The Thesis Committee for Antora Mohsena Haque
Certifies that this is the approved version of the following thesis:

The Impact of Light Rail Transit on Residential Rental Market: Case Study of Dallas Area Rapid Transit

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________
Ming Zhang

____
Jake Wegmann

The Impact of Light Rail Transit on Residential Rental Market: Case Study of Dallas Area Rapid Transit

by

Antora Mohsena Haque, B. Urban P.

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Dedication

I dedicate my work to Afrooza Ahmad, my mother, who let me come to the U.S. and fulfill my dreams of pursuing a master’s degree. Thank you Ammu!

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I would like to express my heartfelt gratitude to two of my advisors, Dr. Ming Zhang and Dr. Jake Wegmann, for believing in me and supporting me in the entire Thesis journey. I want to thank Eric, Chelsea and Rob from UTSOA Tech Lab for arranging TransCAD key to let me finish my work. Last but not the least; I want to thank my dad, my sister and all my friends for their endless encouragement.

Abstract

The Impact of Light Rail Transit on Residential Rental Market: Case Study of Dallas Area Rapid Transit

Antora Mohsena Haque, M.S.C.R.P.

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Supervisor: Ming Zhang

This research was undertaken to quantify the relationship between residential rent and proximity to light rail transit in Dallas, an auto-oriented city. This correlation is of importance to real estate developers and transportation planners as they seek to make the most efficient use of developable land and to decide on the allocation of funding for future transportation projects. This study shows that proximity to DART rail stations is associated with residential rent up to half mile radius area of the stations. Hedonic regression models in simple Ordinary Least Squares (OLS) and semi log form were used for the analysis. The semi log model showed that light rail stations have the strongest relationship with rent in the 0.1 mile to 0.2 mile distance buffer, where the rent/sq. ft. is 20.92% higher than for units between 0.4 and 0.5 miles distance from stations. After 0.2 miles distance from the stations, the rent starts to drop and continues to go down till 0.5 miles distance from a station. The simple OLS model showed similar results and according to this model within 0.1 to 0.2 mile buffer area the rent is 27.6 cents/sq. ft.

higher than the rent/sq. ft. in the 0.4 to 0.5 mile buffer area. This result will help to manage the extent of investment in light rail in Dallas in the future.

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Chapter 1: Introduction

1.1 Background of the Light Rail Transit in U.S.

In the U.S. people have been more oriented towards using private cars than using public transit, even though travelling on public transit produces positive externalities (MacKechnie) that outweigh the temporary comfort and privacy people get from driving a car (Warren 86). In an effort to change this dynamic, rail transit systems like Light Rail Transit (LRT), commuter rail, and heavy rail were launched. After a long period of decline, public transit usage increased in the U.S. beginning in the 1970s (Pucher 33-49).

According to the American Public Transportation Association (APTA), the number of yearly trips by public transit increased dramatically from 7.8 billion in 1995 to 9.6 billion in 2004 (Public transportation fact book 12). This corresponds to an average growth rate of public transportation ridership of more than 4% per year in the U.S. since 1995. This increase is the effect of economic growth that produced more work commute trips. However, measuring potential demand for public transit for commuting trips is an area of study of public transit system that has not yet been explored that much (Yao 535-550). According to a New York Times report, in 2013, more Americans are using buses, trains and subways compared to automobiles since 1956. This is because the public transit services have improved, local economies have grown and travelers required alternative modes of transportation for trips in metropolitan areas (Hurdle).

Among all the forms of public transit in the U.S., the LRT has been established in the most cities in recent years. Initially, an LRT was understood as an urban rail transit form that is lighter and less costly than other rail transit modes. However, the formal definition of LRT was adopted in 1989. and then included in Transportation Research Board's Urban Public Transportation Glossary as, "*A metropolitan electric railway* *system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally, in streets and to board and discharge passengers at track or car floor level*." LRT is credited to have design flexibility because it can be designed to accommodate a variety of environments, such as streets, freeway medians, railroad rights-of-way (operating or abandoned), pedestrian malls, underground or aerial structures, and even the beds of drained canals. This makes LRT different than other rail modes like heavy rail or metro rails. Its cost of construction and operation is far less than heavy rail but it is usually more expensive per mile than commuter rail and streetcars. LRT emerged in North America in the 1970s with antecedents in cable cars, street cars, elevated trains, subways and trolleys (Boorse, Tennyson and Schumann 2-3). As of today there are 27 LRT (one is under construction) systems that are operating in different states of the U.S. (A World of Trams and Urban Transit).

Although LRT has provided another mode choice and reduced automobile dependency, it has also made a significant impact on the surrounding land uses and properties. These impacts range from short term impacts of proximity to LRT like increasing property values and rents to long term impacts like changing land use and increasing population and employment surrounding LRT stations. Studies on San Francisco's Bay Area Rapid Transit (BART) (Cervero and Landis), Washington DC's Metro (Benjamin and Sirmans) and Atlanta's Metropolitan Atlanta Rapid Transit Authority (MARTA) (Cervero; Bollinger and Ihlanfeldt) have been undertaken to see the long term effects of these transit systems. Studies on Austin's Red Line (Yu), Houston's Metro Rail (Pan), Malaysia's Kalana Jaya LRT (Dziauddin et al.), Buffalo's Metro Rail (Hess and Almeida) and Naple's Metro (Pagliara and Papa) have measured the short term impacts and positive relationship between proximity to transit have been found on the surrounding land uses in these cases. The impact has been found to differ among single family houses, multi-family residential properties, office, retail and industrial land uses also. As a positive relationship has been found between proximity to the stations and property value in many of the cases so far, it can be assumed that improvements in Transport Infrastructure will be capitalized into property values.

In all these studies it was noticeable that the extent of the impact area varied between ¼ mile, ½ mile, 1 mile, and 2 miles. Many researchers examined the capitalization of the property inside the ¼ mile area thinking the premium would be the highest there. Other researchers argued that due to the nuisance effect the property value or rent is lower in the closest vicinity of the stations and rail lines, but the proximity effect is stronger inside the half mile buffer area. This analysis led the researcher to think that perhaps the impact of LRT is not only limited to ¼ mile buffer of its station areas and its impact on different neighborhoods will always vary. A literature review revealed that a ½ mile buffer area works as a de facto rail transit catchment area. Because it takes a person 10 minutes to walk this distance at a speed of three miles per hour, it is a common estimate of how far people are willing to walk to get to a rail station (Guerra and Cervero 17-22).

Securing required funds for establishing transport infrastructure is another issue of concern. As infrastructure like LRT has been found to show potential to increase the market value of the property, hence knowledge of the kind of relationship or association between the proximity to LRT and the property value is imperative to efficiently apply value capture tools to gather funding for future transportation projects.

1.2 Past and Present of Dallas Area Rapid Transit (DART) LRT

DART is the longest of all the LRT systems that are operating in the U.S today. It generated $7.4 billion in regional economic activity in Dallas, adding more than 54,000 job-years and increased the value of property near the DART rail stations between 2003 and 2013 (Clower et al.). However, few studies have been undertaken to examine the changes that DART station brought up to its surrounding land uses and property values. In 1999, Weinstein and Clower conducted a comparison of residential and commercial property value within a 0.25 mile radius around 15 DART stations and their control group neighborhoods. Results showed that, value of the properties near DART stations were 25 times larger than properties in the control group. The study also found that office and strip retail properties near DART have higher occupancy rate and generates higher rent (Lyons).

In the follow up study, the study area was taken outside of Dallas' Central Business District (CBD) because many properties in the CBD were redeveloped with the help of Tax Increment Financing (TIF), making measuring the impact of DART difficult inside the CBD. The study area was a 0.25 mile radius around 23 DART stations located outside the CBD area. The authors compared rail station area and control group areas of residential, office, retail and industrial properties. They measured the change in property values between 1997 and 2001 using taxable property values that were collected from Dallas County Central Appraisal District (DCAD). The results showed that the median value of residential and office property increased by 12.6% and 13.2 % respectively in the station areas compared to the control group areas. Also there was no significant change in the median values of retail and industrial properties (Weinstein and Clower 1-5).

Chae carried out an empirical examination to evaluate the feasibility of value capture in the transit impact areas of DART after the recession period of 2007. The study evolved by taking a 1 mile radius area around 20 stations of DART's Green Line, which was launched in 2009 right after the financial crisis. Hedonic regression models were run on sample of 5745 residential parcels during both the pre Green Line (2007-2009) and post Green Line (2009–2011) periods using the percentage property value growth as the dependent variable. The results showed that even in an unstable housing market, transit accessibility was positively related to residential property values. However, benefits of transit accessibility were more capitalized into prices in the pre Green Line period than in the post Green Line period, suggesting perhaps that landowners near the proposed stations anticipated benefiting from them. The limitation of the study was that the distances from the household to the stations were Euclidean distances whereas actual way of getting there should have been through street network distances which are not straight lines. According to Chae the weakest point of the analysis were the time periods as limited time periods cannot really distinguish the difference between impact of transit and other factors, such as the advent of the Great Recession (Chae 6, 9, 16-19, 25, 28, 31).

1.3 Rationale of the Research

As home prices change with the availability of amenities and good qualities of homes, it is at least plausible that the values of homes near DART rail stations will also be higher and might fetch lower prices with increasing distance from the stations. The same might happen for rent. However, in the past, researchers never took the initiative to study whether proximity to DART also has relationship with the rent of the surrounding areas' housing units. Therefore it is also unknown up to what extent and in what magnitude does this relationship exist. One possible reason could be that, the rent data was not available at individual housing unit level for Dallas until in 2015 when Geoff Boeing and Paul Waddell, from the Department of City and Regional Planning, University of California, Berkeley, wanted to see the Rental Housing Market all over the U.S. Using "Big Data"-style web scraping technology they created a data set of 11 million Craigslist rental listings across the entire United States. These housing unit rental advertisements had information that included location (latitude/longitude), rent, size of the housing units in sq. ft., number of bedrooms and date of data extraction. The rents were the ones advertised on Craigslist, not actual negotiated rents that renters sign in the legal contract and agree to pay. However, researchers confirmed that the median rent listed in Craigslist is comparable to the U.S. Department of Housing and Urban Development's (HUD) estimate of Fair Market Rent (FMR) on average (Boeing and Waddell 1-4).

As DART was originally planned to support the regional economy and no studies have been done to identify to what extent proximity to the DART rail station is associated to the property rent at a regional scale, therefore the researcher of this study took the initiative of this analysis.

1.4 Working Hypothesis

If all other conditions remain constant then rent/sq. ft. of the housing units decreases as distance from the LRT stations increases.

1.5 Research Questions

1. What type of relationship exists between proximity to DART stations and rent/ sq. ft. of the housing units?
2. Up to what distance do DART rail stations have this relationship with Housing unit's rent/sq. ft.?

1.6 Key Words

LRT, Public Transit, Housing unit, Rental Market, Rent/sq. ft., Hedonic Regression, Proximity, Relationship, Association.

1.7 Limitation of the Study

1.7.1 Limitation of the Craigslist Dataset

The main challenge of the research was getting rental data at the housing unit level. Nonetheless, when the Craigslist dataset was acquired it showed some limitations. For instance, location information of the housing units was not exactly correct. It was revealed when the housing units were geo-located in GIS using the latitude/longitude information. Many of the housing units did not precisely laid over the Building Footprint of Dallas City. Many of the housing units had the same latitude/longitude which indicated that either the web scraping tool was getting information for all different housing units but was unable to locate it exactly or it was taking information for different apartments in the same building. As Web Scraping is a computer based information scraping system and it is not done by human, these errors could not be corrected. However, it did not pose a big issue for the scope of the research as network distances between housing units and stations were measured taking distances from the nearest street network node of each housing unit. So, minor error in the location data of the housing units did not matter much. Still, due to this limitation, it was not possible to extract more housing unit characteristics information such as number of bathrooms, number of floors of the building and age of the building etc. about these housing units. So the data had to be collected at the Census Tract level and then incorporated in the housing unit dataset.

Hence, many associated variables could not be included in the Hedonic Regression Model which the researchers initially wanted to use. This might have limited the scope of the model to explain the variation in the dependent variable and give the result more reliability.

1.7.2 Limitation of the Hedonic Regression Model

To come up with a better model for this research was another challenge. As hedonic models are background specific and heavily data based so an extensive background research about the rail lines, condition of the surrounding land use, demographic and socio-economic condition of the study area and overall Dallas city were required to decide on which variables could be used to calibrate the models. Part of the dataset of this research was at housing unit level and part of it was at census tract level. So, ultimately when the dataset was created it had a combination of both individual and aggregated data which might have undermined the integrity of the dataset.

After the Dataset was ready, model calibration was the biggest challenge because models showed different results for different combination of independent variables. Researchers looked for spatial auto-correlation in the dataset to avoid any bias in the result. Because of existence of spatial auto-correlation it was necessary to adjust it by including the coordinates of the housing units. Some variables had to be excluded from the model due to multicollinearity between the independent variables even though they were associated with rent. This was the limitation of the model itself. There is no perfect model for hedonic regression. The researcher had to proceed with the work knowing this limitation anyway.

As this analysis was only on DART rail stations and Dallas City's residential rent, the model, might not be applicable on other LRT systems in the U.S. However it can be used for follow up analysis of this research in the future.

Chapter 2: Literature Review

2.1 Condition of Housing Market of U.S.

People have a tendency to set aside a large portion of their income to buy a house or to pay their rent. Among renters, average income households are found to pay one quarter of income and low to very low income households are found to pay almost half of their income in rent. Therefore a minute increase in rent can create a large burden on non-housing expenditures like transportation, food, medicine, education and clothing, etc. (Quigley and Raphael). According to the Department of Housing and Urban Development (HUD) Affordability Index, housing becomes affordable with increase in income and housing becomes less affordable with rising inflation because inflation causes a rise in the interest rate and house prices which counterbalances increases in nominal wages.

The biggest phenomenon in the U.S Housing market in the last decade has been the housing bubble and its bursting, which caused a massive upheaval in the lives of many homeowners. Main reasons behind the housing bubble were low mortgage interest rates, low short-term interest rates, relaxed standards for mortgage loans and irrational exuberance in the market. In 1982, the Federal Reserve, the central bank of the United States, tried to squeeze the inflation out of the economy by increasing the mortgage rate to 18%. However, a recession happened in 2001 and from 2002 to 2004, the Federal Reserve pushed the federal funds rate down to very low levels to strengthen the recovery from the 2001 recession. The two major Government Sponsored Enterprises, Fannie Mae and Freddie Mac, started to issue Mortgage Backed Securities to encourage investment in housing, and so investors became bolder. At that time lower mortgage rates and affordable monthly mortgage payments gave rise to more buyers even though the home prices were rising. In 2002, the mortgage rate was below 6%. At that time home prices were rising faster than incomes, which made home buyers unable to afford fixed rate mortgages. However, Adjustable Rate Mortgages (ARM) helped the home buyers with initial lower interest rate loans. Low short-term interest rates also contributed to the housing bubble by encouraging leveraging. The investors borrowed at lower short term interest rates and invested in higher yielding long-term investments, such as mortgage-backed securities. Within two years, as interest rate on the mortgage adjusted upward, the higher mortgage payments became unmanageable for many home buyers.

