ACCESS TO OPPORTUNITY AND THE IMPACTS ON HOUSING VALUE

by

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Abstract

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Accessibility is the well stablished concept in theories of urban planning and spatial structure. This dissertation measured access to opportunities that incorporate major destinations as well as all jobs for three modes. The study used the most updated transportation network to measure access to opportunities by gravity equation that account for distance and mode. It also used Principal Component Analysis to make the opportunity scores out of several related destinations and to make overall score by incorporating all the opportunities.

The developed access to opportunity scores were applied to evaluate the location efficiencies of major affordable housing units in DFW. I found that most of affordable housing units are located in least location efficient places by walking and transit. However, among them, HCV and LIHTC affordable programs presented a better performance than other ones.

The new score was used to determined areas with the high and low access chances for DFW. Based on the analysis for this research, the residents had poor access to opportunities by walking and transit and good access to opportunities by driving. I also used the developed scores to examine the spatial distribution of new development projects in areas of opportunities. I found that most of the projects are happening in areas that have low access to opportunities by walking and transit, but they have good access by car.

Moreover, the relation to housing value is the topic of large volume of the studies. However, currently, there have been some changes in household travel behavior. Households are reported to commute less to access jobs due to the advances in communication and information technologies. In addition, they travel more to access the destinations other than jobs. Moreover, US families showed the demand to use more active mode of transportation such as biking and walking for commuting to work. These new trends might have the reflection on housing value. This study attempted to examine the topic by developing two models to compare the impact of access to job with the impact of access to the destinations other than job. The result of this study showed that housing market is still influenced by job accessibility.

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Chapter 1

Introduction

Promoting access is one of the goals in urban planning. According to Lynch (1981), access is one of the reasons that cities flourish. Accessibility (or just access) refers to the ease of reaching goods, services, activities and destinations, collectively called “opportunities” (Litman, 2008) and it involves access to social, economic, educational and health amenities. Improving accessibility would lead to social, environmental and economic benefits (Litman, 2010) including increasing workers ‘productivity and income, financial saving and individual welfare (Cervero, 1998; Litman, 2010). Moreover, access to amenities, such as jobs, education, medical care and transportation has been proved to influence real estate market (Basu and Thibodeau, 1998; Militino et al, 2004). Rich amenity locations increase the market competition with greater demand than supply. Hence, quantities and quality of amenities reflect on housing price (Tiebout, 1956) which has been the focus of accessibility and land value studies in planning.

Evaluating location accessibility is also critical for affordable housing units since in the search for affordability, low-income households make critical trade-offs between housing and accessibility. Low-income households are less likely to own a private vehicle while also, due to their limited budget and housing options, suffering from a spatial mismatch. The mismatch between individual needs and the location of critical services has been investigated on the pertinent basis of transportation equity (Welch, 2013; Grønbjerg & Paarlberg, 2001; Archibald & Rankin, 2013; Allard, 2008).

Although HUD has aimed to provide housing welfare participants with access to economic, social, and recreational opportunities (Welch, 2013; Welch, & Mishra, 2013), little is known on how well these housing programs spatially match low-income residents

with high-access-to-opportunity areas. Each year, the federal government spends the colossal amount of 50 billion dollars in housing programs assistance for low-income households (Congressional Budget Office, 2015); however, still severe housing affordability challenges continue to plague American cities and disproportionately affect the most vulnerable communities (Desmond, 2015). This is partially because transportation, location efficiency and the value of accessibility have been missed from the concept of affordability.

Accessibility is also a well stablished concept in theories of urban land market and it is theoretically known that accessibility and the agglomeration of private and public services have significant roles in explaining variations in housing prices (Adair et al., 2000; Thériault et al., 2005; Andersson et al., 2010). In agglomeration economies, housing utilities depend largely on consumption of local services and housing and access to variety of local goods (Rivera-Batiz, 1988). Households are rational decision makers that tend to maximize their utility functions (Aleskerov, et al, 2007) based on the tradeoff between accessibility and housing value which is claimed to decrease as the distance from CBD increases (Kain, 1962; Alonso, 1964; Muth, 1969; Mills, 1972). They attempt to maximize their utilities by locating to desirable place close to activities since living in further distance from CBD are associated with higher commuting costs; therefore, access to work place and commuting costs are the most important explanation for the spatial variation in housing value (Osland, L,2008).

In the same line, individuals decide about their location based on access to bundles of public amenities. Rational decision makers would leave communities with less opportunity access to public goods in favor of those with higher ones. Therefore, households are more willingness to pay for higher housing values in neighborhoods with more local public service access (Tiebout, 1956; Buchanan, 1965).

Although theories of urban housing market focus on access to variety of public amenities, large volumes of housing cost studies have been addressed access to employment opportunity to represent travel activity. While the studies focus on access to job opportunities, National Household Travel Survey (NHTS) reported that 81 % of household trips and 75 % of personal mile travel (PMT) in the United States are for non-work trips (Santos, et al. 2011). Moreover, workers are reported to work more from home. In 2010, the percentages of the workers who worked from home increased from 3.6 percent in 2005 to 4.3 percent due to the advances in technologies (US Census, 2010). In addition, transit household survey showed that in DFW, 55 % of household trips are for non-work purposes (NCTCOG, 2014).

Besides, recently, there has been a shift in trip mode among population. For example, from1990 to 2009, the percentage of car users decreased by 5 % while transit users increased by 5.5 % and walking mode rose from 7.2% to 10.4% (Santos et al. ,2011). Also, based on American Community Survey, the number of commuters who travelled to work by bike showed an increase of 61 % (Circella et al, 2015). This growing shift in household travel pattern should also show its reflection in urban spatial structures and housing market variations.

Therefore, since people make decisions based on their maximum profit and utilities, access to other destinations other than jobs should also be reflected in housing choice location and spatial variations in housing value. This implies that since access is a critical determinant of land prices, any changes on that should be reflected in housing value. Also, the shift in trip mode should be studied in housing cost models and ignoring that would lead to inaccurate results for underestimating the scale of accessibility impacts by different modes on housing value.

To address these gaps in previous studies, this research plans to overcome the limitations of the accessibility and housing cost studies by developing a housing value model that include all destination opportunities and compare the results with another housing cost model that include access to job opportunities.

The methodology for this research has several improvements compared to the literature. First, to construct the two models, this research seeks to generate access to opportunity scores (access to job opportunity and access to major opportunities). For access to major opportunity index, this research incorporates a more comprehensive destination based on the literature review including educational facilities, food sources, health care facilities, service opportunities, child and youth opportunities, elderly and disability facilities as well as job opportunities. Since the policy solutions must be implemented locally at the neighborhood scale, this research intends to create a connection between research and policy decision by developing the smallest scale opportunity access score (census blocks) to represent areas of adequate access or limited access to major opportunities.

For the purpose of this research, using the most updated road and transit network, I have generated access to opportunity index for walking, driving and transit that accounts for travel speed, transit schedules and service frequency. I have also used a method that accounts for the distance decay function based on the mode to generate access to opportunity index for all census blocks based on travel time with higher weights given to the shorter travel time.

Finally, although studies on housing value and accessibility are extensive, they have rarely accounted for multilevel modeling structure, which is mostly appropriate when dealing with different level of data. This research addresses this gap as well.

This study estimates access to opportunity for all neighborhoods in DFW to help the policy makers improve status of the neighborhoods by determining level of opportunity access, which in turn influences individuals' chance of upward mobility. The access to opportunity score determines areas with higher opportunity and lower opportunity in DFW. The findings of this study identify major deficiencies in term of accessibility in the study area, Dallas Fort Worth Arlington (DFW) as the fourth-largest metropolitan area in the United States (US Census, 2016).

The generated index also helps to determine areas worth investment for project development purposes. It also would help households to make location decisions for where to live and for developers to understand where to invest.

In addition, the result of this study helps to understand the impact of multimodal access to all opportunities on housing value, which is useful for property assessment for tax purposes (Ottensmann & Man, 2008).

Problem Statement

Local and national agencies have been involved in the process to address provision of affordable housing in the region. However, in DFW, affordable housing unit residents are spending a higher percentage of their income on transportation since housing project units are located in least efficient location areas where access is limited (Hamidi et al, 2018). Since living in compact, multimodal neighborhoods is associated with less spending on transportation (Ewing and Hamidi, 2014; Todd Litman, & Litman E., 2011), it is important to measure access to opportunity precisely to understand areas of high and lower opportunity access to direct policies accordingly.

In addition, job inaccessibility by transit has increased especially in great cities in the region such as Dallas (Hamidi et al, 2016). This is partly because there is lack of knowledge on neighborhood transit accessibility to help transit agencies to improve or

change any service frequencies by fixed or demand transit system. Moreover, lack of access to services and amenities has caused higher rate of poverty in the region. 30 % of the children in Dallas are reported to live in poverty (Tristan Hallman, 2017). One possible reason is that there is less precise understanding on public service investments in neighborhoods with lower access to opportunities.

Finally, there is less input on land value assessment. While determinants of access and housing value is known, the impact of access to all opportunities is still unknown. This is specifically important for tax policy estimation since ignoring the scale of access to major services might underestimate the impact of access on housing value.

Research Objectives

This research is the attempt to address the problems by determining areas with multimodal and multi-destination access and mapping access to opportunity to show the spatial distributions of areas of higher and lower opportunity chances for all census blocks in DFW. The attempts to develop opportunity access score has been confided to including several related destinations or employment destinations and creating the score through one or two modes of transportation. Moreover, the data sources have been developed at the larger scale.

To address this gap, this research has incorporated all major destinations and employments. The score has included access to these destinations through three modes of transportation. Also, this study creates the scores for smallest possible scale which is census block to reflect a more representative of neighborhood opportunity.

Afterwards, this research employs the developed access to opportunity score to analyze the spatial distribution of affordable housing units in DFW. The objective is to evaluate the location efficiency of major affordable housing programs in areas of opportunities by three modes of transportation. Also, this study uses access to

opportunity scores to understand the efficiencies of locations of new developments in term of accessibility factors. The result of this analysis identifies successful and unsuccessful developments in term of location efficiencies. Also, this section determines which development occurs in most accessible areas and which one occurs in least.

Finally, this research compares the effects of all major opportunity access for three modes of transportation on housing value with the impacts of access to job opportunities for three modes of transportation to determine the scale of the impacts of access. Access to destination opportunities has been proven by previous studies to be a driver of housing value (Morris et al., 1979; Handy and Niemeier, 1997; Zhu and Liu, 2004; Horner and Mefford, 2005). Previous studies, however, are structurally flawed in that they only studied some related opportunities. However, since all destinations opportunities would influence travel behavior (Preston and Raje, 2007; Miller and Ibrahim, 1998; Handy, 1993; Daly, 1997; Hanson and Schwab, 1987), this study has incorporated access to all destination to examine the impacts on housing market to find out whether access to opportunity is still a driving factor for housing market and what mode of transportation has the largest impacts.

Research Questions

This research intends to answer to the following questions:

1. How to improve methods to quantify access to opportunities to include major destinations for multimodal transportation system?
2. Which cities in DFW provide the highest and lowest access to opportunities for the residents?
3. How are the affordable housing units distributed in areas of opportunities?
4. How are the new projects distributed in areas of opportunities?

5. With new trends in household travel pattern, is still access to job a main determinant for housing value?

6. Are the impacts of access to all opportunities on the housing value different from access to jobs?

Research Significance

The result of this study helps policy maker in several ways:

First, access to opportunity scores can help to determine areas of opportunity access for investment. The access to opportunity score determines areas with higher opportunity and lower opportunity for every census block in DFW. The generated index helps to determine areas worth investment for project development purposes. It also would help households to make location decisions. Proved by the literature, access to opportunity is one of the most important determinants in location decisions. This score can benefit households and developers for any investment decisions

Second, the developed score can help planners for land use and housing decisions to bank lands in areas of higher opportunity for affordable housing purposes. Land use tools can be used to control the use of vacant lands in areas of opportunity especially for housing affordable programs. City planners and housing agencies can use access to opportunity as a tool to collaborate for housing affordability purposes.

Third, the findings of this research have implication for policies designed to improve neighborhood status for access to opportunity to enhance quality of life and upward mobility for the residents. The influence of living in neighborhoods with higher opportunity is evident and places affect individual opportunities and life outcomes (Chetty et al., 2013; Ewing et al, 2016; Galster and Killen, 1995). To address that, access to opportunity score can be integrated in policy decision making to determine areas of lower

opportunity chances. Those areas are where investment in infrastructure, public transit and vital services are needed.

Fourth, the result of this study helps to incorporate access to opportunities into transportation programs. This study can help for decision-making policies for transportation priorities and needs. Increasing accessibility for people and freight is among the recognized objectives established by legal federal policies. Transportation Equity Act for the 21st century, commonly known as TEA-21, required increasing accessibility for people among the seven “planning factor” to be considered in the regional transportation plans (FTA, 2015). Aside from that, MAP-21, the Moving Ahead for Progress in the 21st Century Act, enacted in 2012, established a performance- based framework for the federal program to help transportation agencies to invest for system’s growth and development and use resources to support national priorities and state and regional needs (FTA, 2015). In addition, The Fixing America's Surface Transportation (FAST) Act, which was signed in December 2015, continued the MAP-21 framework to assist agencies in implementing performance-based planning. Under the influence of these acts, access to amenities such as jobs, healthcare, education and other services is the primary objective of transportation planning and transportation agencies and as a key in measuring performance of their system (SGA, 2017). For example, Austin 2020 Regional Transportation Plan directly stated, “the primary goal of the CAMPO 2020 plan is to provide an acceptable level of mobility and accessibility for the region’s residents with the least detrimental effects”. Moreover, the aim of Chicago’s 2020 Regional Transportation Plan was to provide an integrated transportation system that improve accessibility to serve different needs of the residents and businesses. (Levinson, & Krizek, 2005).

Improving the quality of transit service performance has its direct impacts in improving accessibility especially for low-income individuals. Kneebone and Holmes (2015) studied the influence of job accessibility among low income and minorities. The result of the study found that low-income residents are mostly reside in high transit coverage, but less job is accessible to them via transit. Therefore, accessing jobs by public transit is a big challenge for low-income job seekers leading to limited opportunities for upward mobility. This score can help transit agencies for assessing neighborhood accessibility by transit and evaluating transit performance.

