/LUESA/CodeEnforcement/Pages/USDC%20Codes.aspx		

After the inconsistencies within the building permit dataset were resolved, other datasets were collected to assist in aggregation of building permits into larger projects, the so-called Units of Development Decision (UDDs). The most important of these for aggregation were several datasets on subdivision applications. A subdivision application is required when a land parcel is being split into multiple lots, usually for the purpose of larger residential construction projects or large multi-use developments. Because subdivisions are organized at the municipal level, subdivision application datasets originated from the individual planning departments in Mecklenburg County: Cornelius Department of Planning and Zoning, Matthews Department of Planning and Development, Mint Hill Planning Department, Davidson Planning Department, Pineville Planning Department, Huntersville Planning Department, and the City of Charlotte (through the Open Data Portal).

One of the challenges associated with the number of subdivision application datasets is the inconsistency in data quality, geographic coverage, and temporal span. For example, the Charlotte subdivision application dataset goes back only to 2000, whereas the Huntersville dataset includes all existing subdivisions (even those with unknown dates). Additionally, the threshold for the number of sub-parcels that would trigger the need for municipal approval in the subdivision varied across municipalities. Also, a number of subdivisions include parcels in two or more municipalities, with possible duplications or gaps or inconsistencies in the data being reported.

To resolve these inconsistencies, spatial data on tax parcels from 2019, also acquired from the Mecklenburg County Open Mapping website, were used. Tax parcels were grouped based on their "neighborhood" attribute, and then manually edited based on the existence of building permits within their boundaries as well as their time stamps. Manual validation was further conducted on each subdivision dataset and the merged tax parcel-neighborhood dataset to ensure consistency in development for UDD assignment. The manual validation process also allowed the creation of "new" subdivisions that were either missing from the Charlotte subdivision application dataset or had a number of parcels under the subdivision application threshold for their municipality. Once cleaned and validated, the datasets collected from the outlying towns were merged with the dataset of edited Charlotte neighborhoods. The original Charlotte subdivision dataset provided by the county was kept separate due to the overlapping nature of these subdivisions requiring an extra computational step (selecting to which of the overlapping subdivisions the building permits belong). The Charlotte subdivision dataset will be referred to as the "subdivision" dataset, whereas the merged dataset will be referred to as the "neighborhood" dataset.

The last dataset used for UDD assignment was the sales dataset, acquired from the Mecklenburg County Open Mapping Data portal. This dataset includes 112,485 sales from the entirety of the county, ranging from 1980 to 2019.

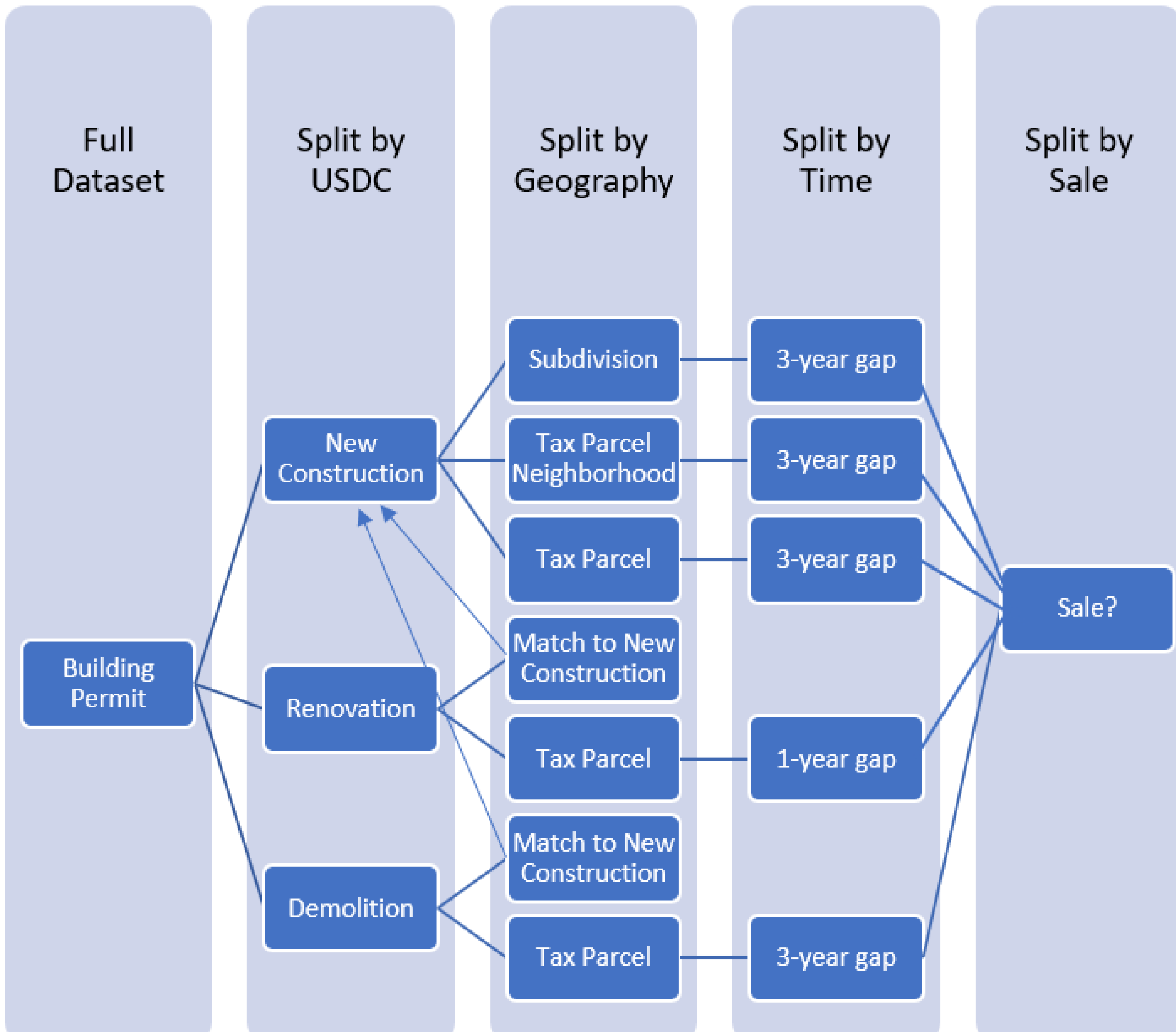
Other data sources used in this project include transit stops/lines, and zoning/rezoning data, both acquired from the Mecklenburg County Open Mapping data portal. Although these datasets were not used in the UDD assignment process, attributes drawn from them served to enrich our aster UDD database.

This study involved three separate phases, data collection and cleaning, UDD assignment, validation, and attribution, and lastly, data visualization. The data was cleaned both manually in Excel and through automation in R and Python. For UDD assignment, ArcGIS Pro, R, SQL (via PGAdmin) and Excel were used.

While building permits, subdivisions, and neighborhood datasets are important in operationalizing our variables of transit infrastructure and physical gentrification, our final dataset combines important attributes from both to form what will become the cases of our study, the Unit of Development Decision (UDD). The end result of the UDD assignment process is the creation of a key or UDD code that identifies which permits are a part of the same development decision. Grouping the building permits into UDDs is the most difficult methodological challenge and our team decided on several rules to ensure spatial and temporal continuity and adjacency. The UDD assignment process can be summarized as depicted in the figure hereunder.

As this figure demonstrates, the first stage of the UDD assignment process was to split the building permit dataset by the three principal construction types, as denoted by USDC codes: new constructions (codes 1XX-3XX), renovations (codes 4XX-5XX) and demolitions (codes 6XX). Among new constructions, we first focus on the property of spatial contiguity. To this end, spatial joins were carried out based on whether permits are located within verified subdivisions, neighborhoods, or stand in individual tax parcels and do not belong to these groupings. Then for all the building permits in the same geographic unit, the same "parent UDD" code was assigned. Next, we turned to the temporal properties of building permits. If there were subsets of building permits issued more than three years apart (three-year gap) on the same geographic unit, then distinct "child UDD" codes were assigned to each of these subsets. A three-year gap was used due to our assumption that projects on hiatus for more than three years are most likely to have not been planned since the beginning, and instead would be a part of different UDDs.

Diagram of Workflow to generate UDDS from Building Permits and Ancillary Data



Once UDD codes were assigned to all new constructions, the same process was repeated with renovations, with two primary differences over the process for new constructions. First, a nested loop was executed to match the renovations with new constructions based on spatial and temporal closeness (same parcel and within one year at most). If a renovation was successfully matched to a new construction, then it would receive the same UDD code as the new construction and would be removed from the renovation dataset. Second, the rest of the renovations were then given their own UDD assignment based on the tax parcel number and a one year instead of three-year gap, due to our assumption that renovation projects are less likely to span a longer time period than new constructions and demolitions.

As for the demolitions, a similar process to the renovations is employed, with the only difference being the one-year gap used for renovations is once again expanded to three years to account for projects on larger multi-building parcels. Once all building permits were assigned an initial UDD code, the dataset is cross-referenced with the sales data, based on our assumption that a new owner makes a new development decision in purchasing the property, especially since they may take the existing project in a new direction. UDDs that were interrupted by a sale were split into separate records.

An additional problem we encountered was the existence of building permits labeled as 'canceled' or 'non-finaled'. These permit applications were either canceled by the contractor or expired due to the lack of inspection by the county staff. These permits are selectively added to the dataset based on the following criteria. For canceled permits, they are added if the permit was a part of an existing UDD (as per our previously explained spatial and temporal rules) and lasted more than a day (the vast majority of these permits were in fact canceled on the same date as issuance, indicating an entry mistake by the contractor, or their change of mind). For non-finaled permits, the permit needed to also be a part of an existing UDD and be open longer than 181 days (indicating the building permit had an initial inspection and was not categorized as non-finaled simply due to lack of initial inspection). These rules ensured that only the canceled/non-finaled permits that were a part of a finished construction, renovation, or demolition project were added to the building permit dataset, and ultimately incorporated into UDDs.

After the assignment of UDD codes, the next stage of the process involved manually validating a significant portion of the dataset to ensure that the scripts not only assigned UDD codes correctly, but also to ensure that the building permit data reflected the reality of the construction process on Google maps, Polaris3G, and our other data sources. The validation checked both the spatial and temporal consistency of UDD groupings and was more robust in areas of interest (particularly along the Blue Line LYNX corridor and extension). Other fields used to validate UDDs include USDC code, Contractor name and ID, permit and project description, and sale records. When errors were uncovered, either in the data or in the process, the data were edited manually and the process was adjusted to account for the specific error, respectively. For example, several geocoding errors involving numerical street names that were mistaken for other streets were detected. Validation occurred in batches based on USDC code, with some validation efforts including all building permits with that code (for example, all townhouse construction permits were validated manually), and others including sampling, based on the number of permits per code and the accuracy of the data.

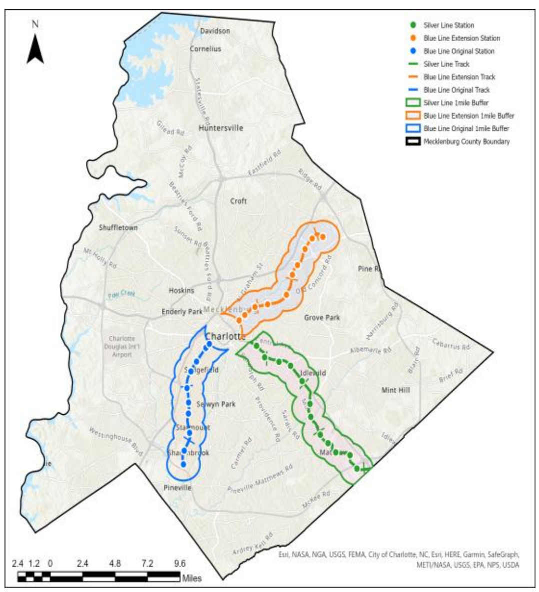
Once the building permit dataset was cleaned and UDD codes were assigned to all permits, attributes were aggregated based on the tax parcel and building permit data. Because this study seeks to measure investments into the physical upgrading of Charlotte, NC, an important variable was the cost calculation field. This cost calculation field includes all costs (building material, labor, etc.) as calculated by either the contractor or the county via the Permit Fee Schedule (Mecklenburg County Permit Fee Schedule, 2022). The building permit dataset spans a period of over two decades, and as such, needed to be adjusted for inflation in construction costs. Furthermore, this inflation adjustment process would need to be tailored to the construction industry. Ed Zarenski (2022) calculated his own construction inflation indices for year-to-year construction cost comparison. The Turner Construction Company has calculated the changes in costs and price trends within the construction industry for over 80 years, using several determining factors such as labor rates, material prices, and the competitive condition of the market (Turner Construction Company 2022). The Turner Index, and several other construction inflation indices, were aggregated by Zarenski to create construction inflation indices for both residential and non-residential construction. Zarenski's index is a national index that does not account for regional variations in labor and material costs. Additionally, the cost calculation process was manually validated, with particular focus on outlier costs and building permits within the transit corridors.

4. Results

4.1. Introduction

The results are reported by spatial aggregation to three corridors identified around the original LYNX Blue Line (BLO), the Lynx Blue Line Extension (BLE), and a control corridor aligned with the portion of the future LYNX Silver Line, south of Uptown Charlotte. The latter is used as a control, because of its housing and population features that roughly match those of the original Blue Line and Blue Line Extension. Buffer of a width of 1 mile (or 0.5 mile) around the actual or future stations in the three alignments are used to define the spatial polygons. This allows us to assess the effect of the proximity to points of access to the light rail system on the decision made by land owners and developers with regard to capital investment/reinvestment in land-based properties.

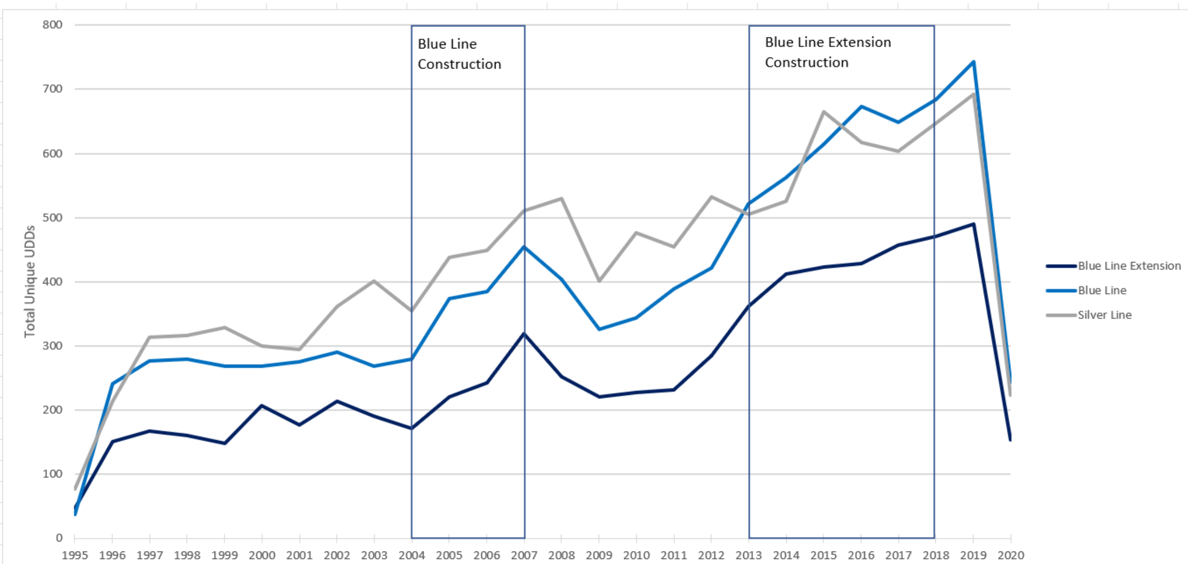
These corridors are visualized on the county map below.



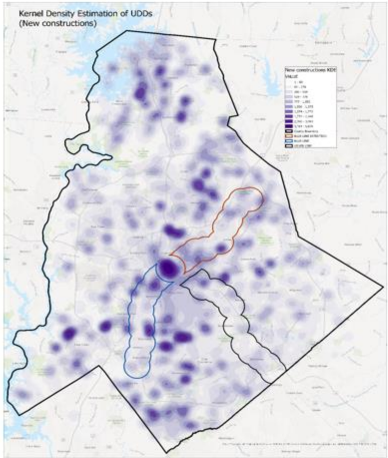
Next, for each of the two corridors of interest (Original Blue Line and Blue Line Extension), we calculate several statistics pertinent to the research question. They are then compared to corresponding statistics along the Silver Line corridor. All the steps described above are iterated annually and curves displaying the evolution of the statistics are plotted on charts reported in this section.

4.2. Intensity of Land Development Activity

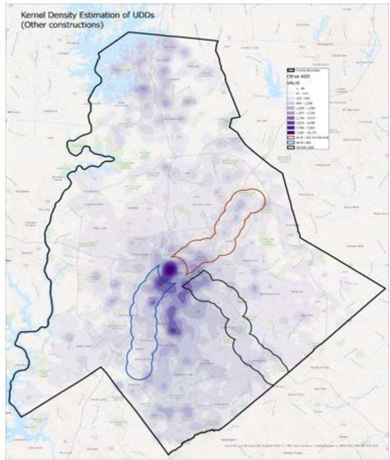
We start with the core question of whether development activity was tied to the LRT construction, both on the BLO and BLE. One-mile buffers are used for this purpose. The first line chart below illustrates the number of unique UDDs for building permits in transit corridors between 1995 and 2020, demonstrating a steady rise during the entire study period, with a steeper grading during the construction phases of the LRT. the changes in real property investment along the three transit corridors of our study. The year was determined based on the issue date of each building permit, which was then aggregated, leading to more drastic changes in levels of investment than if the year was determined based on UDD. By analyzing the investments related to the issue date, we are better able to capture when the decision to invest occurred, rather than smoothing the data out by averaging larger projects over the years. However, similar expansion in planned construction activity can also be seen on the curve for the Silver Line control, which suggests that the surges on the BLO and BLE may just mirror broader trends across the county.



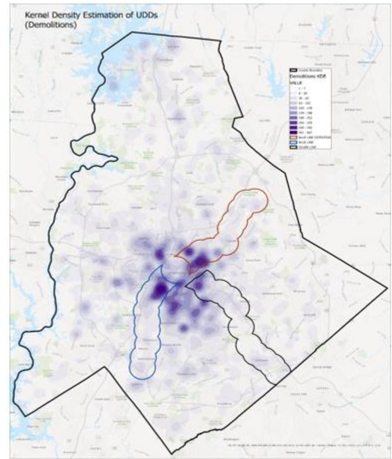
The mapping of UDDs over the 2006-2020 period and alignment with the LRT corridors corroborates this observation drawn from the line charts. The three density maps below for new constructions, renovations and alterations, and for demolitions for the whole period do not reveal higher density within the 1-mile corridors. The set on the next page reports annual maps for new constructions; evidence of spatial correspondence is not perceptible.