During this housing bubble many supposed experts never thought that a nationwide home prices decline would not happen because it never did since the Great Depression. Mortgage lenders provided greater number of subprime mortgages and ARMs that kept the default rates low if the house prices were about to increase. People could not recognize or avoid the irrational exuberance and in fact it was not necessarily advantageous to avoid the exuberance during the price bubble. Hence soon after the bubble burst, home prices started to fall. Decreasing home prices forced home prices to fall more. Many houses were foreclosed, which decreased the value of mortgage backed securities. The wave of foreclosures contributed to a decrease in home prices, and thus discouraged people from buying a home. Thus, eventually people started renting homes (Holt).

2.2 Recent Conditions in the U.S. Housing Market

Presently, the U.S. Housing market is in a stagnant state. The rate of building new houses is not as high as it was during the housing boom. Investors have been buying up a lot of the foreclosed houses since the Great Recession, and these foreclosed houses are provided for rent in the market. Although home building in the U.S. has experienced a modest recovery since the Great Recession, housing starts in 2015 were still lower than that of the level at the height of the boom in 2005. The housing starts in 2015 were 1.11 million units ("2015 Housing Starts End Year Up 10.8 Percent, Permits Up 12 Percent") whereas the housing starts of in 2005 were 2,064,700 (U.S. Census Bureau and U.S. Department of Housing and Urban Development).

Price chasm is another potential cause of the grid lock. Prices of homes classified in terms of price as entry level, mid-level, and premium homes have all gone up but not at the same rate. According to an online real estate site, Trulia, the price gap between the mid and premium price homes has gone higher for owners who used to flip homes and many of the entry level homes owned by homeowners have become unavailable in the market as they are underwater. As a result, owners of the trade up homes are not being able to afford to buy the premium homes and sell the houses they occupy. These homes have become unavailable to the housing market (Davidson).

According to a real estate information company and an online marketplace for foreclosed and defaulted properties in the United States, RealtyTrac, new, localized housing bubbles are forming in some of the hottest housing markets in U.S. like, Buffalo, Birmingham, Pittsburgh, Memphis, Cleveland and many more. The reason behind this local housing bubble is the practice of home flipping. In 2005, 259,192 houses were flipped and in 2015, 179,778 homes were flipped nationwide. Flipped homes accounted for 5.5% of sales in 2015, up from 5.3% in 2014 (Krudy). As mentioned before, as home prices are going higher and becoming less available in the market for buying, more and more people are now renting houses (Avakian).

2.3 Present Condition of Housing and Rental Market of Dallas

The house price in Dallas is 23% below the national average and it has a 90% apartment occupancy rate. The cost of living is low, in fact, way below the national average. Investors prefer to invest in Dallas Housing market as the rate of return is expectedly high (Hartman). Evidence of this can be found in many online housing websites. For example, recently, a residential real estate rental website, “Zumper,” listed the top 20 most expensive American cities for renters in 2015 and Dallas ranked 16th with an average rent of $1,190/ month for a one bedroom apartment (Avakian). More recently, an online Personal Financial Website called SmartAsset calculated the Price to Rent ratio in the 76 U.S cities with populations over 250,000 and found that Dallas has a price to rent ratio of 16.19 as of 2016. By comparison, the national average price to rent ratio is about 19.21, the highest Price to Rent ratio is in San Francisco at 45.88 ($550,560), and the lowest Price to Rent ratio is in Detroit which is 6.27 ($75,240) (Wallace). So even though Dallas is in a better position compared to the national average and some of the highest rent areas, yet it is still high and people prefer to rent their homes rather than buying.

PRICE-TO-RENT RATIO		
City	**Price-to-Rent Ratio**	Home Price (for a $1,000 Rental)
San Francisco, California	**45.88**	$550,560
Honolulu, Hawaii	**40.11**	$481,320
Oakland, California	**38.5**	$462,000
Los Angeles, California	**38.02**	$456,240
New York, New York	**35.65**	$427,800
Seattle, Washington	**35.09**	$421,080
San Jose, California	**34.72**	$416,640
Long Beach, California	**34.6**	$415,200
Washington, District of Columbia	**32.02**	$384,240
Anaheim, California	**31.27**	$375,240
San Diego, California	**30.27**	$363,240
Portland, Oregon	**29.26**	$351,120
Boston, Massachusetts	**28.69**	$344,280
Jersey City, New Jersey	**26.34**	$316,080
Denver, Colorado	**26.01**	$312,120
Chula Vista, California	**25.81**	$309,720
Santa Ana, California	**25.25**	$303,000
Sacramento, California	**24.26**	$291,120
Miami, Florida	**23.36**	$280,320
Austin, Texas	**23.36**	$280,320
Atlanta, Georgia	**22.99**	$275,880
Colorado Springs, Colorado	**22.8**	$273,600
Bakersfield, California	**22.51**	$270,120
Raleigh, North Carolina	**22.37**	$268,440
Riverside, California	**22.35**	$268,200
Lexington, Kentucky	**22**	$264,000
Albuquerque, New Mexico	**21.9**	$262,800
Chicago, Illinois	**21.6**	$259,200
Henderson, Nevada	**21.55**	$258,600
Chandler, Arizona	**21.46**	$257,520
New Orleans, Louisiana	**21.36**	$256,320
Virginia Beach, Virginia	**21.12**	$253,440

Table 2.1

PRICE-TO-RENT RATIO		
City	**Price-to-Rent Ratio**	Home Price (for a $1,000 Rental)
Fresno, California	**21.03**	$252,360
Newark, New Jersey	**20.97**	$251,640
Minneapolis, Minnesota	**20.97**	$251,640
Anchorage, Alaska	**20.88**	$250,560
Phoenix, Arizona	**20.3**	$243,600
Louisville, Kentucky	**20.09**	$241,080
St. Paul, Minnesota	**19.95**	$239,400
Plano, Texas	**19.91**	$238,920
Stockton, California	**19.51**	$234,120
Durham, North Carolina	**19.46**	$233,520
Las Vegas, Nevada	**19.34**	$232,080
Nashville, Tennessee	**19.14**	$229,680
Greensboro, North Carolina	**19.1**	$229,200
Mesa, Arizona	**19.1**	$229,200
Lincoln, Nebraska	**19.09**	$229,080
Oklahoma City, Oklahoma	**19.07**	$228,840
Wichita, Kansas	**18.39**	$220,680
Charlotte, North Carolina	**18.1**	$217,200
Cincinnati, Ohio	**18**	$216,000
Aurora, Colorado	**17.97**	$215,640
Kansas City, Missouri	**17.42**	$209,040
Tulsa, Oklahoma	**17.22**	$206,640
Omaha, Nebraska	**16.7**	$200,400
St. Louis, Missouri	**16.7**	$200,400
Orlando, Florida	**16.62**	$199,440
Tampa, Florida	**16.55**	$198,600
Tucson, Arizona	**16.32**	$195,840
Philadelphia, Pennsylvania	**16.3**	$195,600
Dallas, Texas	**16.19**	$194,280
Laredo, Texas	**15.94**	$191,280
Columbus, Ohio	**15.86**	$190,320
St. Petersburg, Florida	**15.77**	$189,240

Table 2.1

PRICE-TO-RENT RATIO		
City	**Price-to-Rent Ratio**	Home Price (for a $1,000 Rental)
Fort Wayne, Indiana	**15.52**	$186,240
Baltimore, Maryland	**15.48**	$185,760
Arlington, Texas	**15.47**	$185,640
El Paso, Texas	**15.4**	$184,800
Indianapolis, Indiana	**15.35**	$184,200
Houston, Texas	**15.29**	$183,480
Fort Worth, Texas	**14.77**	$177,240
Jacksonville, Florida	**14.34**	$172,080
Milwaukee, Wisconsin	**14.19**	$170,280
San Antonio, Texas	**13.68**	$164,160
Toledo, Ohio	**13.26**	$159,120
Corpus Christi, Texas	**13.14**	$157,680
Memphis, Tennessee	**12.26**	$147,120
Pittsburgh, Pennsylvania	**12**	$144,000
Buffalo, New York	**10.71**	$128,520
Cleveland, Ohio	**10.52**	$126,240
Detroit, Michigan	**6.27**	$75,240

Table 2.1: Comparison of Price to rent ratio in 2016: Where Dallas stands in the country?

According to a website on the U.S rental housing market, Rent Jungle, average apartment rent within the City of Dallas was $2424 in July 2016. Average monthly rent of a one bedroom apartment was $2018 and $2930 for a two bedroom apartment. According to the website, the Highland Park, City Center and Near East neighborhoods of Dallas are the most expensive neighborhoods for apartments whereas Urbandale-Parkdale, Wolf Creek and Southeast Dallas neighborhoods are the cheapest ("Rent Trend Data in Dallas, Texas"). Here, Highland Park and University Park are separate cities that are completely surrounded by the city of Dallas.

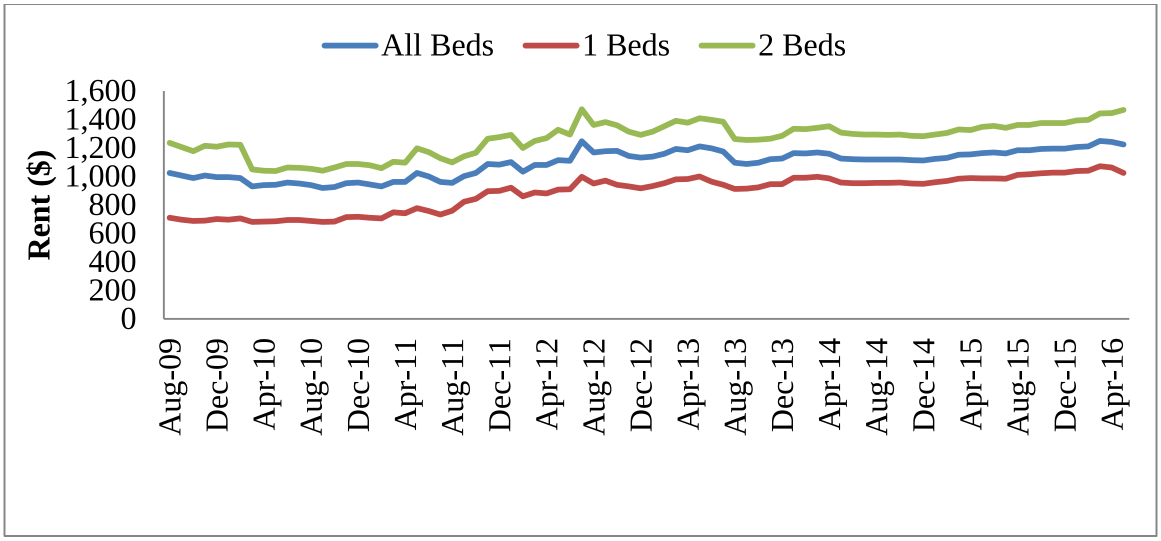

Figure 2.1: Rent Trend in Dallas

2.4 Relationship Between Residential Rent and Proximity to LRT Stations

A rail transit catchment area is the area within which rail service has control over the surrounding land uses, property prices or rent and people's mode choices. People who want to use the rail transit facility choose to stay within a walking distance from the station. People who were already living close to the station they feel more encouraged using the service. Thus people's willingness to live closer to the rail station increases the demand of the housing units. This is called capitalization effect of rail on property which is presented either in terms of increased property value or increased rent. The capitalization effect sometimes becomes negative and lowers the property value or rent due to noise and pollution. Therefore researcher of this study chose to identify the type of relationship between the rent/sq. ft. of the housing units and proximity to the DART rail stations.

This kind of proximity analysis usually involves taking buffer areas of different distances from the stations because in GIS, buffer area means areas of defined width around a specified point, line or polygon. When consecutive buffers of same width are taken around a circle they form shape of rings and thus might be called buffer rings. Buffer rings help to analyze the components falling in those rings separately. A big challenge for this research was to decide on what distances the buffer rings should be taken, to find out how much the rent/sq. ft. was being changed or controlled by the proximity to the stations.

2.5 Role of DART LRT on Regional Economy of Dallas

DART, the LRT system of Dallas, was planned to support the regional economy. President and executive director of DART, Gary Thomas opined that DART illustrates how much value and investment the region has devoted to rail transit because rail transit system not only moves people but it also creates new jobs and economic opportunities that raise the quality of life (Lyons). According to a report prepared by University of North Texas, the North Texas economy succeeded in surviving the vicissitudes of the recession of 2007-2008 and part of the reason was the economic, fiscal and development impact of capital spending and operation of DART. DART continues its long range expansion and Capital Improvement Plans (CIP) to enhance public transportation services that can support regional economic activity and increase the livability of the Dallas area for a growing population. Between fiscal year 2003 to 2013, DART made capital spending of $5.3 billion. From FY 2003 through FY2017, total regional economic activity associated with DART’s CIP is forecast to approach $8.8 billion, and labor income will be boosted by about $3.9 billion and 4,250 jobs will be provided per year on average for this 15 year period (Clower et al.).

2.6 Theory of Hedonic Regression Modeling

Hedonic Regression model is a special kind of linear regression model that breaks down a building to a bundle of utilities that determine its transaction price or rent. The bundle of utilities for a building includes building characteristics, amenities in the neighborhood where it is located, and its proximity to different facilities, such as transit facilities, parks, downtown and grocery stores. Price or rent is taken as the dependent variable, and the building utilities are measured with the independent variables. The modeling results show the correlation of each utility with the price or rent via coefficient values. Hedonic Regression model explains the relationship between the proximity to the LRT stations and property price or rent via the sign, magnitude and significance of the coefficient of the proximity to the LRT stations variable.

By collecting the information about a number of buildings of an area a hedonic regression model can be built and then this model can be used to predict the transaction prices (Monson 63, 64). However, this hedonic regression is a context specific model, so a model for one regional area cannot be applied to another area. According to Monson, the intention of creating such model is to make a predictive model which is accurate. The equation developed with this model looks like the following:

Market Price= f (tangible & building characteristics, other influencing factors)

The coefficients only describe the tangible and building characteristics but there can be other underlying factors for the market price to take its full form which the model cannot explain. The researcher using this model has to find out these underlying factors to justify the result of the model.

2.7 OLS MODEL

The form of the linear regression model used in this study is Ordinary Least Squares, where the best fit line is drawn to minimize the squared deviations from the single observations.

Equation wise it can be presented (Benoit) as follows:

$Y\hat{}_i = b_o + b_1X_i$

Here, Intercept, $b_o = Y_{mean} – b_1X_{mean}$

$b = \sum ((X_i - X_{mean})(Y_i - Y_{mean}))/\sum(X_i - X_{mean})$

Error, $e_i = (Y_i - Y\hat{}_i)$

OLS model tries to minimize summation of square of the error term which is:

$\sum e_i^2 = \sum(Y_i - Y\hat{}_i)^2$

2.8 Problem in the Data and Solution: Spatial Auto-Correlation and Moran's I

"Everything is related to everything else, but near things are more related than distant things." – this statement of Geographer Waldo R. Tobler infers what Spatial Auto-correlation means. It is basically a measurement of how much close objects are in comparison with other close objects. It is important to measure spatial autocorrelation in a dataset because statistics relies on observations that are independent from one another. If spatial auto correlation exists it means that the observations are not independent from one another.