Finally, the impacts of access on housing value are useful for property assessment for tax purposes (Ottensmann & Man, 2008). This model can be used mostly for property appraisal assessment purposes (Detweiler and Radigan, 1996; Renne, 2003; Pagourtzi et al., 2003). Assessing an accurate assessment depends on the comprehensive and accurate model specifications. This model helps them to know the significant effects of location with respect to all opportunity access since ignoring location efficiencies in term of accessibility values might result in errors (Ottensmann, et al, 2008).

Dissertation Outline

The dissertation begins in Chapter 1 by introduction in which background information, research problem, objectives, questions and significant are included.

The dissertation continues to chapter 2 by reviewing and summarizing the literature on measuring access to opportunity and the impacts on housing value . It includes the theoretical framework for housing value, access to opportunity studies, access and housing value.

In Chapter 3, I have explained the steps to operationalize access. I have included components of access to opportunity measurements, introduced the study area, the data and sources used to measure access to opportunity and the method to measure it.

Finally, the chapter is comprised of the analysis and result for access to opportunity measurements.

In chapter 4, I have employed access to opportunity scores for three modes of transportation to evaluate the location of affordable housing units in term of access to opportunities. The chapter include the process for selection of samples and the result of analysis.

Chapter 5 uses the access to opportunity scores to analyze the location of new residential, commercial and specific use projects in term of access to opportunities. The chapter include the process for selection of samples and the result of analysis.

In Chapter 6, the developed access to opportunity scores has been be used for modeling the relation to housing value. For this purpose, two scores of access to major opportunities and access to job opportunities for three modes of transportation have been used for constructing the models. The chapter includes method, analysis, and result of modeling.

Finally, the dissertation ends in Chapter 6 with the discussion of findings, conclusions, limitations of the study, and policy recommendations and any future direction for research.

Chapter 2

Literature Review

Access to Opportunity Studies

Accessibility is a well-known concept in the transportation planning and is defined as “the ease (or difficulty) with which activity opportunities may be reached from a given location using one or more modes of transportation” (Chen et al, 2011, P 58). Therefore, accessibility incorporates transportation system and land use performances in a region and previous studies have provided guidance to develop the methodology to measure access.

The attempts to develop measures to link land use and activity with the transportation networks has started with Hansen (1959). He defined accessibility as interaction potentials, considering the distance between an origin and a destination, and number of opportunities at a destination. His contribution gave rise to the formulation of gravity model with inverse power impedance function (Hansen, 1959).

Zhao et al. 2003 also used gravity-based model to estimate transit and walking accessibility for home trip ends. Their methodology assumed distance attenuation on opportunities. They did not distinguish among opportunities and counted the number of opportunities weighted by their distance to the origin (Zhao et al., 2003). Sanchez et al. (2004) also developed a model to provide empirical evidence to support the positive impacts of public transit accessibility for employment status of low-income individuals. They compared job access by car to job accessibility by transit and they incorporated both transit and auto for job opportunity access based on gravity-based method and the distance decay function. They chose a negative exponential function to represent the travel friction effect (Sanchez et al., 2004).

Chen, Yali, et al (2011) also developed accessibility maps based on three indicators of the number of employees by industry, length of roadways by function, and the number of transit stops in for 10, 20, and 50 minutes' travel times. The accessibility values have been created by counting block characteristics including the number of employees by industry type, length of roadway by functional classification, and the number of transit stops within a buffer of block. The accessibility index accounted for time and space. The generated accessibility index intended to support the development of the Southern California Activity-Based Travel Demand model. However, the index is generated based on using motorized vehicle and did not consider travel speed for access to jobs.

More recently, Liu, Knaap et al. examined the conceptual framework of opportunity mapping developed by the Kirwan Institute for mapping opportunities in the Baltimore region. They finally measured total opportunity index out of six indicators of education, housing and neighborhood quality, social capital, public health and safety, employment and workforce and transportation and mobility by different weights. Specifically, they computed job access by the number of jobs accessible by auto and jobs accessible by transit and accessibility gap between transit and auto. Also, for transportation indicators, they included travel time and transit access by the distance (quarter mile distance from stops). The paper categorized the opportunity index using five quintiles, with the lowest quantile for very low opportunity areas and the highest for very high opportunity areas. The index was overlaid with the public housing project to shows access to opportunities for their residents.

To estimate neighborhood's likelihood to provide high quality housing and conditions, McClure, K. (2011) produce an index for every Census tract and block group in the United States and Puerto Rico using multiple housing, demographic, and economic

criteria. The index was designed to identify neighborhoods with low poverty rate and high employment and education opportunities, with rental units at or below Fair Market Rent limits. The index helped Public Housing Authorities (PHAs) with the HCV as well as other HUD programs to select area of opportunities. The index has been generated using six factors of poverty, minorities and dropouts, educational attainment, race and ethnicity, low-cost rental housing, turnover of housing and large-scale housing markets with commuters at two levels of tracts and block groups. The research used a large scale and recommended developing opportunity index using microscale data for poverty rate, educational attainment, employment levels and, ease of access to employment, race and ethnicity and presence of other assisted households (McClure 2011).

Finally, Wilson and Greenlee (2016) examined the distribution of opportunities in rural areas in the United States during 2000 to 2010 for counties for 48 states. They developed multidimensional index using indicators of job and local economy, education, civic life and health. The result showed that while urban counties held the highest opportunity index, nonmetropolitan and rural areas had the lowest. The paper found that not only spatial location of high opportunities shifted from the Northeast to Midwest regions but also areas such as the Mississippi Delta, Lower Rio Grande Valley and Appalachia were getting the lowest rank. However, this research also suggests using smaller scale data for more detailed location insights.

Recently, there have been some practices to develop access to opportunity indices at different scales, from neighborhood units to the national level by different mode to make accessibility data available to the public and policy decision makers. The "Access across America" series (2013) measured access to jobs through various modes of transportation and access time. The study measured job accessibility by transit, car and by walkingfor major metropolitan areas in the United States using a weighted

average methodology. The study weighted the highest to residential location with access to jobs in 10 minutes or less while resident locations with access to jobs in 60 minutes or more were given less weight. The study also accounted for travel times. For transit, travel time was calculated using detailed pedestrian networks and full transit schedules for 7:00 to 9:00 a.m. period considering components of a transit journey. For driving time, the study compared the result for travel time of 8 a.m. Wednesday morning departure with 4 a.m. to estimate the impact of road and highway congestion on job accessibility. The research, finally, ranked the metropolitan areas by averaging person-weighted job accessibility for six travel time thresholds and distance weighted function (Owen et al., 2015a; Owen et al., 2016; Levinson, 2013).

Center for Neighborhood Technology (CNT) also created AllTransit website using General Transit Feed Specification (GTFS) data – as the largest source of transit connectivity, access, and frequency data across America- to rank places based on transit performance. This website measured accessibility through some developed metrics for economic opportunities, job accessibility, health accessibility, transit equity and quality and mobility network within 30-minute transit ride. The website finally ranked cities based on their performance score, accessible jobs within 30-minutes' ride, connectivity to other routes and the number of employees using transit to commute. As examples, the website ranked New York City—with the score of 9.60— as the highest and Arlington, TX— with the score of 0.13— as the lowest (CNT, 2013). The study took 30-minute transit ride to access job, which is the threshold for the study as well.

While the study provided basis to quantify access and quality of public transit at national level, it came with some limitations. The website created the index by focusing only on access to employment (in general) and many major daily destinations such as health care, food, education, senior facilities, nursing and childcare are missed from this

index. Moreover, normalization method on the scale of 0 to 100 to develop the index from the data has some limitation. For example, this normalizing method would scale outliers to very small intervals. Finally, the study used Longitudinal Employment-Household Dynamics (LEHD) that is highly aggregated by employment sector and it is not possible to break it down for specific destination.

Conceptual Framework For Housing value

Housing is a unique commodity since while some might have similar features, they have specific characteristic. Housing is" spatially immobile, highly durable, multi-dimensional heterogeneous, physically modifiable commodity" (Arnott, R., 1994, P 2) which requires large amount of capital investments. These diverse characteristics make housing studies a complex one viewed by different approaches. Housing studies started to develop by late 1960s; Pugh (1986) mentioned that complex nature of housing market makes it difficult to fit into a single theoretical framework.

Neoclassical approach to housing drew its theoretical framework from neoclassical economics that related supply and demand economics to individual rationality and ability to maximize utility. This approach viewed society as collection of individuals whose preferences shape the economy (Pugh, 1986). They shifted the focus from production circumstances toward the needs and preferences of individual consumers (Bassett & Short, 1980). In this theory, households demand goods and services that meet their preferences to maximize their utility. They claimed that a rational decision maker tends to maximize his utility function when facing a condition to choose among alternatives (Aleskerov et al, 2007). Rational choice model determines the process of available options and choosing the most preferred one based on some consistent criterion. The theory assumes that people try to maximize their advantages and minimize their costs (Gorg, and Strobl, 2006; Basile et al, 2009).

Neoclassical economics is based on four assumptions: First, the consumer preferences reflect the production of goods and services. Second, households and individuals have perfect information. Third, households and firms intend to maximize their utility and profits. Fourth, the production is assumed to be flexible and its factors are easily interchangeable (Colander, 2000).

Although, neoclassical economics had their mainstream in Europe and North America, their assumptions facilitate the framework for housing structure studies including model of residential location and the hedonic price modellings.

Models of residential location focus on the relationship between location of housing space and travel costs. The general hypothesis is that households make residential location decisions based on the tradeoff between accessibility and housing value, which decreases, as distance from CBD increase (Kain, 1962; Alonso, 1964; Muth, 1969; Mills, 1972). Accordingly, commute costs, distance, housing value and income are included in this framework to predict spatial variations in housing market. Monocentric models of urban land values such as Alonso (1964), Mills (1972), and Muth (1969) are examples of models based on this theoretical framework. These monocentric models were based on Von Thünen's (1825) theory of agricultural land use claiming that households living in further distance from CBD are compensated for higher commuting costs and lower housing price. The most important explanation for the spatial variation in housing value are access to work place and commuting costs (Osland, 2008).

In the same line, the model of local public goods claimed that individuals decide about their location based on access to bundles of public amenities. Based on this model, rational decision makers would leave communities with less opportunity access to public goods in favor of those with higher ones. This approach assumed more willingness

for higher housing values in neighborhoods with more local public service access (Tiebout, 1956; Buchanan, 1965).

The hedonic price model, however, deals more features such as site, physical features, legal characteristics and location factors to explain the spatial variation in housing value. Hedonic modeling estimates the extent that opportunity access can be capitalized into property prices. Developed by Lancaster (1979) and Rosen (1974), the model is one of the most common framework used to explain local variation in housing value and prices assuming that housing price is “a smooth, differentiable and continuous function of its attributes” (Nilsson, 2013, P 23). Therefore, in this model, housing units are heterogeneous goods that are differentiated by their quality attributes and consumers make their decision based on the number of attributes and price of each quality attribute (Nilsson, 2013; Xiao, Y., 2017).

According to Rosen 1974, the total price of a housing unit is based on sum of the value for each homogenous attribute, which has a unique implicit value in an equilibrium market. This implies that the value of a housing unit can be regressed on its attributes to assess the extent of each feature contribution to the overall composite unit price (Xiao, 2017).

The hedonic approach has two significant advantages over other models to measure the values of commodities in housing market. First, the inclusion of multiple features of housing into one dimension allows to use a homogenous commodity assumption and avoid the complexity of multi-commodity models. Second, the model gives weights based on the differences in the value of feature (Xiao, 2017).

Many different attributes influence house prices including housing attributes, neighborhood specifications and locational attributes (Freeman, 2003). The structural attributes include the size of the property, house area, and other improvements. The

locational attributes are comprised of the accessibility to different land uses and buildings and environmental amenities. Neighborhood specifications include neighborhood features such as ethnicity, income and socio-economic factors (Treg, 2010).

Housing value and Access to Opportunities

Theoretical framework for the relationship between housing value and accessibility was first introduced with work of Von Thünen (1863) who explained farmland value variations in term of accessibility. In subsequent studies, economists like Alonso (1964) and Muth (1969) developed bid-rent theory claiming that accessibility affects land value with higher values for higher accessibility to goods and services. In bid rent model, accessibility was measured through distance from central business district (CBD) that was the dominant factor for explaining land value changes (Alonso, 1964; Muth, 1969). Therefore, early studies were mostly concerned with central location effects – mostly CBD – on land or housing values and were frequently studying with environmental attributes (Richardson,1971; Pollakowski, 1982), air pollution (Anderson & Crocker, 1971) and commuting costs (Henderson, 1977).

However, transportation technology changed the demand pattern by attracting households to properties close to investment area (Fejarang, 1994) and CBD was no longer as the attractive quality. With introduction of hedonic price model, characteristics of demand side of housing market were also added. As a result, microscale and mesoscale qualities were recognized to influence housing prices.

The relation between access to amenities and housing value has been heavily studied in literature through hedonic modeling to examine structural features as well as neighborhood qualities, which influence housing prices differently.

- *Property Qualities Of Housing value*

Previous literature has recognized the importance of attributes of the properties, which refer to characteristics that households are willing to pay relative to shelter locations (Koramaz & Dokmeci, 2012). The recognized features include the number of bedrooms, bathrooms and living room, availability of elevator, parking, patio, pool and fireplace. Using 32 variables for seven metropolitan areas in the United States, Palmquist (1984) concluded that twenty-three factors in housing units are related to housing value including year of construction, number of bathrooms and finished interior area. Studies found a positive relationship between dwelling floor and values since units in higher floors enjoy better views and a quiet environment (Marks, 1984; Tseng et al., 2005). However, units in ground floor are easily accessible and might be used for retail activities. This might also influence their value positively.

Age of the structure, however, is recognized to influence the land value negatively. The prices of properties often decrease as the age of the buildings increase (Guntermann and Norrbin, 1987; Lin, 1993; Marks, 1984; Sirmans et al., 1989; Tseng et al., 2005).