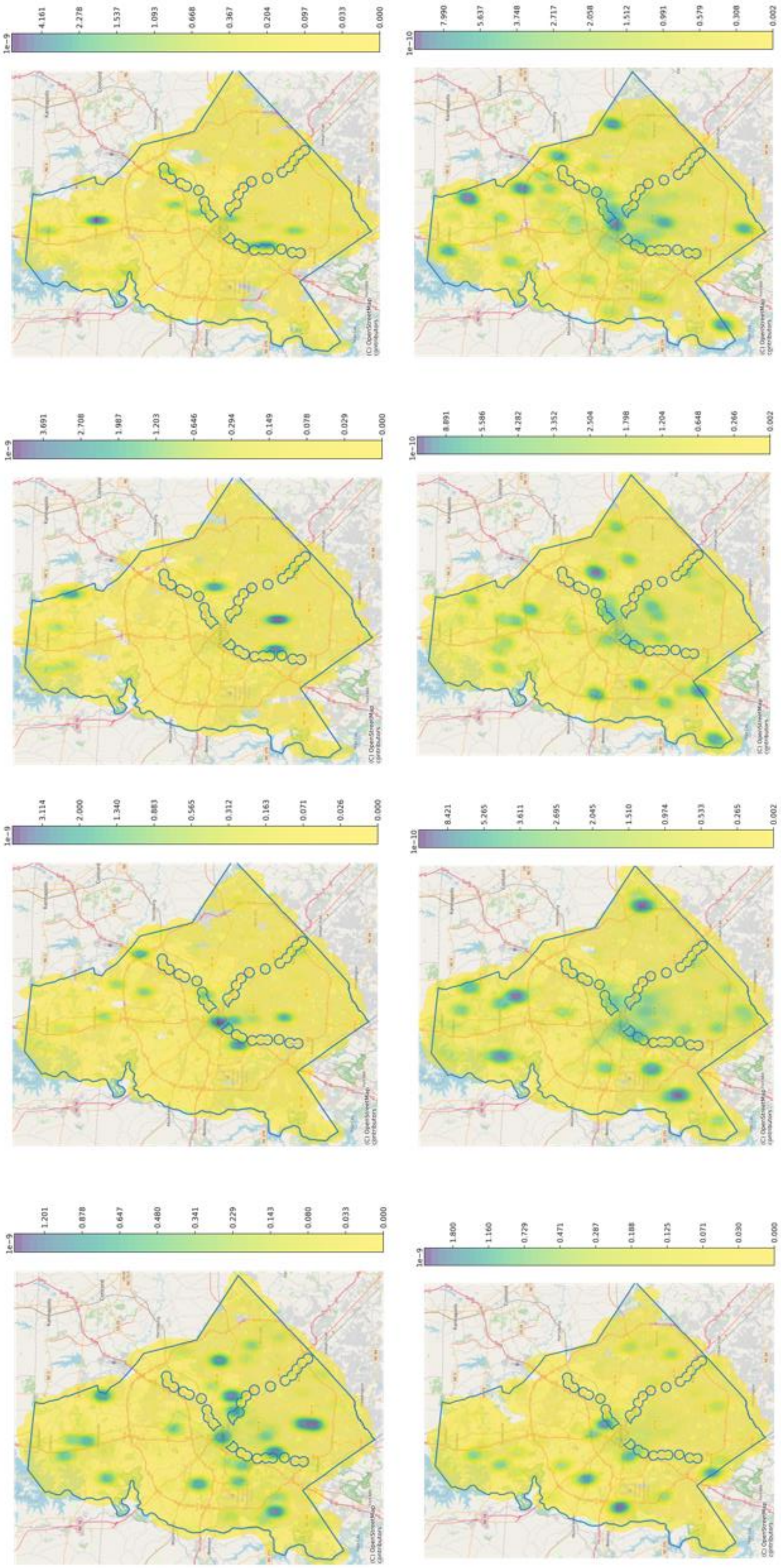
Kernel Density Estimation of UDDs
(New constructions)



Kernel Density Estimation of UDDs
(Other constructions)

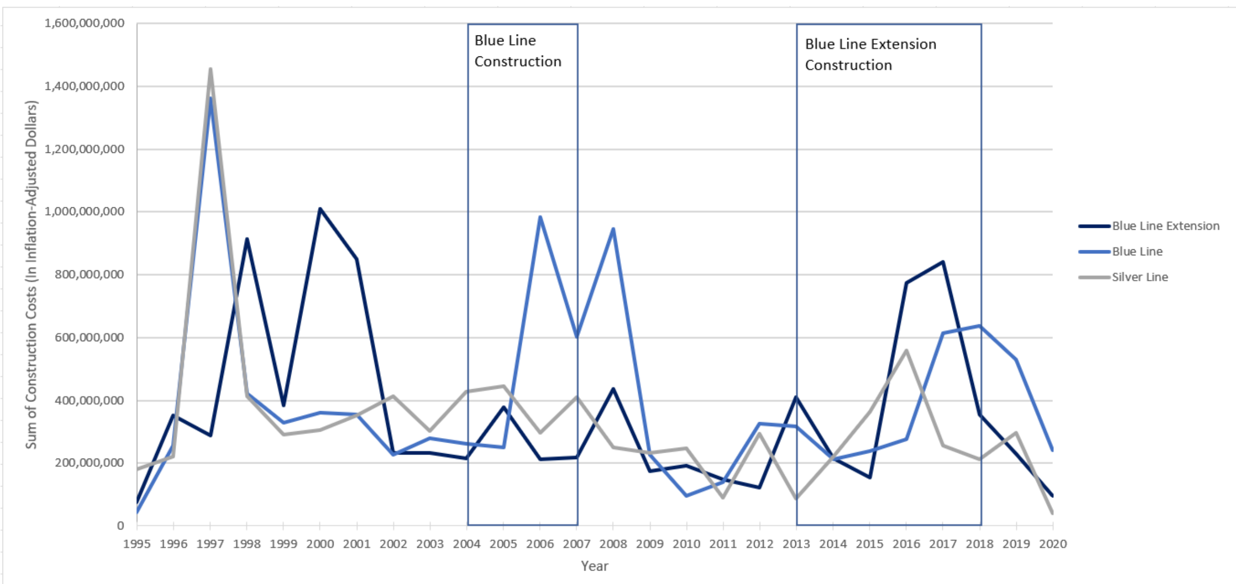


Kernel Density Estimation of UDDs
(Demolitions)



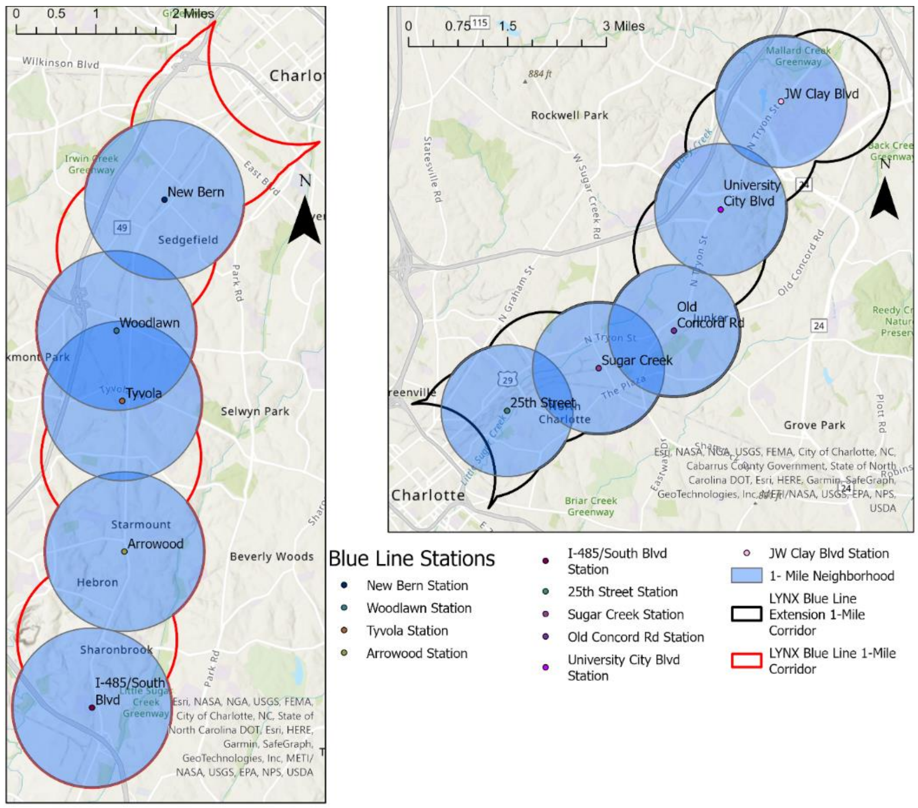
2006 through 2020

The line chart displayed below illustrates the changes in real property investment in one-mile buffers along the three transit corridors of our study. The year was again determined based on the issue date of each building permit, which was then aggregated, leading to more drastic changes in levels of investment than if the year was determined based on UDD. By analyzing the costs related to the issue date, we are better able to capture when the decision to invest occurred, rather than smoothing the data out by averaging larger projects over the years. Importantly, there appears to be a rise in planned investment during the construction phases of each portion of the Blue Line (BLO and BLE). These spikes are associated with a handful of very large development projects that have sprung up in close proximity to LRT stations, both along the BLO and more recently the BLE. Planned construction activity has remained much more stable along the Silver Line control, in comparison. Furthermore, given the rise in investment on the Blue Line during the construction phase of the Blue Line Extension, there may also exist network effects: the expansion of the line may also have contributed to more investment along the original line.

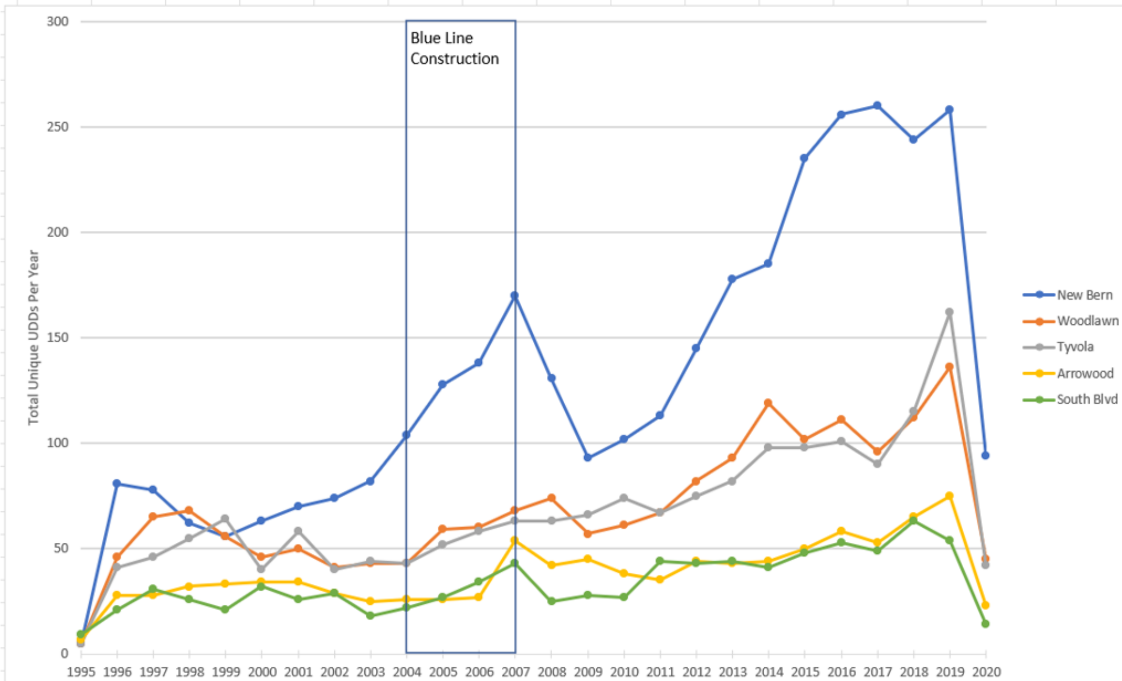


To further study the impact investment to the LRT system, we took a closer look at the intensity of construction activities around individual stations. These stations are sorted from closest to furthest from uptown as follows: New Bern-Woodlawn-Tyvola-Arrowood-SouthBoulevard and 25thStreet-SugarCreek-UniversityCity-JWClayBlvd. For this purpose, to avoid double counting, we focused on 5 stations on the BLO and five stations on the BLE, as identified on the maps below. In all these cases a 1-mile circular buffer is drawn around each station. These figures demonstrate that the comparative counts of unique UDDs for individuals Blue Line stations for each year across our study period. As we expected, based on our aggregated corridor data, the stations closest to Uptown Charlotte have the most unique UDDs. New Bern saw the highest level of different projects in the area, with substantial increases during the construction phase of the Original Blue Line. AS for the BLE, as expected based, the stations closest to Uptown Charlotte, the 25th Street and Sugar Creek stations have the largest number of UDDs for each year. The 25th Street station also saw a very large increase in UDDs during the construction phase of the Blue Line Extension. Thus, proximity to the CBD of the city has been a critical factor of the flurry of construction activity. Given the secondary peaks of activity around the 25th Street and Sugar Creek stations in the mid-2000s, over ten years before the opening of the BLE, it is patently clear that many factors are at play and LRT cannot be credited for this growth alone.

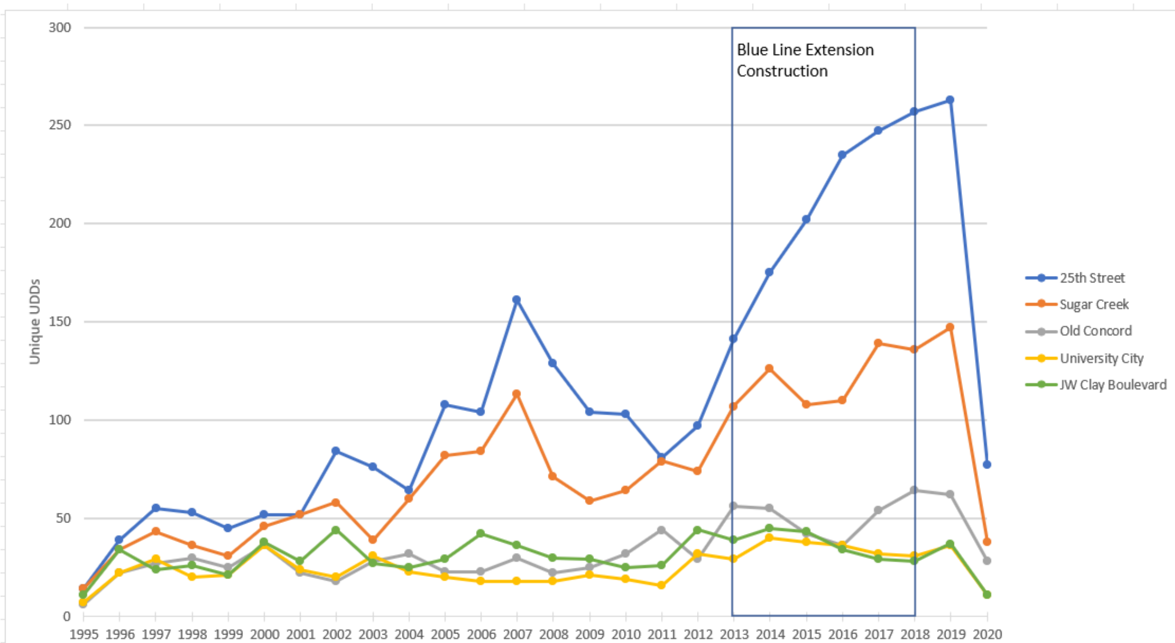
Select Stations under Study along the BLO and BLE



Year-to-Year UDD Count of Individual Blue Line Stations, 1995-2020



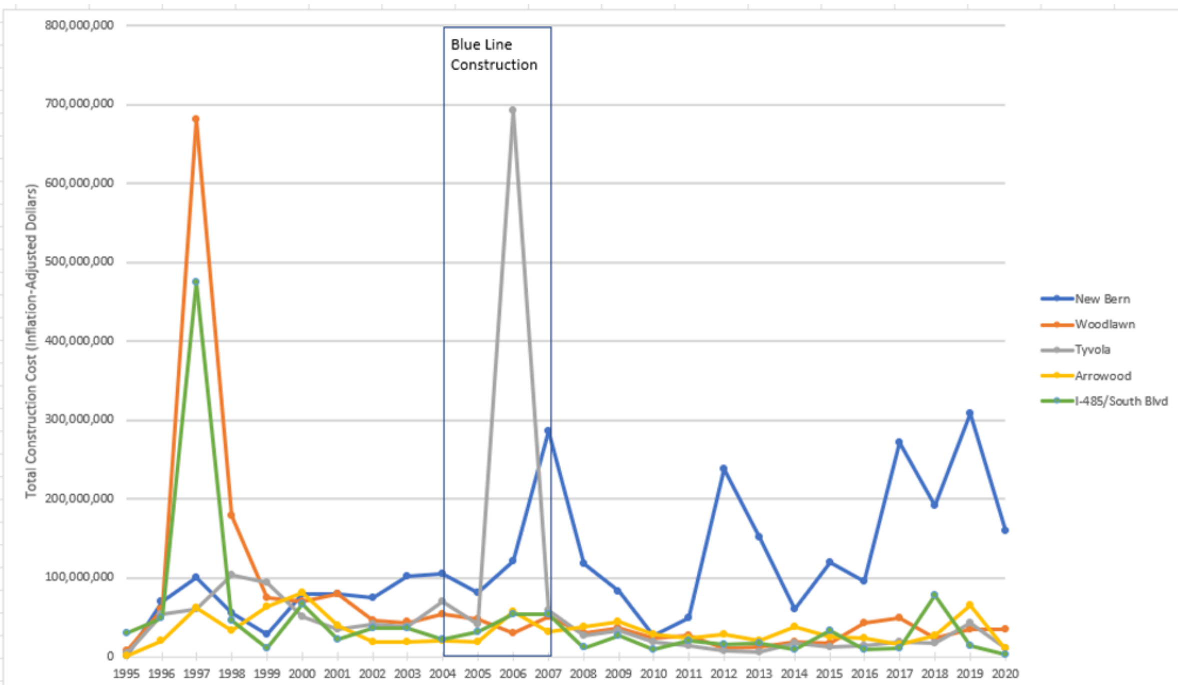
Year-to-Year UDD Count of Individual Blue Line Extension Stations



We also looked at the capital invested in these projects. The figure below looks at the areas around the stations of the original Blue Line, (From North to South, New Bern, Woodlawn, Tyvola, Arrowood, and I-485/South Boulevard). Notably, the area around New Bern station, closest to Uptown Charlotte, is generally the highest, with the exception of years where areas around other stations saw spikes in investment. Several spikes in the data are captured, which signal the inception of large subdivision projects, one of which coincided with the construction phase of the original Blue Line (Tyvola). The

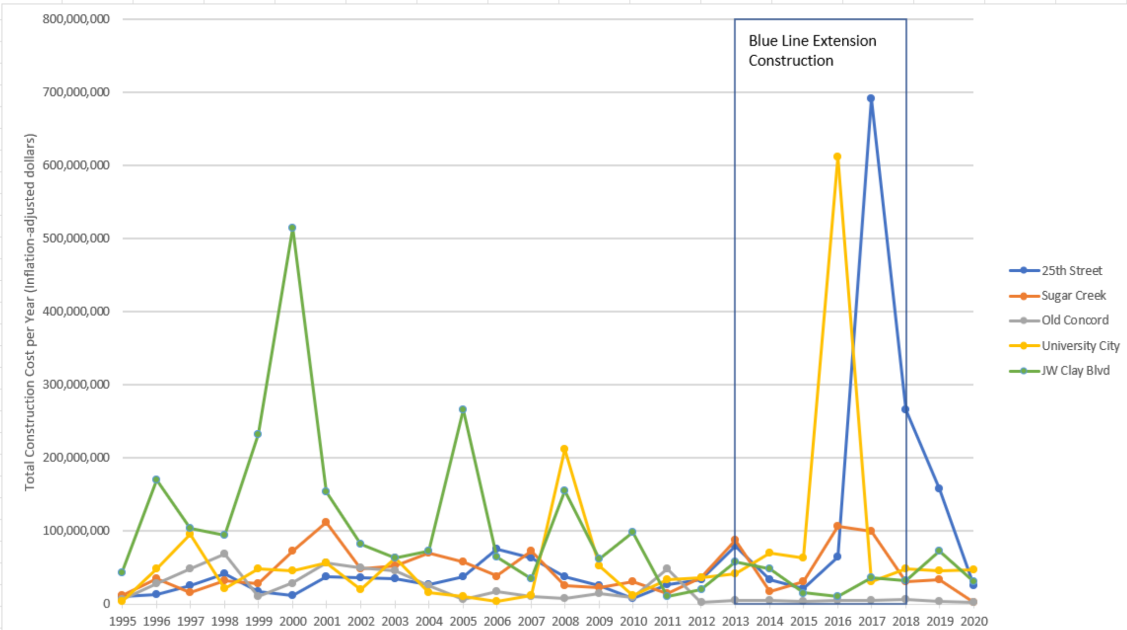
Woodlawn spike captured the construction of large residential developments on the other side of 77-South near Yorkmont Road, likely unrelated to the Blue Line. The I-485/South Boulevard spike captured the construction of Carolina Pavilion, a large commercial shopping center, as well as the construction of several residential developments near Sharonbrook in the late 1990's. The area around Arrowood station saw the least amount of investment with no spikes in investment.

Total Investment in Blue Line Individual station 1-mile buffers, 1995-2020



Along the BLE (figure below), unlike the original Blue Line, the area around the station closest to Uptown Charlotte (25th Street) does not become the area with the highest investment until 2018, when it spikes due to the commercial redevelopment of Optimist Park and its surrounding apartment complexes. The University City Blvd station also saw a spike during the construction phase of the Blue Line extension, explained by the development of apartment complexes and redevelopment of commercial spaces near Tom Hunter station (which fell within the 1-mile buffer of University City Blvd). The 2008 spike near the station is the construction of the commercial properties near Ikea Blvd. The JW Clay Blvd station also saw spikes in investment which predated the construction of the Blue Line Extension, which include the redevelopment of the Shoppes at University Place, the construction and upgrading of the Atrium Health facility, mixed-use developments near McCullough Station, the construction of apartment complexes on the far side of the UNC Charlotte main campus. The areas around the Sugar Creek and Concord Rd stations saw a relative lack of development during this time.

Total Investment in Blue Line Extension Individual station 1-mile buffers, 1995-2020



In sum, evidence of impact of LRT on land development exists, but LRT development may not be a preponderant factor. Proximity to the CBD is extremely important, and LRT is a compounding factor. What we found also is that LRT has a notable impact on the scale of the land development projects, and therefore their cost.

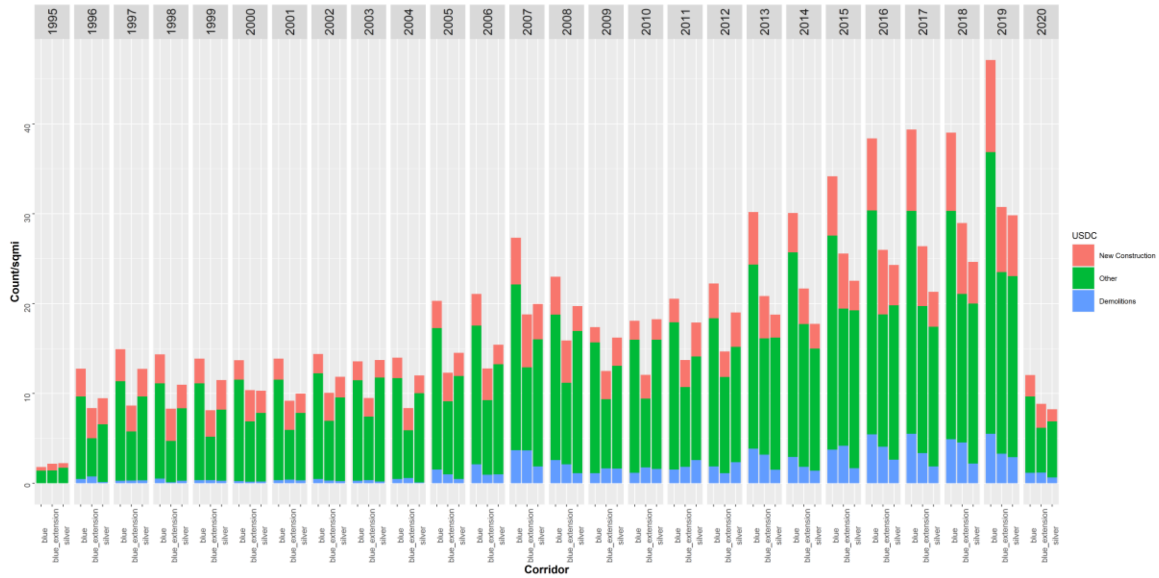
4.3. Nature of Land Development

A second set of research questions concerned the influence of LRT on the types of land development projects. Here we specifically looked at UDDs' mix of new constructions, other constructions (renovations and alterations), and demolitions. We also looked at the whether developments had a residential component or not. The evidence that was examined was drawn from the master database of UDDs summarized down to the three corridors mentioned earlier, BLO, BLE, and the Silver Line control within 0.5-mile buffers. Statistics are counts of UDDs encompassing specific building permits standardized by the land area of each buffer polygon (square miles).