Moran's I Index is used to measure Spatial Auto-correlation in a dataset. The value of Moran's I Index ranges from -1 to +1 and Moran's I can mean positive auto-correlation, negative auto-correlation and no auto-correlation. Presence of positive spatial autocorrelation means similar values are clustering together in a map. Presence of negative spatial auto-correlation means dissimilar values are clustering together in a map ("Spatial Autocorrelation and Moran's I in GIS").

2.9 Related Studies

Author, Year	Study Area	Findings
Xu and Zhang, 2016	Wuhan, China	Examines the extent to which the spatial impact of different public transit exists in the housing market. It shows that the transit impact area is different from the conventional accepted values considered by Wuhan planning Agency. MLR, SAR and SEM models were used in this research.
Yu, 2015	Austin, TX	Austin Metro Rail has a positive relationship with property values and the transit premium varies in different neighborhoods. The hedonic regression model was applied on a 1/2 mile buffer area and it was found that with every 100 meter increase in distance away from the station the property value decreases by about $13,068/acre.
Dziauddin et al, 2014	KL, Malaysia	Kelana Jaya LRT system's relationship with property values was measured using the Geographically Weighted Regression model because the relationship differs spatially which this model can explain well. The results showed that, around a 2 km radius of stations the variations in property values are affected in some neighborhoods but not everywhere.
Pan, 2013	Houston, TX	Identified the positive effect of Houston Metro Rail on residential property values along its Main Street corridor. OLS and Multi level regression models were used and results showed that within quarter mile radius area the property value is negatively related to the proximity to the stations.

Table 2.2

Author, Year	**Study Area**	**Findings**
Chae, 2012	DART Green Line, Dallas	Changes in property value after recession period of 2009 have been examined around 1 miles buffer area of GREEN line and it was found that, transit continues to have impact on the property prices, although a little less in magnitude. A Standard Hedonic Regression model was used and Euclidean distance was used for measuring proximity.
Billings, 2011	Charlotte, North Carolina	Property value of single family, condominium and commercial properties were measured and results of hedonic regression models on before and after announcement of LRT was that LRT had association with the property value of single family housing units and condominiums that are within 1 mile of the station. No association was found on commercial properties.
Pagliara and Papa, 2011	Naples, Italy	This study examined the impact of rail transit system on both residential and non-residential property prices around newly built stations. A 500 meter radius around each station was used as the buffer area considering the walking distance to station and comparison of percentage change in properties have been done between catchment and control areas.
Chalermpong and Wattana, 2010	Bangkok, Thailand	The study showed impact of Rail Transit stations on Office rents of the Bangkok Metropolitan area. As office rents are spatially auto correlated so the researchers showed how results of a hedonic regression model can be improved by utilizing spatial dependence structure in the geographic data.

Table 2.2

Author, Year	Study Area	Findings
Hess and Almeida, 2007	Buffalo, NY	The hedonic model was applied to a 1/2 mile radius area of 14 stations taking both Euclidean and street network distance. As homes get every foot closer to the station the average property value increases by $2.31 in total if the distance is measured by Euclidean distance and only by $0.99 in total on an average if it is measured by network distance. Also, effects are positive in high income station areas and negative in low income station areas.
Benjamin and Sirmans, 1994	Washington DC	This study examines the impact of Mass Transit on apartment rent near DC's Metrorail station and showed that with a 1/10th mile increase in distance from the station the rent goes down by 2.5%

Table 2.2: Hedonic Regression Modeling approach to measure effect of Rail Transit Systems

LRT has been a well-accepted technology in U.S. and many other countries around the world. Many studies have shown that LRT starts to have an impact on the surrounding property value from the announcement of its construction. Like in Charlotte, North Carolina, neighborhood impact of 4% for Single family households and 11.3% for condominiums sold within one mile of the station area was observed after the announcement of LRT (Billings). The effect is even more clearly visible and recognizable after the construction of the system. A mature system gives a better picture of how LRT has impacted land use along that rail line. Researchers around the world have been working on finding out how much each of the LRT systems has impacted the surrounding land uses. Studies on BART in the San Francisco Bay Area, DART, Washington DCs Metrorail, and Houston Metro rail all have shown a positive relationship between proximity to LRT and real estate prices in surrounding areas. However the effect is not the same in all types of land uses and every neighborhood. This is because the effect of a public transit system depends on the geographic, economic and demographic contexts of the area and the maturity of the system. Knowing more detail and investigate to the core of this variation in impact is important. Recently researchers have started using different sophisticated models of hedonic regressions to investigate the situation. For example, Dziauddin et al. applied weighted average regression and could see how increase in property values varies in different neighborhoods of Kuala Lampur, Malaysia. Another researcher, Yu, in 2015, showed that how property values changed differently in different station areas of Austin’s Red line.

Chapter 3: Methodology

The process of data preparation and analysis has been done using ArcGIS 10.3, TransCAD 5.0, R and SPSS 16. The brief descriptions of the chronological steps followed for the research are provided in this chapter. Detail descriptions of some of the tasks are attached in Appendix A, B and C.

3.1 Selection of the Hedonic Regression Models

The following Hedonic OLS model was selected to determine the impact DART LRT has on residential property rent:

Rent/Sq. Ft. = f (D + A + H + N)

Where,

D = Dummy Variables

A = Accessibility Factors

H = Housing Unit Characteristics

N = Neighborhood Characteristics

The semi log model used for the research had all the same independent variables and only the dependent variable was the log of Rent/Sq. Ft.:

Ln(Rent/Sq. Ft.) = f (D + A + H + N)

3.2 Data Collection

3.2.1 Housing Unit Data

At first the dataset of housing unit information was collected from a subset of Craigslist's rental listings made during June-August 2014. The reason for not using Census ACS Data is that they are not available at the individual housing unit level. Craigslist includes rents of garage apartments, condominiums and houses for rent, selfmanaged apartment buildings and granny flats along with usual rental houses (Boeing and Waddell). A sample of 23,928 housing units fell inside the Dallas City boundary.

3.2.2 Other Independent Variables

Other information like, age of average housing unit, median household income, percentage of Non-Hispanic White only population, percentage of Non-Hispanic Black or African American only population and percentage of Hispanic population were collected from the U.S. Census at the Census Tract level for year 2014 . These were 2014 ACS 5 Year estimates data. The information was associated with each housing unit.

3.2.3 GIS Shapefiles

Shapefiles of the Dallas City Boundary and its streets were collected from the City of Dallas' GIS shapefile website. The shapefiles of the DART rail network and rail stations were collected from North Central Texas Council of Governments (NCTCOG). All these shapefiles were for the year 2014. The Tigerline shapefiles website was used to collect Dallas County's census tract shapefiles for 2010 as the shapefiles for 2014 were not available.

3.3 Data Preparation

3.3.1 Preparing GIS Shapefiles

As housing unit data had latitude and longitude of their locations, they were geocoded in ArcGIS and made into shapefiles of the housing units. GIS Shapefiles of the Dallas CBD, Employment Centers and Highway Intersection were created by digitization. The CBD centroid was created from the Dallas CBD using the 'Feature to Point' tool. A street network file was created from the Streets shapefile using the 'Network Dataset' tool.

3.3.2 Measuring Network Distance

TransCAD 5.0 was used to measure the network distance between the CBD centroid and housing units; and between nearest station and housing units using ‘Point to Point Distance’ measuring tool (Detailed steps in Appendix A). Network distances between nearest park and housing units; between nearest highway intersection and housing unit; and between nearest employment center and housing units were measured in ArcGIS using Network Analyst Tool (Detailed steps in Appendix A). Measuring network distances instead of taking Euclidean distances gave the result of the proximity analysis more accuracy.

3.3.3 Creating Dummy Variables

21 dummy variables were created using the network distance between nearest station and housing units’ variable in SPSS. Each of the first 20 dummy variables indicated every tenth mile of the area around the rail stations up to 2 mile radius area from the stations. The 21st dummy variable indicated the area from 2 miles from the station and beyond within the city boundary. These dummy variables were created to measure the relationship between proximity to the stations and the rent/ sq. ft. of those housing units. Another dummy variable called parks within quarter mile was created to see whether housing units have parks within quarter mile radius of them. This was also done in SPSS from the network distance between nearest park and housing units variable.

3.3.4 Missing Values

As there was no census tract shapefile for Dallas in 2010, the census tract level information for 2014 had to be added to year 2010’s shapefile. This caused some census tracts to have null or missing values. Median Property Values were missing in many of the census tracts. To get a good result the median property value of those census tracts were calculated applying the Weighted Average method. Weights were assigned to neighboring census tracts based on their population. First, census tracts touching the boundary of the census tract missing the value were selected. The selected Census Tracts' Median Property values were multiplied by their respective populations and their summation was divided by the summation of their populations. (Detailed steps in Appendix A).

3.3.5 Multicollinearity and Spatial Auto Correlation

Before selecting the variables for the models, a correlation matrix was prepared and based on the p-value, three of the variables - median property value; distance between housing units and their nearest employment centers; and percentage of Non-Hispanic White only population - were excluded from the model. The correlation matrix is attached in Appendix B.

Spatial Auto correlation was found in the data samples using Moran's I value. The R Script of Moran's I calculation is attached in Appendix C. A simple technique of including the Housing Unit Longitudes and Housing Unit Latitudes in the model was done to control Spatial Autocorrelation.

3.4 Selection of the Study Area

At first, the DART rail stations falling inside Dallas city were selected. 43 out of 62 DART rail stations fell inside the city. Then a semi log regression model was run for all the sample housing units (total 23,928) falling inside Dallas City. The rent premium found for this model, for the first 20 dummy variables that are displayed in figure 3.1, helped to understand up to what extent proximity to DART had association with per sq. ft. rent of the housing units. R2 of the model was 0.528 which meant the model could explain 52.8% of variation in the dependent variables.

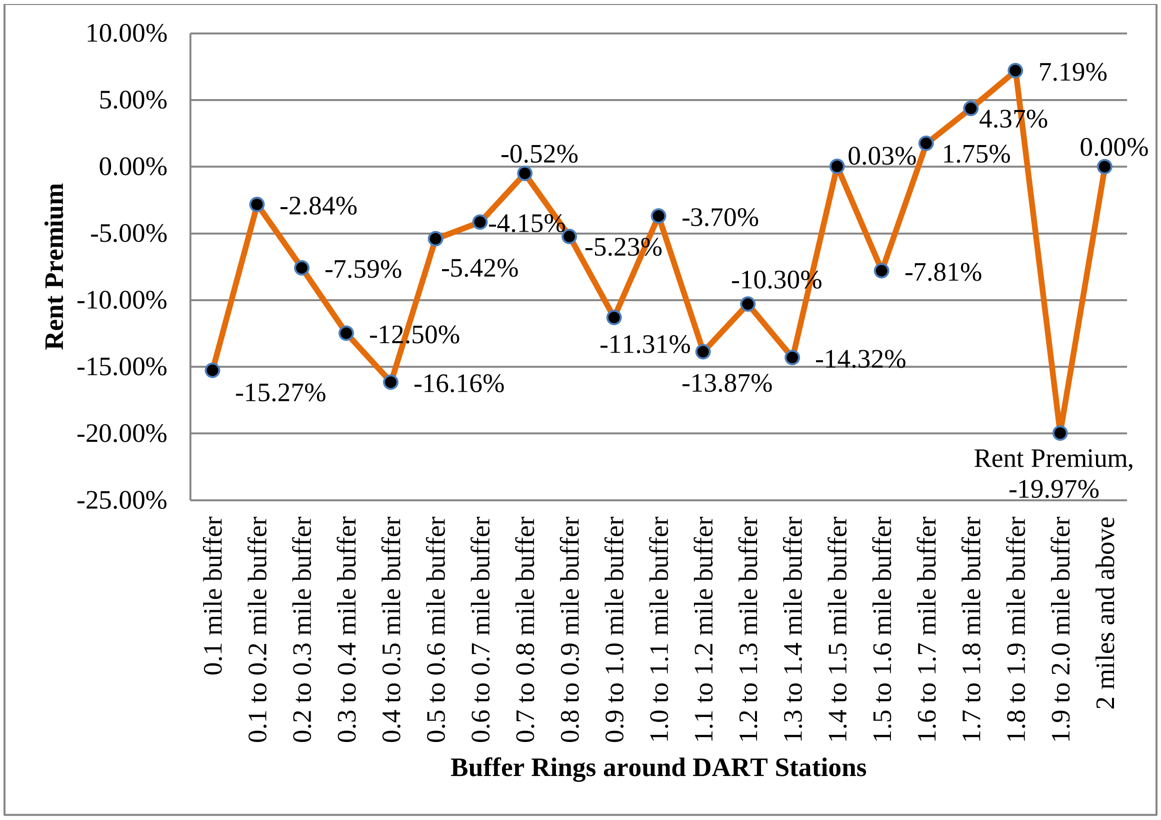

Figure 3.1: DART rail stations' Rent Premium in the Semi-Log Model for the entire Dallas City

This analysis basically helped to determine what should be the extent of the study area for this research. The trend line in figure 3.1 indicates that, in general, rent/sq. ft. first rises inside 0.1 to 0.2 miles buffer area and then keeps decreasing till 0.4 to 0.5 miles buffer area. The rent/ sq. ft. rises again at 0.5 to 0.6 miles buffer area. Analyzing this trend the researcher came to deduction that, the residential rent/sq. ft. is associated with proximity to DART stations up to 0.5 mile radius area from the station. The increase in rent after that is not related to proximity to transit. In fact after 0.5 miles radius area the rise and drop of rent/sq. ft. is somewhat random and cannot be explained with accuracy. However it can be assumed that this rise and drop of the rent might be because of other factors like proximity to CBD, proximity to employment centers or proximity to highway intersections. The trend might also be because of many other external factors that were not included in the model. Hence it could be explained why rent went up and down in certain areas. Nonetheless, this was for certain that, for the dataset provided, the rent/sq. ft. of the housing unit is related to being close to a public transit stations until 0.5 mile radius area of these DART rail stations.

Thus, 0.5 mile buffer areas from the stations were selected as the study area of this research. A total of 5,114 housing units that fell inside the half mile radius from the 43 DART rail stations were taken as samples for the analysis. Figure 3.2 shows study area map and sample housing units of this research. Figure 3.3 shows the five buffer areas inside the half mile buffer area around the stations.

3.5 Running the Models and Interpreting the Results

The regression analysis was done in SPSS and results are described in Chapter 5 in details.