- *Neighborhood Qualities Of Housing value*

The impact of the neighborhood features on property values can mostly be explained by two theories of social interaction theory and Tiebout (1956) theory of local expenditure and consumer choice. Social interaction theory focuses on the role of neighborhood to influence social capital, human capital and cultural capital. Fu (2007) has recognized three social interactions that amenities in the neighborhood can influence: human capital, social capital, and cultural capital. Neighborhoods can influence human capital through knowledge, information and skills spillovers. This implies that well educated people tend to attract each other since by living together they can get higher

utilities (Rauch, 1993). The utility of social capital effect of neighborhood through obtaining labor market information is also capitalized into housing market. Cultural capital refers to customs, tradition and belief that can identify certain social groups. Dubin and Sung (1990) study showed that racial and cultural differences have a major impact on housing price.

Moreover, in Tiebout model, rational decision makers would tend to pay to live in communities with higher access to more local public service access. In addition, in his theory of local expenditure, he claimed that households of similar interests tend to make homogeneous neighborhoods (Tiebout, 1956). Based on that, urban households in one neighborhood can afford to pay for similar social, economic and physical demand.

Neighborhood features are considered as public amenities since they are “locally intrinsically non-excludable and non-rivalrous” (Zoppi, et al., 2015, P 370); as a result, as the quantity of public bad increases, the value of houses would decrease and vice versa (Zoppi, et al, 2015). For example, crime rate would decrease the value of housing nearby; however, quality school would influence the industry positively.

Neighborhood features of housing value include factors such as socioeconomic variations (Chen and Lin, 2010; Risselada et al., 2013; Can, 1992; Fotheringham, et al, 2003; Yu et al., 2007), population density (Bowes and Ihlanfeldt, 2001) and school quality (Zoppi, et al, 2015).

Socioeconomic conditions of the neighborhood such as median income, rate of unemployment and education level also recognized to affect housing price (Chen and Lin, 2011; Risselada et al., 2013). Studies show that housing segregation - a result of income and education variation - is evident in the United States (Can, 1992; Fotheringham, et al, 2003; Yu et al., 2007). Residents with similar socioeconomic characteristics have similar preferences for housing choices. Glaeser and Gyourko

(2005) showed that high income and white households overpay to live in exclusive neighborhoods. Also, highly educated people may prefer to live in compact communities (Lewis and Baldassare, 2010). Low-income residents also might prefer to live in neighborhoods with better transit access than high-income individuals did. This racial segregation affects the land value (Nelson, 1998; Bowes and Ihlanfeldt, 2001).

The results of studies on population density are mixed. While high population concentration would lead to premiums on commercial properties due to influence on retail activities, it would attract more criminal activities, which in turn decrease value of land (Bowes and Ihlanfeldt ,2001).

Accessibility is a central concept in hedonic cost modeling and is defined as the ease with which individuals can reach activities or destinations (Morris et al., 1979; Handy and Niemeier, 1997; Zhu and Liu, 2004; Horner and Mefford, 2005). Changes in accessibility drive changes in value of land. Literature has recorded large volume of the studies on the topic.

However, the effect is different by the mode. For example, Du and Mulley (2012) examined car and public transit accessibility effect and observed different price effects. Also, there are variations in term of examined destinations and opportunities. The extensive hedonic pricing literature reveals that property values are functions of access to job, services and amenities. The models have been used to examine the impact of access to parks, schools, job and other facilities.

The literature has recognized both positive and negative impacts of accessibility on housing value. Access to job opportunities has always been a positive determinant of land prices. For example, Edlund, et al. (2015) study proved that places within five-mile distance of urban center witnessed significant premium in 2010 and neighborhoods more than ten miles away from city centers experienced decline in value since 1980. Also,

using transaction data from Los Angeles, Giuliano, et al. (2010) also found that job accessibility positively affects land prices. However, the effect of job access by transit is different from access by car. Du and Mulley (2012) found that housing value increase as travel time by car increases but it decreased with increasing commute time by transit.

Educational resources are also the key consideration of house buyers since quality of school affects good initial education. Many scholars have explored the impact of access to school quality on house values and found a positive correlation between school accessibility and housing value (Oates, 1969; Gibbons and Macchin, 2008; Fack and Grenet, 2010). School proximity has advantages of reduced school commute time with more security benefits for children, parents' involvement with their children education progress and strengthened communication of school and families.

Empirical research also showed that proximity to recreation centers such as lakes, rivers, parks, and mountains have substantial effects on the housing price since residents are willing to pay additional prices for natural amenities (Loomis and Feldman, 2003; Hill et al., 2007; Sander and Polasky, 2009). Changes in property values, though, are limited to a certain distance and size of the recreation centers (Zhong et al., 2009; Lutzenhiser and Netusil, 2001; Hobden, et al. 2004).

However, negative externalities of access to amenities such as noise and traffic congestion might depress the value of nearby properties. Negative externalities such as noise, traffic and parking problems, pollution from automobile or the operating hours as well as architectural incompatibility from church or schools would influence real estate market (Do et al., 1994; Babawale & Adewunmi, 2011). Likewise, properties in proximity to airport might experience reduced value (Nelson, 2004; McMillen, 2004).

Table 2-1 Table of Major Finding for Reviewed Studies

Variables	Source	Major Findings
Access to job by walk	Cortright, J. (2009); Leinberger & Alfonzo (2012)	(+) (-)
Access to job by car	Pendall, et al. (2014)	(+)
Access to job by transit	David E. Boyce et al (1972); Pendall, et al. (2014)	(+)
Age of the structure	Can A. (1990); Tian, et al. (2017); Can, A. (1992); Tseng et al. (2005); Cortright, J. (2009).	(-)
Number of bedroom	Can, A. (1990); Waddell, P. (1993); Tian, et al. (2017); Can, A. (1992)	(+)
Number of bathroom	Petersen & Coe (2017); Tian, et al. (2017); Can, A. (1990); Can, A. (1992); Palmquist (1984)	(+)
Square footage	Kolowe, P. (2014); Tian, et al. (2017); Can, A. (1990); Can, A. (1992)	(+)
Crime Rate	Pope, D. G., & Pope, J. C. (2012); Dubin & Goodman (1982)	(-)
Population Density	Waddell, P. (1993); Bowes and Ihlanfeldt (2001)	(-)
Employment Density	Tian, et al. (2017); Wang et al, (2012)	(+)
Racial Diversity	Wang et al, (2012)	(-)
Compactness Score	Lewis and Baldassare (2010); Nelson, et al (2015)	(+)
Entropy	Song& Knaap (2004); Rodriguez and Mojica (2009); Van Cao& Cory (1982)	(+)
Education Attainment	Tian, et al. (2017)	(+)
School Performance	Gibbons and Macchin (2008); Fack and Grenet (2010); Nguyen-Hoang & Yinger (2011)	(+)
Property Tax	Oates, W. E. (1969); Sirmans et al (2008)	(-)

– *Other Qualities Of Housing value*

City features might influence housing market. Tiebout theory claimed that consumers choose the communities that offer various local public services as well as tax programs that maximize their utilities. Therefore, city public services and tax influence the

location decision process and local property values. Oates, W. E. (1969) studied the impact of local expenditure and tax rate on local property values and he found a significant negative relationship.

Crime rate can also be viewed as a dis-amenity in housing market and is negatively related to property values. Pope, D. G., & Pope, J. C. (2012) estimation showed that the elasticities of property values with respect to crime ranges from −0.15 to −0.35.

Integration Of Access To Opportunities And Location Decision

Individual decisions form the basis for most of economic analysis including the model of rational choice in decision-making. Rational choice model determines the process of available options and choosing the most preferred one based on some consistent criterion. One of the most important family decisions is the place to live. Residential choice decision is also an important aspect of the planning process because it determines the demand for community facilities and services (Pinto, 2002; Lin & Long, 2006). A large body of research has studies location choice by households (Dieleman, 2001; Michelson, 1977; Baerwald, 1981; Bassett & Short, 1980; Bell, 1968). According to the traditional utility maximization theory, households make residential location decisions based on their job accessibility to minimize commute costs. However, they have frequently been influenced by other factors too. Housing location decision is a complex one, affected by the factors that can be broadly categorized into five, including neighborhood features, transportation costs, demographic and socioeconomic status and regulatory and policy measures (Lasley, 2017).

Socioeconomic status of the families such as race, income and stage of life is one of the predominant criteria for residential location decisions (Bourne, 1981; Rossi, 1955; Clark & Huang, 2003; Clark et al., 1984). Clark and Dieleman (1996) examined the

influence of life stage on housing choice and concluded that in each stage of life, families have different preferences based on their need. Also, Kotkin (2015) examined the views of the baby boomers and millennials on housing locations and types. He founded that Millennials prefer the suburban locations to urban livings due to their concerns such as job location, traffic congestion and quality of neighborhood (Kotkin, 2015). The National Association of Realtors study (NAR,2000a) pointed out that the declined number of household headed by persons aged 25 to 35 might cause the increase the demand for city living.

Race and ethnicity also influence housing location decision since people might prefer to live mainly in neighborhoods of the same race (Gabriel & Rosenthal, 1989). Even race and income have been an evident factor for government investment for residential project decisions. Examining affordable housing projects location decisions, the researchers found that LIHTC projects have mainly been built in areas with higher concentration of minority residents with higher rate of poverty in suburban locations (McClure, 2006). The result suggested that race, poverty and distance from central cities are the important determinants of assisted housing projects. Also, in Oakley (2008) study, variables such as poverty rate, rate of unemployment, vacancy rate, and median income were also significant.

The effects of neighborhood characteristics on residential location decision choices are well documented in the literature (Li and Brown, 1980; Maher and Saunders, 1994; Daokmeci and Berkooz, 2000; Chhetri, et al.2006). In survey of the National Association of Realtors in 1999, for most of the homebuyers, neighborhood was the main reason for choosing a location (NAR, 2000b). Features such as crime rates, income levels, racial segregation, proximity to local amenities, and school quality have always been important criteria for choosing a place to live (Chhetri, et al., 2006; NAR, 2000b).

Families prefer to live in areas with access to high quality schools, good local amenities, accessible recreation spaces and safe and socially homogenous neighborhoods (Hur & Morrow-Jones, 2008; Karsten, 2007).

The effect of transportation costs on housing choice location has been reinforced with theories supporting the integration of decisions in both transport and land use models (Le Roy and Sonstelie, 1983; Brown, 1986). Aside from the location decision factors, they have frequently included travel variables such as mode of travel-to-work, automobile ownership, trip distance and parking costs (Lerman, 1976; Levine, 1998; Quigley, 1985; Sermons and Seredich, 2001). Brown (1986) also suggested that travel mode and residential location are dependent from each other. In a recent study, DeSalvo and Huq (2005) found that high-income individuals use faster travel mode but have shorter travel distance, meaning that they are more likely to live further from CBD. In addition, the results of the research by Horner et al. (2005) showed that individuals prefer residential locations with shorter commuting time, and lower transport costs.

However, some study showed that as long as people can afford flexible means of transport, the accessibility and transportation cost impacts on the residential location choice are significantly less important (Giuliano, 1989; Molin and Timmermans, 2003; Eliasson and Mattson, 2002; Mun et al., 2005). In the report “Smart Growth: A Resource for Realtors”, prepared by the Economics Research Group of the National Association of Realtors, in household residential location, transportation factors such as access to stores, traffic congestion and workplace proximity was ranked lower than other attributes of neighborhood(NAR,2000a). Therefore, the importance of transportation variables is less evident.

State and local regulatory policies influence location decisions since it might steer specific types of development. Cervero (1989) identified several of these measures

such as zoning (including exclusionary zoning), tax structure and tax base sharing, tax incentives to developers, transportation pricing, and private sector initiatives. In addition, policies might give direction to specific type of development. For example, to achieve transit-oriented development policies, Calthorpe and Fulton (2001) recommended an average residential density of at least ten to fifteen dwellings per acre. Also, Evans et al. (2007) suggested TOD land-use pattern of residential, employment and shopping opportunities designed for pedestrians and cyclists without excluding cars. These regulatory policies have change location decision including residential ones.

- *In the Context of Texas and DFW*

Expansion and relocation of major industries has led to regional economic growth in DFW (Hethcock, 2015). Despite its status as a magnet for major corporate headquarters and company operations with low costs of living and affordable housing opportunities, and access to a strong transportation system, the region has ranked below average for access to opportunity. (Child Trends and Opportunity Nation, 2017). Therefore, it is critical for a dynamic region such as Dallas Fort Worth Area (DFW) to move toward a more resilient environment by understanding the potentials and linking them with the investment decisions. This section reviews some studies for residential location decisions in Texas and DFW.

To understand residential location choice in Austin, Bina, et al. (2006) did a survey of more than 900 homebuyers. The survey included Household characteristics, housing features and location attributes. The paper intended to examine the role of access in residential location decisions by investigating housing priorities and tradeoffs. The study modeled home value, amenity preferences, home type and location choice. The study showed that while access was significant particularly for certain demographic

groups, other factors such as commute costs, land value, and lot size were prominent in the home location decision (Bina et al., 2006).

In another study, Habib & Kockelman (2008) surveyed home movers in Austin to examine recent mover preferences for location choice and home type. By using a series of nested logit models, the study showed that home type is an upper-nest decision, relative to location. The study also show that people prefer areas with more households but lower population density with fewer children. Income also was an important factor for location decisions.

Waddell, P. (1993) also examined the role of workplace in residential location decisions in DFW. The study found that workplace plays an important role since people tend to balance their commuting distance. However, income and family status influence their preferences. The study proved that socioeconomic status, stage of life cycle, and race and ethnicity, affect choice of residential location.

Guo & Bhat (2001) also examined household residential location choice by using a sample of single wage-earner households from the Dallas-Fort Worth region in Texas. While accessibility was generally recognized as the dominating factor in residential location choice, access to employment opportunities was not an influencing factor except for educated workers. Other factors such as school quality and land use mix were identified as influencing residential location choices. The study found that land use is also an important consideration and higher percentages of office spaces is associated with less number of residential locations. Furthermore, the study found racial segregation and racial group preferences for specific types of neighborhood attributes.

These studies add to the literature of business and housing location decisions in Texas particularly in DFW; however, with the growth potentials in this area, there should be more studies to steer the direction for new development investment in this region.

Overview of National Housing Programs

U.S. Department of Housing and Urban Development (HUD) provides a number of different subsidized housing programs in the United States that can be categorized in three major types. These three major types are public housing, housing choice vouchers (HCVs), and multifamily housing. Housing choice vouchers (HCVs) is also referred to as tenant-based rental assistance (TBRA) while multifamily programs have historically been known as project-based rental assistance (PBRA) (Helms, Veronica et al, 2017).