The bar chart below shows that

1. The announcement of the alignment of the BLO did not trigger a construction boom of any kind.
2. The construction phase of the BLO coincided with an increase in renovations and alterations along the BLO, while activity started to creep up elsewhere. Increases were notable in new constructions, renovations and demos.
3. The announcement of the alignment of the BLE coincides with an expansion of activity along the BLE compared to the control, but for the rest of the period, the BLE behaves very much like the control.

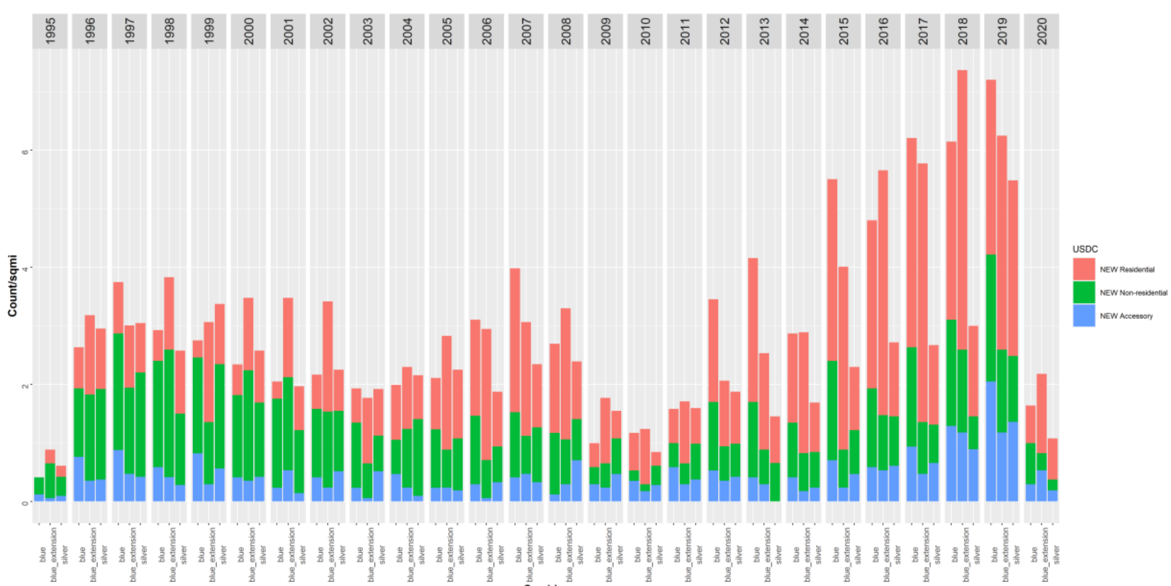
Intensity of new constructions, renovations/alterations and demos over time



Looking more closely at new constructions specifically, we find that:

1. The expansion of the pre-Great Recession years consisted largely in residential developments (2004-2007). Residential came back very strong a few years after the end of the recession and fueled the expansion of the construction industry. The chart below shows this to be particularly the case on the BLO, while the BLE reached a similar level a few years later (likely driven by the construction of the LRT and the anticipation on the part of the real estate industry.
2. Since after the recession, new non-residential construction on the BLO has consistently outstripped the BLE and control corridor, which were about even. The BLO is quickly become a major business hub for the city, right outside of the CBD.

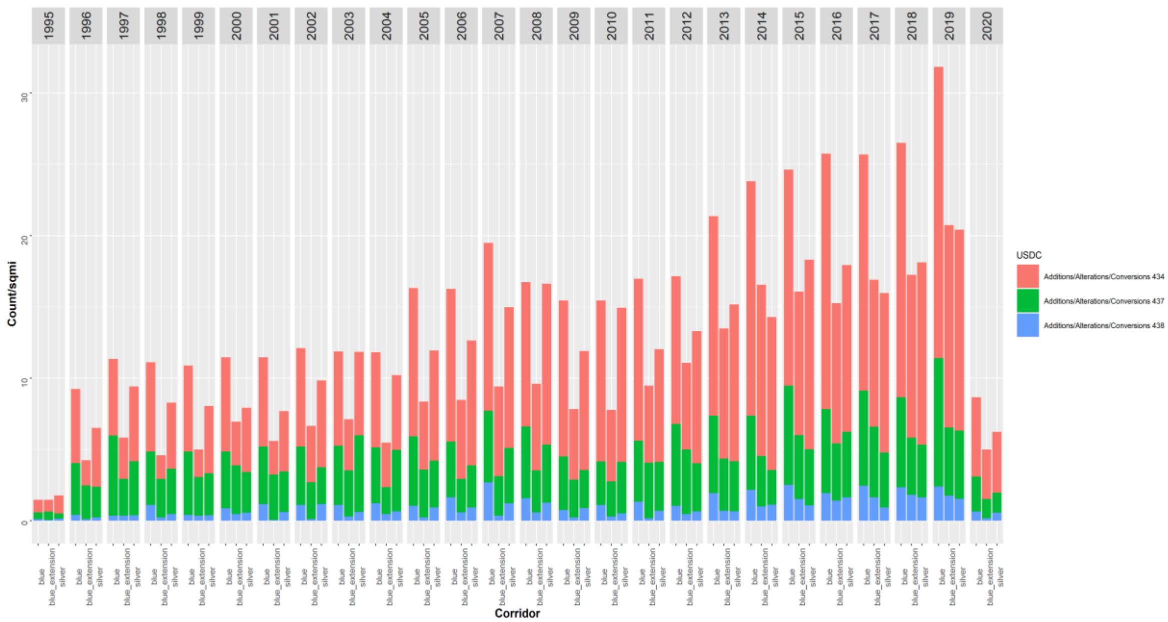
Intensity of new residential, non-residential and accessory buildings over time



Trends among the renovations and alternations show some similarities with new constructions, but also some differences.

1. Most of the expansion here is residential (434 code in the chart) after 2004, a sign that gentrification came into full force on all three corridors.
2. While BLO always saw more renovations/alterations than the other two corridors, it decisively surpassed the control area after the great recession, while the BLE very closely follows the trend set by the control in spite of the construction and opening of the LRT service.

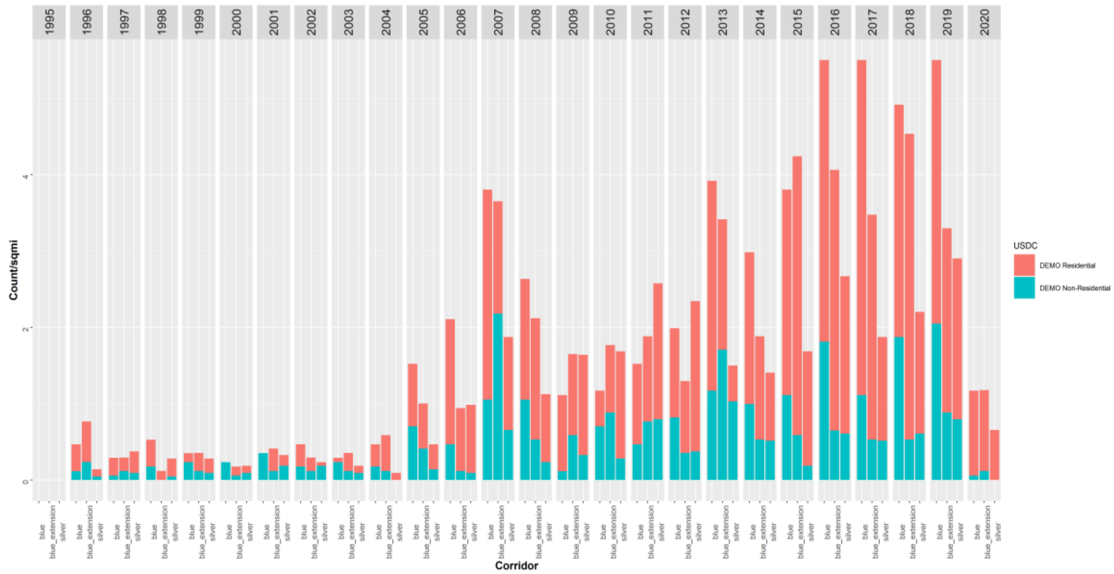
Intensity of renovations and alterations by type (residential, non-residential and accessory buildings) over time



Demolitions were rare occurrences in any corridor until 2005. They took off (except for the slump of the great recession) and remain a major fixture of the Charlotte cityscape, particularly the BLO.

1. BLE has seen more demos that the control, but less than the control on average.
2. In the mix, residential demos have come to dominate in ways that are uniform between the three corridors.

Intensity of demos by type (residential and non-residential) over time

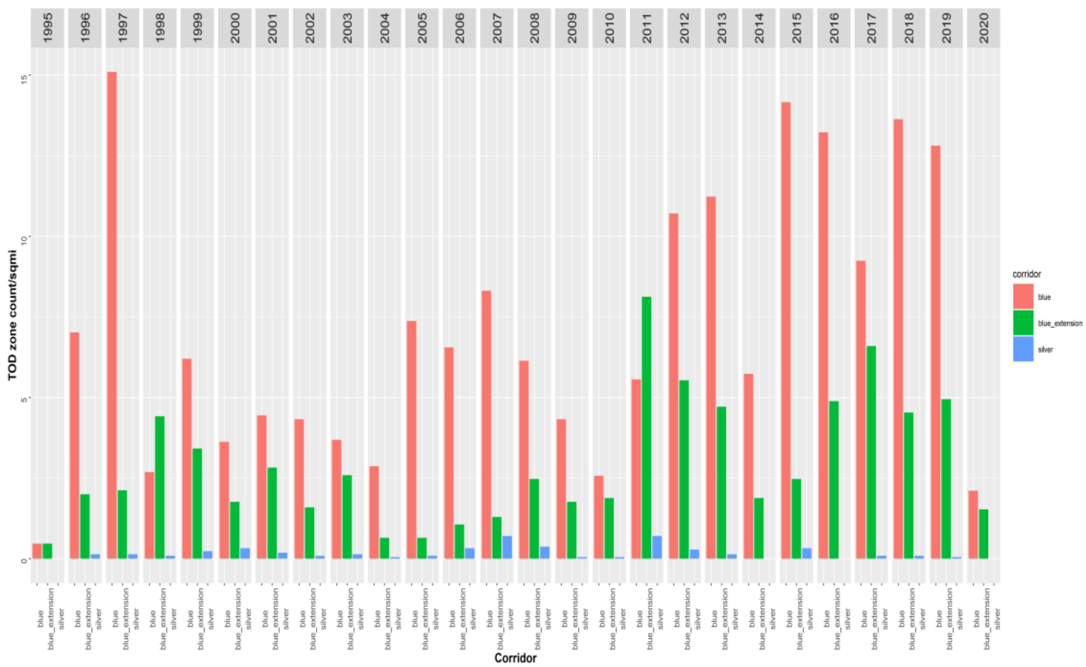


To sum up, we find that many similarities in the construction activities of the two corridors (BLO and BLE) compared to each other and compared to the control. There are difference and also changes in the activities that may coincide with the phases od development of LRT, but these differences are secondary.

4.4. Transit-oriented Development (TOD) Zoning Designations

In this section, we look at the practice of OD designation on the BLO and BLE corridors on the timeline of LRT implementation. These data are sourced from the zoning maps of Charlotte and the from the city's rezoning petitions. This is depicted in the chart below. In most years, BLO surpasses the BLE, which is in line with expectations given the longer history of LRT planning along this alignment. Many petitions were filed before the alignment was announcement; a first lasting peak of petitions happened during the construction years of 2004-2007, and resumed even stronger after the great recession. Along the BLE, petitions took off in earnest after the great recession and continue to lag behind the BLO. Looking at this chart in parallel with the charts on the previous pages, it is clear than TOD designation is seen by developers as an effective tool in the process of capital investment in the LRT corridors.

Intensity of TOD designations over time

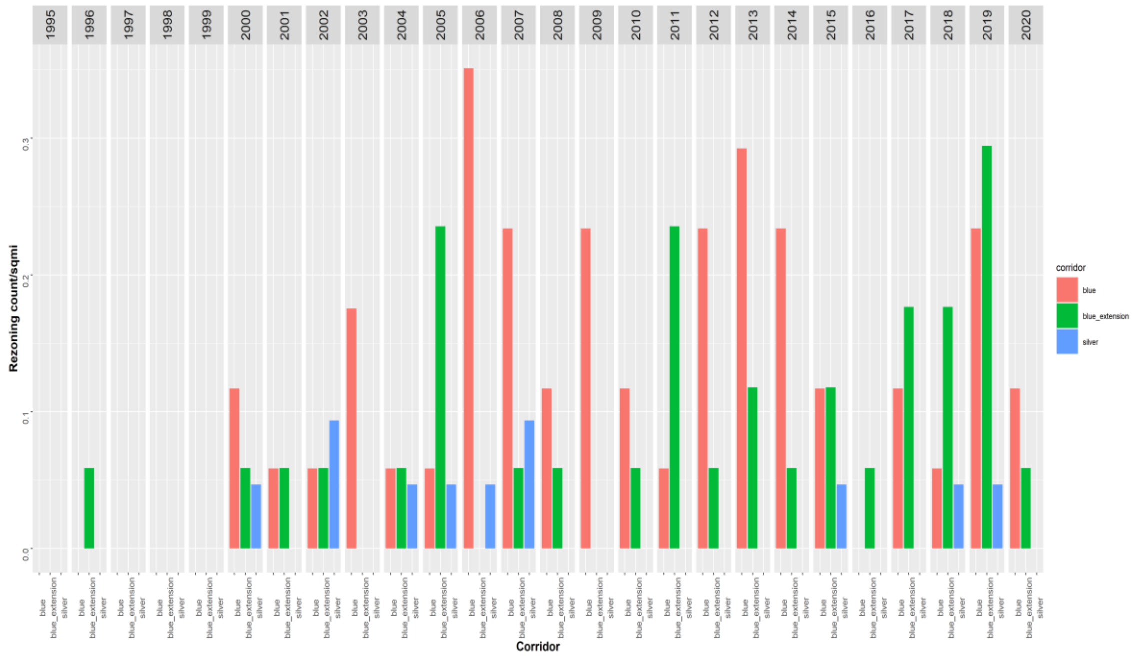


4.5. Rezoning Applications

Here we start by looking rezoning applications on the BLO and BLE and compare to the densities noted annually in the control corridor. This is reported in the bar chart below. Several points can be made on this basis.

1. The number of rezoning applications is very small along the Silver Line corridor. There rather rare event may be surprising given the overall level of construction activities in this corridor. However, this would be in line with the anticipation that the future built environment in this area will not depart from the past. Space is being reproduced and not transformed.
2. Conversely, rezoning is a regular occurrence on the BLO dating back to year 2000. The pace of rezoning maps well against the construction activity on this corridor. It was particularly strong during the decade of 2005-2015, coinciding with the fast transformation of the BLO.
3. The BLE has seen a steady but fairly low pace of rezoning applications through 2012. Coinciding with the start of construction on the LRT, rezoning has skyrocketed.

Intensity of TOD designations over time



In summary, the transformation under way in the BLO and BLE are more than mere demolitions followed by new constructions, or renovations/alterations/conversions. They often involve a departure from older land uses and associated zoning designations for new ones, more often than not encompassing some residential use. This is consistent with the passenger transportation function of LRT. This reinventing of the city, parcel by parcel, is specific to proximity to access point to the LRT system.

5. Conclusions

The analysis of land development and construction activity as a function of the proximity to rail stations found some evidence that proximity matters. However, the magnitude of land development and its modalities are strongly influenced by proximity to Charlotte's CBD. There is a strong gradient with distance to the CBD. The effect of LRT is stronger for the BLO than for the BLE, which is expected given the longer history behind the construction of this corridor.

A distinction needs to be made between the number of construction projects (UDDs) and their cost. Our analysis showed that development close to stations are larger, involving a much large capital investment.

While we detected a certain anticipation in the real estate community for the BLO, with significant investment much before the opening of the line, this was much less so along the BLE. It is likely the market was still focused on extraction value on the safe bet of the BLO rather than turn to the next, but still unproved, opportunity offered by the BLE. The BLE has behaved for some time as demonstrated by the control corridor rather than in line with the BLO.

The effect of LRT on various facets of land development may be less sharp that the effect demonstrated to exist on single family housing property values by the NCSU Team working on this project. Land development is a very complex issue, with many subtle variations. This may explain with the effect of LRT did not appear stronger.

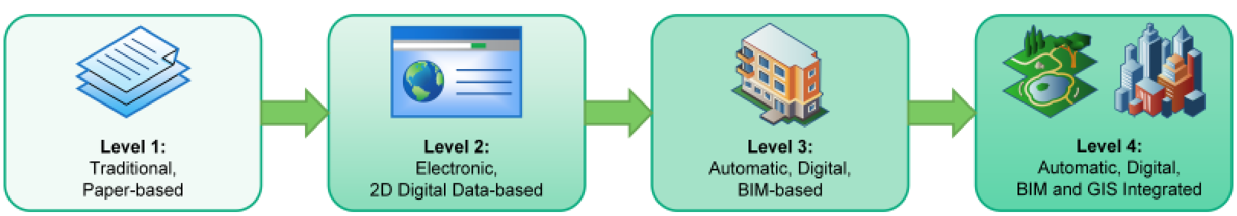
The mix of constructions activities has been rather similar on the BLO and BLE, with much new residential development. In most recent years, BLO and BLE have evolved quite differently however, with BLO becoming more non-residential, while the BLE follows the trend of the control area, and stays mainly residential.

Development in the BLO involves much demolition and construction of new structures, often involving rezoning; this is also the area where TOD thrives. Residential units are particularly affected by demos. Development here involves a remaking of the city on different principles. While proximity to rail matters, it may well be because of the new housing and amenities brought to these areas.

One of the core objectives of this study was to demonstrate the feasibility of using extensive institutional datasets as source of data to evaluate the impacts of rail transportation investments. Throughout the process of cleaning, aggregating, and visualizing the building permit dataset, our results suggest that there is potential for the diversification of uses for building permit data. Methodological issues, such as the appropriate way to aggregate text attributes to the UDD level and the challenge of balancing accuracy and ease of manipulation in creating UDD geography, limited the scope of our study and will require building permit data and UDD data to work in tandem for future research. Another limitation involved the transit corridors examined in this study, which were created by a simple 1-mile or 0.5-mile buffer, and therefore did not take into consideration blockages to accessing transit stations, for example, the apartments in Yorkmont being included in the Woodlawn station's area, despite being blocked from the station by Route 77. Additional research should ensure that areas within buffers are either within a convenient walking distance of stations or have other ways of accessing stations (park and ride facilities, bike lanes, micro-mobility, etc.). The data were also skewed heavily by spikes in construction cost, which may or may not be reflective of actual investment into the project. Further validation of these costs is needed to ensure permitting attribution is correct.

Building permit data are not consistent across local governments in the United States. Many challenges, including knowledge gaps, technology deployment and a lack of standardization, limit applications beyond the specific cities in which permits are issued. Noardo et al. (2022, 2-3) describe a four-tiered approach to digitalization of building permit data (See Figure hereunder).

Evolution of building permit issuing (Noardo et al. 2022)



Charlotte's system is currently at the second of the four tiers and can be greatly improved by incorporating Building Information Modeling (BIM), 3D digital views of the physical, spatial, and functional characteristics of buildings (Samasoni and Rotimi, 2014) into the building permit approval process. There are many potential advantages related to digitalization of the permitting process, including economic savings and efficiency increases (Noardo et al. 2022). Samasoni and Rotimi estimated an approximate economic benefit of $67.3 million per year for New Zealand (2014). The economic windfall to Charlotte for properly digitizing its building permit system is likely to be less lucrative, but it can also ensure an increase in data accuracy, which would support a broad range of public administration tasks, not the least of which would be more timely and more accurate monitoring of land development trends, more responsive planning, and better interfacing of land development with the transportation planning process. Building permit data is a public asset that can be leveraged for the greater good of the community with a small investment to make them more useable and easier to interface with other datasets.

While the accuracy of Charlotte's building permit dataset has improved greatly in recent years, there remains significant issues that affect data quality, including a lack of proper verification of permit attributes and an often contradictory and inconsistent construction classification system in repurposing USDC codes. As illustrated in our UDD assignment process, the project-level aggregation of building permit data has been ad hoc. To properly plan future development in Charlotte, having a firm understanding of past development decisions and their consequences is integral, particularly as Charlotte continues to grow. Although our results are specific to Charlotte, there is still great potential for research using building permit data in other cities, and various methods of aggregating them, to study important socio-economic issues like gentrification, as well as other forms of urban change. Further study may be able to make use of more advanced building permitting systems and uncover potential statistical correlations between investment into physical infrastructure of neighborhoods and other data sources like land value, rents, and/or crime.

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C. Vehicle Ownership

1. Introduction

Public infrastructure investments in urban transit systems are often made with a certain level of anticipation that user behaviors will be adjusted to the new reality of mobility options available and to the new qualities of the mobility services resulting from these investments. This is particularly central to the design and deployment of effective policies of urban transportation under the financial constraints of public budgets, the continued growth of urban centers, and the renewed emphasis of population and elected officials on greater livability of urban communities.

The theoretical argument that is held is that by lowering the generalized cost of public transit, a modal shift would occur towards transit and away from other modes of transportation, particularly motorized modes, such as car driving. A correlate of this trend would be a decreased need for owning a motorized vehicle, and as a result, decisions made by local residents to forgo owning one, or reducing the number of cars owned within their households. This part of the project aimed at assessing the validity of this argument by analyzing the rate of ownership/effective use of light duty vehicles (cars) within Mecklenburg County. The analysis looked at these rates within their geographic context (proximity to the LYNX Light Rail Corridors) as well as within their temporal context (timing with respect to the operation of the rail service).