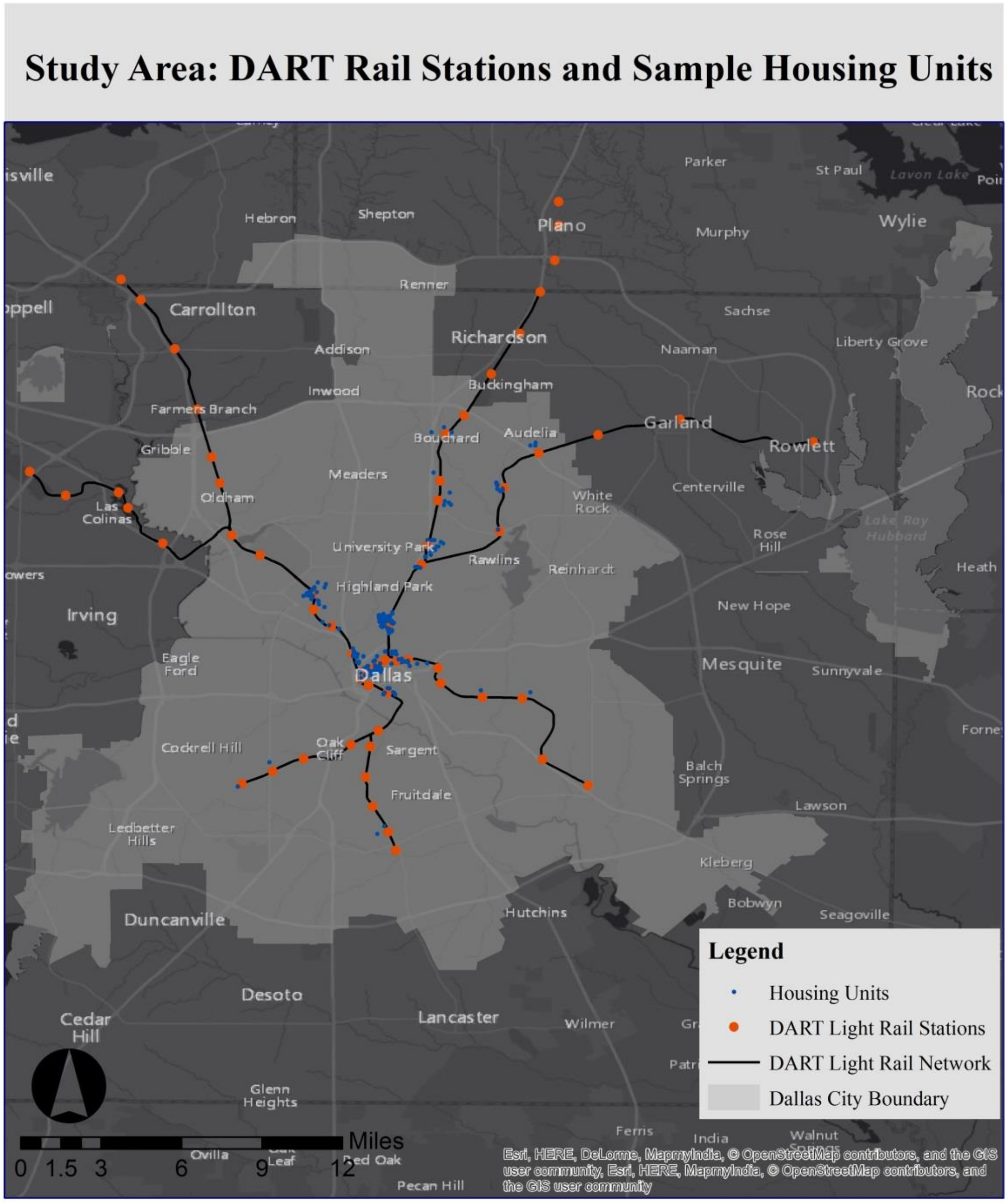

Figure 3.2: Study Area

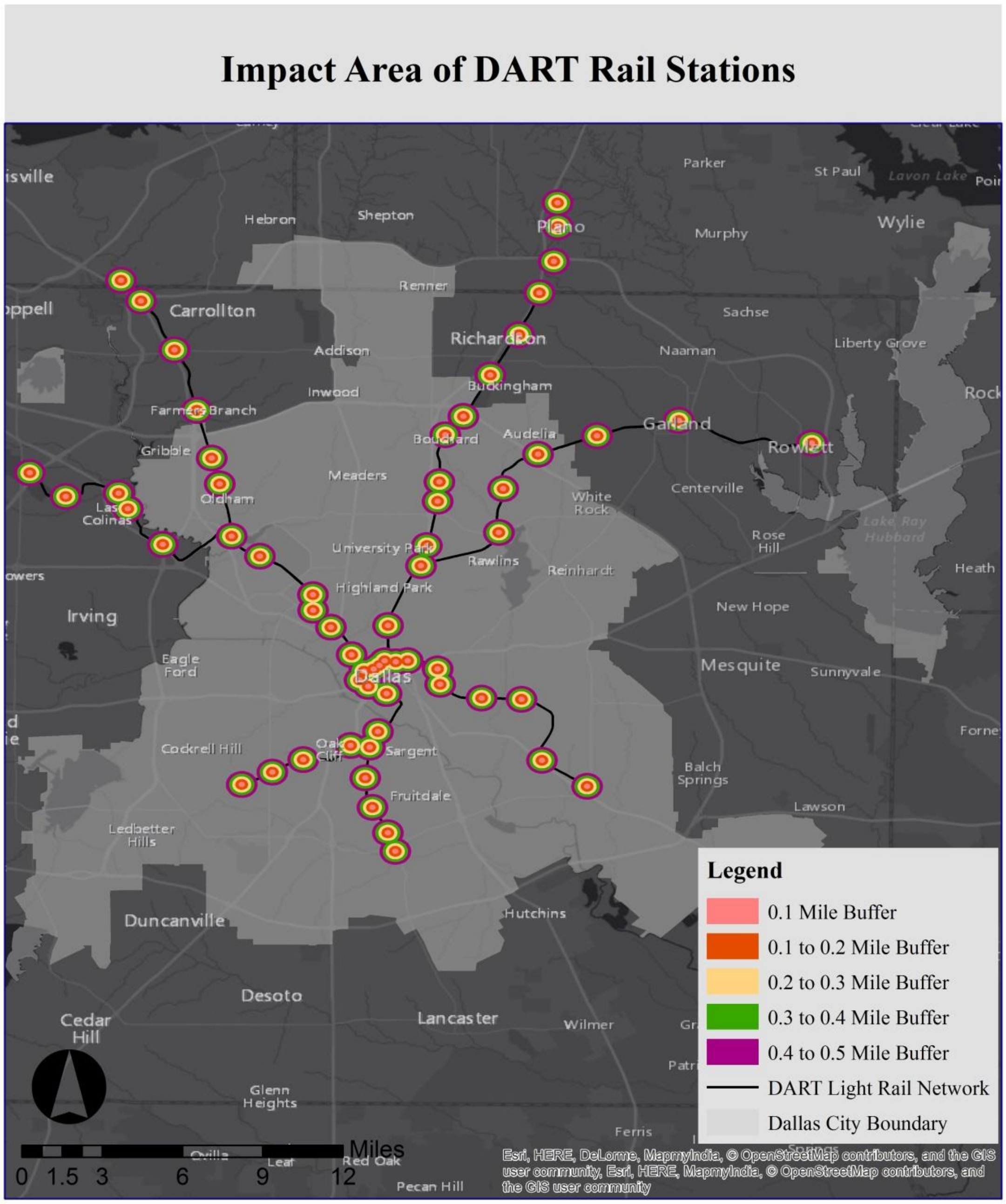

Figure 3.3: Buffer Areas around the Stations

Chapter 4: Study Area

4.1 DALLAS-FORT WORTH-ARLINGTON MSA AND DALLAS CITY

Dallas-Fort Worth Arlington, TX , Metro Area is one of the top 10 Metropolitan Statistical Areas (MSA) of U.S. with a population of over 7 million in 2015 (“DFW, Houston Population Increases Highest in U.S.”). Within this MSA Dallas city had the population of 1.3 million in 2015 (“Dallas City, Texas”). Dallas is the third largest city by land area and population (“Largest U.S. cities by land area”) in Texas, and Dallas MSA stood as the second MSA in U.S for highest job growth in June, 2016 (“Dallas – Fort Worth Area Employment - June 2016”). The MSA has a sales Tax rate of 8.25%, income tax rate of 0%, per capita income of $29,132 and Median Household Income of $58,190 (Sperling).

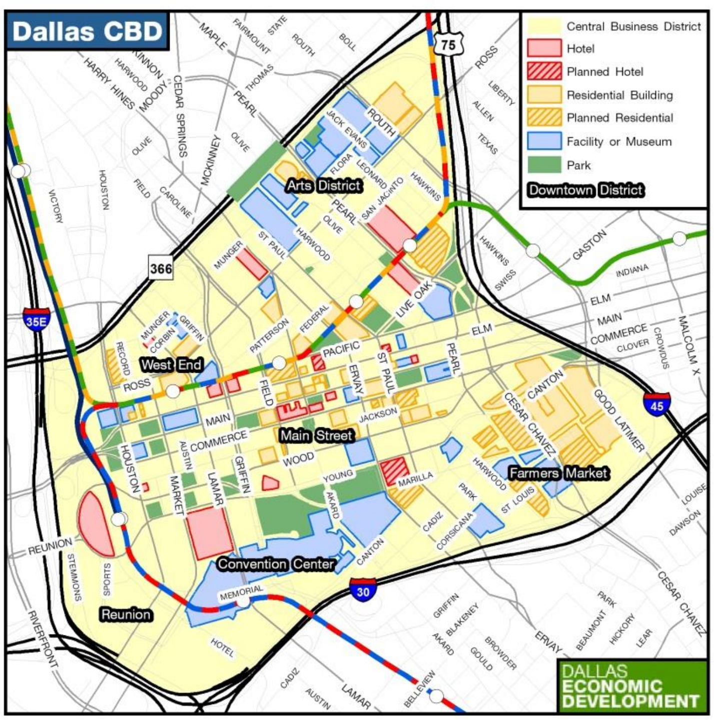

Figure 4.1: Dallas CBD Area

The average commute time in Dallas is the same as the national average of 25 minutes. Even though there is a decent public transit system in Dallas, yet it is still considered as a “Motor City.” Giant skyscrapers and sprawling suburban commercial centers provide evidence that Dallas is growing (Sperling). The growth is evident in the northern direction of its CBD area and somewhat in the western part of Dallas city. This sprawl can be for being located in North Texas, where sprawl is happening due to cheap land, good schools, low unemployment, no income tax and lax zoning laws (Opfer). Therefore, there will be longer commutes in Dallas city if it keeps on sprawling. Figure 4.1 shows the CBD area of Dallas (“Downtown Dallas”). Figure 4.3 shows the Highway Intersections inside Dallas City.

4.2 DART RAIL SYSTEM

DART LRT is the regional Light Rail Transit system of Dallas and is the longest light rail system in the entire U.S. Funded by a 1% sales tax, DART’s LRT was first launched in 1996 and its last installment was the Orange Line’s extension in 2014. Currently, DART’s rail network is 90 miles long and has 62 stations. It has 4 lines, the Blue, Red, Green and Orange, each of which runs towards Dallas’ CBD. The Rail Network of DART is shown by Figure 4.2 (“DART Rail System Maps”). In Fiscal Year 2015, DART LRT’s ridership was 29.9 million passenger trips (“Facts about Dallas Area Rapid Transit (DART)”). Since its launching the property prices around its lines have increased. Currently DART has 4 rail lines and a brief description of their route and stations are provided below:

The Red line is, along with the Blue Line, one of the two original DART rail lines. It has 25 stations. It starts from the southwest of Dallas at Westmoreland and connects Parker Road station on the north east side of Dallas ("DART Schedules DART Rail Red Line").

The Blue line is another original line of DART. It starts from the UNT Dallas station and goes through Dallas' downtown, reaches Mockingbird Station and then connects the downtown of Garland and finally ends at the downtown Rowlett station. It has 21 stations in total ("DART Schedules DART Rail Blue Line").

The Green Line started service in September 2009 and the last extension of the line started its service in December 2010. It has 24 stations and runs toward the south east from North Carrolton, Farmers Beach, and then in Dallas it runs through Bachman Station, Inwood/Love Field Station, West End station, Pearl Station, M.L.K Jr. and then ends at Buckner station. Extension of Green Line is ultimately going to make DART LRT network into a 93 mile long network by 2019. ("Facts: Green Line").

The Orange line is 14 miles in length with 6 stations. From Downtown Dallas to Bachman Station it runs parallel to the Green Line in Northwest Dallas. From there extensions head towards the northwest; starting from Bachman Station to Las Colinas Urban Center that was opened on July 30, 2012; to Belt line that was opened on December 3, 2012 and finally to Dallas/Fort Worth International Airport that was opened on August 18, 2014 ("Facts: Orange Line").

DART is currently working on its 2040 Transit Plan, a part of which is the D2 project which aims to add an additional light rail alignment through Downtown Dallas by 2040 ("D2: Dallas Central Business District (CBD) Second Light Rail Alignment"). This project will serve new areas and increase the capacity of DART LRT system to serve commuters.