- *Public Housing*

Originated in 1937, U.S. Department of Housing and Urban Development (HUD) built housing projects as the main housing federal assistance for families to provide housing for individuals and families that cannot afford private market due to poor health condition, low income or unemployment (Sandler, 2017). The program replaced New Deal initiative that finance the development of low-income housings and it issued bonds to finance interest and principal costs by federal government and operating cost through tenant rental payments (Schwartz, 2014).

The Housing Act of 1949 introduced a new and comprehensive approach to housing through determining income limit and arranging subsidies to incentivize private development of affordable housing, which was further expanded in the late 1960s. However, in 1980s, lack of political support declined development of public housing government started new approaches in federal assistant and Hope VI funds were used to tear down distressed public houses (Andersson, F., et al, 2016).

The programs provide safe and decent housing different size and types from single-family houses to high-rise apartments. The U.S. Department of Housing and Urban Development (HUD) provide aid to local housing agencies (HAs) that are in charge of managing low income housing for residents with affordable rents based on income limits

which varies in different geographic locations. Currently, 3,300 local housing agencies are managing public housing units, which serves approximately 1.2 million households (HUD.GOV, 2017).

Several programs have been recognized to transform public housing.

a. Hope VI

Born out of National Commission on Severely Distressed Public Housing work to propose a national action plan to eradicate strictly distressed public housing stocks, Urban Revitalization Demonstration (URD), or HOPE VI, program has had a vital role in transforming public housing projects (HUD.GOV, 2016). The program addressed changing the physical appearance of public housing, providing incentives for self-sufficiency of the residents to empower residents, reducing poverty concentrations by placing them in no poverty neighborhoods, creating mixed-income communities and stablishing partnerships with other local agencies and government entities to leverage support (HUDGOV, 2017).

A variety of activities are permitted under revitalization and main street grants including but not limited to demolition, rehabilitation, reconstruction, and other physical improvements; management improvements; supportive services and planning activities (HUD.GOV, 2016). Moreover, the program offered some tenants housing vouchers to find housing elsewhere or any other public housing projects units (Andersson, F., et al, 2016). Approximately $6.2 billion were awarded under 262 revitalization grants from 1993 to 2010 (HUDGOV, 2017) and about $500,000 available award were announced in 2016 for main street grants (HUD.GOV, 2017). For this program, any PHAs that has distressed public housing units in its inventory can apply.

b. Public Housing Homeownership (Section 32)

Section 32 of the U.S. Housing Act of 1937 stablished public housing homeownership program, which replaced public housing homeownership Section 5(h). The program provides low-income families an opportunity to purchase public housing dwelling units through converting rent into a mortgage payment (HUD.GOV, 2016). Under this program, PHA may sell all or a percentage of a public housing development to eligible residents in public or non-public housing residents; assist public housing residents through Capital Fund to purchase homes; or, provide low-income families with Capital Fund assistance to acquire homes. PHA may ensure to sell the homes to the qualified homebuyers with income at or below 80% Area Median Income (AMI) or a Purchase and Resale Entity (PRE) (HUD.GOV, 2017).

c. Public Housing Capital Fund

This program combines the former legacy public housing modernization programs which was including the Comprehensive Grant Program (CGP), the Comprehensive Improvement Assistance Program (CIAP), and the Public Housing Development Program (which encompasses mixed-finance development), into the Capital Fund Program (CFP). It allows PHAs to request an exception for Total Development Cost (TDC) for utility management and capital planning and related activities of public housing projects (Lanham, 2013).

Fifty percent of the fund is allocated for modernization need and the other half is based on accrual needs. Quality Housing and Work Responsibility Act of 1998 (QHWRA) is also allowed to repay the debts to finance public housing rehabilitation and development (Djoko, 2011).

- *Housing Choice Vouchers (HCVs) (Tenant-Based Rental Assistance (TBRA))*

Currently, the most prevalent form of housing assistance is offered to low-income families, the elderly, and the disabled under this program. While public housing and privately owned rental housing support the construction and development of affordable housings, this program enables low income families to access housing in private market by providing direct rental assistance to housing tenants through vouchers (Schwartz, 2014; Andersson, F., et al, 2016; Wood & Mills, 2008). Since housing assistance is provided on behalf of the family or individual, participants are able to choose apartment of their choice that meet the requirements; therefore, there might be more growth in the number of voucher requests (Lens, 2014). 1970 US house legislation laid the groundwork for the Experimental Housing Allowance

Program (EHAP) to allow families to choose their housings to test the practicality of tenant-based assistance. At the same time, Section 8 Housing Certificate program of Housing and Community Development Act of 1974 enabled the renters to find privately owned housing within the jurisdiction of the housing authority that provide assistance. By the 1980s, HUD added vouchers to the Section 8 program to expand resident choice and decentralize poverty. In 1998, the two programs were merged into a single program of the Housing Choice Voucher (Varady, D. P., & Walker, C. C., 2003).

The program allows low-income families to afford renting housing in private market that meet quality standard through contracts with private property owners. Vouchers have no determined maximum rent and low-income households agree to pay the excess over the payment standard, which is determined by Fair Market Rent (HUDUSER, 2017). Fair Market Rent is a local based housing-cost benchmark corresponding to the 40th or 50th percentile rent for a rental housing unit with standard quality (Bieri, D. S., & Dawkins, C. J., 2016; Eriksen, M. D., & Ross, A., 2013).

The U.S. Housing Choice Voucher currently provides housing subsidies to more than 2.1 million low-income households through variety of major sub-programs:

a. Homeownership Voucher Program

Under this program, an eligible family that tend to purchase a dwelling unit is provided with monthly tenant-based assistance (HUD, Federal Register, 2003). This program support Housing Choice Voucher families to buy homes. Not all PHAs participate in the program and the program is relatively small. Local PHA needs to conduct initial housing quality standards inspection for potential homes and independent home inspection. Since the program is portable, Eligible families may purchase a home outside local PHA boundary (HUD.GOV, 2017).

b. Project Based Vouchers

Initially, the program was enacted in 1998 as part of the statutory merger of the certificate and voucher tenant-based assistance programs. However, in 2000 the project-based voucher law was revised significantly (Federal Register, 2005).

As a component of housing choice voucher program, under this program, public housing agencies can attach a maximum of 20 percent of assistance to a specific housing unit if the owner rehabilitate or construct the unit. It provides rental assistance to the qualified families that tend to live in privately owned buildings or units meaning that the families do not get to choose the unit to live in (HUD.GOV, 2017). Except for units designated for the elderlies, disabled, or special supportive units, approximately, 25 percent of the multifamily project units might have project-based voucher assistance (Federal Register, 2005).

c. HUD Veterans Affairs Supportive Housing Program (HUD-VASH)

Started in 1990s, this is the largest permanent housing support program for homeless veterans, which operates at over 130 Veterans Affairs (VA) facilities in the whole

nation. In combination with the Department of Veterans Affairs (VA) case, management and clinical services provided for very low-income homeless Veterans, HUD provide housing assistance through its Housing Choice Voucher Program. To participate in the program, the veteran has to agree to involve in treatment plan that involve other management and clinical services (Perl, 2015).

d. Section 8 Moderate Rehabilitation Program

As an expansion of the rental certificate program, the program was designed in 1978 to upgrade national housing stock. The program attaches Housing Choice Voucher (HCV) rental assistance to rehabilitated privately owned units; therefore, assistance is attached to units, not to tenants. The program was repealed in 1991 and no project is authorized to develop under this program; however, it no longer continues to accept new additional units under this program (HUD.GOV, 2017).

e. Section 8 Rental Certificate Program

The program is authorized by Section 8(b) (1) of 1937 U.S. Housing Act for existing rental housing and Section 89(d) (2) for project-based certificates. It was merged with the Section 8 Housing Choice Voucher program in 1998. There are a few units under this program and the current funding supports only for renewal of assistance for families in the assisted housings. The qualifying households may use the fund in any rental unit in which the property owner agrees to participate in the program (HUD.GOV, 2017).

– *Multifamily programs (project-based rental assistance (PBRA))*

The third major rental assistance is a collection of programs referred to as multifamily assisted, or, project-based rental assistance (PBRA). Their common similarity is that they provide assistance for property owner of private housing who agrees to have a certain percentage of their housing units at affordable rates. Therefore, unlike a tenant-based rental assistance program (e.g., HCV), it is tied to the property, and it does not follow

the tenants when they move to another property. The subsidies pay the difference between total rental cost and tenant rent (HUDUSER, 2017).

Multifamily properties mostly have more than four dwelling units. Some are developed with some subsidized units and some with market-rate. There are many different types of multifamily housing programs with their own rules. Relevant programs are described below.

a. Section 221(d)(3) Below Market Interest Rate (BMIR) Multifamily Housing

The program insures the mortgage loan to facilitate construction or rehabilitation of multifamily rental housing through reduced mortgage interest rate within a range of 1% to 3%. To improve the financial status of the projects, project-based rental assistance through Section 8 Loan Management Set-Aside (LMSA) can be used to BMIR projects with higher operation cost (HUD.GOV, 2017).

b. Section 236 Multifamily Housing MF Housing

Established by the Housing and Urban Development Act of 1968, the program combined mortgage insurance and reduced interest rate for the mortgagee to develop low rental housings. The program provides subsidies to reduce the interest rate as low as 1 percent. All the tenants have to pay at least the Section 236 basic rent for their property or might pay a rent up to the Section 236 market rent depending on their income. HUD might allocate project-based rental assistance through Section 8 LMSA or Rent Supplement or Rental Assistance Program (RAP) to a Section 236 property to reduce operating costs. The program no longer provides insurance or subsidies for new mortgage loans (HUD.GOV, 2017).

c. Section 236 Rental Assistance Program (RAP)

Established by the Housing and Community Development Act of 1974, it was only applicable to Section 236 properties. The program reduces rent payment to 10 % to 30% of income. Most of the program contract were converted to Section 8 LMSA contracts. Currently there are 120 active contracts with 12,219 units (Trust, 2015).

d. Project-based Section 8 Assistance for Multifamily Housing

As the largest one, the program was authorized in 1974 and provides rental assistance for families that tend to live in newly constructed, rehabilitated rental apartment projects. Other programs support the rents for project. In addition, the assistance became available for Section 221(d) (3) and Section 236 development with financial problems. These subsides are "project-based", meaning that the assistance is available for the assisted units of a particular mortgaged property for a determined period (Development, 2013).

e. Section 202 Housing for the Elderly Program

As part of the Housing Act of 1959, last authorized in 2003, the current Section 202 program provides capital grants and rental assistance to developers to build affordable housing for very low-income elderly households. The program has changed several times since its inception and its history can be divided into three separate phases; during 1959 to 1974, the program extended the low interest loans to developers for construction of affordable units to moderate-income elderly households and households with a disable adult member. Between 1974 and 1990, the program added project-based Section 8 rental assistance to subsidize tenant rents. Beginning in 1990, the Section 202 loan program was replaced with capital grants and PRAC (project rental assistance contracts) with units available to very low-income elderly households (Perl L., 2010).

f. Section 202 with 162 Assistance –Project Assistance Contract (PAC)

This section give assistance in form of Project Assistance Contract (PAC) to facilitate affordable 202 projects for the disables. The contract covered the difference between property cost and tenant rents as well as loan debt services (HUD.GOV, 2017).

g. Section 811 Supportive Housing for People with Disabilities

Created by the National Affordable Housing Act of 1990, the program provides assistance to develop housings for low-income disable households to facilitate to their independent life through providing rental assistant in housing with supportive services for the disabilities. This program operates in two ways through providing interest free capital advances and project rental assistance. Interest-free capital advances are granted to sponsors to finance the construction and development of rental housing with required available services. This can cover the difference between property cost and tenant rents as well. Through project rental assistance, which was first implemented in 2012, housing agencies in partnership with human services and Medicaid agencies can apply for Section 811 Project Rental Assistance for new or existing affordable housing developments to ensure housing availability with supportive services for target population (HUD.GOV, 2017).

h. Rent Supplement Program

This program is an early form of rental assistance available for Section 221(d) (3) and Section 236 and Section 202 properties. Since the program was suspended in 1973, the owners with rent supplement contracts were converted to project-based Section 8 assistance. Some developments still have their assistance through this program (Housing, 2007).

– *Others:*

A number of other major programs support development of affordable housing units for low income household**.** Below, the description for two of them is provided:

a. Self-Help Homeownership Opportunity Program (SHOP)

Authorized in 1996, the congress created this program to provide funds to national and regional nonprofits to assist low-income families with building their own homes using a “sweat-equity” model. The fund is restricted to pay for land and infrastructure costs, including streets, utilities, and environmental remediation. However, the recipients are required to spend hours to work in building homes (Strauss, 2017). Community Frameworks, Habitat for Humanity International, Housing Assistance Council and Tierra Del Sol (Western States Housing Consortium) are among four national organization that received the total amount of $10,000,000 in SHOP in 2016 (Programs, 2017).

Table 2-2 Organizations that received SHOP funds in 2016. Source (Programs, 2017)

Organization	**Grant Amount**
Community Frameworks	$1,676,280
Habitat for Humanity International	$5,898,895
Housing Assistance Council	$1,145,625
Tierra del Sol (Western States Housing Consortium)	$1,279,200
Total	**$10,000,000**

From 1996 to 2015, Habitat for Humanity used up $ 197,837,307 to complete 17,371 homes and have 941 homes in process to be completed. In Texas, this organization completed 1,098 homes and had 19 homes in the progress to be completed through $ 12, 155,414 grants (Humanity, 2016).

b. HOME Investment Partnerships

Authorized by Title II of the Cranston-Gonzalez National Affordable Housing Act, the program is the largest federal block grants to protect investment in safe, decent and affordable housing for low-income households.

Flexibility of the program allow the user to use the fund for “grants, direct loans, loan guarantees or other forms of credit enhancements, or rental assistance or security deposits” (Sparks, 2007, p. 18). The program requires the jurisdictions to provide 25 percent on non-federal leverage and 15 percent of grand distribution to Community Housing Development Organizations. There are 579 local government recipients nationally, 42 of them are located in Texas (Sparks, 2007). From 2003 to 2016, State of Texas had received $ 1,363,237,803 in HOME grants (HUD Exchange, 2017).