2. State of the Art

While there are a number of studies on the rate of car ownership and its determinants (for instance, Blomjous, 2019; Chatman, 2013; Ding and Cao, 2019; Dixon et al., 2021; Holmgren, 2020; Kaewwichian et al., 2019; Wu et al., 2016; Zambang et al., 2021; Zhong and Lee, 2017), surprisingly few of them are geographically disaggregated enough to single out factors of relevance to this project, namely the proximity to urban rail infrastructure, and incorporate the temporal dimension that would allow for the identification of the synchronicity of car ownership and the rail service.

In general, car ownership has been found to be related to demographic variables of the households (number of residents, household composition (number of adults, number of children), socio-economic variables (disposable income, socioeconomic strata, employment status, housing tenure), and built environment variables (urbanity, population density, means of distance travelled to work). Issues that are often raised in the research literature include the difficulty to handle endogeneity/self-selection considerations, multicollinearity between possible predictors, data quality concerns, and the sheer complexity of the interrelationships between vehicle ownership, other mobility demand decisions (when to travel, where to, how often, etc.), and locational decisions of households as far as work and residential matters are concerned. Causality has been very difficult to establish. Finally, many studies have been conducted outside the United States, where the social, economic and urban contexts are quite different. Transferability of results from such studies to the US context, especially cities of North Carolina where the tradition of modern rail transit is rather is not well grounded, may be quite questionable.

An important and eminently relevant study is that conducted by Chatman (2013, 2015) because it was conducted in the US (New Jersey) and because a point of interest was the role of the proximity to train stations. This author found an inverse relationship between car ownership per capita and proximity to a rail station, but also concluded that once controlling for housing type, parking availability, population density, bus availability, and other built environment measures, proximity to a rail station fails to be a significant predictor of auto ownership. Instead most of variation in car ownership is due to parking availability; none to rail access. This is meaningful, as this calls into questions the true urban mobility consequences of rail transit systems, and Transit-oriented developments (TOD) that are often seen as favored public tools of intervention to harness congestion and GHG emission in contemporary cities.

3. Data and Methods

The vehicle registration data used in this portion of the project were sourced from NCDMV. Other data sources include Data Axle historical residential database and the American Community Survey (Bureau of the Census). These datasets are now briefly discussed in turn.

The annual vehicle registration data were obtained for the period of 2000 to 2020 (except for 2001, which could not be provided). Data point pertain to passenger and light duty vehicles registered for use in Mecklenburg, North Carolina. The locational information (address) is therefore not the home address of residence of the owner of the vehicle, but the address of the user of the vehicle. The addresses were spatially aggregated to census block groups to preserve the confidentiality of the information. The research team conducted significant data cleaning and geospatial data manipulation in order to assemble a consistent dataset spanning two decades, that could be used to generate the results reported below.

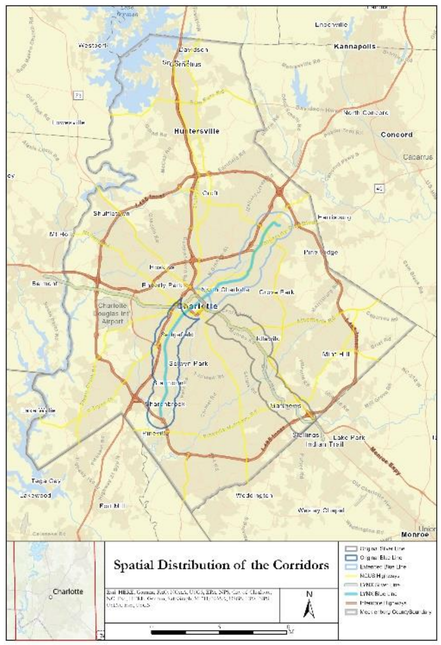
The annual historical population data layers sourced from Data Axle were used to produce an annual count of families and persons in each census block group. The original anonymized data records included geospatial locational information (geographic coordinates, as well as census unit identifiers). Given the inconsistencies in the data and the significant volume of missing data, extensive geospatial data processing was necessary, as well as data imputation of longitudinal time series. Families were also expanded to individuals by using the family size attributes included in the data. Data Axle uses a proprietary algorithm of data analytics and fusion based of multiple sources to assemble these annual data. This is a unique dataset, which is also used in the project to conduct the analysis of population displacement. DataAxle historical residential data are available for the period of 2006-2019. Family and person records were aggregated using geospatial analytic tools to census block group. Given the nature of the DataAxle data, it is not possible for us to establish the validity of the data derived from it.

Because the DataAxle historic residential data do not cover the entire period of interest, especially prior to the start of operation of the Lynx Service on the Original Blue Line, population data from the American Community Survey (ACS) of the US Bureau of the Census are also incorporated in the analysis. Data are used here as well at the geographic granularity of the block group within Mecklenburg Co. The These annual estimates are available for the years of 2000, and 2010-2020 annually.

The count of registered vehicles, family counts and population counts (both sourced from DataAxle and from the ACS) were then aggregated spatially to three corridors identified around the original LYNX Blue

Line, the Lynx Blue Line Extension, and a control corridor aligned with the portion of the future LYNX Silver Line, south of Uptown Charlotte. The latter is used as a control, because of its housing and population features that roughly match those of the original Blue Line and Blue Line Extension. Three different buffer widths are used to define the spatial polygons, namely 0.25 mile, 0.5 mile, and 1 mile around the actual or future stations in the three alignments. This allows us to assess the effect of the proximity to points of access to the light rail system on the decision made by local residents with regard to vehicle ownership/usage.

These corridors are visualized on the county map below.



Next, for each of the two corridors of interest (Original Blue Line and Blue Line Extension) and each of the three buffer widths (0.25, 0.5 and 1 mile) we calculate the ratio of the number of registered vehicles to the number of families and number of people estimated by DataAxle and the ACS. These rates are then compared to the corresponding rates along the Silver Line corridor. Because the 0.25 mile buffers are very small in relation to the areal extent of block group for which ACS population estimates are provided, the associated ratios could not be calculated. All the steps described above are iterated annually and curves displaying the evolution of the standardized rates are plotted on charts reported in the result section below.

4. Results

Results include a number of line charts showing the trend on an annual basis in the rate of vehicle registration to a certain measure of population in each light rail buffer of interest to the buffer of same width along the planned Silver Line. Values over 1 are indicative of vehicle registration rates above the control value (Silver Line); values under 1 stand for vehicle registration below the value estimated in the control region. Trends on a per family basis closely align with trends based on DataAxle population counts as well as with those calculated on the basis of the ACS population estimates.

For the interpretation of the results, the following dates are to be kept in mind:

2000 – announcement of the alignment of the Original Blue Line (BLO)

2004-2007 – BLO construction and opening

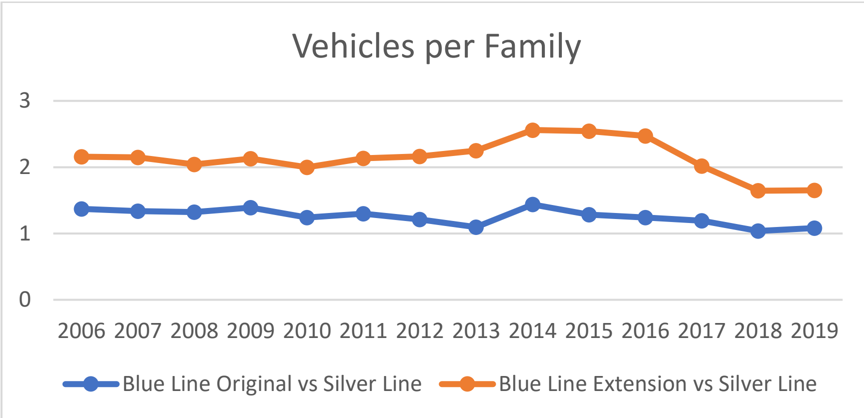
2006 – announcement of the alignment of the Blue Line Extension (BLE)

2013-2018 – BLE construction and opening.

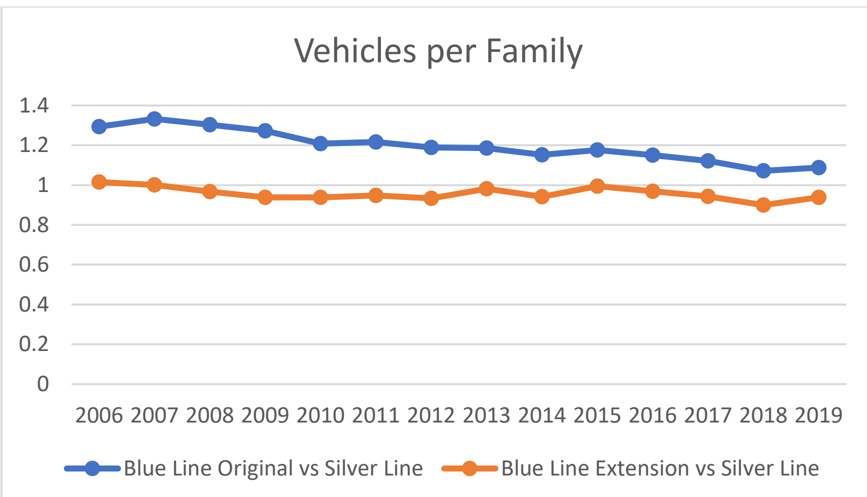
The analysis of these line charts leads us to make the following observations:

1. The rate of vehicle ownership is consistently higher in close proximity (0.25 mile) to the BLE rail alignment compared to the BLO, although the discrepancy appears to have been shrinking over the most recent years under study. The orange curve is above the blue curve.
2. The reverse holds when we look at the situation with the coarser lens of the 0.5-mile or the 1-mile buffer. The blue curve is above the orange curve. Hence there is some evidence that proximity to train stations would to be a factor in vehicle ownership and registration.
3. Within 0.25 and 0.5 mile, there is an historic tendency for vehicle registration along the BLO and BLE to converge toward the rate in effect along the control Silver Line (or continued to lag the rates of the silver line as indicated by rates based on ACS data). For the BLO, such trend is discernible earlier than for the BLE (where it shows only in post 2018) which would support the assertion that this effect may have been triggered by the opening of the LYNX service on BLE.
4. However, given that the relative rates for the BLO remain stubbornly above the critical threshold of 1 for many of these graphs, except for the most recent years, on can conjecture that proximity to a train station alone does not suffice to lead people to forgo vehicle ownership and other effect may be at play. Maybe a change in the demographic composition of the resident population, possibly triggered by different characteristics of the housing stock with the different buffer along the corridors.

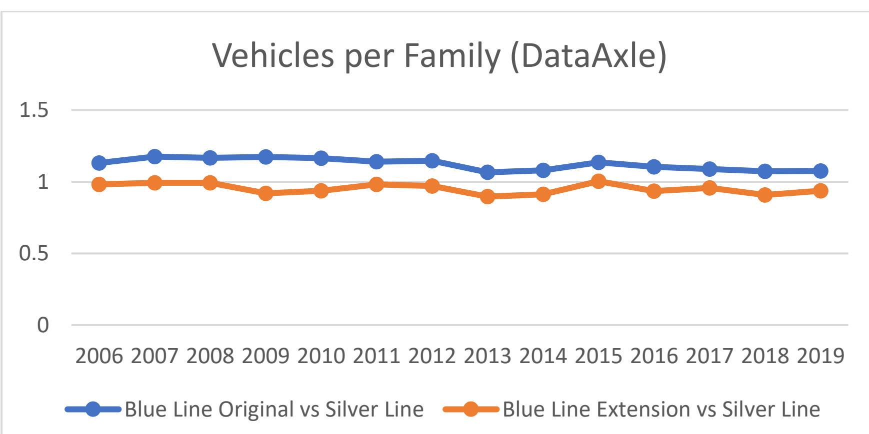
Relative rates of vehicles per family (DataAxle) calculated within 0.25-mile buffers



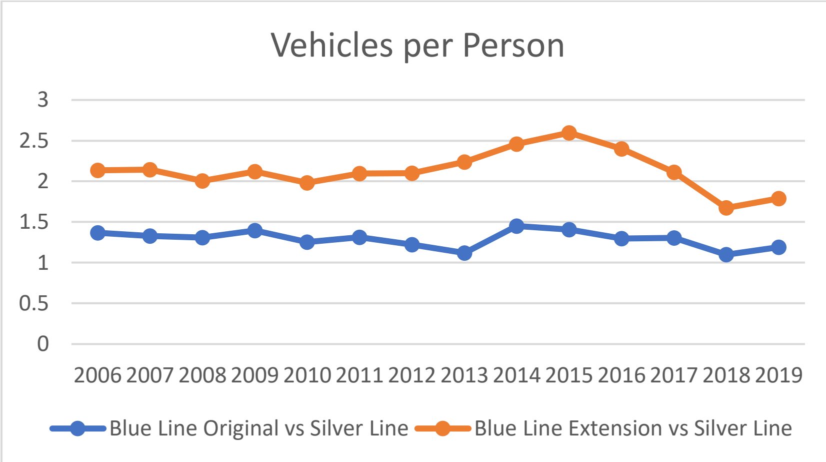
Relative rates of vehicles per family (DataAxle) calculated within 0.5-mile buffers



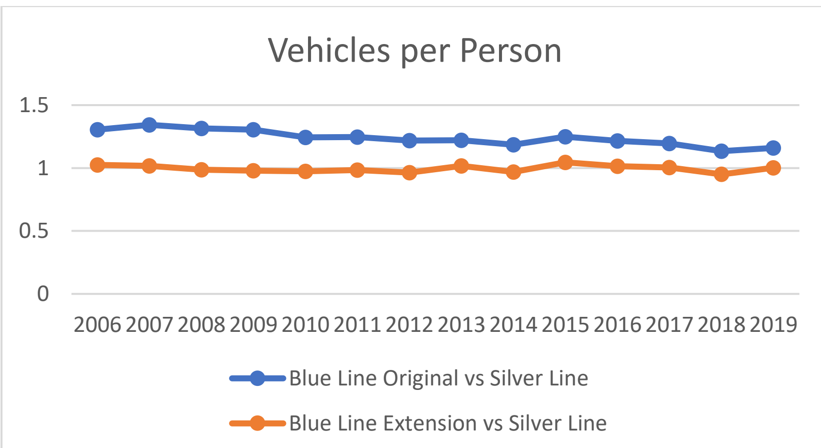
Relative rates of vehicles per family (DataAxle) calculated within 1-mile buffers



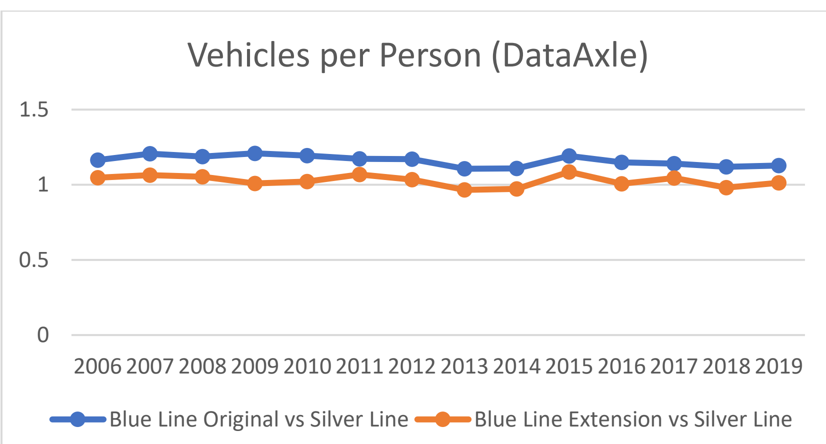
Relative rates of vehicles per person (DataAxle) calculated within 0.25-mile buffers



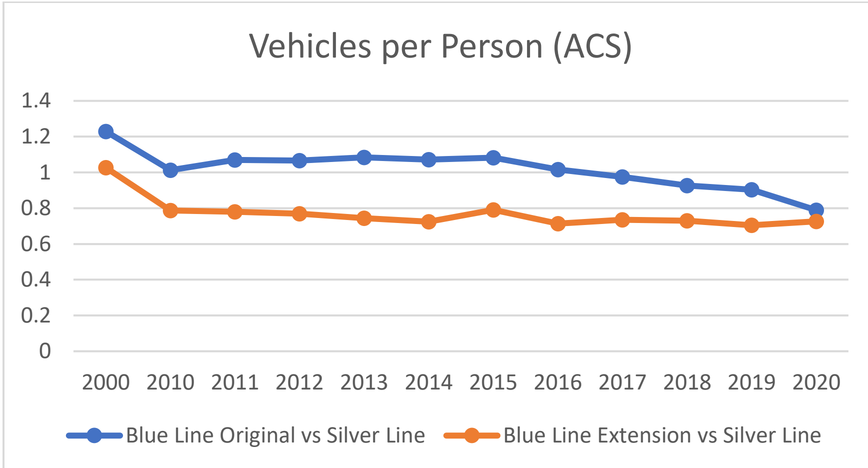
Relative rates of vehicles per person (DataAxle) calculated within 0.5-mile buffers



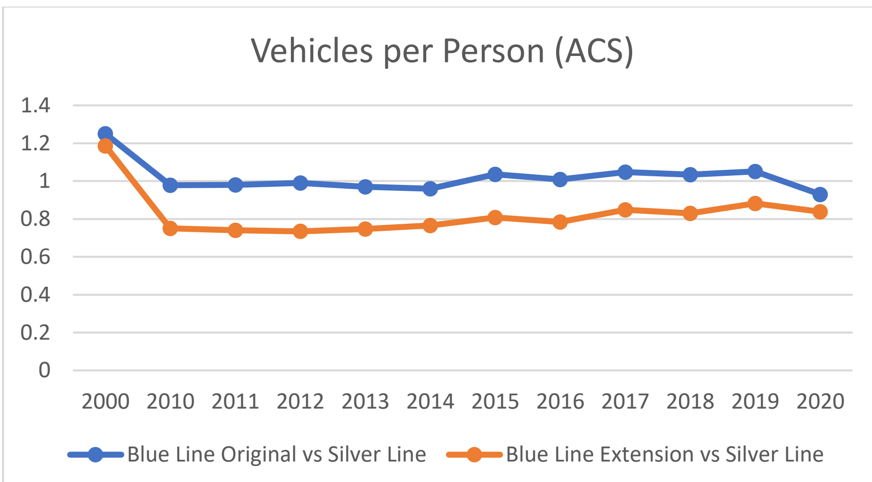
Relative rates of vehicles per person (DataAxle) calculated within 1-mile buffers



Relative rates of vehicles per person (ACS) calculated within 0.5-mile buffers

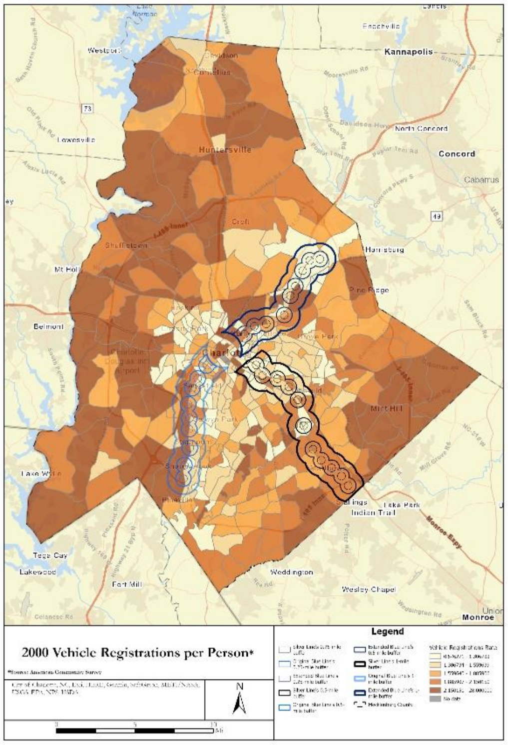


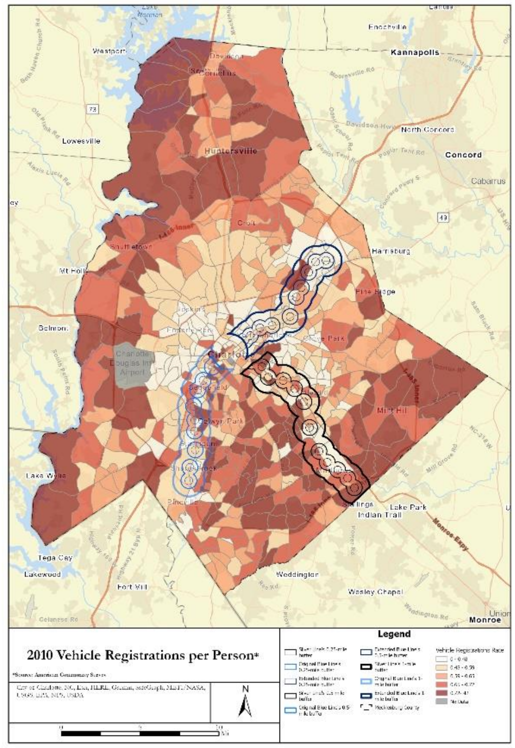
Relative rates of vehicles per person (ACS) calculated within 1-mile buffers

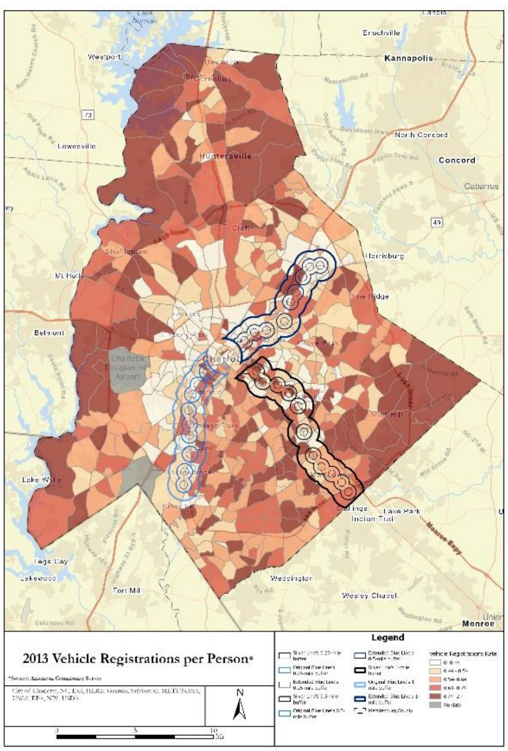


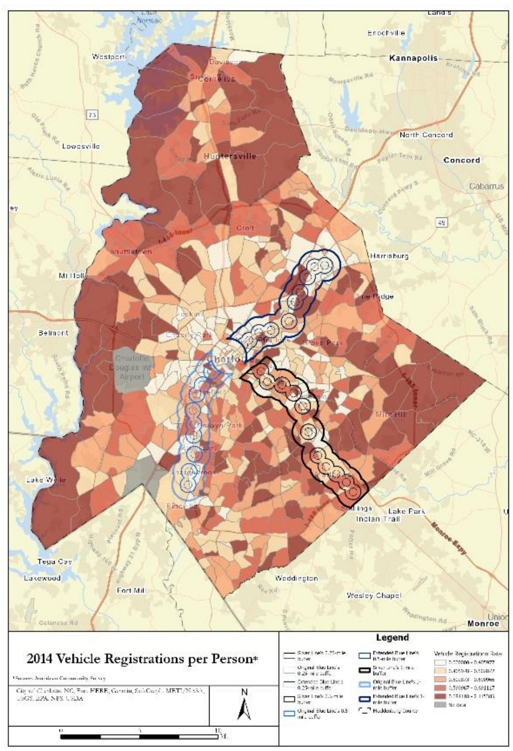
These observations are also broadly consistent with the series of maps of vehicle registration rates and the overlay of rail corridors buffers provided below[1]. The construction and operation of the LYNX line has not fundamentally changed the rates of vehicle registrations near the rail line compared to the control corridor, not in comparison to values in the rest of the county.