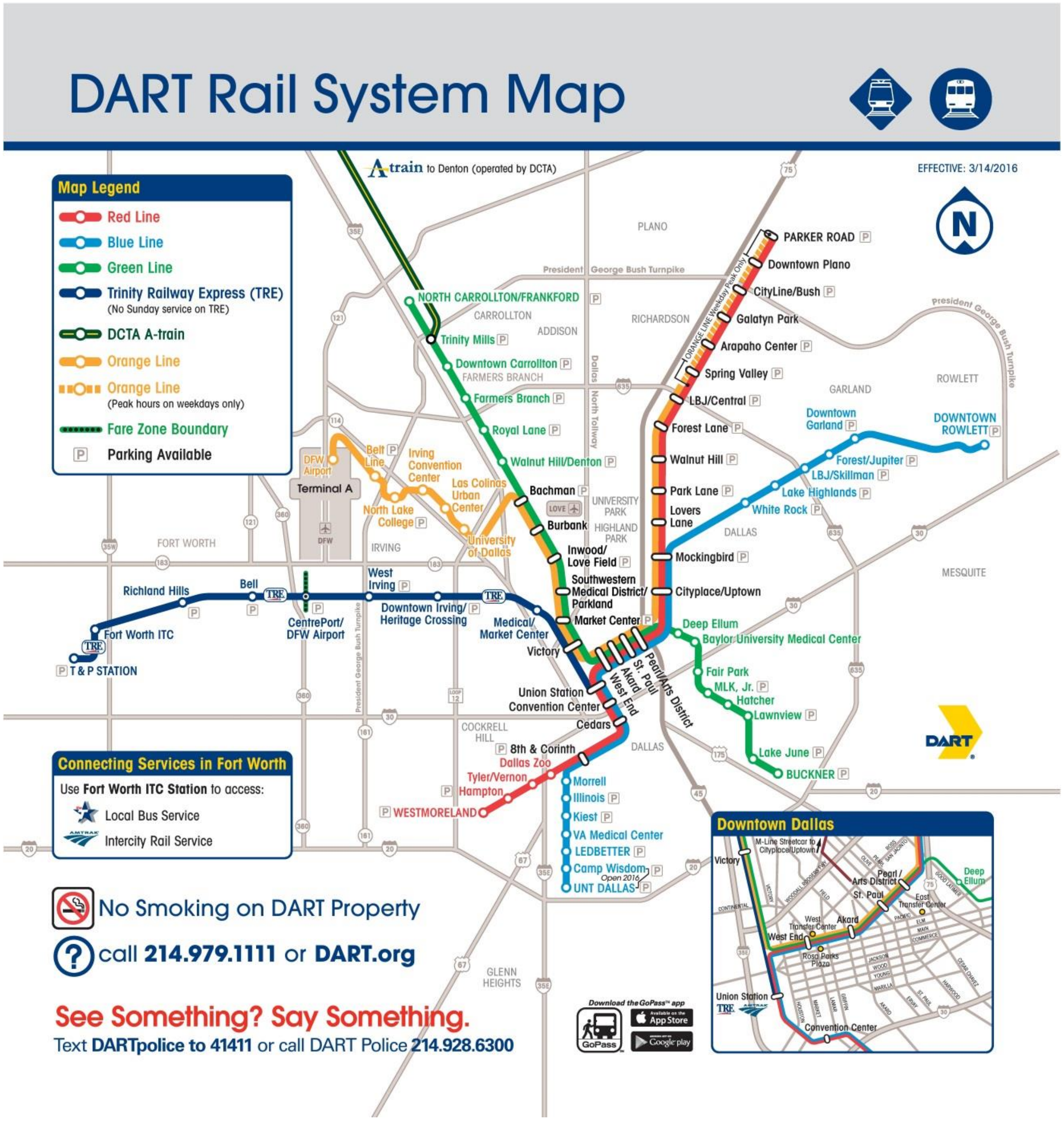

Figure 4.2: DART Rail System Map

4.3 SOCIO-DEMOGRAPHIC CONDITION OF THE CITY OF DALLAS BASED ON CENSUS TRACT LEVEL DATA

According to Median Household Income in the Census Tract level data from 2014, it is visible that most of the affluent people within the City of Dallas reside in the north central portion (Figure 4.4). People whose median household income is above \$75,000 are found mainly in the North central portion. People whose median household income is less than \$36,000 are mostly found in the southern portion and some in the eastern portion of the City of Dallas. It is a typical U.S. pattern of racial and economic segregation that, affluent neighborhoods in the north central portion of the city of Dallas are majority Non-Hispanic White. Figure 4.5 shows, distribution of Non-Hispanic White only population percentage in census tract level and it is conspicuous that census tracts in the North central Dallas has higher majority of this race. Geographically this northern portion of Dallas is located between the Red and Green lines north of the DART junction lying to the north of Dallas' CBD.

The Black or African American population percentage is higher in the southern portion of the city where most of the low-income people live (Figure 4.6). Figure 4.7 shows that, Hispanic people cluster around the south-eastern and south-western portions of the city.

Age of the building also plays an important role in deciding the rent. If there are two identical apartments, then comparatively newer apartment will presumably seek higher rents. Dallas is an old city and at the same time it is a booming city. This evoked the researcher to see where the newer and where the older buildings were located. This information was also availed from the census tract level and it was evident from Figure 4.8 that buildings that are from 0-20 years of age on an average are mostly located in the CBD, western portion and in the southern periphery of Dallas city. Some of the oldest buildings that are 60 -75 years old are located outside the CBD area, most of the buildings of the eastern side of Dallas are 45- 60 years old. So ultimately it can be said that, western portion and CBD of Dallas has comparatively newer buildings than eastern portion of Dallas. So it can be assumed that rent will be higher in the CBD and western portion of Dallas.

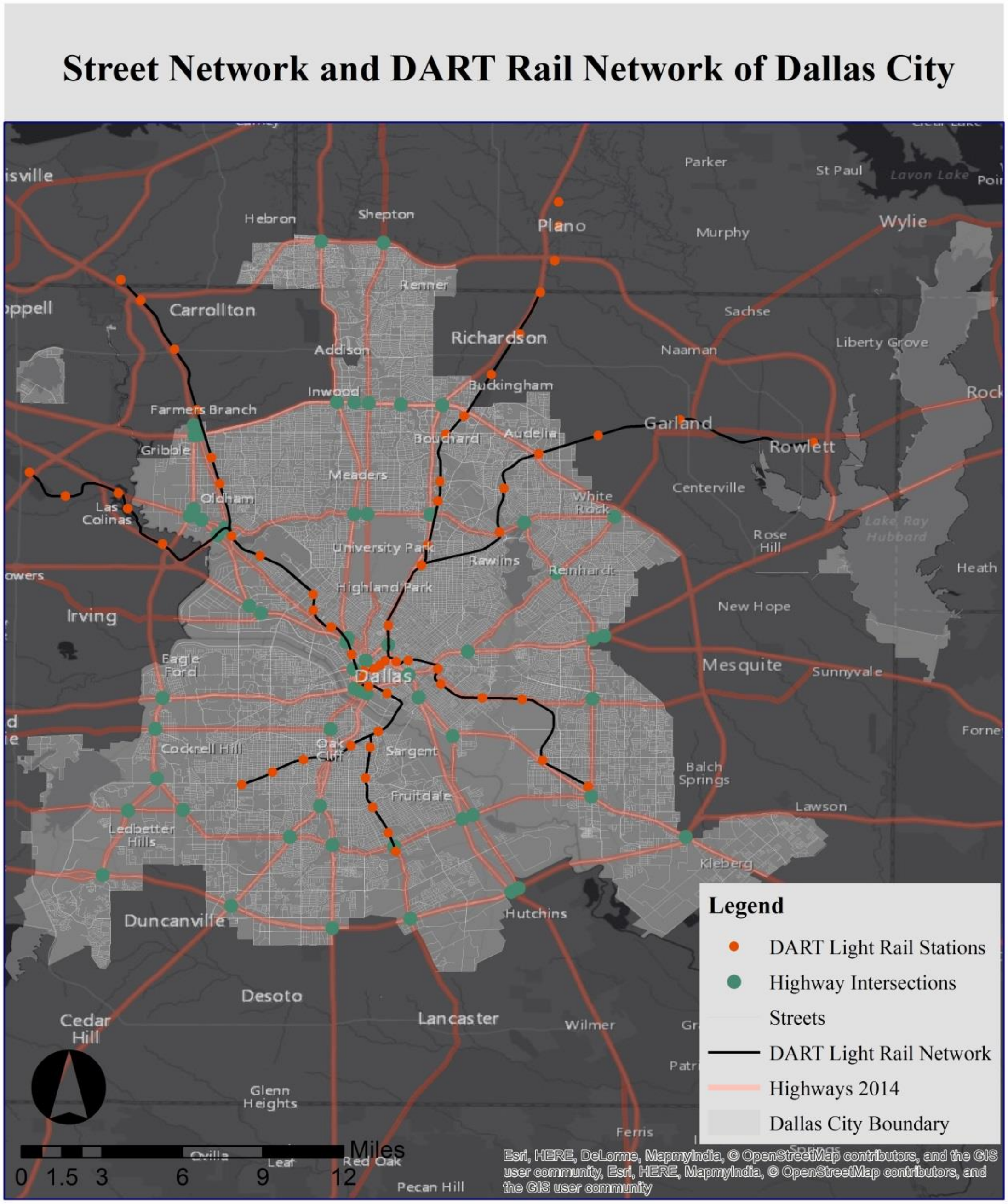

Figure 4.3: Highway Intersections in the City of Dallas

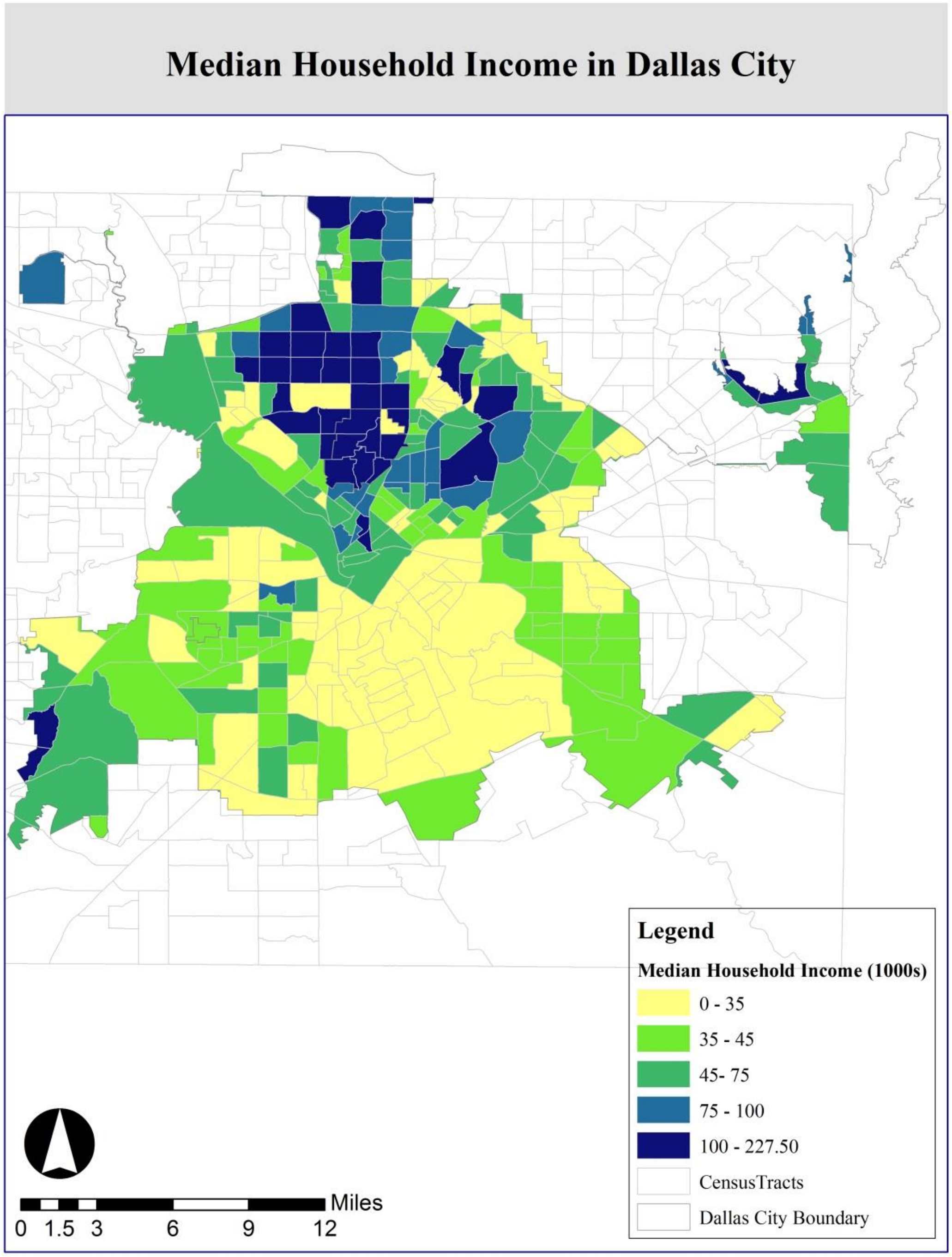

Figure 4.4: Median Household Income (in 1000s) in 2014 in the City of Dallas

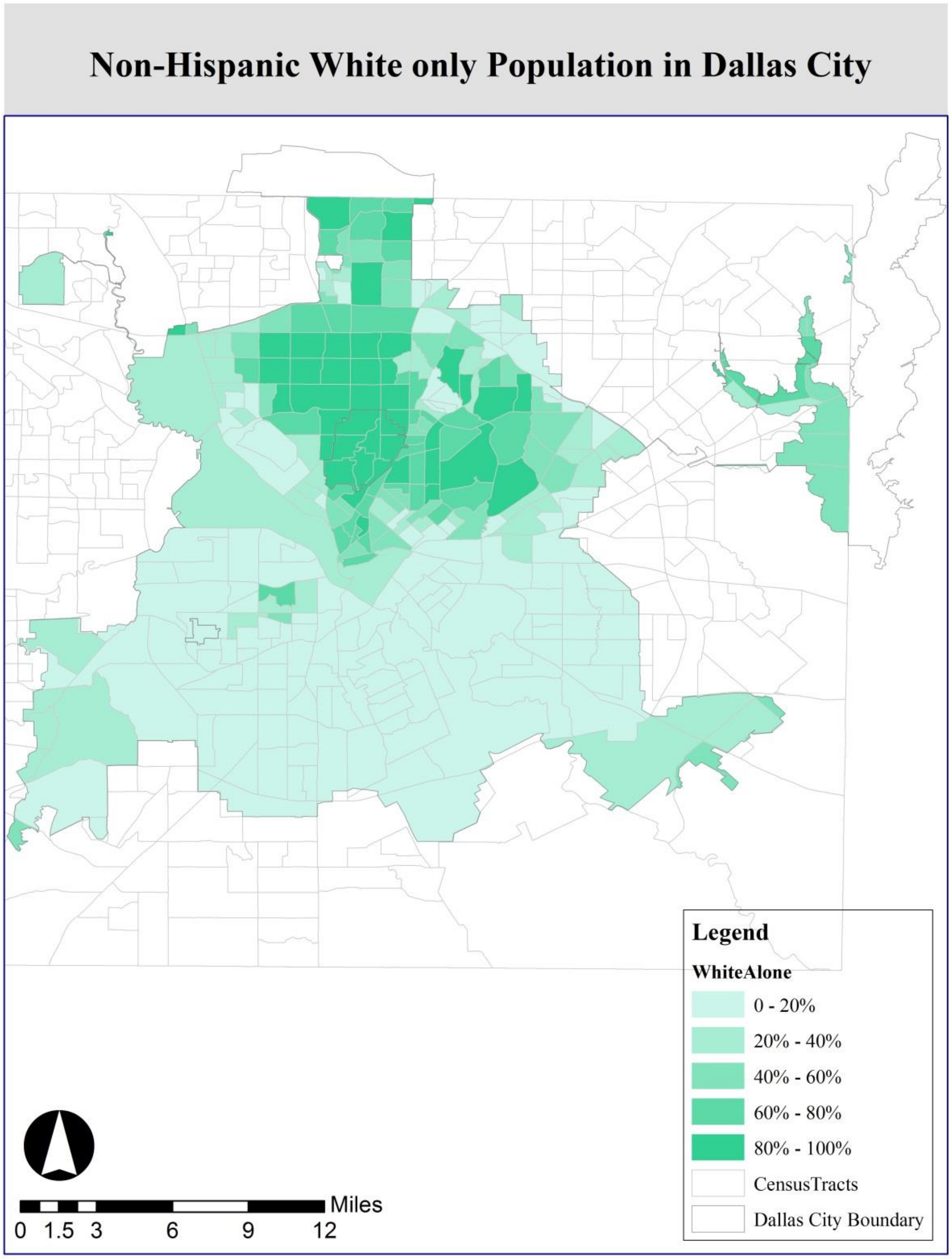

Figure 4.5: Non- Hispanic White only Population (in percentage) in 2014 in the City of Dallas