Literature On The Concept Of Location Efficiency And Low-Income Population

Location-efficient areas are characterized by high access to services, opportunities and jobs by less driving through less number of trip or using other modes such as walking, biking or transit (Litman, 2017; Newmark et al. 2015; CNT, 2015). Location-efficient neighborhoods are the ones where residents enjoy access to their daily destination by different transportation options. Researchers have determined diverse factors for location efficiency. In Holtzclaw, et al (2002) study, residential development compactness and proximity to public transit within a walkable distance are the determinants of location efficient areas.

In addition, the mix of the services, shorter travel distance, more opportunity to walking or use transit and bike characterizes location-efficient areas. Living in a location efficient area allows people to save to drive less, own fewer car and save on energy cost. Such areas are of particular importance especially for low income households or for those who cannot afford to own a car since this provide them a chance to save on their

transportation cost (Hamidi et al, 2016; Litman, 2010; Ewing and Hamidi, 2014; Todd Litman, & Litman E., 2011).

The concept has been used very closely with the concept of “affordability” and some researchers focus on the affordability of location in term of transportation cost. The Center for Neighborhood Technology (CNT) and Center for Transit Oriented Development (CTOD) introduced the location efficiency tools that included housing and transportation costs as the determinants of affordability and location efficiency.

Location efficiency studies are mostly popular especially for assisted housing programs. Studies found that affordable housing units should be in location efficient places to be truly affordable. For instance, Koschinsky and Talen (2016) study concluded that only 23% Housing Choice Voucher (HCV), Public Housing and Project Based Rental Assistance programs are located in location efficient places.

Moreover, in another study, Hamidi et al. (2016) evaluated the location efficiency of major affordable housing programs in the Dallas Fort Worth (DFW) region. They found LIHTC properties to be the most affordable, Continuum of Care, and section 202 properties as the least affordable ones.

Location efficiency include both commercial and residential development. As litman (2010), defined, location-efficient development refers to “residential and commercial development in accessible areas with relatively low transportation costs” (Litman, 2010 P 14).

Considering low-income population definition, classification as below or above low-income level is determined based on the poverty index (US census, 1971). Although the concept might vary regionally, a family of four with two children and income of $24,339, a family of three with one child and income of $19,318 and a family of two with

one child with $16,543 income are considered to make 2016 federal poverty threshold (FPT) (NCCP, 2018).

US Census Household Income Survey of 2017 also classified the income range of less than $ 25,000 as the federal poverty level and the income range of $25,000 to $34,999 is considered as low-income level (US Census, 2017).

Chapter 3

Measuring Access to Opportunity

Introduction

This chapter measures access to opportunity scores for 15 opportunities including bank, credit unions and insurance, k1-12, higher education, health care non-mental specialists, health care mental specialists, health care laboratories, hospital and clinic, child and youth facilities, elderly and disability facilities, pharmacies, fitness, entertainment and recreation, healthy food store, unhealthy food store, social and religious services. Then, it analyzes the result of the model for the entire study area for top 15 largest cities for three modes of transportation – walking, driving, and transit.

Research Design

- *Study Areas*

All census blocks in Dallas-Fort Worth metropolitan area (DFW) have been used to develop access to opportunity scores. It is critical for a dynamic region such as Dallas Fort Worth Area (DFW) to move toward a more resilient environment.

Table 3-1 Frequency Distribution and Percentage of Jobs in Counties in DFW

Counties	Job Counts	Percentage	Counties	Job Counts	Percentage
Wise	2,635	1.00%	**Ellis**	4,995	1.90%
Parker	4,508	1.70%	**Hood**	2,356	0.90%
Rockwall	3,221	1.20%	**Johnson**	5,296	2.00%
Hunt	3,262	1.20%	**Somervell**	433	0.10%
Collin	32,277	12.30%	**Denton**	22,039	8.40%
Dallas	106,694	40.80%	**Tarrant**	70,144	26.80%
Kaufman	3,547	1.30%	**Total**	261,407	

Even though DFW has been a magnet for major corporate headquarters and company operations with low costs of living and affordable housing opportunities, and

access to a strong highway system, the region holds a rank below average for creating an area of opportunity for residents (Opportunity Nation, 2017).

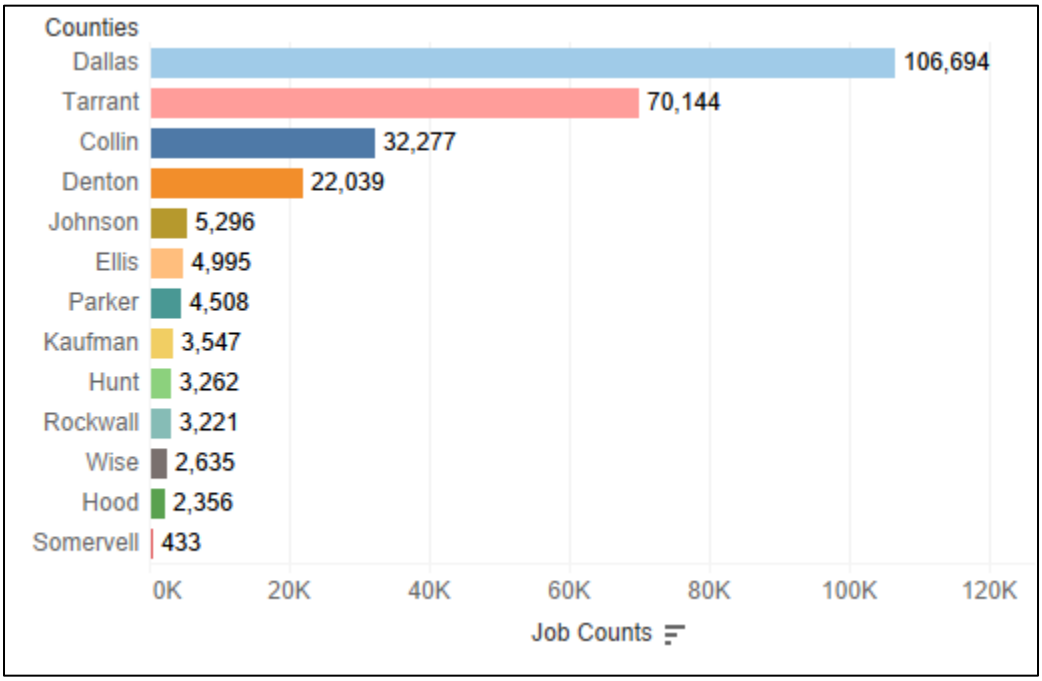

Figure 3-1 Job Distribution in DFW Counties

Dallas–Fort Worth–Arlington, TX Metropolitan Statistical Area (DFW) is comprised of 13 counties. With an area of 9,286 square miles, it accommodated 7,233,323 in 2016 (US Census, 2014), made it the fourth largest MSA in the United States. This area includes 261,407 number of jobs and 43,425 number of major destination. As shown in table 3-2, healthy food store constitutes the largest, while health care mental specialist is the smallest destination category.

Table 3-2 Opportunity Categories for all Counties in DFW

Opportunities	Wise	Parker	Rockwall	Hunt	Collin	Dallas	Ellis	Hood	Johnson	Somervell	Denton	Tarrant
Pharmacies	0.8%	1.9%	1.4%	1.1%	13.4%	36.4%	1.9%	0.7%	1.8%	0.1%	9.5%	30.9%
Bank, Credit Unions and Insurance	0.3%	1.3%	0.3%	0.3%	10.9%	43.9%	1.3%	0.0%	1.3%	0.0%	6.6%	33.7%
Child and Youth Facilities	0.4%	1.4%	1.0%	1.0%	13.4%	35.8%	2.2%	0.9%	1.8%	0.0%	10.3%	31.6%
Elderly and Disability Facilities	1.0%	1.2%	2.1%	1.3%	11.2%	39.2%	2.7%	1.7%	2.5%	0.2%	10.0%	26.9%
Entertainment and Recreation	0.8%	1.9%	1.3%	2.9%	12.9%	38.3%	2.5%	1.5%	1.7%	1.7%	9.8%	24.6%
Fitness	0.5%	1.3%	2.0%	1.0%	16.5%	39.9%	1.4%	0.7%	1.2%	0.1%	10.4%	24.9%
Healthy Food Store	0.7%	1.2%	1.3%	1.0%	13.1%	41.3%	1.9%	0.7%	1.7%	0.1%	8.8%	28.2%
Higher Education	0.7%	1.2%	0.0%	1.5%	4.9%	43.8%	1.0%	0.0%	1.7%	0.7%	12.8%	31.5%
Hospital and Clinic	1.4%	1.5%	1.0%	1.3%	14.9%	35.9%	1.6%	1.2%	1.5%	0.3%	7.7%	31.7%
K1-12	1.5%	2.4%	1.5%	2.6%	13.6%	35.4%	3.5%	0.7%	3.6%	0.4%	9.6%	25.3%
Laboratory	0.5%	2.7%	1.1%	1.1%	12.5%	38.4%	0.8%	0.8%	1.1%	0.0%	10.6%	30.2%
Mental Specialists	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%
Non-Mental Specialists	0.7%	2.0%	1.7%	1.1%	18.9%	34.4%	1.3%	0.8%	1.3%	0.1%	9.7%	28.0%
Social and Religious Services	1.5%	2.2%	0.9%	2.6%	8.4%	40.9%	3.1%	1.1%	2.9%	0.2%	7.7%	28.6%
Unhealthy Food Store	0.8%	1.3%	1.2%	1.2%	11.4%	37.9%	2.0%	0.9%	2.4%	0.2%	9.7%	30.9%

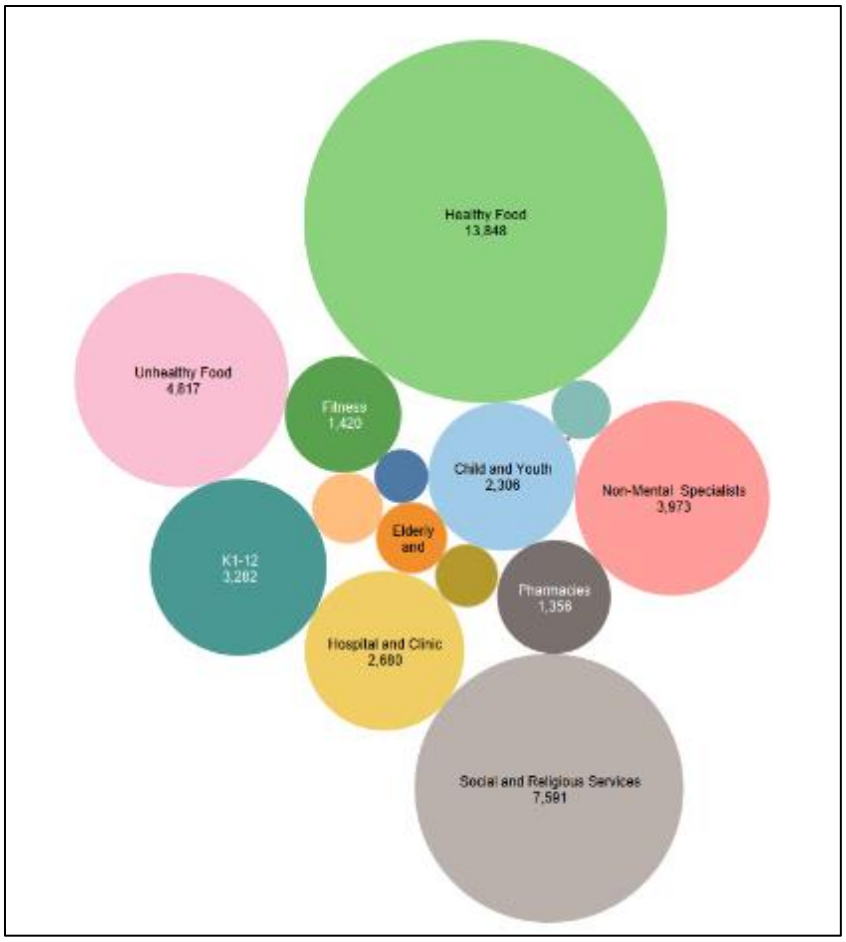

Figure 3-2 Destination Frequencies in DFW

Four major transportation agencies provide fixed route transit services to the study area: Trinity Metro, Dallas Area Rapid Transit (DART), Denton County Transportation Authority (DCTA) and STAR Transit. This study has not included demand

respond transit service since the system has no consistent route to include for modeling purposes. Figure 3-3 shows the extent of the transit service providers in this region.

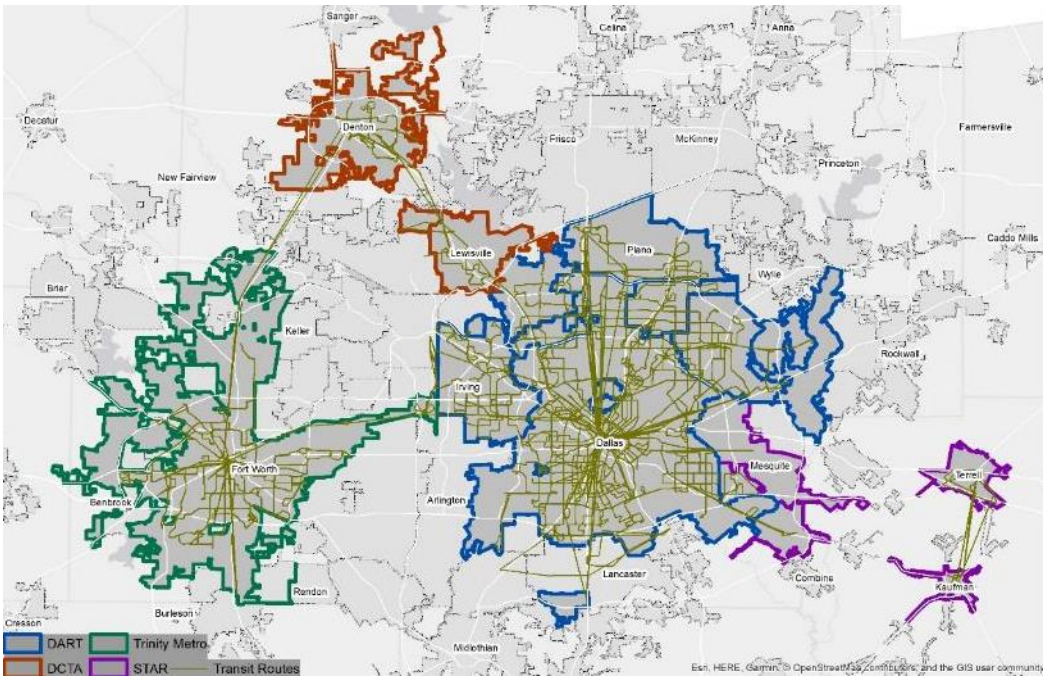

Figure 3-3 Major Fixed Route Public Transit Services in DFW

– *Data and Variables*

This chapter measures access to opportunity for all census blocks in DFW for three modes of transportation including walking, driving, and transit based on the optimized travel time for each mode. Census block has been used to develop the score as the smallest scale to represent real neighborhood situation in providing adequate access or limited access to major opportunities to help decision-making process at neighborhood scale. I have extracted Census Block 2010 TIGER/Line File from National Historical Geographic Information System (NHGIS) to represent the boundary.