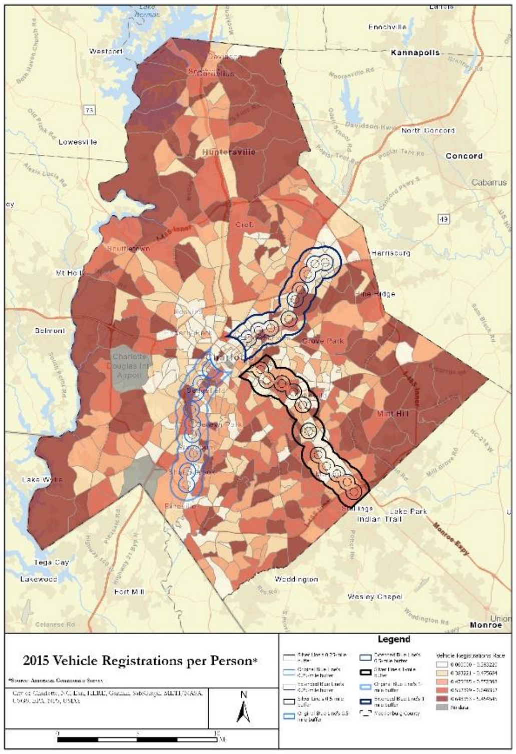
[1] In the maps, block groups are classified based on the quantile method.

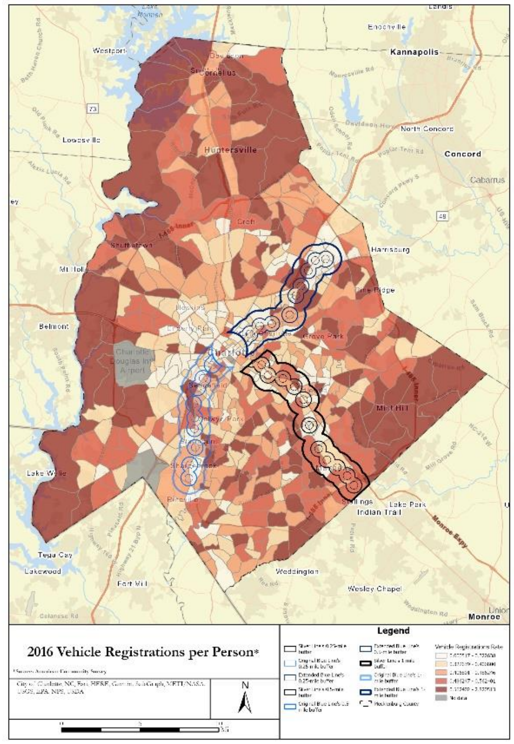

2000 Vehicle Registrations per Person*
Legend

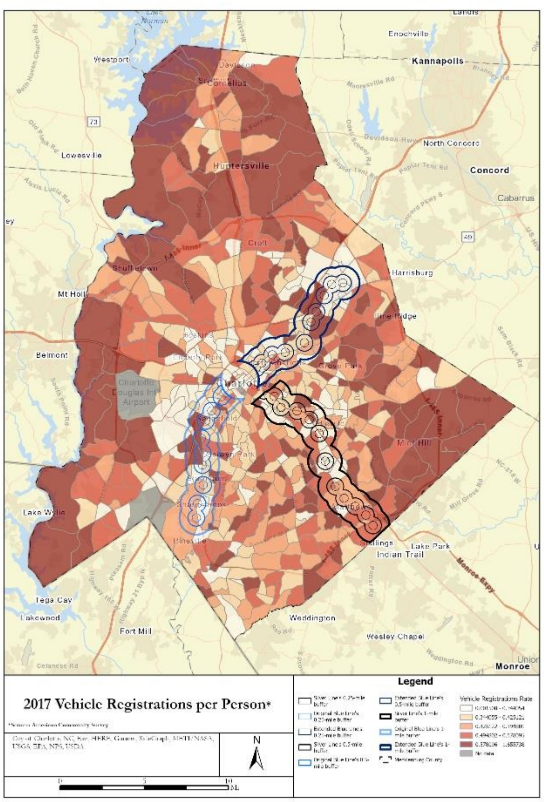

2010 Vehicle Registrations per Person*
Legend

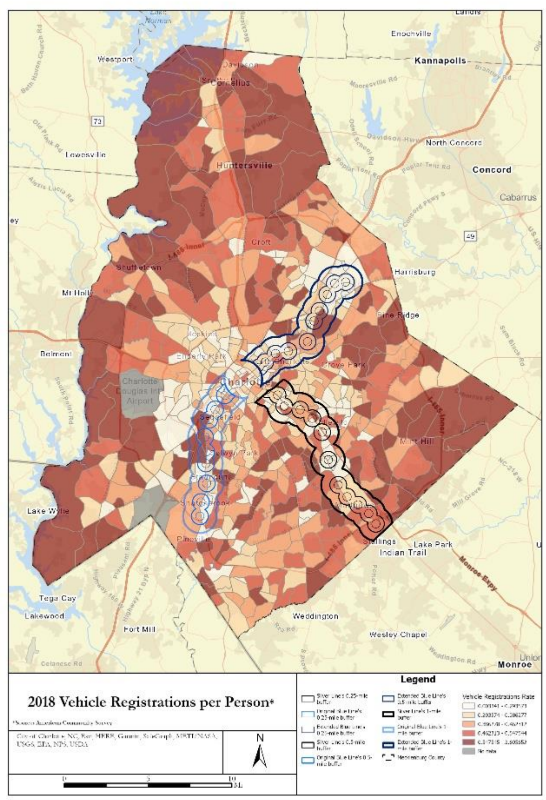

2013 Vehicle Registrations per Person*
Legend

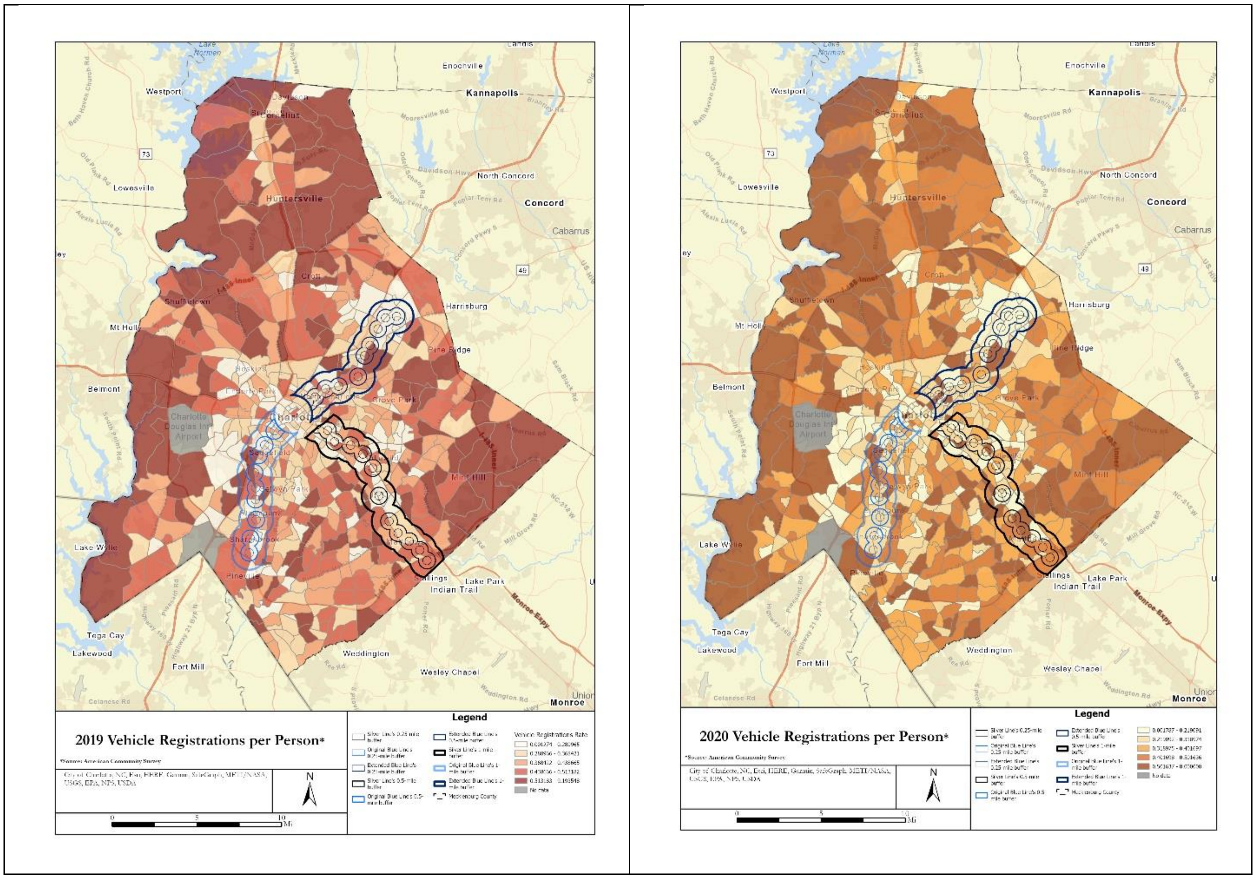

2014 Vehicle Registrations per Person*
Legend


2015 Vehicle Registrations per Person*
Legend


2016 Vehicle Registrations per Person*
Legend


2017 Vehicle Registrations per Person*
Legend


2018 Vehicle Registrations per Person*
Legend



5. Conclusions

The analysis of vehicle registration rates as a function of proximity to rail stations found some evidence that this proximity may be a factor. However, the effect appears to be small, and not always consistent between the two corridors, accounting for timing of the construction and opening of services, in reference to the Silver Line control. This is broadly in line with the results by Chatman (2013 and 2015), and also with the local perception that congestion has not been easing out in recent years in close proximity to rail stations. In fact, land use ordinances in Charlotte have not been adjusted to reduce the required parking space to housing unit ratios. Charlotte developers are only starting to test the waters in seeking waivers of these requirements. These car-free housing complexes (Buffo, 2022) may be a game changer that will fully leverage the opportunities afforded by transit oriented developments (TOD) or accessibility oriented developments (AOD) (Deboosere et al., 2018). Proximity to light rail stations may be a necessary condition for the drop in motor vehicle ownership, but it does not appear to be a sufficient condition.

The results our analysis points to intimate that further analysis of car registration data is warranted to shed a clearer light of the trends and opportunities that can be in the making.

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D. Population Displacement

1. Introduction

Public transit investment has been identified as a potentially significant source of population displacement. This displacement may be direct, in the sense that right of way may need to be cleared of existing built structures inhabited by local residents, who need to relocate to some other location within the urban fabric, or further afield. Direct displacement is planned, predictable, and limited. Alternatively, as indicated in other parts of this collaborative project, the transit infrastructure investment may trigger a process of change in its vicinity, which would typically involve land use changes, reinvestment in real property by private parties with upgrading and filtering up in the use of the buildings. This second form of displacement is typically longer term; it may be intentional, fitting a deliberate urban redevelopment strategy of the local municipality for economic development; however, it may not be inclusive, leaving behind certain socio-economic classes unable to cope with the new economic realities of the places, and also exposed to community dislocation. Gentrification is the concept often associated with such a process. Accompanying this change in the physical layout and use of the land, populations may be forced to relocate when housing is demolished to make room for redevelopment or sold prior to redevelopment. Also, they may relocate on their free will to escape housing conditions that may have become too expensive on land parcels in highly desirable locations as a result of private market forces. Both processes described above may have been at play in Charlotte along the corridors of the Original Blue Line (BLO) and Blue Line Extension (BLE) of the LYNX Light rail system. Since shortly before the opening of the BLO) in 2007, Transit Oriented Developments (TOD) have steadily become more commonplace, often involving rezoning in the vicinity of stations.

Gentrification is not a new phenomenon in Charlotte. Over the past two or three decades, it has affected a number of neighborhoods encompassing the city center (Uptown) as well as neighborhoods adjacent to it (Cherry, Elizabeth, Dilworth, Wilmore, Sedgefield, NODA come to mind). These and many other neighborhoods of Charlotte have experienced a tremendous growth of their resident population assorted with densification, often in conjunction with a transformation of the built environment. An important question associated with this process is whether this net increase in population is accompanied with a replacement and turnover of population, and what happens to population that is being displaced.

In this part of the project, we studied the magnitude and intensity of population displacement in relation to the proximity to access points to the light rail service (rail stations) and to the timing of the announcement, construction, and opening of rail transit services. In short, we studied transit-induced displacement. For this study, we used the DataAxle historical residential dataset to track the residence of families over time, and we characterized some of the socio-demographic characteristics of stayers, in-movers and out-movers. This is a large-scale analysis that entailed the establishment of a unique longitudinal dataset compiled from massive annual population datasets.

2. State of the Art

There is a body of literature spanning over three decades on transit-induced displacement (Baker and Lee, 2019; Baker et al., 2021; Delmelle and Nilsson, 2020; Dong, 2017; Jones and Ley, 2016; Kahn, 207, Moore, 2015; Nilsson and Delmelle, 2020). Marcus (1985) and Zuk et al. (2018) elaborated on the different pathways that relate transit development and population displacement. In detail, four types are discussed, namely direct, economic, exclusionary, and displacement pressure. The evidence on the magnitude of displacement in relation to certain neighborhood change processes such as gentrification (whether transit-induced or not) remains the subject of a certain amount of debate (Billingham, 2017; Delmelle, 2021; Delmelle et al., 2021; Delmelle and Nilsson, 2020; Ellen and O'Regan, 2011; Freeman, 2005; Kohn, 2013; Nilsson and Delmelle, 2020; Rayle, 2015; Slater, 2009) in several communities of researchers focused on urban population and urban environments.

Overall, as summarized by Delmelle (2021) recently, evidence of significant displacement of population in the wake of transit-induced redevelopment and gentrification is still to be found. Also, evidence is lacking to support the hypothesis that low-income residents are displaced in favor of higher-income residents moving in. Reasons can be multiple; in particular, many studies rely on small datasets or data that may not be well suited to handle the fine geographic and temporal granularity necessary to pick up trends regarding displacement in relation to the proximity to fixed rail access points and the timing of the establishment of light rail service. Hence the socio-economic impacts of transit infrastructure investments measured by population displacement remains unsettled.

3. Data

The primary dataset used for this part of the project is the DataAxle historical data. The complete dataset contains datapoints for each family residing in the United States on an annual basis. Each data record includes a unique identifier for the family. In addition, a number of attributes are provided, including the complete street address of the family's residence, latitude and longitude of the residence, zip code, block group FIPS code, census tract FIPS code, city, county and state of residence, archive version year, social economic information (estimated income, estimated home value, purchasing power, wealth, marital status, home ownership status, age of the head of the family, number of other family members), years of residence at the current address. The family ID is tied to the head of the family.

DataAxle maintains annual instances of the historical residential database for each year between 2006 and 2019. This time period enables us to capture population relocation and displacement right before the opening of the LYNX original Blue Line (BLO) and the opening of the LYNX Blue Line Extension (BLE). Given the objective of this project, a subset of the national dataset was pulled. The extraction requirement was for a family to have resided at least one year in Mecklenburg County at any time during the 2006-2019 period.

Data Axle uses a proprietary algorithm of data analytics and data fusion based on multiple sources to assemble the annual datasets. The actual data fed into this algorithm cannot be identified. Also, it is quite possible that DataAxle has tweaked its algorithm over time, which means that data quality may not have remained constant during the 2006-2019 period. Given the nature of the DataAxle data, it is not possible for us to fully establish the validity of the data derived from it. However, some steps were taken to compare aggregate counts derive from these data to Bureau of the Census estimates. This comparison strongly suggests the data are valid for the purposes of this research. This is a unique and complex dataset that required extensive processing in multiple steps to be of use in measuring family residence trajectories and therefore trace the possible relocation of families. These steps are summarized below.

Given the inconsistencies detected between variables in the data and the significant volume of missing data, extensive geospatial data processing was necessary, as well as data imputation of longitudinal time series. Because some of the areal location identifiers were missing or erroneous (inconsistencies with the street address), the analysis was conducted first at the level of the family address. Only when the quality of this address information was questionable, did we use aggregate location identifiers instead. The length of residency available in the dataset was also used for imputation and for cross-validation. Family IDs that appeared in multiple annual datasets were related using techniques of relational database management to create longitudinal residential trajectories. Similarity of street addresses and of their geographic coordinates was used to determine whether a family stayed at the same address or relocated.

Certain life circumstances (immigration, death, marriage, divorce, college graduation, etc.) may explain the appearance a new family trajectory, or the disappearance of a trajectory. The dataset contains no information that could reliably be used to identify such events. No conjecture can be made on such cases to maintain the integrity of the data. The family ID is tied to the head of the family and all dependents of this family and living in the family housing unit are tallied as part of this family.

Overall, 1.6 million unique families were identified, each one having lived at least one year in Mecklenburg County. A residential trajectory is associated to each of these families; it is formed of a sequence of positions encompassing a time stamp t, an x coordinate, and a y coordinate. Hence the triplet (t, x, y) depicts the spatio-temporal dimensions of each of the residential trajectories.

In addition, the analysis used a number of key variables of land development, zoning and real estate activity (demolitions, renovations, new constructions) constructed by the research team on the basis of the building permits, rezoning petitioning, etc, that were collected as attributes of Units of Development Decision (UDD). The reader is referred to an earlier section of this report for further detail on how these datasets were compiled.

4. Results

Several specific research questions were investigated. They are treated in separate sub-sections hereunder.

For the interpretation of the results, the following dates are to be kept in mind:

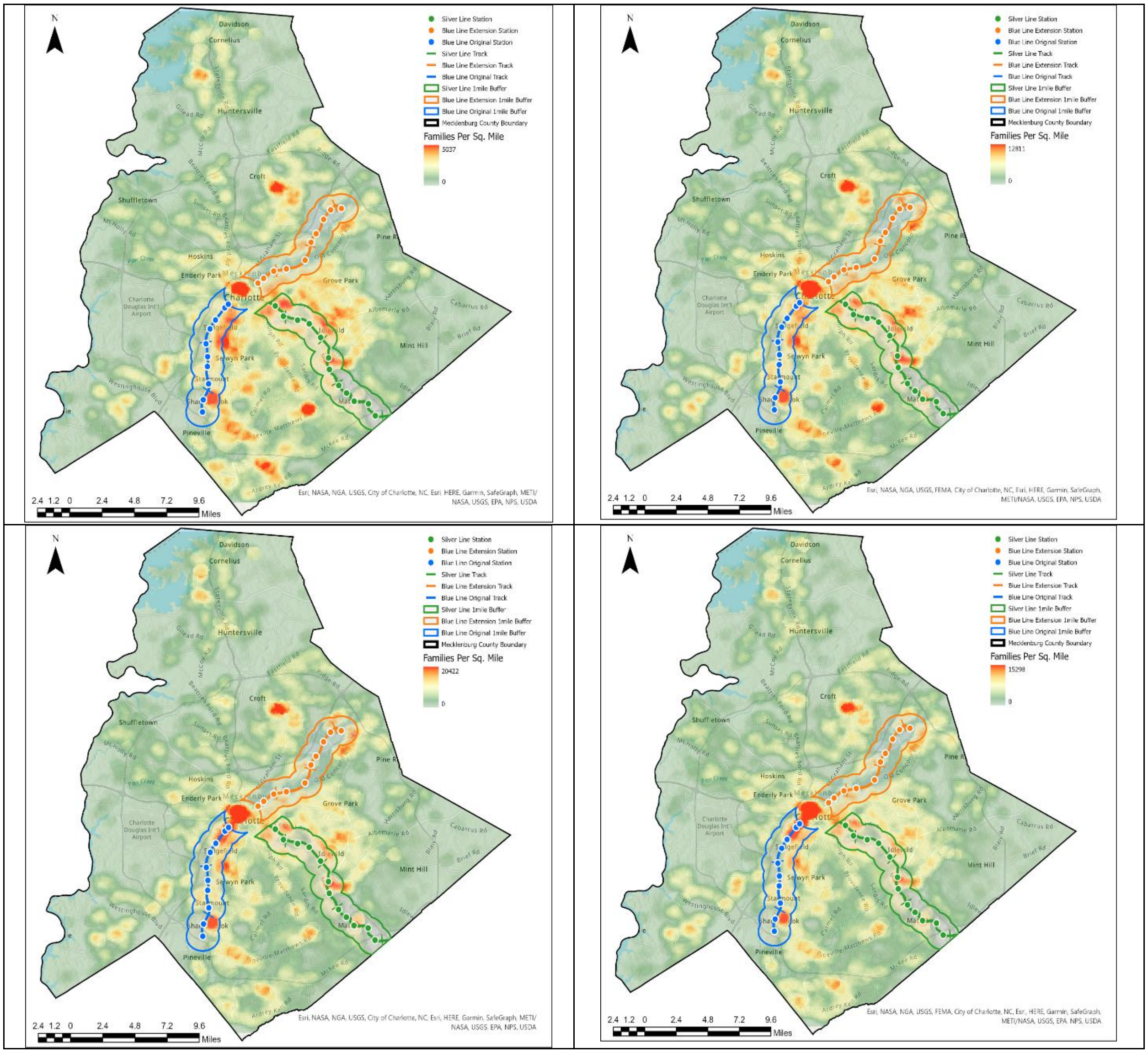
2000 – announcement of the alignment of the Original Blue Line (BLO)

2004-2007 – BLO construction and opening

2006 – announcement of the alignment of the Blue Line Extension (BLE)

2013-2018 – BLE construction and opening.