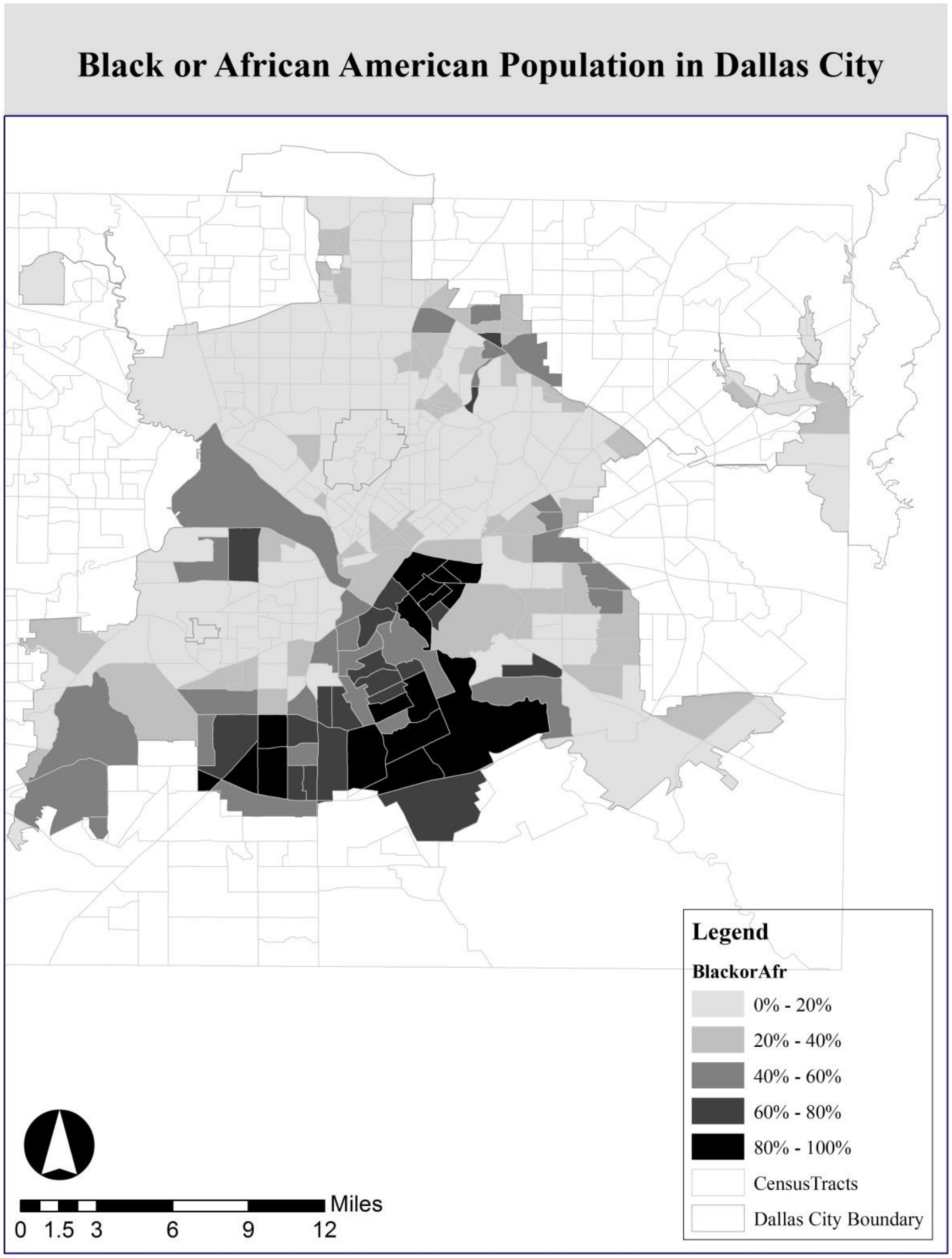

Figure 4.6: Non-Hispanic Black or African American Population (in percentage) in 2014 in the City of Dallas

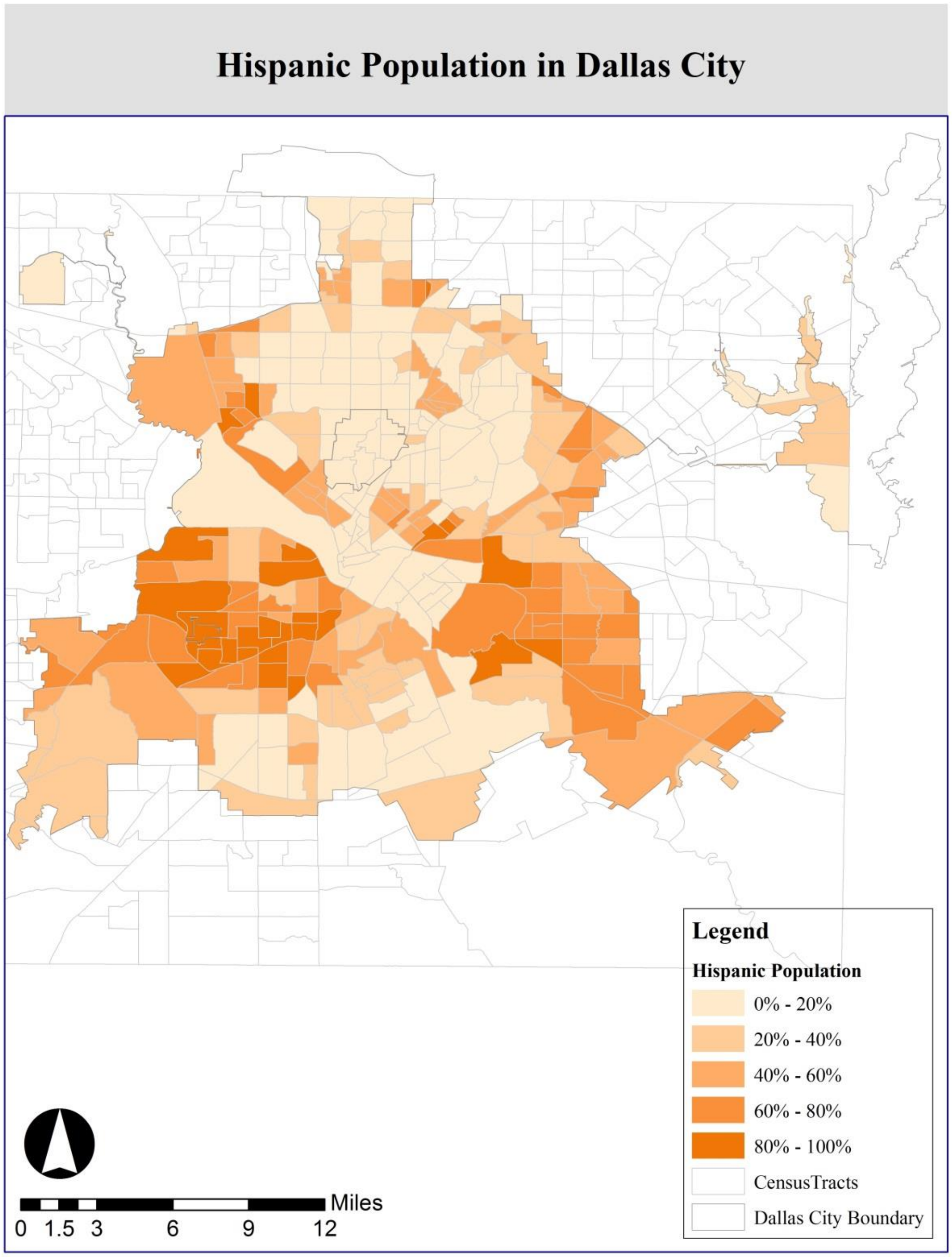

Figure 4.7: Hispanic Population (in percentage) in 2014 in the City of Dallas

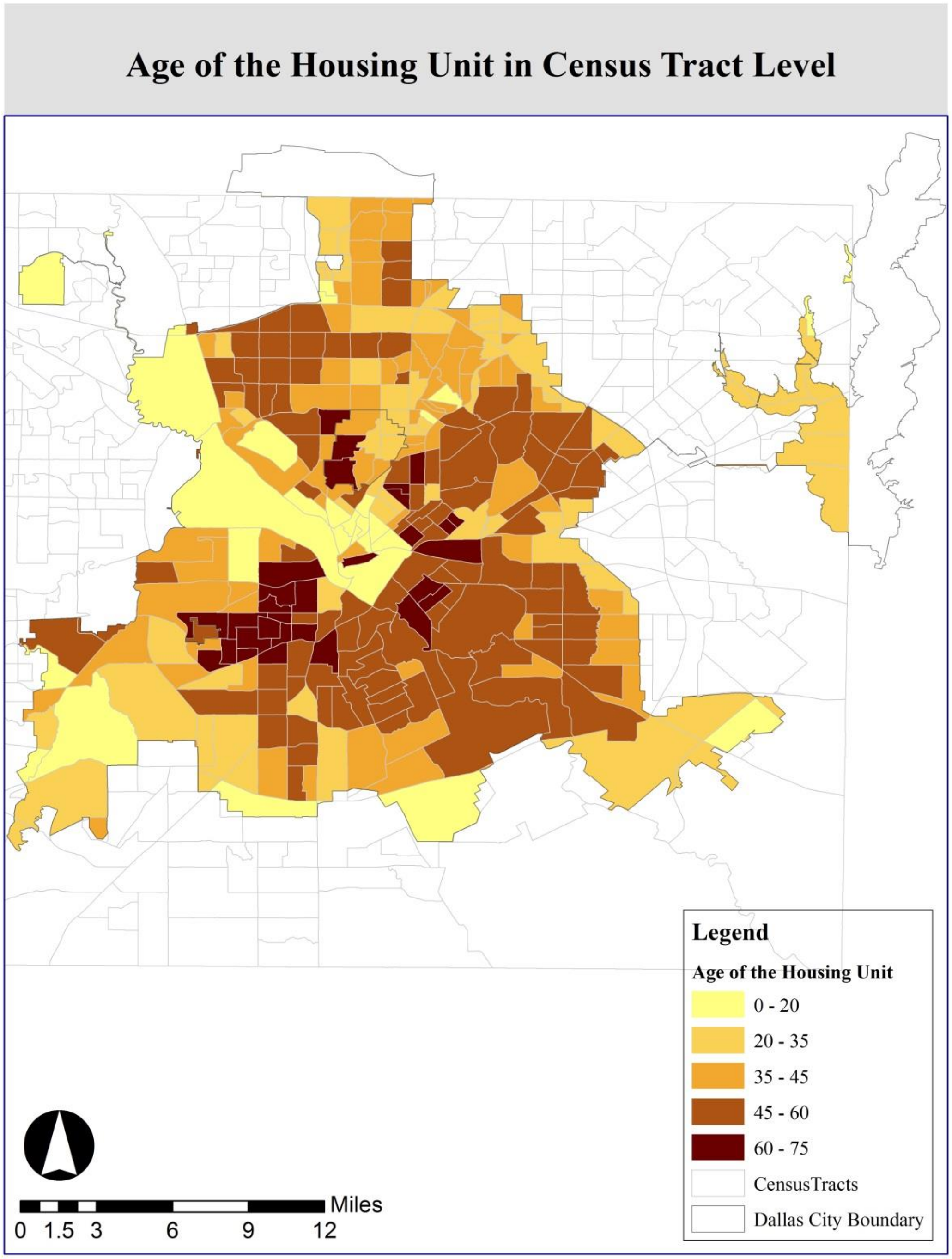

Figure 4.8: Age of average housing unit in 2014 in the City of Dallas

Chapter 5: Data Analysis and Results

5.1 Spatial Autocorrelation in the Dataset: Moran's I and its Correction

The value of Moran's I was 0.181 for this dataset. It means although there is a positive spatial auto-correlation in the data set yet it is closer to zero.

To correct this bias of dataset, the researcher could have followed a sophisticated model. Instead the researcher followed a simple method of including the latitude and longitude of the housing units inside the models. The justification behind this decision is when the model was run for the first time, t value for most of the coefficients of the OLS model of this research was very high and they were significant. Moran's I index was 0.181 which meant that the ratio of the OLS standard error and True standard error would be close to 1 (Darmofal 37). Hence, even after correction the change in the coefficient values would have been negligible. So, the researcher ultimately used simple OLS and semi log models and tried to correct the spatial autocorrelation by including the latitude and longitude of the housing units.

5.2 Descriptive Statistics

A total of 5,114 housing units fell inside the half mile radius from the stations. The majority of the housing units in the data set fell inside the 0.2 to 0.3 mile buffer ring area, followed by the number of housing units in 0.1 to 0.2 mile buffer ring, 0.3 to 0.4 mile buffer ring and 0.4 to 0.5 mile buffer ring areas respectively. The number of housing units that fell within 0.1 mile buffer area was so minimal that it was tough to interpret much about that buffer ring. Among all the sample housing units only 1,490 housing units had parks within walking distance (0.25 miles). There were 1,187 housing units that were within 0.5 mile of highways intersections of which 42 housing units were within 0.25 miles area of highway intersections. The descriptive statistics of the dataset is provided in Table 5.1. Results of both the models are presented in Table 5.2 and Table 5.3.

Category	Variable	Min	Max	Mean	Std. Dev
Dependent	Rent/Sq. Ft.	0.18	4.77	1.58	0.3
Independent					
Accessibility Factors	0.1 mile buffer	0	1	0	0.05
	0.1 to 0.2 mile buffer	0	1	0.27	0.44
	0.2 to 0.3 mile buffer	0	1	0.31	0.46
	0.3 to 0.4 mile buffer	0	1	0.25	0.43
	0.4 to 0.5 mile buffer	0	1	0.17	0.38
	Distance between CBD and housing unit (miles)	0	10.79	1.51	1.5
	Park within 0.25 miles of a housing unit	0	1	0.29	0.45
	Distance between nearest highway intersection and housing units	0	3.44	0.8	0.45
	Housing Unit Longitude	-96.87412	-96.7134	-96.8012465	0.01543
	Housing Unit Latitude	32.69238	32.91206	32.7955186	0.01976
Housing Unit Characteristics	Number of bedrooms	0	4	1.54	0.61
Neighborhood Characteristics	Age of average housing unit (tract)	7	70	16.39	7.81
	Median Household Income in 1000s	18.19	227.5	89.78	19.96
	Percentage of Non-Hispanic Black only Population	0	0.99	0.03	0.09
	Percentage of Hispanic Population	0	0.91	0.15	0.06
	N = 5114				

Table 5.1: Descriptive Statistics

5.3 MODELS

5.3.1 The OLS Model

In the OLS model, the dependent variable is Rent/ sq. ft. of the housing units. R^2 of this model is only 0.299. One of the main reasons behind such low value of R^2 could be the other factors which were not included as variables inside the model.

Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-759.014	58.960		-12.873	.000		
0.1 mile buffer	.103	.067	.019	1.551	.121	.960	1.042
0.1 to 0.2 mile buffer	.276	.014	.405	19.803	.000	.328	3.047
0.2 to 0.3 mile buffer	.240	.014	.368	17.636	.000	.315	3.173
0.3 to 0.4 mile buffer	.124	.015	.178	8.329	.000	.301	3.323
Distance between CBD and housing unit (miles)	.002	.010	.010	.198	.843	.056	17.885
Park within 0.25 miles of a housing unit	.064	.010	.096	6.381	.000	.609	1.642
Distance between nearest highway intersection and housing units (miles)	.025	.016	.037	1.543	.123	.243	4.113
Housing Unit Longitude	-6.159	.469	-.315	-13.132	.000	.239	4.190
Housing Unit Latitude	4.998	.683	.328	7.314	.000	.068	14.602
Number of bedrooms	-.120	.006	-.243	-20.386	.000	.969	1.032
Age of average housing unit (tract)	-.009	.001	-.244	-9.225	.000	.197	5.077
Median Household Income in 1000s	.006	.001	.386	10.087	.000	.094	10.649
Percentage of Non-Hispanic Black only Population	.355	.126	.102	2.826	.005	.107	9.386
Percentage of Hispanic Population	.370	.122	.073	3.041	.002	.238	4.207

a. Dependent Variable: Rent_SqFt

Table 5.2: Simple OLS Model

In the U.S, the longitude is negative as it is on the west side of the globe and latitude is positive as the U.S. is in the northern hemisphere. If all else remain constant, with increase of 1 mile towards west the rent/sq. ft. of the housing unit will go up by \$1.06/sq. ft. In general rent/sq. ft. of the housing units in the west will be higher than the housing units in the east. For latitude, if all other variables remain constant then, with 1 mile distance increase towards North, the rent/sq. ft. will go up by 7.2 cents. It suggests that housing units in the northern part of Dallas will have higher rent/ sq. ft. than housing units in the southern part. This pattern reflects the historic north-south socio-economic and racial division in Dallas. Portion of Dallas City located on the North of Trinity river is predominantly rich whereas south portion of Dallas city of Trinity river is mostly poor.

According to the model if all other variables remain constant, then with increase of each number of bedroom the rent/sq. ft. decrease by 12 cents. For instance, within the half mile radius sample data, on average the rent/sq. ft. of housing units with one bedroom was \$1.66 and two bedrooms was \$1.48. The sample data also showed that, minimum and maximum size of 0 bedroom housing units is 441 sq. ft. and 1372 sq. ft., one bedroom housing units is 458 sq. ft. and 1750 sq. ft., and two bedroom housing units is 717 sq. ft. and 2977 sq. ft. The maximum sized zero or one bedroom housing units are presumably the luxurious - efficiency or studio apartments that are bigger in sizes. With the increase in numbers of bedrooms the area of the housing units do not increase; rather it gets divided into smaller bedrooms if the land price is high in higher demand areas. Sign of the age of average housing unit (tract) indicates that, housing units that were built comparatively long time before 2014 will have lower rents. It is because newer housing units or apartments have more demand and hence their rent is higher.

If all other variables remain constant then with each \$1,000 increase in tract household income, the rent/sq. ft. increases by 0.6 cents. It can also be said that, comparatively expensive housing units are rented in areas inhabited predominantly by higher income people. With each percentage increase of Black population in the census tract, ceteris paribus, the rent/sq. ft. of the housing unit will increase by 35.5 cents. With each percentage increase in Hispanic population in the census tract, if all other variables remain constant then, the rent/sq. ft. will increase by 37 cents. It can be said that overall, rent/sq. ft. of the housing unit is lower in census tracts with higher percentage of Black population compared to census tracts that have higher percentage of Hispanic population.

Finally from this model, it can be said that, if all other variables remain constant, then rents for housing units inside a 0.4 mile radius are higher than for housing units that are within the 0.4 to 0.5 mile ring. More specifically according to this model if all other variables stay constant, then rent/ sq. ft. of housing units within 0.1 mile of DART stations will be 10.3 cents higher than the rent/sq. ft. of the housing units that are within 0.4 – 0.5 miles radius area. Rent/sq. ft. of housing units within 0.1 to 0.2 miles radius are 27.6 cents higher than the average rent of housing units within 0.4 - 0.5 miles area. After 0.2 miles the rent starts to decrease and it is 24 cents per sq. ft. higher than the housing units located within 0.4 to 0.5 mile radius area. The rent drops even lower in the 0.3 to 0.4 miles radius area where the rent/sq. ft. is only 12.4 cents higher per sq. ft. of the housing units compared to the housing units within 0.4 to 0.5 mile. The reason rents are lower within 0.1 miles than for units from 0.1 to 0.2 mile could be related to the fact that in Dallas, many of the DART rail lines are parallel to freight rail with their attendant noise and safety disamenity effects. However, the 2nd buffer area possibly has the highest rent within this half mile buffer area because it is closer to the station but not too close to be as affected by proximity to a freight corridor. But after this area with every 1/10th increase of a mile in distance causes decrease in rent and it keeps on decreasing.

Among the other accessibility variables, presence of parks within quarter mile has the strongest relationship with rents. According to the model if all else stays equal then the rent per square foot of a housing unit will increase by 6.4 cents if there is a park within a quarter mile. If all else stays the same then, with 100 feet distance from the CBD centroid the rent increases by 0.003 cents/sq. ft. which is very negligible. It indicates that housing units' rents are almost constant in a CBD area. Proximity to a highway intersection is considered unfavorable for housing units because of exposure to fumes and hence threat of air pollution and health risks. The positive sign of this coefficient supports the supposition that as the distance from the highway intersection increases the rent also increases.

5.3.2 The Semi-Log Model

The difference between the OLS model and the Semi-Log model of this study is that, the dependent variable is the log value of the Rent/sq. ft. of the housing units. The Semi log model explains 35.6% of the variation in the dependent variable compared to 29.9% in the OLS model. The signs and significance are similar for all independent variables across the two models except "Distance between CBD and housing unit (miles)" and "Percentage of Non-Hispanic Black only Population" as both of their signs are negative for the Semi log model. In the OLS model coefficient of "Distance between CBD and housing unit (miles)" is not significant. In the Semi log model the coefficients for "Percentage of Non-Hispanic Black only Population" and "Percentage of Hispanic Population" is not significant.

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-511.085	36.545		-13.985	.000		
0.1 mile buffer	.081	.041	.022	1.959	.050	.960	1.042
0.1 to 0.2 mile buffer	.190	.009	.432	22.024	.000	.328	3.047
0.2 to 0.3 mile buffer	.167	.008	.395	19.751	.000	.315	3.173
0.3 to 0.4 mile buffer	.094	.009	.210	10.255	.000	.301	3.323
Distance between CBD and housing unit (miles)	-.008	.006	-.065	-1.374	.170	.056	17.885
Park within 0.25 miles of a housing unit	.043	.006	.100	6.933	.000	.609	1.642
Distance between nearest highway intersection and housing units (miles)	.017	.010	.040	1.741	.082	.243	4.113
Housing Unit Longitude	-3.971	.291	-.314	-13.659	.000	.239	4.190
Housing Unit Latitude	3.871	.424	.392	9.140	.000	.068	14.602
Number of bedrooms	-.075	.004	-.235	-20.629	.000	.969	1.032
Age of average housing unit (tract)	-.005	.001	-.217	-8.586	.000	.197	5.077
Median Household Income in 1000s	.003	.000	.297	8.111	.000	.094	10.649
Percentage of Non-Hispanic Black only Population	-.002	.078	.000	-.025	.980	.107	9.386
Percentage of Hispanic Population	.032	.075	.010	.423	.673	.238	4.207

a. Dependent Variable: Ln_Rent_Sq

Table 5.3: Semi-Log Model

The coefficient of the housing unit's Longitude says that, if all else remains the same, and then if the longitude of the housing unit increases by one degree (means housing is located towards west), then the rent/ sq. ft. will decrease by 98.9%. But Dallas falls in 32°46'59" N latitude and 96°48'24" W Longitude or Latitude 32.7830600 and Longitude -96.8066700 in decimal degrees ("Geographic Coordinates of Dallas, Texas, USA"). So a change of one degree would mean that housing unit will fall out of Dallas city and this is beyond the scope of the study area. Considering the situation, it can be said that, if all else stays constant, then with an increase of 1 mile distance towards west the rent/sq. ft. will increase by 98.3%. Then, if all other variables remain constant, then with 1 mile distance increase towards North, the rent/sq. ft. will increase by 5.8%.

According to the semi log model, if all else stays same, then with increase of each number of bedrooms the rent/sq. ft. goes down by 7.23%. As the building gets older by each year, ceteris paribus the rent/sq. ft. goes down by 0.5%.

If all else remain constant then, with increase of $1000 in median household income of a neighborhood; the rent/sq. ft. of a housing unit located in that neighborhood increases by 0.3%. It means comparatively affluent neighborhoods have higher rent/sq. ft. From the coefficients of neighborhood characteristics, it is visible that, racial segregation has strong impact on the rent/sq. ft. It can be said that, ceteris paribus, 1% increase of Black population in a census tract decreases the rent/sq. ft. of a housing unit located in that census tract by 0.2% and 1% increase of Hispanic population in a census tract increases the rent/sq. ft. of a housing unit located in that census tract by 3.25%. Clearly these value percentages indicate that, a housing unit located in Black majority census tract pays comparatively the lowest rent/sq. ft. than census tract with higher percentage of other races.

If all other variables remain the same then, a housing unit that is located inside 0.1 mile radius of a DART rail station, its rent/sq. ft. will be 8.44% higher than that of a housing unit that is located within 0.4 to 0.5 mile radius of a station. However, inside the 0.1 to 0.2 mile radius of a DART rail station the rent/ sq. ft. is 20.92% higher than rent/sq. ft. of a housing unit located inside 0.4 to 0.5 mile radius, if all other variables remain constant. The reason behind this is, 0.1 to 0.2 mile is still a walkable distance to the station but not so close to get the noise and crowd – phenomena that housing units in the closest vicinity suffer. The positive effect of being close to the rail station starts to go down from 0.2 miles radius. The coefficients of 0.2 to 0.3 miles and 0.3 to 0.4 miles are lower than 0.1 to 0.2 miles radius buffer area.

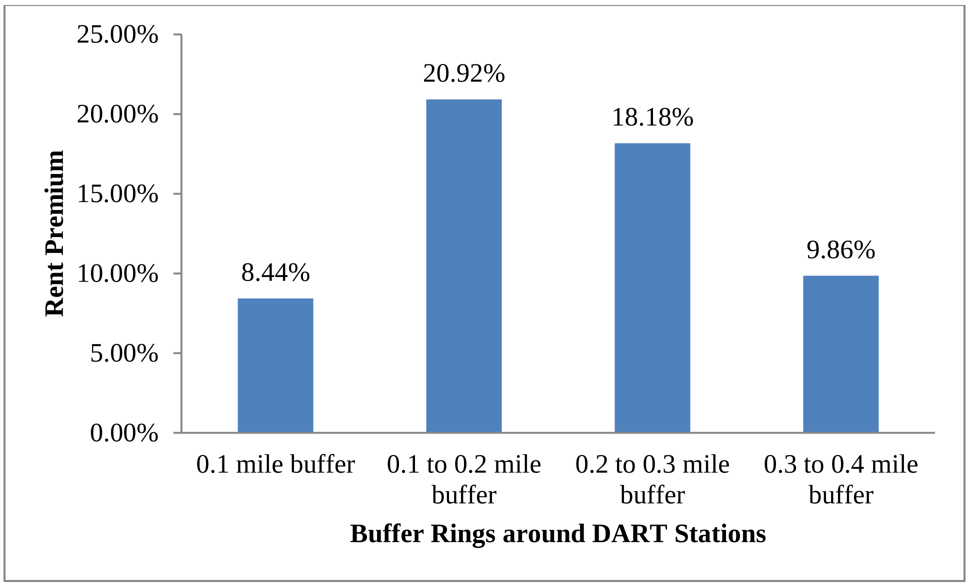

Figure 5.1: DART rail stations' Rent Premium in the Semi-Log Model.

Figure 5.1 shows the trend of the Rent Premium that transportation planners and real estate developers can certainly use. They can use this information and decide on investing more inside 0.1 to 0.2 miles radius followed by 0.2 to 0.3 miles radius, 0.3 to 0.4 miles radius and within 0.1 mile radius area of the DART stations to have maximum profit. Local government can apply density bonus program by allowing highest FAR in the 0.1 to 0.2 mile buffer ring to make efficient use of the land.

If all else stays the same, then with each mile increase in the distance between the CBD center and the housing unit then, rent/sq. ft. of the housing unit goes down by 0.8%. However this number is not significant. If everything else remain the same, then housing units located within quarter mile radius of a park or parks will have 4.39% higher rent/ sq. ft. then the housing units that do not have parks within quarter mile distance of a station. With each mile increase in the distance between a housing unit and a highway network, ceteris paribus, the rent/sq. ft. increases by 1.71%. People definitely prefer to stay away from the traffic, noise and pollution and this variable clearly proves that.

Chapter 6: Policy Recommendations and Conclusions

6.1 Discussion

The intension of such kind of analysis as done in this thesis is to help collect funding for future transportation projects such as extension of the existing LRT system or a new system. This kind of analysis collaborates land use with mass transportation and uses this affiliation to improve both the land use and transit system. As residential rent is found to be associated with proximity to DART stations, so this relationship should be used for development of both real estate and the transit system. Housing units should take advantage of being located closer to the stations and transit system should try to take advantage of being laid out in a place from where it can generate more profit. However, the background research finds out that, the ridership of DART is not as high as compared to the other similar LRT systems of U.S. High ridership is the factor that gives the developers the credibility about the system which encourages them to invest in the properties in the vicinity of the station.

Comparing the context with other regional transit systems of the nation that has higher ridership can help to understand why the ridership of DART is not as high as how it should have been. Empirical studies have shown that, LRT ridership is high in busy areas. For example, in Houston, Washington D.C., New York, Philadelphia, in all these busy cities, their metro system runs through busy corridors. However, Dallas itself is a very big sprawling city. The density is not that high. On the other hand, high ridership (more than 700,000 a day) of Metro in Washington D.C ("Metrorail"), can be credited to their walk able streets and dense development around the stations. In contrast to D.C., surrounding land use and streetscape of DART rail stations is not supportive of the LRT system. Many station areas along the Orange Line of DART, especially between the Airport and Downtown are surrounded by parking lots and bus bays (Russel). These are large ample places which could possibly be used for other residential, retail or office services that could add to the density of the area.

Another reason for low ridership is that DART is a regional system and its lines are laid out in a way to serve the suburbs. Hence, majority of the riders are assumed to be the one who come from suburb to work in the city or people who do not want to drive between the center and the suburbs. DART network does not cover many of the busy corridors of Dallas city except for the downtown area where the 4 lines are laid out. According to another online news website “Dallas Observer”, the orientation of public transit system of Dallas is such that, DART rail radiates from downtown towards the suburbs and the bus systems radiate from the rail stations. DART is convenient for people who can drive and park in the parking lots or for people living within walking distances during peak hours. However, riding in DART is difficult for people who do not have a car or people who want to travel in the off peak hours when the bus or train is not frequent.