Table 3-3 Data Variables and Sources for Access to Opportunity Scores

Data	Definition	Data Source	Year
Transit Network	Network used by 4 major transit agencies including DART, DCTA, FWTA and STAR	GTFS Data	2016
Road Network	Street Network	ESRI Business Analyst	2016
Business Locations	List of businesses licensed from Info group with their name and location, franchise code, industrial classification code, number of employees, and sales	ESRI Business Analyst	2016
Destination Locations	Major destination locations extracted from ESRI Business Analyst Desktop with the recognized NAICS industry classification codes	ESRI Business Analyst	2016
Census Block 2010 TIGER/Line File	Boundaries derived from the U.S. Census Bureau's 2010 TIGER/Line files	NHGIS	2010

NHGIS provides population, housing, economic and agricultural economic data, as well as GIS-compatible boundary files, for all available scale for the United States from 1790 to the present (NHGIS,2017). Necessary analysis has been performed on raw material using Geographic Information Systems (GIS) and ESRI Business Analyst Desktop.

In this study, I have accounted for access to all job opportunities and major destinations. Major destination has been determined based on the literature review presented in table 3-4. This study has recognized 15 major destinations in the study area: bank, credit unions and insurance, k1-12, higher education, health care non-mental specialists, health care mental specialists, health care laboratories, hospital and clinic, child and youth facilities, elderly and disability facilities, pharmacies, fitness, entertainment and recreation, healthy food store, unhealthy food store, social and

religious services. A detailed description of destination classification with NACIS code and subcategories is provided in table 3-5.

Table 3-4 Literature Review for Major Destination Categories

Opportunities	Sources
Employment	Clifton et al., 2016; Lacono et al, 2010; TTI, 2010.
Local Neighborhood stores	Limanond, and Niemeir, 2003; Clifton et al., 2016; Scott and He, 2012; Singleton and Wang, 2014.
Recreation and Amusement	Scrogin et al., 2010; Clifton et al., 2016; Scott and He, 2012.
Food Stores	Lacono et al, 2010; Scott and He, 2012; Singleton and Wang, 2014.
Social and cultural Services	Scott and He, 2012; Singleton and Wang, 2014.
Health Opportunities	Singleton and Wang, 2014; Witten et al., 2008.
Education	Witten. Et al, 2008.
Day Care	Witten. Et al, 2008.
Financial Facilities	Witten. Et al, 2008.
Senior Facilities	Singleton and Wang, 2014.

The location of destinations and businesses has been extracted from ESRI Business Analyst Desktop, which provides a comprehensive list of businesses licensed from Infogroup for more than 13 million U.S. businesses including name and location, franchise code, industrial classification code, number of employees, and sales. The Business Locations database classifies businesses based on location SIC and NAICS industry classifications, annual sales, number of employees, etc. (ESRI, 2017). This study has included all business data for access to job opportunity in the study area.

Table 3-5 Major Destination Classification with NACIS Code and Detailed Subcategories

Categories	Detailed Sub-categories	Categories	Detailed Sub-categories
Bank, Credit Unions and Insurance	Monetary Authorities-Central Bank	**Fitness**	Fitness and Recreational Sports Centers
	Credit Unions	**Entertainment and Recreation**	Museums
	Mortgage and Nonmortgage Loan Brokers		Historical Sites
	Direct Health and Medical Insurance Carriers		Zoos and Botanical Gardens
K1-12	Elementary and Secondary Schools		Nature Parks and Other Similar Institutions
Higher Education	Junior Colleges		Amusement and Theme Parks
	Colleges, Universities, and Professional Schools	**Healthy Food Store**	Supermarkets and Other Grocery (except Convenience) Stores
Health Care Non-Mental Specialists	Offices of Physicians (except Mental Health Specialists)		Full-Service Restaurants
Health Care Mental Specialists	Offices of Physicians, Mental Health Specialists		Limited-Service Restaurants
Health Care Laboratories	Medical Laboratories		Cafeterias, Grill Buffets, and Buffets
Hospital and Clinic	General Medical and Surgical Hospitals		Snack and Nonalcoholic Beverage Bars
	Freestanding Ambulatory Surgical and Emergency Centers	**Unhealthy Food Store**	Convenience Stores
	Nursing Care Facilities (Skilled Nursing Facilities)		Snack and Nonalcoholic Beverage Bars
Child and Youth Facilities	Child Day Care Services		Drinking Places (Alcoholic Beverages)
	Elementary and Secondary Schools		Full-Service Restaurants
	Child and Youth Services		Limited-Service Restaurants
Elderly and Disability Facilities	Services for the Elderly and Persons with Disabilities	**Social and Religious Services**	Religious Organizations
	Nursing Care Facilities (Skilled Nursing Facilities)		Civic and Social Organizations
	Assisted Living Facilities for the Elderly		Community Food Services
Pharmacies	Pharmacies and Drug Stores		

(Source: US Census)

– *Methods*

To calculate the opportunity scores for each census blocks in DFW, it is critical to calculate the distance between origins (census blocks) and destination through OD Matrix using the ArcGIS Network Analyst tool. The OD cost matrix measures the distance along the network from multiple origins to multiple destinations based on determined impedance and restrictions (ESRI, 2017). For driving, I have used 45-minute driving network from the center of each census blocks to each destination. I have used 45-minute travel time selected by other similar studies (Ramsey & Bell, 2014; Wickstrom, 1971). For walking, I applied 15 minutes walking time from the center of each census blocks based on the literature review (WalkScore, 2016; Huang, 2014; Ramsey & Bell, 2014) and for transit, I have used 45-minute transit travel time (15-minute walking and 30-minute transit ride) (Ramsey & Bell, 2014).

I also was required to adjust the distance value using distance decay function. For walking, based on average speed of 3.1 miles per hour, it would take 15 minutes for a person to take 0.75 mile. For driving and transit, I have used the distance-decay function formula from "Travel Estimation Techniques for Urban Planning" (NCHRP 365, 1998), illustrated below:

$$DestAcci=\sum_{j=1}^{n} desj \times f(t)ij$$

Where

DestAcci is the destination accessibility for Census Block i,

des$_j$ is the number of destinations in Census Block j,

f (t)$_{ij}$ is the travel time decay function for census Block i and destination j with following formula:

$$f\ (t)\ ij=a\times t_{ij}{}^{-b}\times e^{-c\times (tij)}$$

Where, a = 1, b = 0.3, c= 0.07; and e is the exponential function (Ramsey and Bell, 2014).

The outcome from the f (t) ij function produced the curve presented in Figure 3-4. This equation decays as travel time increases and it approaches zero as travel time goes beyond 40 minutes.

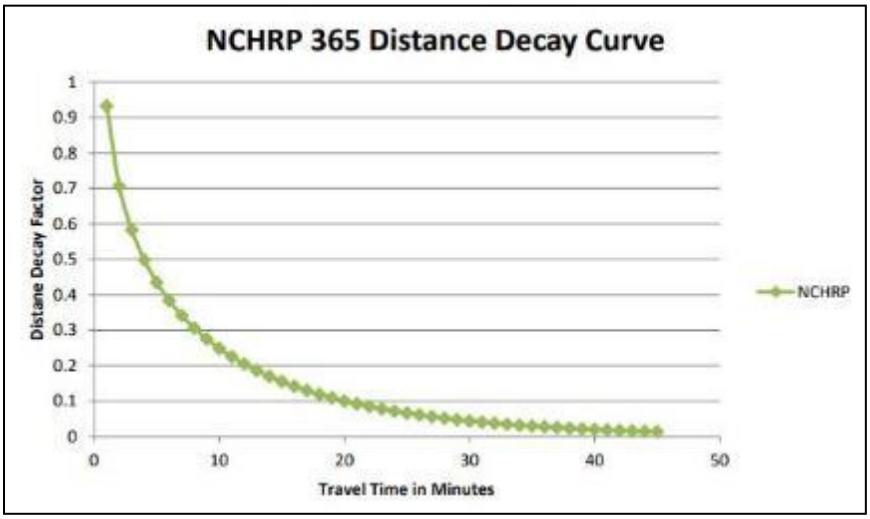

Figure 3-4 Travel Time Decay Curve
(Source: Martin & McGuckin, 1998; Ramsey& Bell, 2014)

As a result, accessibility scores for each three modes of transportations (walking, driving and transit) for all census blocks in the study area have been developed.

After getting the measures from the previous step, I used principal component analysis to combine individual destination scores to one overall score. Principal Component Analysis (PCA) is a special type of factor analysis, used to obtain one or more factors from a larger number of correlated variables. The derived factor is a weighted combination of the original variables. In PCA, communality values represent the proportion of the variance accounted for by the factor solution. As a rule of thumb, the

values should explain at least 20 percent of each original variable's variance, so the communality value for each variable should be 0.20 or higher.

Factor loadings represent simple correlations between the variables and the factors, meaning that the higher the loadings, the greater the correlation between a variable and a component. Loadings can range from -1 to 1 and a value closer to 1 indicate that the factor strongly affects the variable while the value close to zero indicates that the factor has a weak effect on the variable. Factor coefficient in the table of PCA is a value by which a variable is multiplied.

PCA also generates table of total variance, which is influenced by the correlation among the variables. For each mode, PCA model with the larger variance shows the best-fitted one. Moreover, the percentage of explained variance determines the variability of datasets explained by the model.

In table of total variance, PCA produces eigenvalues that explains the power a principal component and is a number that tell you how much variance is in the data. It also shows the direction. As a common “rule of thumb” eigenvalues more than one worth interpreting. Moreover, percentage of explained variance determines variability of dataset explained by the model (Hamidi et al, 2015). Figure 3-5 shows how I extract overall opportunity from all destinations.

To simplify analysis, I have factored the 12 categories to 4 categories of Food Opportunities (Healthy Food Store; Unhealthy Food Store), Health Opportunities (Health Care Non-Mental Specialists; Health Care Mental Specialists; Health Care Laboratories; Hospital and Clinic; Pharmacies; Fitness), Education Opportunities (K-12; Higher Education), and Services Opportunities (Bank, Credit Unions and Insurance; Social and Religious Services). I have reduced 2 variables of Healthy Food Store, Unhealthy Food Store to one Food Store; 6 variables of Health Care Non-Mental Specialists, Health Care

Mental Specialists, Health Care Laboratories, Hospital and Clinic, Pharmacies, Fitness to one (Health).

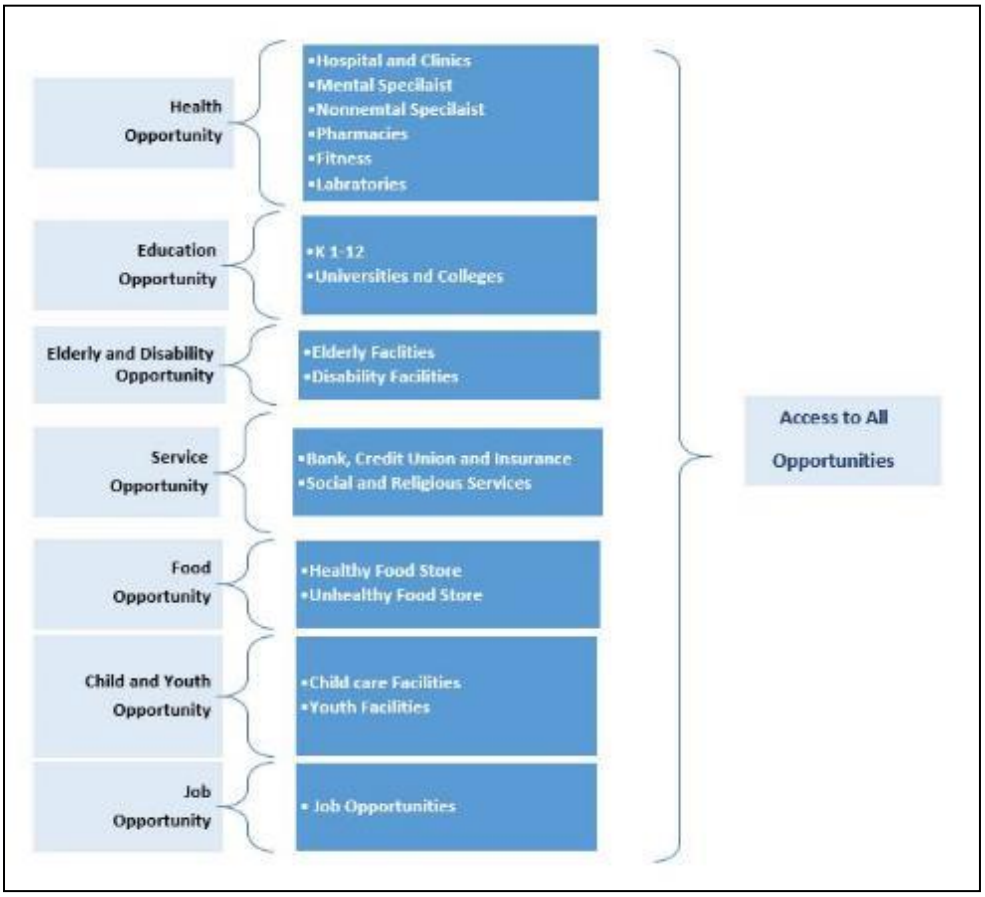

Figure 3-5 Factor Analysis Diagrams for Destinations and All opportunities

I created education out of two variables of K1-12 and Higher Education. In addition, service was created out of 2 variables of Bank Credit Unions and Insurance, Social and Religious Services.