In order to provide context to the analysis in terms of the spatio-temporal reality of the demographic of Mecklenburg County in relation to the construction of the LYNX LRT system, we share some maps below, namely 2006, 2010, 2015, and 2019, from the top left to the bottom right. The maps report the estimated density of families as revealed by the DataAxle historical residential database. Maps were created with ArcGIS Pro using the Point Density tool in the Arc toolbox, with a 0.5-mile radius specifying the neighborhood size. In in the interest of brevity, not all annual maps are depicted.



Most of the results are reported by corridor, namely the BLO, BLE, and the future Silver Line corridor, as defined in earlier parts of this report. For the sake of comparability, statistics are standardized by the land area of each of the respective corridors.

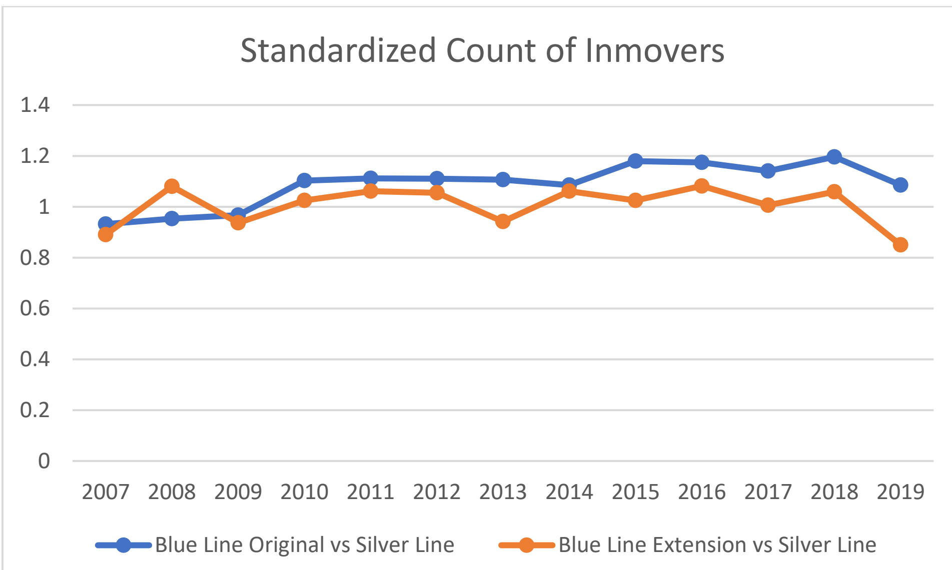
4.1. Population Displacement and LRT Implementation

Arguably, the most critical question regarding the population geography of Mecklenburg County between 2006 and 2019 was whether it was spatially associated with the investment in the LYNX LRT system. In other words, the question was whether the spatio-temporal trends in inmovers and outmovers could be tied to proximity to the LRT stations. For this purpose, we studied population movements for the BLO and BLE corridors, in terms of standardized counts of inmovers, standardized counts of outmovers, and ratio of these counts (net balance), and we compared them to the situation along the Silver Line corridor (used as a control). This analysis was done on corridors formed of 1-mile buffers around the stations in each corridor, as well as corridors defined on 0.5-mile buffers.

Starting with a one-mile lens, the line chart below depicts inmoving behavior to the BLO and BLE compared to the Silver Line corridor. In this chart, a value of 1 means parity between the targeted corridor and the Silver Line control. A couple of observations can be made here:

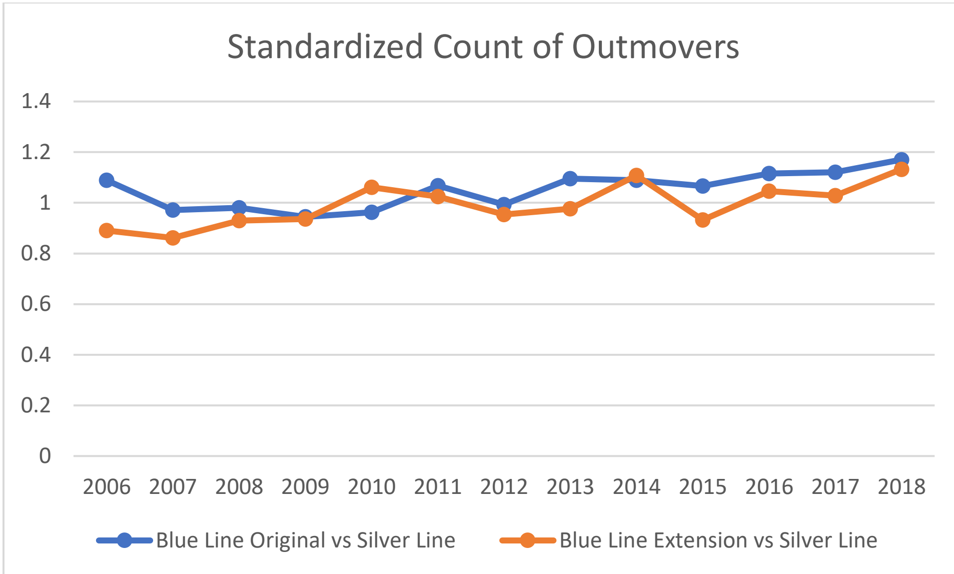
1. For the entire study period, inmigration rates to BLO and BLO exceed inmigration rates to the Silver Line. This excess is held fairly constant over time. BLE particularly does not seem to exhibit a change in trend compared to the Silver Line after the announcement of the alignment of the right of way, nor the start of the construction in 2013.
2. The rate of inmigration to the BLO slightly exceeds the rate for the BLE, and this gap has grown over time.

This provides evidence that the LYNX service has drawn inmovers to reside in 1-mile proximity of stations, although no anticipation was detected in this respect along the BLE.

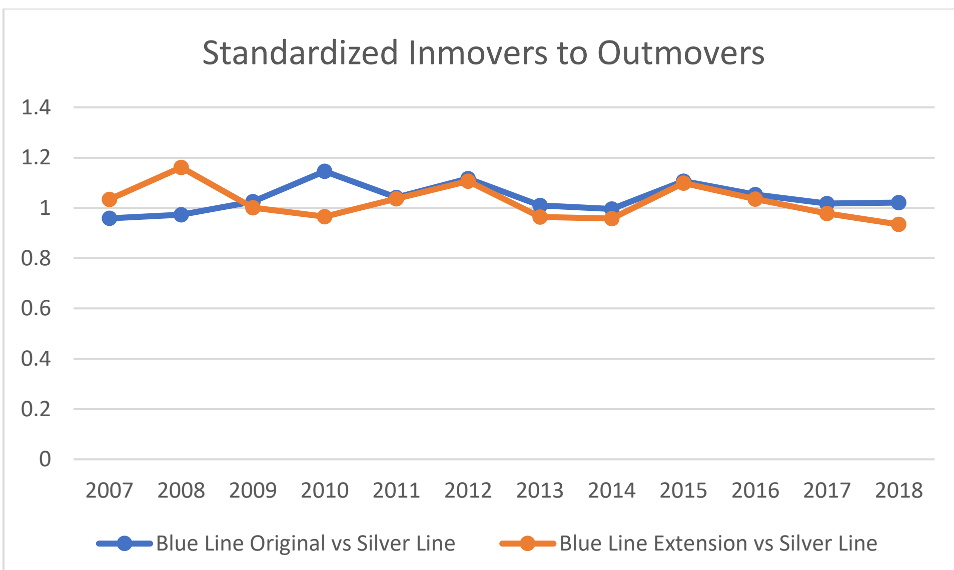


As far as outmovers at the 1-mile resolution are concerned, on the basis of the line chart reported below, the following observations can be made:

1. Outmigration rates are usually higher in BLO than in BLE, and this does not appear to depend on the progress towards opening of LYNX service on the BLE.
2. Over time, outmigration rates in BLO and BLE have exceeded rates in the control corridor (Silver Line).

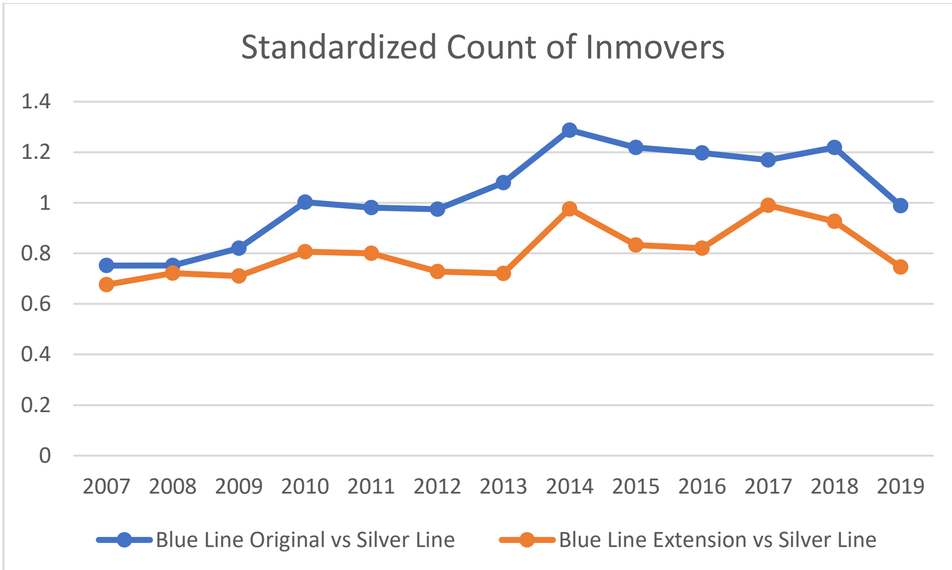


Finally, still at the 1-mile resolution, the balance of inmovers to outmovers in BLO and BLE compared to the Silver Line corridor is very stable over time. This can be interpreted to mean that when groups of inmovers and outmovers are studied together at this geographic resolution, there is no discernible difference based on the existence and proximity to LRT service.

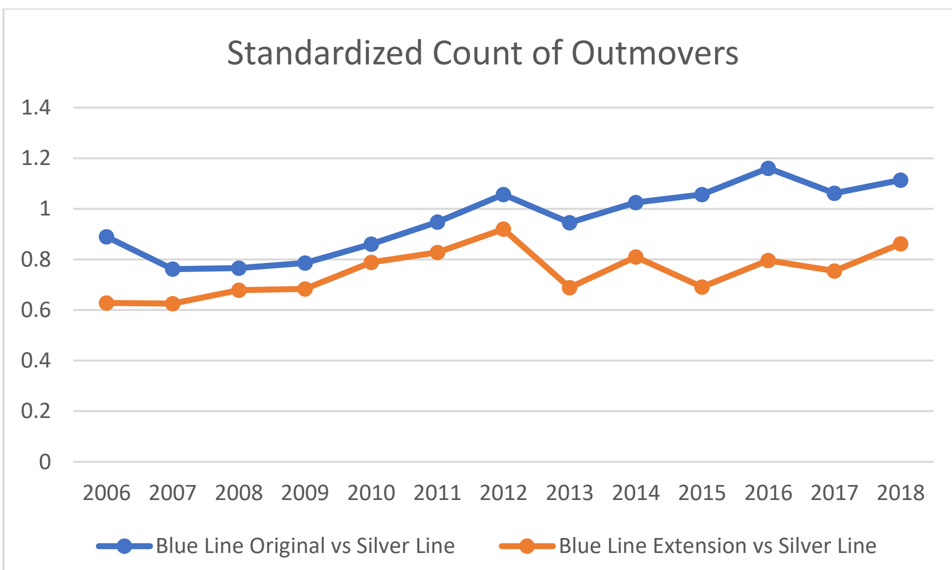


One-mile may not be a relevant enough characterization of good access to LRT in a city like Charlotte. Therefore, the above line charts were recreated on the basis of a 0.5-mile threshold. The analysis proceeds with this evidence now.

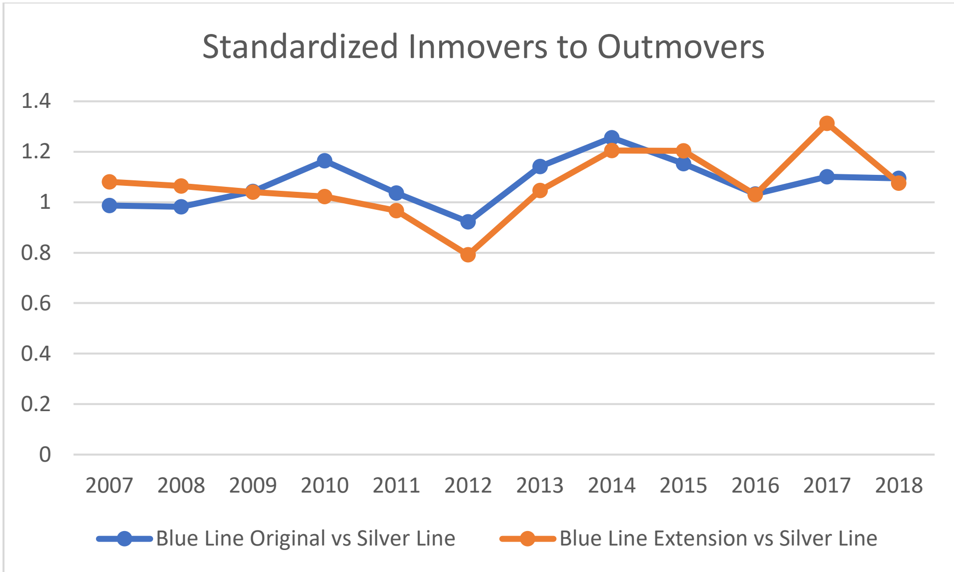
At the 0.5-mile resolution, the following chart portrays trends that are quite contrasted with those at the 1-mile resolution. What we find is a sharp upward trend of inmigration on the BLO over time, compared to the Sliver Line, while a more subtly upward trend is found for the BLE, especially post 2013 (although inmovers in the BLE are still outpaced by inmovers along the control corridor). Thus inmigration in close proximity to stations on BLO outpaced the situation on BLE, with in turn outpaced the Silver Line, and increasingly so. Proximity to LRT serves as a magnet for population, as long as it is at short distance. The fact of the matter is that CATS has taken some rather timid steps to redesign their bus routes as feeder services onto LRT stations, which may explain why the population geography is not impacted in a meaningful way beyond 0.5 mile of stations.



As far as outmovers are concerned (chart below), trends similar to those described for inmovers are observed.



Finally, still at the 0.5-mile resolution, the balance of inmovers to outmovers in BLO and BLE is usually positive compared to the Silver Line corridor. The trend is fairly stable over time, but an overall uptick can be detected over study period. The behavior of population movements on balance is surprisingly similar for the BLO and BLE. The BLO is more dynamic that the BLE, but in terms of families that move in and families that move out, hence the noted net similarity.



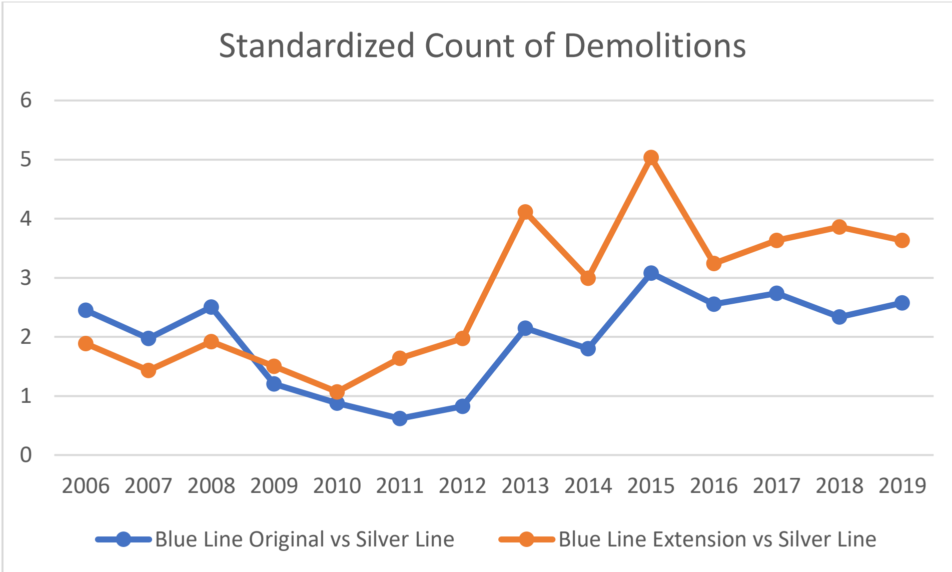
To sum up, within the range of 0.5 mile from LRT stations, some impact on population can be detected, contrary to the broader trends over 1 mile. The sheer magnitude of population dynamics is one degree higher along the BLO than the BLE, and even more so along the control corridor.

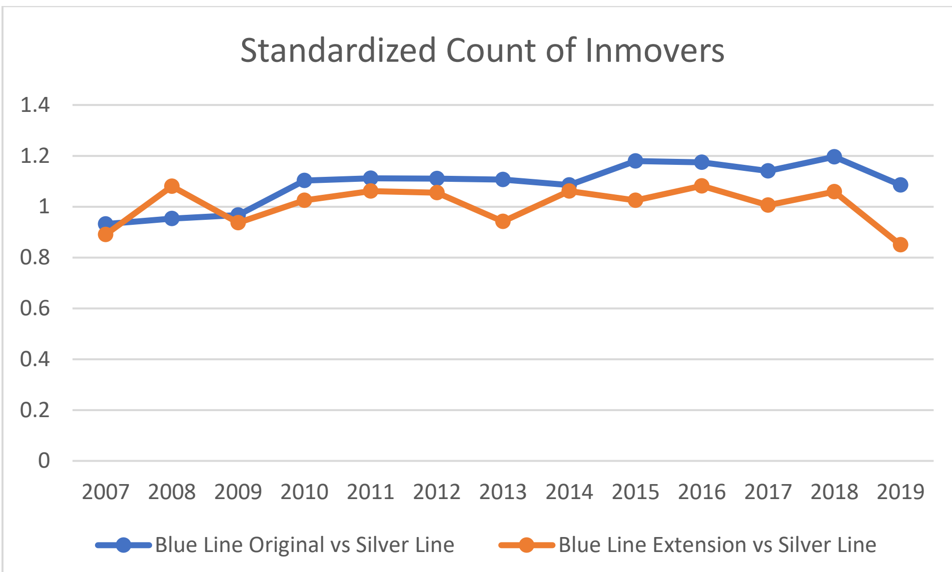
4.2. Population Displacement and Changes to the Building Stock

The first question investigated here was whether population displacement as measured by the standardized number of inmovers of a LYNX rail corridor (families moving into the 1-mile buffer delineated around the stations of the said corridor from any other location) correlated with specific changes in the building stock of the corridor (standardized by the land area). This question was tested for both the BLO and BLE. A follow-up question was whether the associations were different from those identified on the control corridor of the Silver Line.

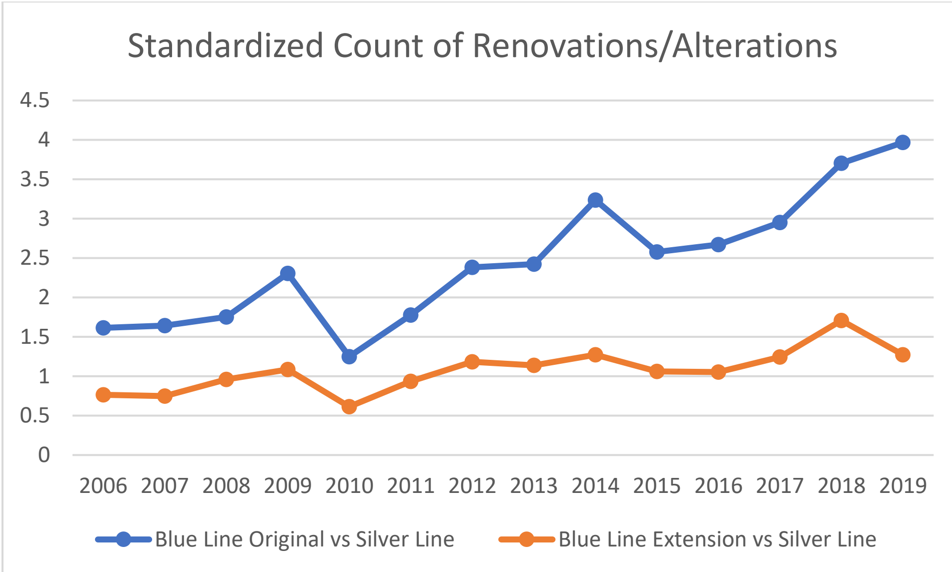
Changes in the building stock in each corridor in each year were measured by the number of said changes in UDDs that were active in that year in this corridor. Changes that were tracked included demolitions, renovations and alterations, new constructions, and new residential constructions.