If the system could be laid out in a grid system over less expanded area, that would have increased its ridership. The rationale behind DART’s such layout is that DART is funded and governed by a coalition of Dallas city and dozen suburbs who coveted light rail. According to GB Arrington, a rail consultant of Portland who also worked in projects of DART thinks that, the development around DART stations are not Transit Oriented Development and they are basically Transit Adjacent Development. Many development projects are adjacent to the stations not only because of the station but because of proximity to highways also. There are many station areas like George Bush Turnpike Rail station in Richardson, where parking area has been given priority over walkability. This kind of mindset needs to be changed (Nicholson).

6.2 POLICY SUGGESTIONS

Based on the analysis and discussions following four policy suggestions are given that will help to increase ridership of DART LRT system, encourage transit oriented development and that will eventually aid in collection of greater amount of funding.

1. Inside the half mile buffer area of the stations, large parking lots and bus bays could be reduced in size or be totally eliminated. This place should be dedicated more for building housing units. Along with that the streetscape can be improved by providing connected sidewalks, safe crosswalks and trees for shading. If the stations can be reached by foot in comfort and safety then more people will be willing to walk to the transit system and use it. Hence the ridership will increase.
2. City Planners and DART TOD planners can come to consensus and work together to provide policies that will allow or encourage the developers to build more 1-2 bedroom apartment complexes, condos or multi-family housings inside half mile buffer area of the stations. They can change the land use inside the half mile buffer area of the station and allow only 1-2 bedroom housing units or apartment complex to increase the density of residences in this area. As the rent of the housing units within 0.4 to 0.5 miles and area within 0.1 mile are least associated with DART, so city planners can set up policies or change the land use to more of retail or office use than residential use in these buffer rings. In this way the land will be properly utilized and no place will be left unused.
3. To get better ridership, instead of expanding their rail lines more towards the suburbs new extensions should be provided in the busiest corridors and that might increase the ridership of the system. For instance, it can apply the strategy of Houston MetroRail which has 2,700 passengers per mile on weekdays whereas DART has only 1,000 passengers per mile on weekdays. This is because Houston

Metro runs only through the busy part of the central Houston. DART can expand its lines in the busy areas where there would be more ridership (Keatts).

4. Incentives should be provided to attract developers to build housing projects inside half mile radius area of the stations. Employees should be provided with free transit passes if they agree not to use car and instead use the transit to come to their working places in the station areas.

6.3 CONCLUSION

Overall, DART LRT is positively associated with the rent/sq. ft. of the housing units and the transit capitalization rate is the highest within 0.1 to 0.2 mile radius area around the stations. Rent/ sq. ft. decreases as the distance from the DART rail stations increase within the influence area. The Rent premium is the lowest in the closest vicinity which is not a surprising fact because DART rail lines have been laid beside the freight lines and the land use round the stations is not planned and developed as transit oriented development. Noise and air pollution here demean the rent premium. However, according to the semi log model, the average premium inside the 0.4 miles area is 14.35% higher compared to the rent premium of the housing units inside 0.4 to 0.5 miles area. This implies that housing units located any place inside the 0.4 mile radius of the stations will receive higher rent/sq. ft.

Previous studies on DART LRT system showed that proximity to DART rail stations is positively associated with property value within quarter mile of the station for the entire system and DART LRT is positively associated with residential property value within 1 mile for DART's Green line stations. However, the result of this study supports the fact that the de facto rail transit catchment area or influence area is half mile area around LRT stations and DART is no exception of that when residential rent is considered. The result of this research adds to the existing knowledge about DART's association with residential property value by showing that, besides property value, proximity to DART stations is also associated with rent/sq. ft. of housing units'. This study is unique because instead of taking Euclidean distance between the housing units and the stations, the current study measured street network distances which gave the proximity analysis more accurate and reliable results. However, due to unavailability of some variables the model had some limitations in explaining the variation in the sample dataset. Yet the model can be used for follow up analysis and the results can be improved by using more sophisticated hedonic models.

This result will be helpful for the city planners of Dallas so that they can update the land use development to be transit oriented and not transit adjacent. As DART is a regional transit system and its influence of residential rent is a regional phenomenon, so city planners will be able to plan for a regional scale transit oriented development.

The identification of influence area of DART will help in decision making for the appraisers who make market-derived rent adjustments. Real Estate developers can help to make proper utilization of the land and increase the density by prioritizing taking up of projects in the most influenced areas. Property managers will also be benefitted by being able to set property rents accordingly. Such kind of analysis gives scope to academics who are interested to research real estate market and how it can be incorporated with transportation sector for the sustainable development of a region.

On the other hand, tax assessors will be able to collect more property taxes if it is imposed based on the influence of transit and housing market demand in different areas accordingly. More people will be able to stay near the stations if there are more housing units available because of the increased residential units in these influence areas. If more people stay near transit then possibility is more people will use the transit and this will increase the ridership of the system. Therefore DART will be able to increase their both direct (ride fare) and indirect income (influenced rent and property taxes) from transit that will go for funding of the new extension lines of the system. Empirical studies have shown that if more job opportunities are created in the vicinity of the rail stations then more number of employees will be encouraged to use the LRT which will also increase the ridership of the system. Eventually such kind of research holds great significance for City Planners and Transportation planners who can collaborate to create a sustainable plan for the region as a whole.

Appendices

APPENDIX A. DETAILED DESCRIPTION OF SOME METHODS

A.1 Steps to create a Street Network file in TransCAD

Open the Street Shapefile in TransCAD. Then export the shapefile as a "Standard Geographic File" by clicking Tools > Export > Standard Geographic File. Thus both nodes and links of the streets were created.

A.2 Steps to measure "Point to Point Distance" between Housing units and their nearest stations and between Housing Units and CBD

1. The nearest Node to the CBD and Nearest Node to each housing unit were needed to measure the distance between each housing unit and the CBD.
2. Two new fields in the Housing Unit table called "NearestNodeToCBD" and "NearestNodeToHH" were added first.
3. "NearestNodeToHH" field was selected by clicking Fill, and then the field was Tagged by Using Layer---> Node and Tag with ---> ID. Thus the Nodes that are nearest to each housing unit were found.
4. In the CBD table, a new field called "NearestNodeToCBD" was added, "NearestNodeToCBD" field was selected, after clicking Fill it was Tagged by using Layer ---> Node and Tag with ---> ID. Thus the Node that is nearest to the CBD was found.
5. Then Point to Point Distance was used. Latitude and Longitude were selected as Origin Method for both housing units and CBD to measure the distances between them.

A.3 Steps to measure Network Distance between Housing units and Parks, Highway Intersections and Employment Centers

1. At first from the street shapefile, a street network dataset was created by enabling Network Analyst Tool. This dataset had street segments and nodes connecting those segments.
2. Network distances were measured using "New Closest Facility" tool. In the Network Analyst Window at first Housing Units were loaded as Incidents.
3. When measuring distance between Housing units and parks, park centroids were loaded as Closest Facility. When measuring distance between Housing Units and Highway Intersections, Highway intersections were loaded as Closest Facility. Then again when measuring distance between Housing Units and employment centers, employment centers were loaded as Closest Facility.
4. In the layer properties – Analysis Settings, Length was selected as the Impedance and Distance Units was selected as Miles.
5. After the set up the analysis was solved and the attribute Table of the Route consisted of the measured network length between the housing units and the parks, highway intersections. And employment centers.
6. Later on these tables were added to the Housing unit shapefile based on the Housing Units' unique ID number.

A.4 Calculating Missing Property Values in Census Tracts using ArcGIS

Suppose,

Census Tract Cn is missing median property values. Census Tracts surrounding Cn are C1, C2, C3…….Cm and their population are P1,P2, P3……..Pm respectively. So the weighted average median property value for Cn would be,

$$Cn = ((C1*P1)+(C2*P2)+(C3*P3)+\ldots\ldots(Cm*Pm))/ (P1+P2+P3+\ldots.+Pm)$$

Following the formula all the missing median property values were calculated. Some of census tracts that did not have median property value were located side by side. In this case the census tract that was surrounded by more available data was selected to be used first for the calculation. All this was done in ArcGIS and MS Excel.

APPENDIX B. CORRELATION MATRIX FOR MULTICOLLINEARITY

		Rent_Sq Ft	0.1 mile buffer	0.1 to 0.2 mile buffer	0.2 to 0.3 mile buffer	0.3 to 0.4 mile buffer	CBDto HU_ mile	Park_ Within_ quarter mile	HWInter sectiont ToHU Miles	Emp Center To HU Miles	Bed rooms	Age_ HU	MedHH Inc 1000s	Med PropV	White%	Black%	Hispanic %
Rent_ SqFt	Pearson Correlation	1	-0.017	.225**	.045**	-.088**	-.108**	.183**	-.071**	-.091**	-.238**	-.318**	.315**	.261**	.354**	-.334**	-.267**
	Sig. (2-tailed)		0.217	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
0.1 mile buffer	Pearson Correlation	-0.017	1	-.033*	-.036**	-.031*	-.036*	.053**	-0.022	-.036*	0.011	-.032*	0.021	.046**	0.011	-0.01	-0.015
	Sig. (2-tailed)	0.217		0.019	0.01	0.025	0.011	0	0.116	0.011	0.431	0.023	0.142	0.001	0.425	0.475	0.268
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
0.1 to 0.2 mile buffer	Pearson Correlation	.225**	-.033*	1	-.403**	-.349**	-.120**	.200**	.048**	-.220**	.082**	-.215**	.172**	.066**	.165**	-.096**	-.068**
	Sig. (2-tailed)	0	0.019		0	0	0	0	0.001	0	0	0	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
0.2 to 0.3 mile buffer	Pearson Correlation	.045**	-.036**	-.403**	1	-.387**	-.174**	.170**	-.236**	-.097**	-0.02	0.014	-.095**	-.132**	-.085**	.081**	.098**
	Sig. (2-tailed)	0.001	0.01	0		0	0	0	0	0	0.149	0.32	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
0.3 to 0.4 mile buffer	Pearson Correlation	-.088**	-.031*	-.349**	-.387**	1	0.008	-.219**	-.203**	-.085**	-.045**	0	.253**	.320**	.173**	-.034*	-.191**
	Sig. (2-tailed)	0	0.025	0	0		0.575	0	0	0	0.001	0.972	0	0	0	0.016	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
CBDtoHU_ mile	Pearson Correlation	-.108**	-.036*	-.120**	-.174**	0.008	1	-.479**	.798**	.845**	.042**	.602**	-.290**	0.017	-.377**	.392**	.077**
	Sig. (2-tailed)	0	0.011	0	0	0.575		0	0	0	0.003	0	0	0.213	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115

Park_Within_quartermile	Pearson Correlation	.183**	.053**	.200**	.170**	-.219**	-.479**	1	-.222**	-.475**	-.073**	-.273**	.216**	.103**	.219**	-.139**	-.122**
	Sig. (2-tailed)	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
HW IntersectionToHUMiles	Pearson Correlation	-.071**	-0.022	.048**	-.236**	-.203**	.798**	-.222**	1	.805**	-0.005	.537**	-.314**	-.052**	-.391**	.337**	.157**
	Sig. (2-tailed)	0	0.116	0.001	0	0	0	0		0	0.741	0	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Emp CenterToHUMiles	Pearson Correlation	-.091**	-.036*	-.220**	-.097**	-.085**	.845**	-.475**	.805**	1	.030*	.580**	-.382**	-.086**	-.414**	.263**	.151**
	Sig. (2-tailed)	0	0.011	0	0	0	0	0	0		0.03	0	0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Bed rooms	Pearson Correlation	-.238**	0.011	.082**	-0.02	-.045**	.042**	-.073**	-0.005	.030*	1	0.015	-0.02	-.041**	-0.022	.049**	-0.004
	Sig. (2-tailed)	0	0.431	0	0.149	0.001	0.003	0	0.741	0.03		0.297	0.157	0.004	0.11	0	0.775
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Age_ HU	Pearson Correlation	-.318**	-.032*	-.215**	0.014	0	.602**	-.273**	.537**	.580**	0.015	1	-.598**	-.310**	-.796**	.753**	.588**
	Sig. (2-tailed)	0	0.023	0	0.32	0.972	0	0	0	0	0.297		0	0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Med HHInc 1000s	Pearson Correlation	.315**	0.021	.172**	-.095**	.253**	-.290**	.216**	-.314**	-.382**	-0.02	-.598**	1	.875**	.927**	-.674**	-.774**
	Sig. (2-tailed)	0	0.142	0	0	0	0	0	0	0	0.157	0		0	0	0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Med PropV	Pearson Correlation	.261**	.046**	.066**	-.132**	.320**	0.017	.103**	-.052**	-.086**	-.041**	-.310**	.875**	1	.768**	-.541**	-.721**
	Sig. (2-tailed)	0	0.001	0	0	0	0.213	0	0	0	0.004	0	0		0	0	0

	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
White%	Pearson Correlation	.354**	0.011	.165**	-.085**	.173**	-.377**	.219**	-.391**	-.414**	-0.022	-.796**	.927**	.768**	1	-.838**	-.841**
	Sig. (2-tailed)	0	0.425	0	0	0	0	0	0	0	0.11	0	0	0		0	0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Black%	Pearson Correlation	-.334**	-0.01	-.096**	.081**	-.034*	.392**	-.139**	.337**	.263**	.049**	.753**	-.674**	-.541**	-.838**	1	.544**
	Sig. (2-tailed)	0	0.475	0	0	0.016	0	0	0	0	0	0	0	0	0		0
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115
Hispanic %	Pearson Correlation	-.267**	-0.015	-.068**	.098**	-.191**	.077**	-.122**	.157**	.151**	-0.004	.588**	-.774**	-.721**	-.841**	.544**	1
	Sig. (2-tailed)	0	0.268	0	0	0	0	0	0	0	0.775	0	0	0	0	0	
	N	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115	5115

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX C. SPATIAL AUTO-CORRELATION AND MORAN'S I

The "R script" of calculating Moran's I to observe the existence of Spatial Auto-Correlation:

```
rm(list=ls())


install.packages('geosphere')

install.packages('spdep')


library(geosphere)

library(spdep)


# loading the data - change your path to be the right one!

data <- read.csv('D:\\USA\\4th Semester\\Thesis A\\Master Data Preparation\\MasterData_halfmile.csv')

data_short <- data[data$StationToH <= .5,]


# creating the inverse distance matrix

# this version places a small distance (10 meters) between points that are in the same location

dists <- distm(data_short[,c('HH_longitu','HH_latitud')], data_short[,c('HH_longitu','HH_latitud')],

        fun=distCosine)

dists[dists == 0] <- dists[dists == 0] + 10

dists <- 1/dists
```

```
diag(dists) <- 0


# create a spatial weights object from the inverse distance matrix

listw_obj <- mat2listw(dists)


# fit the model

model <- lm(Rent_SqFt ~ bedrooms + CBDtoHH_Di + Age_bldg_2 + BlackorAfr +
Hispanic_o +

            X.1_10Mile + X.1_10to2_10 + X.2_10to3_10 + X.3_10to4_10 +
HW_Ndist_Miles +

            MedHHInc1000s, data=data_short)


# test moran's I!

lm.morantest(model, listw_obj)
```

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