As presented in table 3-6, the total variance explained for access to health opportunity was 59. 8 % for walking, indicating that this one factor accounted for 59 % of the total variance in the dataset. For driving, the percentage variance explained by the model was 94.4 %, which accounted for about 94 % of the total variance in the dataset.

In addition, for transit, the percentage variance explained was 76.9 %. The model also presented an eigenvalue of 2.99 for walking, 5.66 for driving and 4.62 for transit.

In the walking model, access to hospitals and clinics had the highest loading while access to fitness facilities had a low loading. In the driving model, access to access to fitness facilities had the highest loading while pharmacy showed a low loading. In transit model, access hospitals and clinics had the highest loading while access to mental specialist showed a low loading. All the factors loaded positively to health opportunity score by all three modes.

The total variance explained by the model for access to education opportunity was 57.9 % for walking, 97.7 % for driving and 86.4 % for transit. This means that this one variable (for each mode) accounted for about 57 -95% of the total variance in the dataset. The model also presented an eigenvalue of 1.15 for walking 1.95 for driving and 1.73 for transit. In all three models, the factors loaded positively to education opportunity score.

For access to service opportunities, the model presented an eigenvalue of 1.3 for walking 1.93 for driving and 1.8 for transit. The total variance explained by the model for access to service opportunity was 65.4 % for walking, 96.8 % for driving and 90.2 % for transit.

For access to food opportunities, the model presented the total variance percentage of 90.7 % for walking, 99.55 % for driving and 99.18 for transit indicating 57 - 95% of the total variance in the dataset. The model also presented an eigenvalue of 1.81 for walking 1.99 for driving and 1.98 for transit. In all three models, both factors loaded positively to access to food opportunity score.

Table 3-6 Factor Loadings of Four Destination Opportunities

Destination Categories		Transit	Driving	Walking
		Factor Loadings	Factor Loadings	Factor Loadings
Health	Access to Pharmacy	0.949	0.985	0.669
	Access to Health Care Non-metal Specialists	0.942	0.993	0.873
	Access to Health Care Mental Specialists	0.290	0.88	-
	Access to Health Care Laboratories	0.958	0.99	0.845
	Access to Hospitals and Clinics	0.985	0.983	0.920
	Access to Fitness facilities	0.925	0.993	0.473
Eigenvalue		**4.62**	**5.66**	**2.99**
Explained variance		**76.93**	**94.44**	**59.85**
Education	Access To K-K12	0.930	0.989	0.761
	Access to Higher Education	0.930	0.989	0.761
Eigenvalue		**1.73**	**1.95**	**1.15**
Explained variance		**86.44**	**97.72**	**57.95**
Service	Access to Social and Religious Services	0.950	0.984	0.809
	Access to Bank, Credit Unions and Insurance	0.950	0.984	0.809
Eigenvalue		**1.8**	**1.93**	**1.3**
Explained variance		**90.28**	**96.87**	**65.44**
Food	Access to Healthy Food	0.996	0.998	0.952
	Access to Unhealthy Food	0.996	0.998	0.952
Eigenvalue		1.984	**1.99**	**1.81**
Explained variance		99.184	**99.55**	**90.72**

PCA was also used to create access to all major opportunities. A principal component representing access to all opportunity score was extracted as a weighted sum of fifteen separate variables including child and youth facilities, elderly and disability facilities, healthy food store, unhealthy food store, health care non-mental specialists, health care laboratories, hospital and clinic, pharmacies, fitness, K1-12, higher education,

entertainment and recreation, bank credit unions and insurance, social and religious services and job opportunity factors. For walking, health care mental specialist was excluded to get a better-fitted model.

Table 3-7 Factor Loadings of Access to All Opportunities

Destination Categories		**Factor Loadings**		
		Transit	**Drive**	**Walk**
All Opportunities	Access to Pharmacy	0.95	0.99	0.65
	Access to Health Care Non-Mental Specialists	0.86	0.98	0.50
	Access to Health Care Mental Specialists	0.24	0.82	-
	Access to Health Care Laboratories	0.92	0.99	0.57
	Access to Hospitals and Clinics	0.95	0.99	0.66
	Access to Fitness facilities	0.96	0.99	0.73
	Access To K-K12	0.91	0.99	0.44
	Access to Higher Education	0.871	0.97	0.39
	Access to Social and Religious Services	0.921	0.96	0.63
	Access to Bank, Credit Unions and Insurance	0.881	0.95	0.59
	Access to Healthy Food	0.981	0.99	0.84
	Access to Unhealthy Food	0.98	0.99	0.79
	Access to Recreation and Entertainment	0.91	0.99	0.59
	Access to Jobs	0.97	0.81	0.78
	Access to Child and Youth	0.96	0.99	0.65
	Access to Elderly and Disabilities	0.91	0.99	0.35
Eigenvalue		**13.02**	**14.91**	**5.89**
Explained variance		**81.42**	**93.23**	**39.28**

For walking, a principal component representing walking total opportunity score was extracted from the data set as a weighted sum of fifteen separate variables. The model presented an eigenvalue of 5.89 and a total variance of 39.28, which accounted for 39 % of variance in the data sets. In the model, healthy food store had the highest

loading while elderly facilities had a low loading. All the factors loaded positively to total opportunity score by walking (Table 3-7).

For driving, the model presented an eigenvalue of 14.91 and a total variance of 93.23, which accounted for 93.2 % of variance in the data sets. In the model, access to healthy and unhealthy food, pharmacy, laboratories, hospitals and clinics, fitness facilities, k-k12, recreation and entertainment, child and youth and elderly and disabilities showed the highest loading while access to job had a low loading. All the factors loaded positively to total opportunity score by car (Table 3-7).

Table 3-8 Descriptive Statistics for the Standardized Opportunity Scores

Transportation Mode	**Transit**		**Driving**		**Walking**	
Destination Categories	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Access to Health Opportunity	89.59	474.35	67.381	195.055	91.383	705.89
Access to Entertainment Opportunity	91.77	594	65.42	186.36	94.81	711.13
Access to Elderly and Disability Opportunity	89.13	1389.17	64.65	173.53	92.54	418.62
Access to Child and Youth Opportunity	87.91	360.25	64.69	166.21	87.16	347.9
Access to Job Opportunity	90.23	445.43	76.42	267.44	87.11	613.62
Access to Food Opportunity	89.16	409.54	64.09	174.74	88.19	514.09
Access to Service Opportunity	89.31	708.88	64.98	173.1	87.97	576.87
Access to Education Opportunity	88.97	409.05	67.38	195.05	88.58	788.49
Access to All Opportunity	89.01	389.89	65.66	178.66	85.57	469.63

For transit, the model had an eigenvalue of 13.02 and a total variance of 81.4. Access to unhealthy Food had the highest loading while health care mental specialists showed a low loading. All the factors loaded positively to total opportunity score by transit (Table 3-7).

For the remaining four destinations (child facilities, elderly facilities, jobs, and entertainment & recreation), individual opportunities were used.

Finally, I have normalized the score based on mean of 100 and a standard deviation of 25. The values above 100 represents better access (for each destination category) while the ones below 100 represents relatively poor access.

Table 3-8 presents descriptive statistics for access to opportunity categories and access to all major opportunities. As shown, the minimum score is for access to food by driving and the maximum score is for access to elderly and disability opportunity by transit.

Moreover, figures 3-6 to 3-8 show the frequency histogram of access to all major opportunity by three modes. As shown, for the three modes, the values are skewed right (positively skewed). This is because most of the region has the values less than average for access by each three modes. Most of the region get the lowest value for access by transit and walking and only a small portion has values above average.

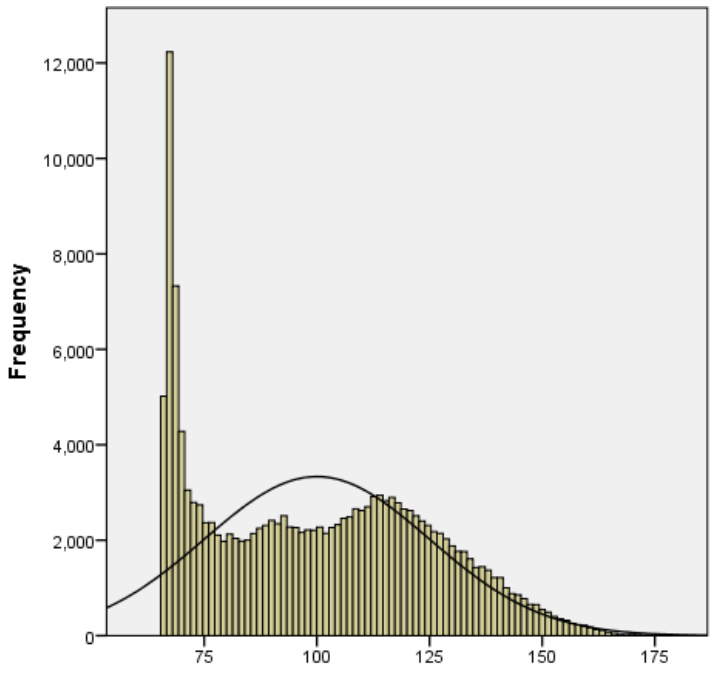

Figure 3-6 Frequency Distribution of Access to All Major Opportunities by Car

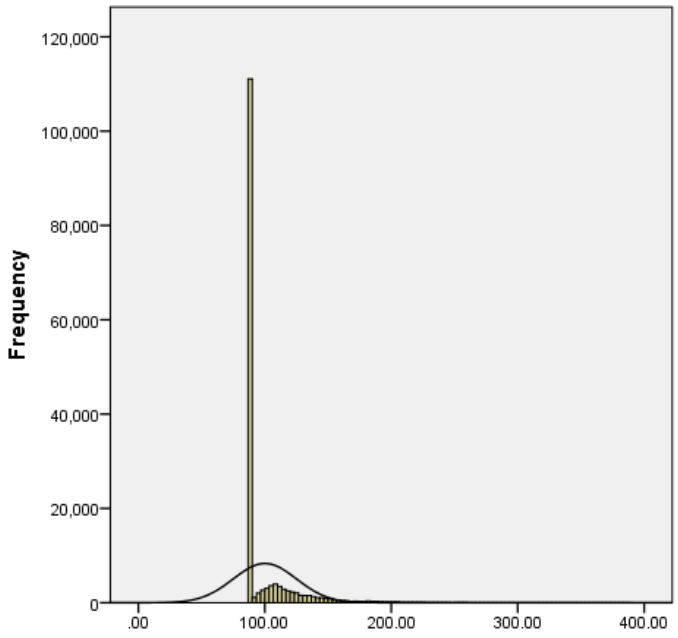

Figure 3-7 Frequency Distribution of Access to All Major Opportunities by Transit

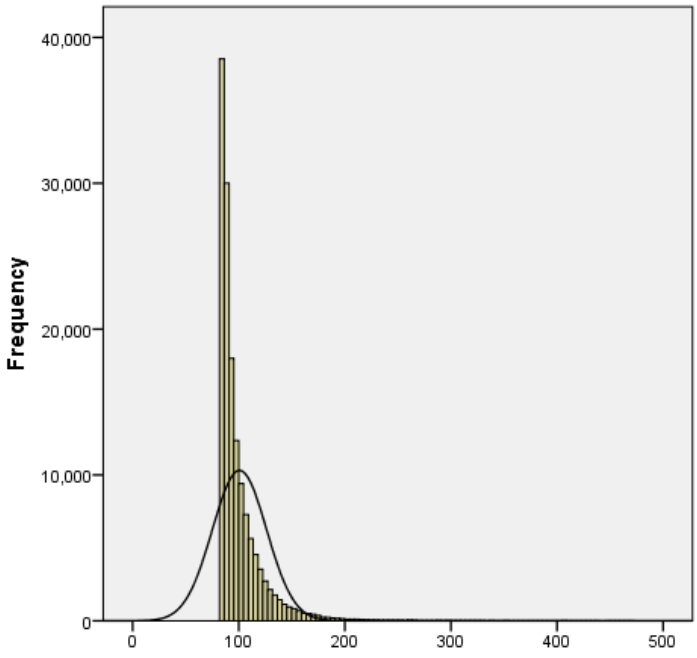

Figure 3-8 Frequency Distribution of Access to All Major Opportunities by Walking

Analysis And Result

This section focuses on analyzing access to opportunities for the entire study area and for the top 15 largest cities including Dallas, Irving, Richardson, Denton, Garland, Arlington, Fort Worth, Plano, Mesquite, Carrollton, Grand Prairie, Lewisville, McKinney, Allen and Frisco. The analysis include access to opportunity for three modes of transportation – walking, driving, and transit.

- *Access To Opportunities By Walking*

Table 3-9 shows the percentage of population living in areas with high access to opportunities. High access to opportunity is defined as the areas with scores better than the regional average (the score above 100). As evident, the City of Dallas ranks the highest (1st) for providing the residents with high access to all opportunities by walking. About half of the residents enjoy living in areas with better access to opportunities. The city also ranks the highest for access to food, education and service opportunities.

The cities of Irving and Richardson hold the second and third ranks with the highest percentage of their population living in high access to opportunity area. In both cities, more than 40 % of population have access to major opportunities by walking. The city of Irving ranks the highest for access to job and for access to elderly care and health care; the city of Richardson stands at the top. City of Carrollton provides the highest access to childcare opportunities and the City of Frisco has the highest rank for access to entertainment opportunities.