The standardized number of permitted demolitions in the control corridor exhibits a virtually flat trend over the study period; demolitions along the BLO and BLE exhibit much greater variation. Demos expanded sharply starting in 2010 on the BLE and 2012 on the BLO, and on the BLE more so than on the BLO. For the BLE, this would be contemporaneous of the construction of the LRT line. BLO and BLE show strikingly similar trends after 2011, in contrast to the control corridor, as seen on the chart below. However, no parallel can be drawn between building demolitions and families moving in a year later.

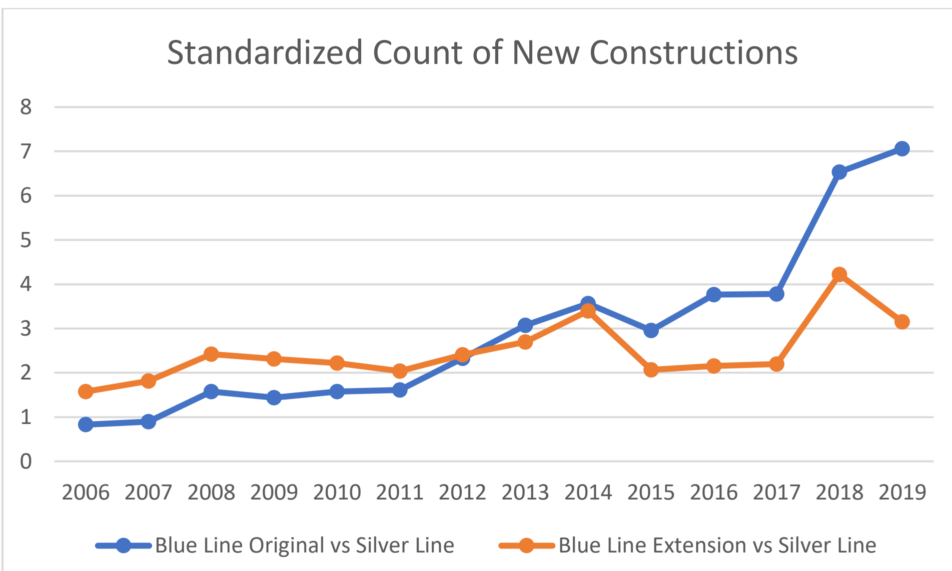




The line chart for renovations/alterations is reported hereunder. We find an uptick of renovations and alterations after 2012 in all three corridors (but especially strong on the BLO and to a lesser degree on the BLE) and a somewhat higher pace of inmigration; inmigration is higher on the BLO, possibly mirroring the flurry of activity on renovations and alterations there, but the pace of the latter far outstrips inmigration (as show on the chart above).

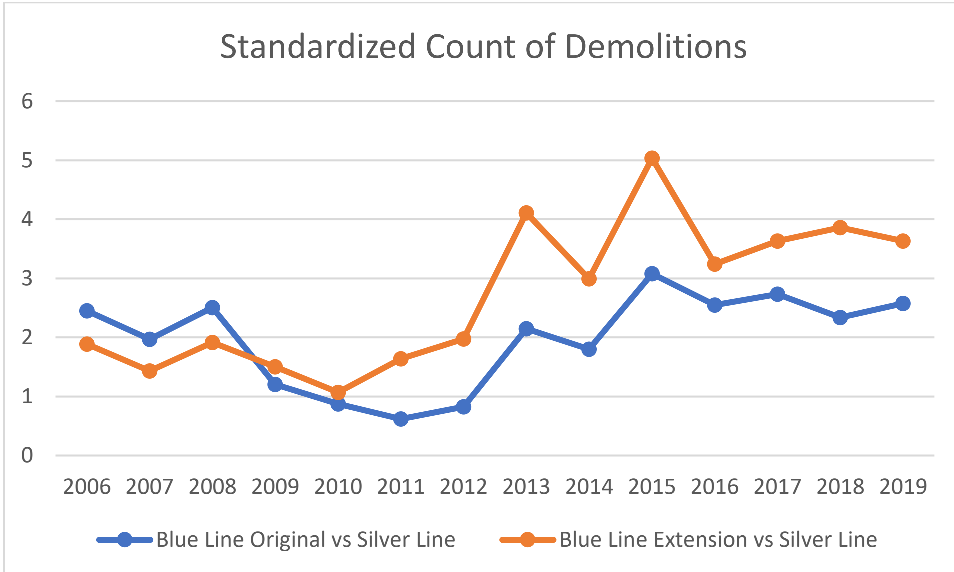


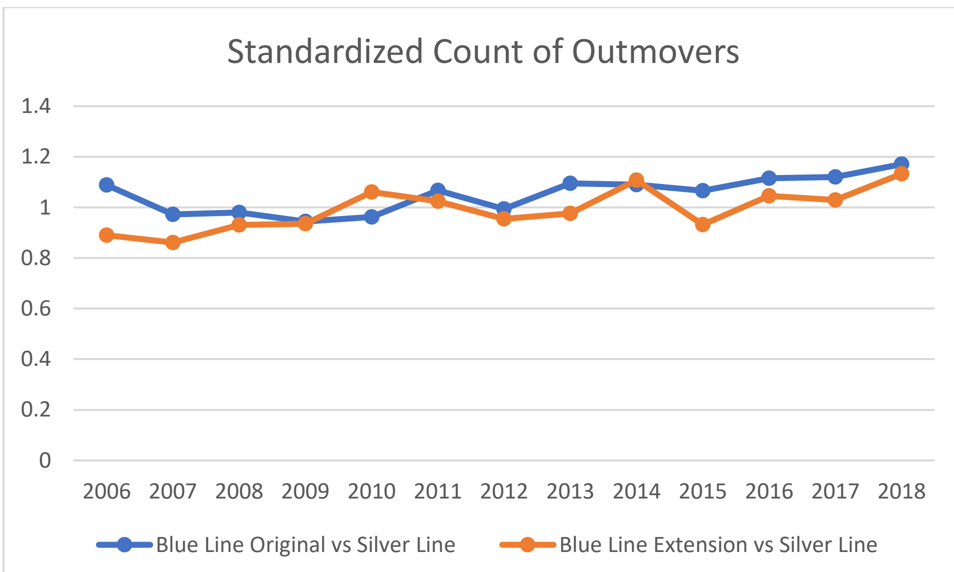
The line charts for new constructions is reported hereunder. We find a sharp rise in new constructions after 2012 in the BLO, a short-lived expansion on the BLE, which contrast with a contraction on the Silver Line. These trends are somewhat mirrored in the inmigration trends, but with much less differentiation between the three corridors. Very similar trends can be observed when looking at new residential constructions specifically.



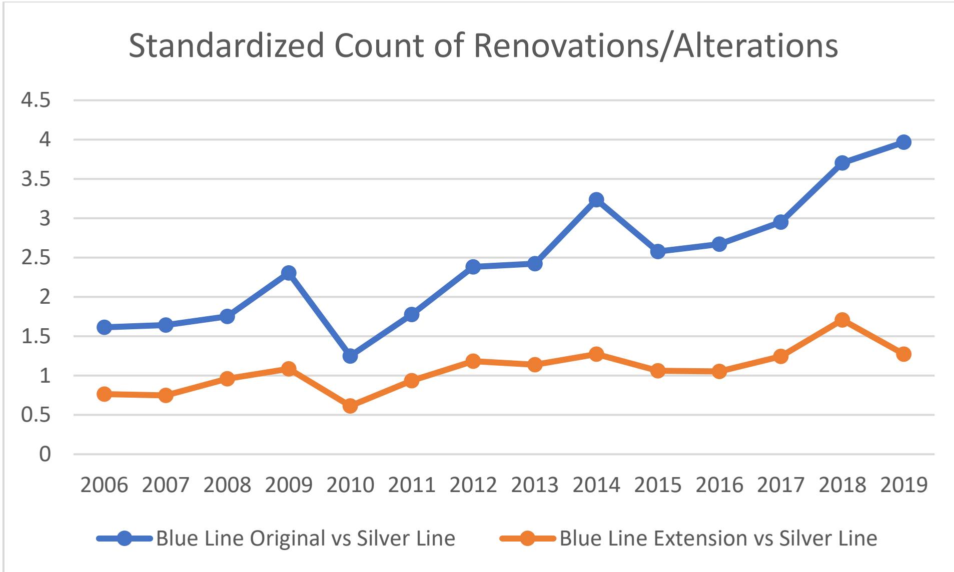
The next question investigated whether population displacement as measured by the standardized number of outmovers of a LYNX rail corridor (families moving out of the 1-mile buffer delineated around the stations of the said corridor to any other location) correlated with specific changes in the building stock of the corridor (standardized by the land area). This question was tested for both the BLO and BLE, using the Silver Line as a control.

The line chart below indicates that families moving out of the respective corridors follow virtually the same trend for the BLO and BLE, and also the Silver Line. Overall, there is an upward trend. Compared to the trends of demolitions in the three corridors, some similarity in the upward trends for BLE and BLO can be seen compared to the control, but disparities in demolition activity is much more marked.

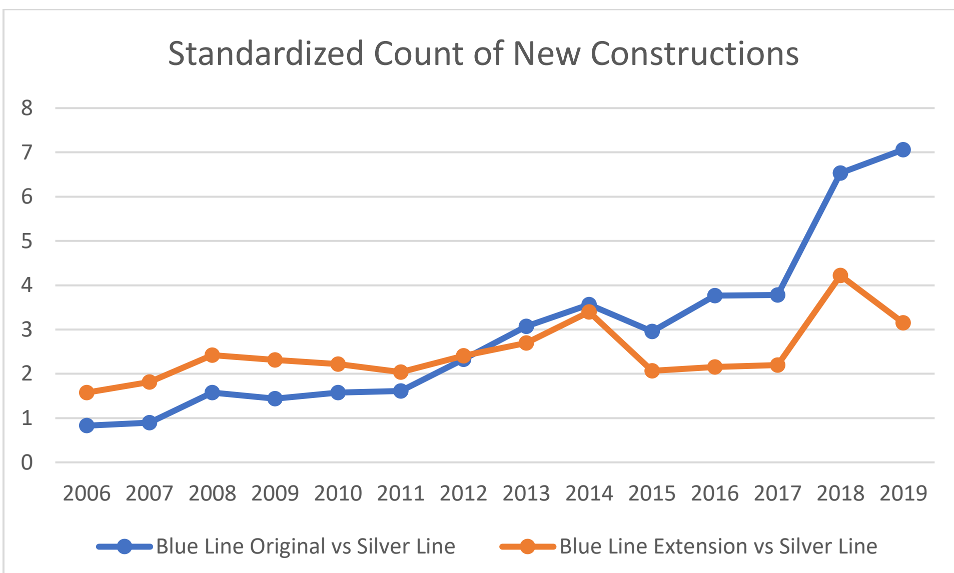




The line chart for renovations/alterations are reported hereunder. We find an uptick of renovations and alterations after 2012 in all three corridors (but especially strong on the BLO) and a somewhat higher pace of outmigration (chart above); outmigration is higher on the BLO, possibly mirroring the flurry of activity on renovations and alterations there, but the pace of the latter far outstrips inmigration.



The line chart for new constructions are reported hereunder. We find a sharp rise in new constructions after 2012 in the BLO, a short-lived expansion on the BLE, which contrast with a contraction on the Silver Line. These trends are somewhat mirrored in the outmigration trends, but with much less differentiation between the three corridors. Very similar trends can be observed with looking at new residential constructions.

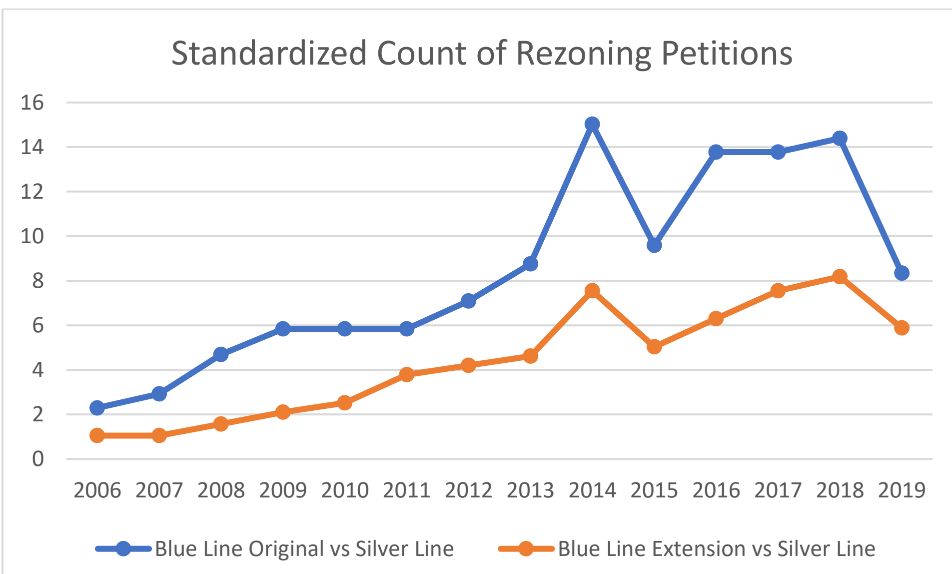


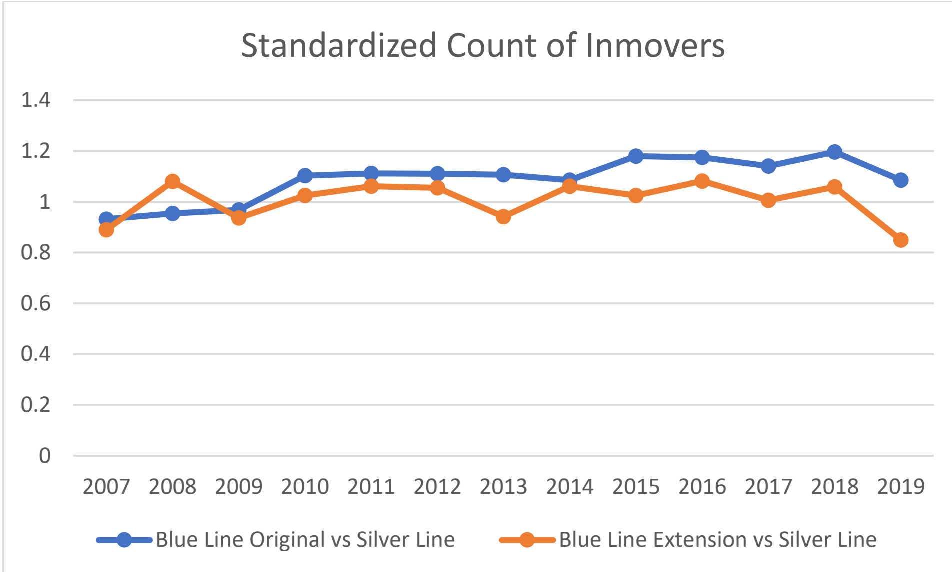
In conclusion, we found partial confirmation by empirical evidence of an association between the population mobility (both inmovers and outmovers) and transformation of the built environment in the fixed rail corridors. This is the case for renovations and alterations and new constructions (the latter only for the BLO). However, this conclusion must be qualitied. Indeed, the apparent association does not align with the announcement, construction, and opening of the LYNX services. Also, some of the same association was seen along the Silver Line (where no rail service is not yet available). Finally, the measure of number of building permits of a certain type may be too coarse a proxy for the magnitude of changes in the built environment. In future work, better measures should be used.

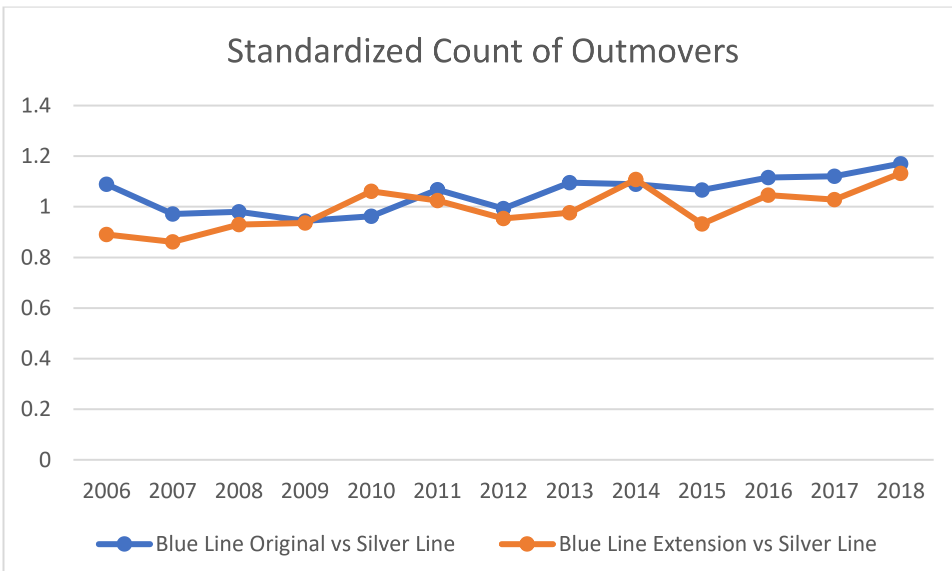
4.3. Population Displacement and Zoning Change

Here we tested for an association between population displacement and the intensity of rezoning activity. The first question investigated here was whether population displacement as measured by the standardized number of inmovers of a LYNX rail corridor (families moving into the 1-mile buffer delineated around the stations of the said corridor from any other location) correlated with specific changes in the building stock of the corridor (standardized by the land area). This question was tested for both the BLO and BLE, using the Silver Line as a control.

The intensity of rezoning is measured by the number of rezoning petitions filed with the city planning department. Rezoning in each corridor in each year was measured by the number of petitions approved in UDDs that were active in that year in this corridor. The rezoning count in each corridor is standardized by the land area of the corridor. The line chart below displays the ratio of this count for the BLO and BLE corridors to the ration on the control corridor. Hence, a value of 1 is indicative of aa relative excess of petitions on one of the targeted corridors compared to the control. For all years, the actual value is over 1. Rezoning petitions are a scarse occurrence in the control, but have become quite common both on the BLO and BLE; on the BLO petition frequency outstripped petitions on the control corridor by a factor 10 after 2014. While some upward trends were found for inmovers and outmovers, these are a fraction of the trends in rezoning petitions. One can note also that the upward trend in petitions on the BLE started as early as 2008, soon after the public announcement of the alignment of the BLE. Given that rezoning would be a precursor to actual redevelopment on a parcel, rezoning can be seen as a marker of future shifts in population geography and of population displacement.







4.4. Geographic Focus of Relocating Families

Given that we identified some evidence that patterns of outmoving from the fixed rail corridors may have been triggered by the announcement, construction and operation of the LRT service, especially in close proximity to the stations, and given the locational desirability of the affected neighborhoods, one is lead to inquire whether families relocating from the LRT corridors would seek to resettle in certain neighborhoods outside the LRT corridors. In essence, this involves testing whether there is anomalous geographic clustering at a local scale among vectors that represent family relocations in the geographic space.

We tested for such instances using a spatial data mining technique developed by Tao and Thill (2019) called FlowAMOEBA. The test was applied annually to all relocation vectors from a block group in

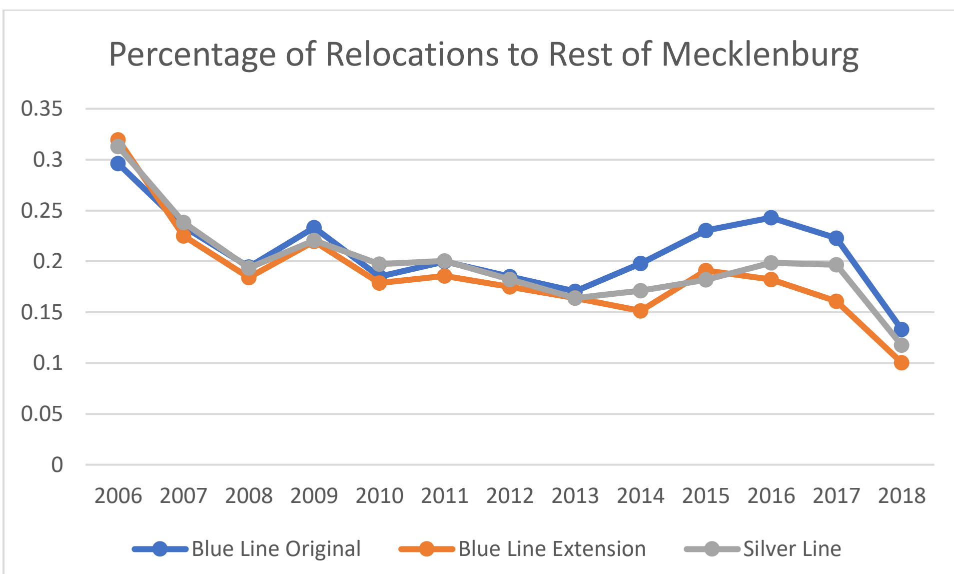
Mecklenburg County to a location in another block group in Mecklenburg County or one of the counties adjacent to it.

The analysis performed well as expected, identifying a number of anomalous pairs of block groups with relocations that were more common that expected. However, none of these statistically significant instances originated in the 1-mile BLO or BLE corridors. Therefore, we were left to conclude that relocation from the vicinity of LRT stations was not geographically focused, whereby certain more desirable or more affordable relocation neighborhoods would be selected more often than according to some random expectation patterns.

4.5. Relocation Destinations

In this section, we looking at the general destination of families relocating from the BLO, BLE, and compared to families who moved out of the 1-mile buffer of the Silver Line control area. Of particular interest here is the proportion of families relocating to some other neighborhood in Mecklenburg County.

In 2016, about 30% of families who relocated from the BLO, moved inside of Mecklenburg County. Percentages were slightly higher for the BLE and the Silver Line. We find that through 2014, destinations of relocations were quite similar for the 3 corridors, dropping down to 16-17% for the rest of Mecklenburg County. Over the past few years, there has been a rebound or a few percents. At the same time, the relocation behaviors of residents of the three corridors became more distinct. Yet, the BLO and BLE have remained largely in line with the trend in the Silver Line.



4.6. Socio-demographic profiles or inmovers and outmovers

It has been argued that transit infrastructure investments trigger wholesome changes in the socio-demographic makeup of the population in the vicinity of LRT stations. With the DataAxle data, we are in a position to attempt to address this hypothesis.

To this end, the relevant socioeconomic attributes for both inmover and outmover families were computed annually. These socioeconomic attributes were median and mean incomes, family wealth, and family purchasing power all recorded in dollar amounts, marital status of household heads, age-group of household heads and number of children in the family. The measures of income were modelled estimates generated through proprietary processes of DataAxle. The median incomes, wealth and purchasing power were computed from the pool of inmovers or outmovers for the respective years.

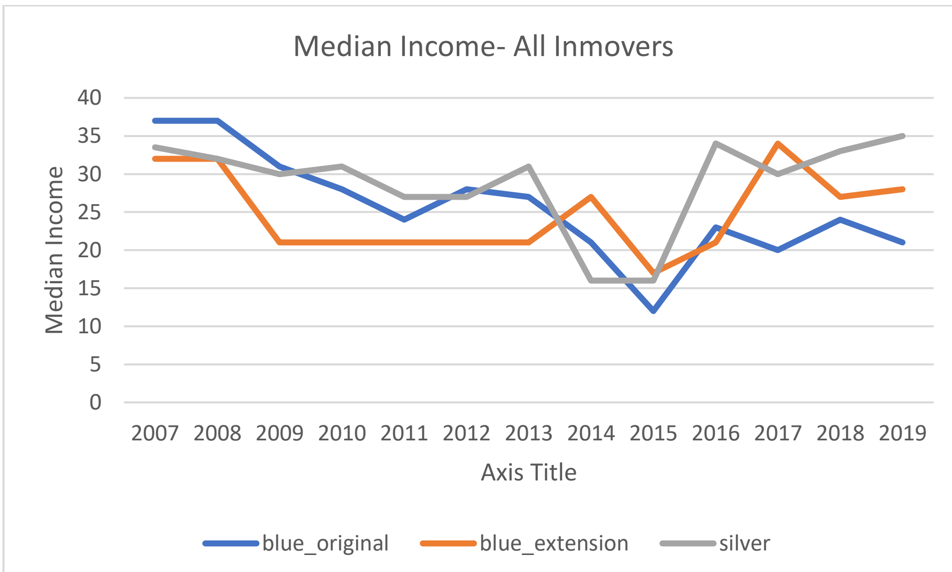
The measure of marital status was determined based on reported data or a likelihood score. A score of 0 indicates the household head was reported single while a score of 9 indicates the household head was reported married. Between these two extremes, are likelihood scores for household heads whose marital status could not be ascertained. Scores between 1-4 represent the likelihood of the household head being single and scores between 5-8 represents the likelihood that the household head is married. Hence, a household head was considered single if the score ranged between 0 – 4 and single if the score ranged between 5 – 9.

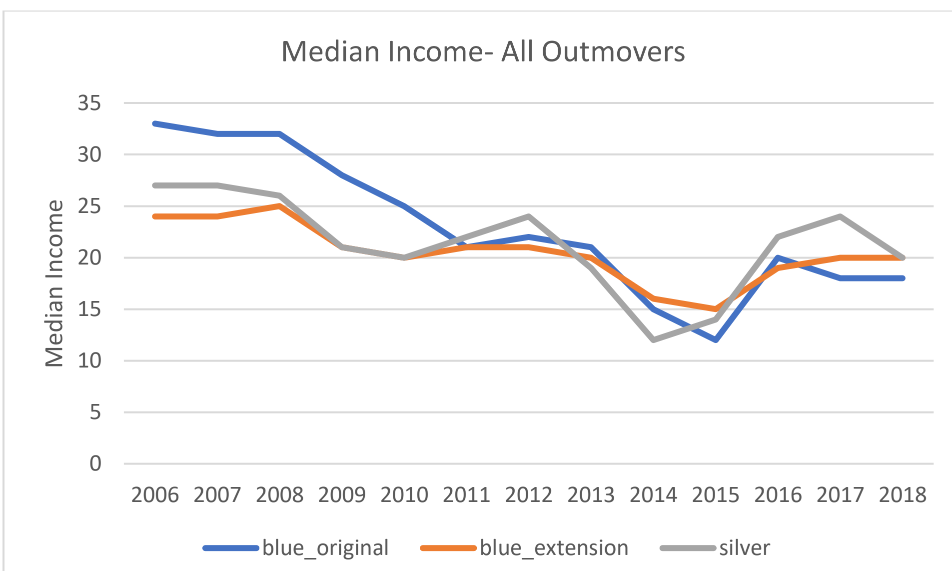
The counts of children have been normalized per 100 families. The age-group of household heads was also binned in 10-year intervals. The figures for the aforementioned socioeconomic variables for both the one mile and half mile buffers are used in the results reported below.

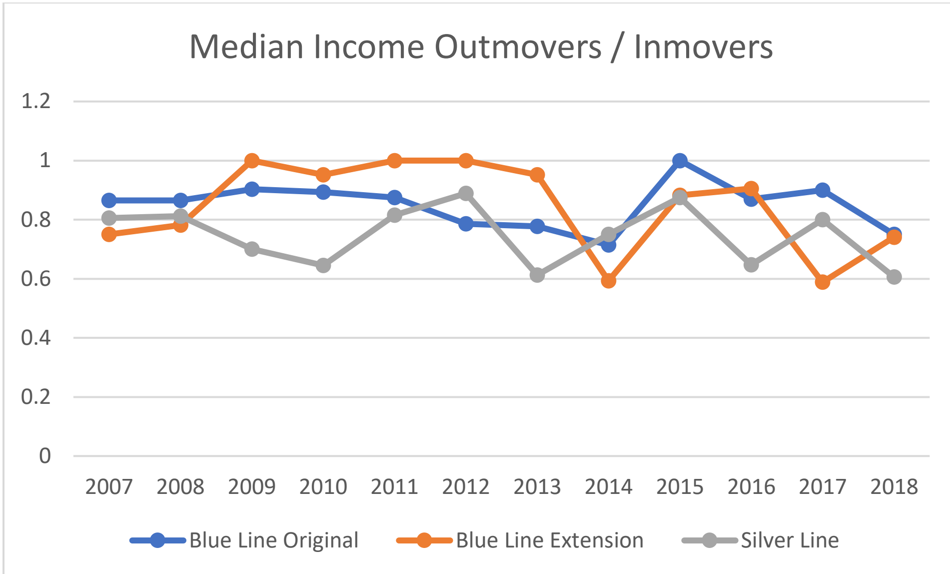
Let us look first at the median income characteristic reported in the charts below for the 0.5-mile buffers. The main results are as follows:

1. The median income of inmovers to the BLO and BLE is usually lower than for the reference group.
2. The median income of inmovers to BLO shows a downward trend between 2007 and 2015 before stabilizing in subsequent years.
3. On the BLE, income of inmovers went down through 2016, before turning around sharply, possibly a sign of gentrification tied to the flurry of construction in the corridor timed with the opening of the LRT service there.
4. Median income of outmovers in all three corridors show a downward trend, with the BLE very similar to the control group, while the BLO exhibiting sharpest and sustained drops in income of outmovers through 2015. Displacement has affected poorer people, and while there is a latent gentrification, some of the income-based displacement would appear to be induced by rail investment.
5. When the ratio of median incomes of outmovers and inmovers is calculated, we see a ratio that is always under 1. This demonstrates that in any year and on any corridor, outmovers are replaced by more affluent residents; the gap is large for the control group, but for many years it is in fact smaller (ratio closer to 1) on the BLO and BLE, which is counterfactual evidence that LRT does not displace less affluent people for richer ones more than in the control group.
6. Timing with LRT service does not correlate with disproportionate income patterns on inmovers and outmovers.

Broadening the scope of the income analysis to a 1-mile buffer around rail stations, we find that most of the trends discussed above with 0.5 mile carry over (charts not included), although the LRT-induced effect is even weaker and harder to discern. Taken together, these results point to the fact that latent changes in the built environment (esp. gentrification) are strong and dwarf the effect induced by access to LRT service. While proximity to LRT may matter, it is because of the heavier changes to the built environment there (including TOD), not changes in accessibility through transit. The key observation is that timing of the construction and opening of the LRT does not correlate with income.







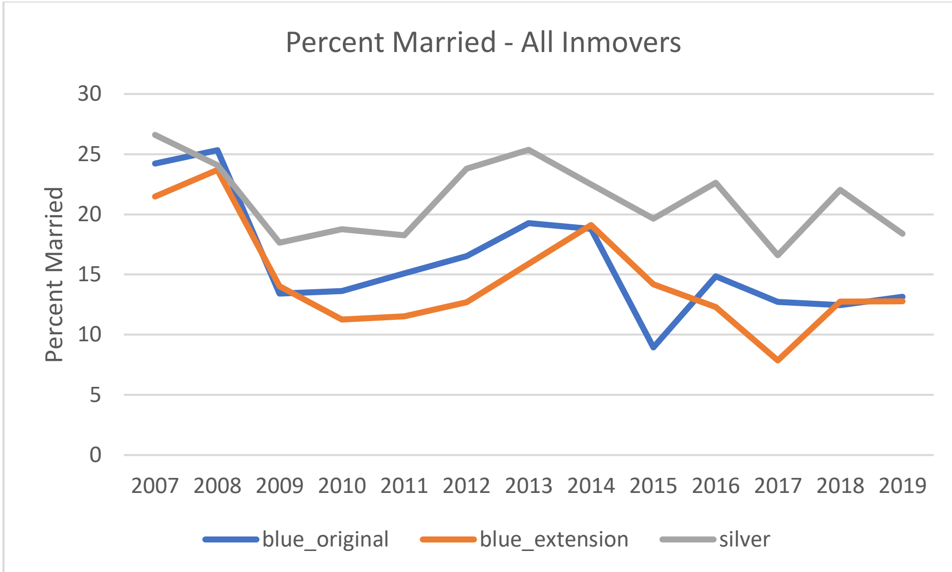
Regarding the marital status (see charts below), within the 0.5-mile buffer around the stations of each of the three corridors, we find that

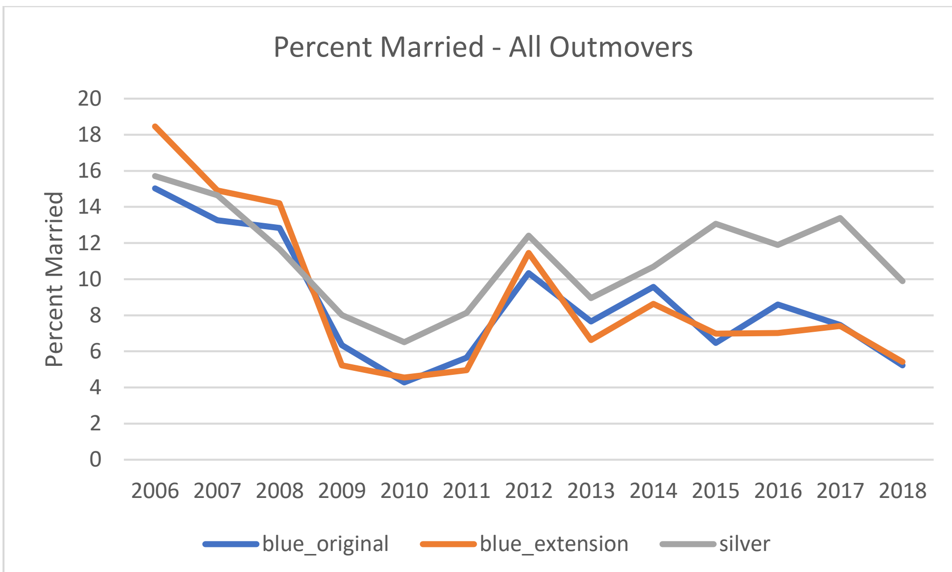
1. Inmovers and outmovers of the BLO and BLE are less likely to be married than for the control group.
2. Inmovers and outmovers of the BLE and BLO are equally likely to be married.
3. Marriage trends have been dropping over the years for both BLO and BLE, but much less so for the control group, and the trend has roughly been flat for the past ten years in the control group.

For comparison purposes, when the buffer that defines the three buffers is extended to 1 mile, the following observations can be made (charts not included):

4. Inmovers and outmovers of the BLO and BLE are less likely to be married than for the control group.
5. Inmovers and outmovers of the BLE are less likely to be married that in the BLO.
6. Marriage trends have been dropping over the years for both BLO and BLE, but much less so for the control group, and the trend has been flat for the past ten years in the control group.

These observations reveal significance resemblance with the situation within 0.5 mile, but also some differences, like fewer married inmovers in the BLE and BLO (no differences in the control area) in close proximity to stations, and BLO and BLE being almost identical to each other in close proximity, but somewhat more distinct when less proximate areas are looked at. The phase of operation of the LRT service makes no material difference in this respect.





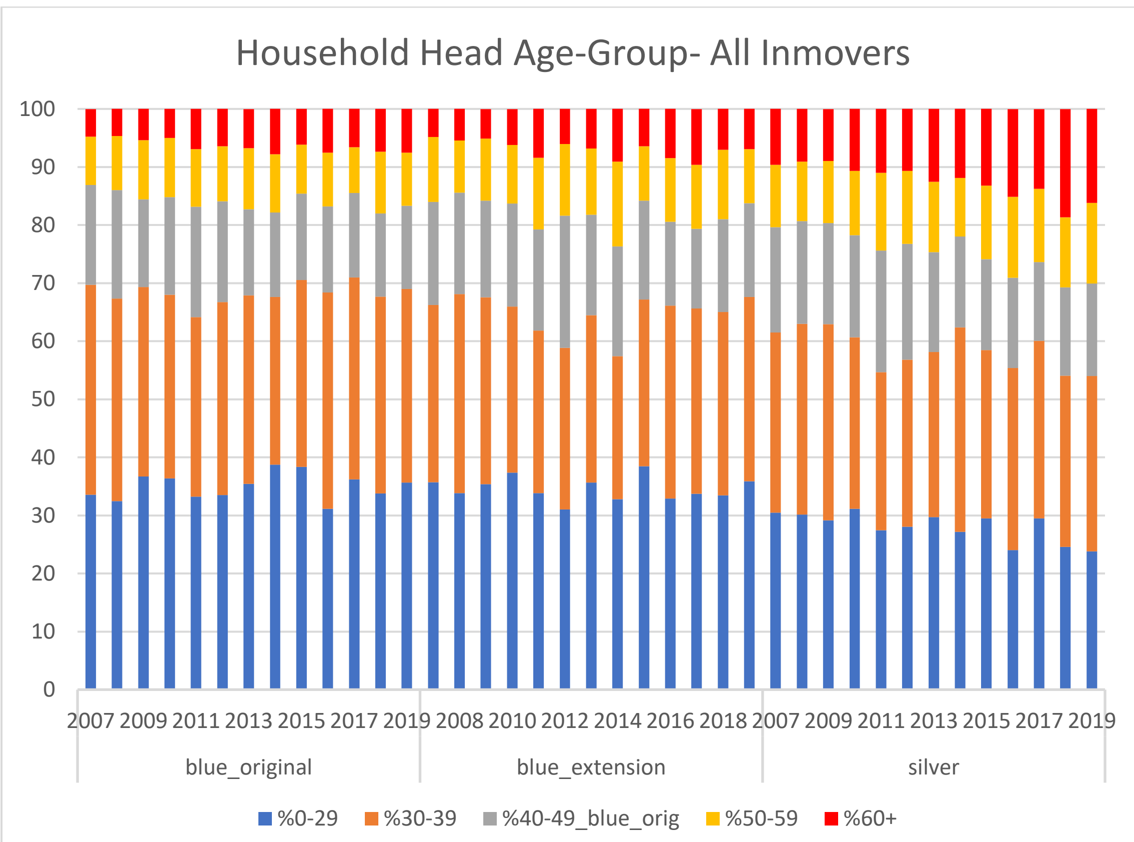
The number of children in families is a demographic indicator available in our data. The main results here are as follows:

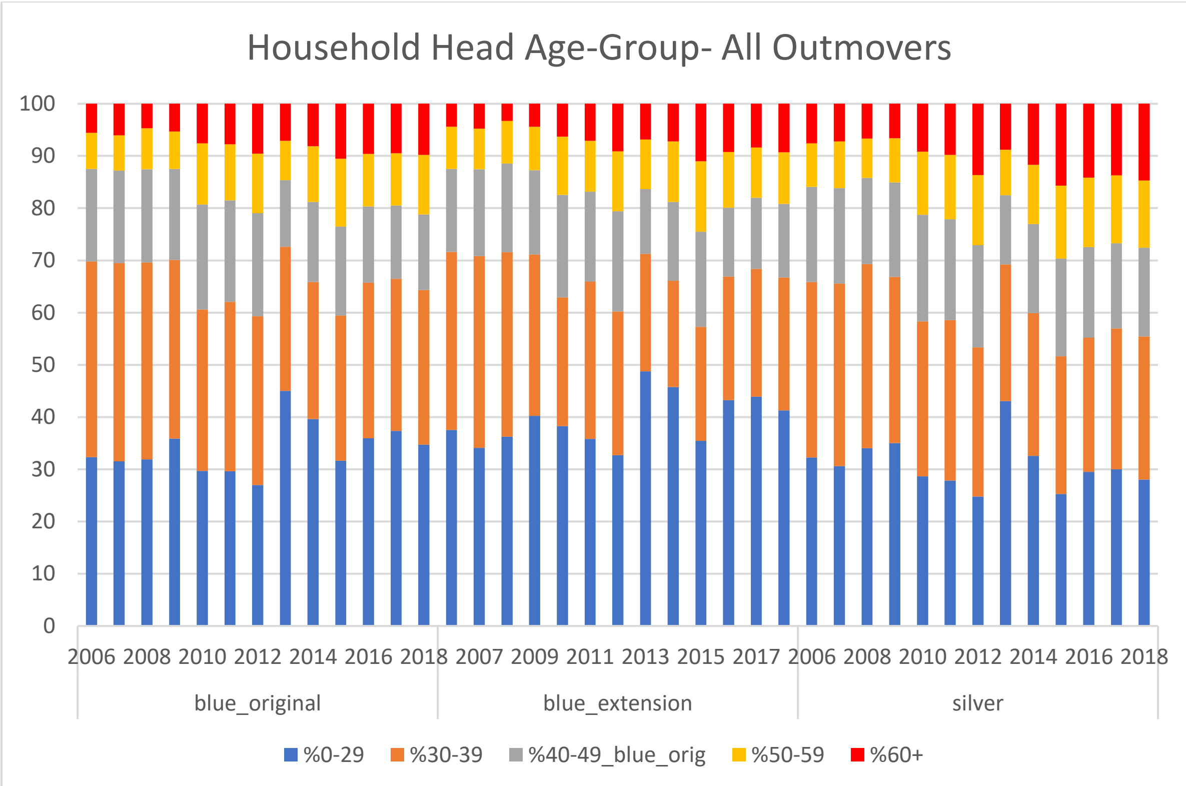
1. Among inmovers, the number of children is identical in all three corridors; starting in 2016, children are quite more common in the control group than along the BLE or BLO.
2. Among outmovers, families in the control group have more children on average than on BLE or BLO. The control area is more family oriented than the two rail corridors, and no longitudinal trend can be tied to the LRT service.

In terms of age distribution within (see charts below), we find that

1. Inmovers are younger in the BLO and BLE compared to the control group.
2. Also, the age cohorts under 30 years of age has been on the rise among the BLO inmovers, while inmovers aged 50-59 have shrunk, the age distribution of inmovers has remained stable for BLE; for the control inmovers are increasingly less likely to be under 30 and amore like to be over 60.
3. As for outmovers, we find that BLE and BLO are fairly similar (BLE having more outmovers under 30 – possibly a college student effect, the Silver Line's outmovers are older (much larger proportion of 50 and above).
4. Over time, 50+ people are more common among outmovers from the three corridors.
5. Also, outmovers from BLE and BLO are increasingly more likely to be under 30.
6. Finally, in all three corridors, people ages 40-50 are increasingly less like outmovers.

Trends are fairly similar when the broader 1-mile buffer is examined (chart not reported). In conclusion, in spite of the differences between the BLO and Solver Line, because BLE and BLO are so similar, and because there is no traceable difference in the age distribution in the BLE and BLO that can uniquely be linked to LRT service, evidence on the effect of LRT service on demographics of the population is unsubstantiated.





In summary, population change has been significant in the LRT corridors. Typically, richer residents replace the outgoing population. New population tends to be younger than elsewhere, and so is the departing population. Population that moves in is a bit younger than population that moves out. Inmovers are overwhelming not married, and increasing so, a sharp contrast with other areas of the city. The lack of coincidence with LRT service, however, prevents us to conclude that the rail infrastructure investment is the cause of these trends, spatially and temporally. More than anything else, in an ambient environment experiencing tremendous growth, the change in the built environment brings changes and opens up new lifestyle opportunities that are attractive and desired by certain segments of the population, while others find themselves unable or unwilling to match their aspirations to the new urban living context.

5. Conclusions

The analysis of population displacement found some evidence that proximity to LRT stations may be a factor in displacement. By analyzing the data thoroughly over different definitions of proximity, we found that the effects are much more pronounced in close proximity (within 0.5 mile) than over large spans of distance (1 mile). Areas devoid of access to LRT have experienced less displacement.

Population displacement is associated with the intensification of land redevelopment, and rezoning applications. Thus, this analysis, however incomplete it may be, and however uncertain the quality of the data may be, provide consistent evidence for displacement, which will be an important addition to the extant literature.

Populations of inmovers and outmovers exhibit clear socio-demographic profiles. Inmovers are young, riches, unmarried, contrary to outmovers. One can conjecture that inmovers are college educated and professional, while outmovers would be so less often. Hence, gentrification that accompanies transit infrastructure investment has a strong demographic component. However, the causality cannot be established and the association is likely to be indirect, driven by land development and redevelopment decisions. Unfortunately, due to data limitations it was not possible to analysis the population impacts on the racial and ethnic makeup of populations of inmovers and outmovers.

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