Table 3-9 Percentage of population living in areas with in high access to all major opportunities for the top 15 largest cities in the study area

Rank	City Names	Access to All Opportunity	Access to Jobs	Access to Health	Access to Food	Access to Education	Access to Entertainment	Access to Service	Access to Youth and Child Care	Access to Elderly and Disability Care
1	Dallas	**47%**	39%	36%	44%	44%	10%	42%	44%	18%
2	Irving	**44%**	40%	36%	41%	46%	7%	33%	35%	12%
3	Richardson	**42%**	35%	39%	35%	49%	16%	33%	37%	22%
4	Denton	**37%**	29%	29%	30%	34%	15%	30%	31%	21%
5	Garland	**34%**	29%	22%	35%	43%	8%	35%	33%	16%
6	Arlington	**34%**	28%	32%	34%	37%	8%	26%	38%	14%
7	Fort Worth	**34%**	27%	23%	31%	39%	8%	35%	40%	10%
8	Plano	**34%**	31%	33%	28%	39%	14%	20%	40%	13%
9	Mesquite	**32%**	21%	30%	31%	38%	8%	32%	37%	16%
10	Carrollton	**30%**	28%	24%	28%	35%	8%	24%	45%	10%
11	Grand Prairie	**27%**	23%	18%	28%	39%	11%	27%	26%	19%
12	Lewisville	**24%**	29%	20%	33%	32%	11%	18%	31%	17%
13	McKinney	**22%**	18%	14%	20%	32%	12%	21%	24%	16%
14	Allen	**17%**	12%	18%	17%	40%	6%	5%	37%	5%
15	Frisco	**16%**	12%	23%	12%	35%	20%	8%	29%	8%

On the other hand, the Cities of Frisco and Allen rank the lowest in the region in terms of the access to major opportunity score by walking. About 15 % Frisco residents live in areas with high access to opportunity. Frisco also ranks among the lowest for access to food opportunities. The city of Allen has the lowest access to job, service, entertainment and elderly care opportunities. Low access to health and childcare opportunities put the City of McKinney in the third lowest rank in the region. Figure 3-9 shows the spatial distribution of walking access to all opportunities in DFW.

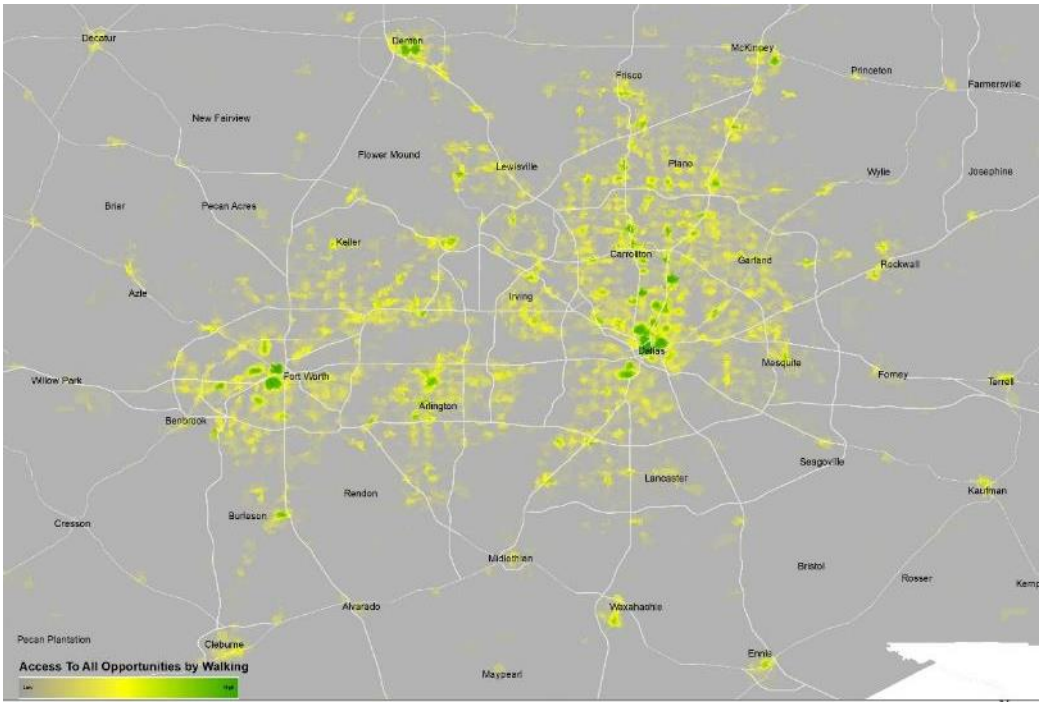

Figure 3-9 Access to All Major Opportunities by Walking

All cities in the region offer poor walking access to most of major opportunities. Education opportunities are out of reach for many neighborhoods for those who prefer to walk. More than 50 % of the population in all the cities live in neighborhoods with scores below average (100). The Cities of Lewisville and McKinney are offering the lowest access and city of Richardson is offering the highest access to education opportunities by walking (49 % of the residents).

Access to food opportunities by walking is also poor for most of the cities (Figure 3-10). Over 56 % of the people are living in areas below average score. In the cities of Frisco, Allen and McKinney, over 80 % of population are living in neighborhoods that offers low walking access (below average). However, more number of the residents of residents of Dallas and Irving are enjoying high access to food destinations by walking (more than 40 %).

Access to education opportunities is similarly confined to small clusters (Figure 3 11). In all these cities, less than 50 % of the population lives in neighborhoods with opportunity scores above 100(average score for education access by walking). About 49 % of the residents of city of Richardson enjoys relatively high health accessibility compared to the other cities. City of Lewisville offers less than average walking access to this destination to almost 68 % of the residents.

The same applies to access to health opportunities. More than 60% of the populations are living in areas scoring below average, making this destination rather inaccessibly by foot. About 40 % of the residents in Richardson enjoy better walking access to health opportunities compared to the other cities due to the presence of heath care facilities such as Methodist Richardson Medical Center, Methodist Family Medical Group, Baylor Richardson Medical Center all throughout the city.

In Dallas, uneven clusters of health accessibility are evident with lowest scores being mostly in southeast and southwest. The city offers low waking access to health opportunities to 64% of the residents. In Irving, pocket of high access to health opportunities is spread through the city making this destination accessible to 35 % of the population. McKinney, Grand Prairie and Allen are the cities that offer the poorest access. In these cities, more than 80% of their population are living in areas with health access, with McKinney having the highest percentage of the residents living in the inaccessible areas (86%). The city holds only 3% of the health centers in DFW (Figure 3-12).

Access to entertainment and recreation opportunities is similarly poor by walking in DFW (Figure 3-13). More than 80% of the populations are living in low access areas.

Almost 94 % of the residents in the City of Allen are living in low access areas. The city only locates about 1.5% of the recreation centers in the region while it is among the top fifteen populous ones in the region. City of Irving also offers low access to recreation services. Regionally, the city is the location of about 3 % of the entertainment centers. The cities of Dallas and Fort Worth are also among the cities with less than 10 % of their population living in accessible areas. They locate only 19 % and 10 %, respectively, of recreational facilities in the region. Therefore, lack of recreational services might be the reason for low access to the destinations.

The city of Frisco's entertainment and recreation opportunities are within a walkable distance of 20 % of the population, making the city to have a better status for the pedestrian access compared to other cities. The city offers a better walking access to recreation and entertainment opportunities such as Wilderness Adventures, Heritage Museum, Discovery Center and some more locations. The cities of Richardson and Denton also offer a better walking access to this destination in the region.

Although the Cities of Dallas and Fort Worth do not yield high ranks as other smaller cities in the region, they have areas offering high walking access. In Dallas, multiple recreation destinations such as Thanksgiving Square, Dallas World Aquarium, Dallas Holocaust Museum and Museum of Nature & Science are within walkable access to 10 % of the population, mostly in Downtown and South Dallas, and Fair Park neighborhoods. Similarly, in Fort Worth, destinations such as Sid Richardson Museum, GC Museum, and Sid Richardson Museum are centrally located in the city.

DFW's walking access to service opportunities is similarly confined to very small clusters. More than 58% of their population living in neighborhoods with low access

(below average). More than 90 % of the residents in the cities of Allen and Frisco are living in low walking access to service opportunities. Clusters of higher accessibility, however, are located in Fort Worth and Dallas, making them to have high ranks for this destination.

Pockets of high scores in Dallas are located in neighborhoods such as East Dallas and Downtown Dallas Neighborhoods. About 42 % of population in Dallas are enjoying high access to service destinations. Also, service destinations such as St. Patrick Cathedral, First United Methodist Church, and some social clubs such as Young Women's Christian Association (YWCA) and City Club of Fort Worth offer higher access by walking to 35% of residents (Figure 3-14).

Elderly and disability services are found to be spread throughout the regions (Figure 3-15). The residents of Richardson and Denton enjoy the highest walking access compared to other cities. However, the destination is highly accessible by foot to less than 22 % of the population in these cities, indicating insufficient walking access to these facilities in the region.

Access to child and youth opportunities is similarly poor by walking in DFW (Figure 3-16). More than 50% of populations are living in low access neighborhoods (scores under the average score of 100). Cities of McKinney, Grand Prairie and Frisco yield the lowest ranks, with more than 70 % of their population living in neighborhoods with low walking access to this destination. However, City of Carrollton ranks the highest for walking access to child and youth opportunities.

For walking access to job opportunities, all these fifteen cities have less than 40 % their populations living in high access neighborhoods. The cities of Irving and Dallas

rank at the top for high access to jobs by foot. While 33 % of the regional jobs are located in the Cities of Irving, Dallas, Richardson and Plano, less than 40 % of population in these cities are within walking distance of job opportunities. Example of pocket of higher opportunities for walking access to jobs in Irving are in Plymouth Park, McArthur, Pioneer, Cottonwood and Belt Line neighborhoods.

However, higher concentration of job inaccessibility by walking are mostly evident in the cities of Allen, Frisco and McKinney where less than 20 % of the residents of are experiencing high walking access to jobs (Figure 3-17).

Generally, most of the residents in the region does not have access to their destinations by walking and cluster of high access is confined to limited areas mostly in downtown of big cities. In Dallas, uneven clusters of accessibility are evident. For example, while higher concentration for access to destinations are in Central Dallas Neighborhoods (such as City Center District, Main Street District, Arts District, Government District, and West End Historic District) and in Northeast Dallas Neighborhood, southeast and southwest neighborhoods are the areas where there is less access to almost all destinations. Except for the central part of the city, most of the neighborhoods in Fort Worth have low access to destinations by walk.

In conclusion, walking access is facilitated to the areas around service types and since the concentration of destination and resources is not even around the region, access to them is poor. Also, regionally, access to some destinations such as entertainment and elderly and disability facilities are poor since their frequencies are not sufficient or walking infrastructure is poor.

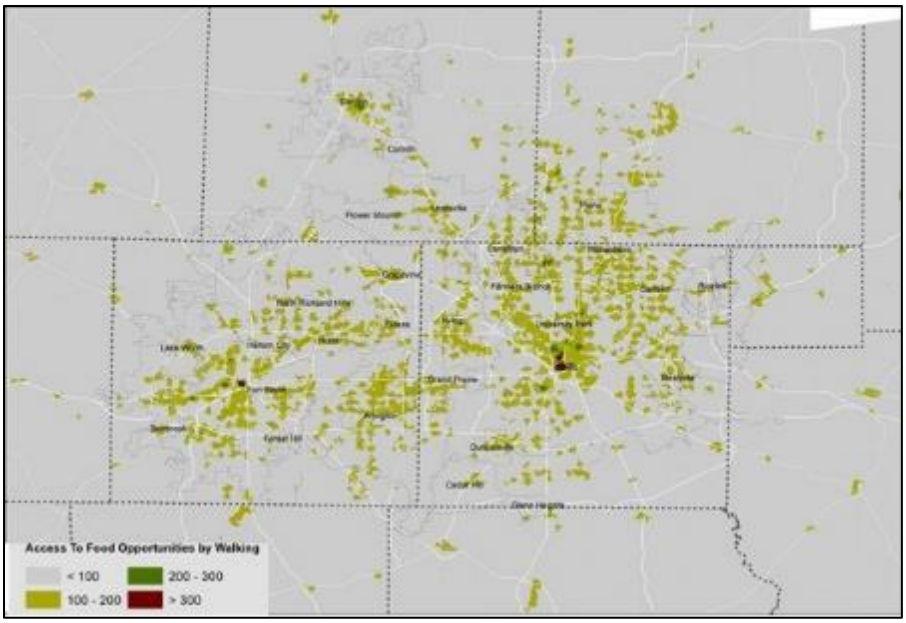

Figure 3-10 Access to Food opportunities by Walking

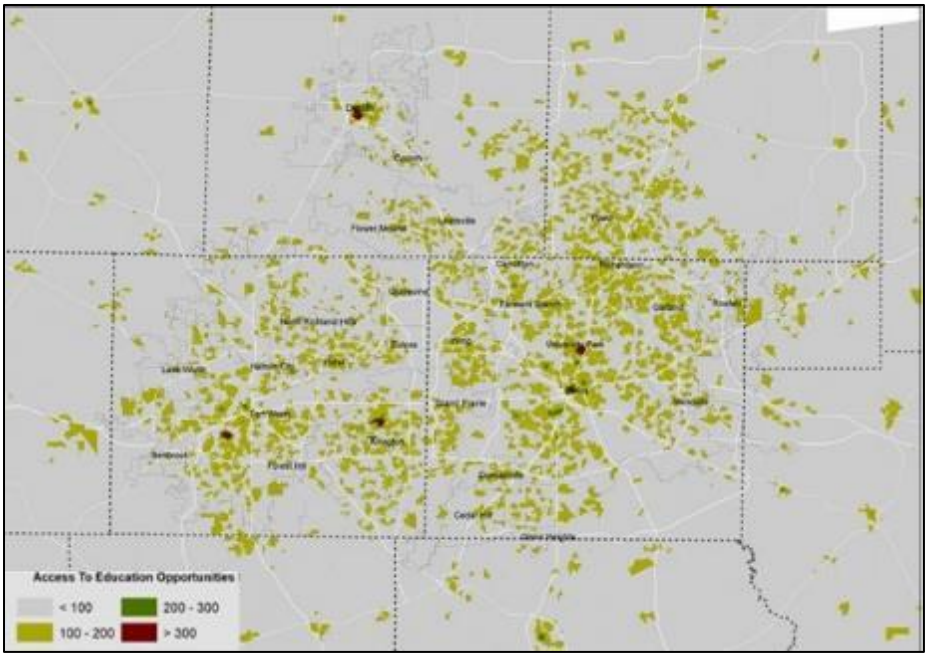

Figure 3-11 Access to Education Opportunities by Walking

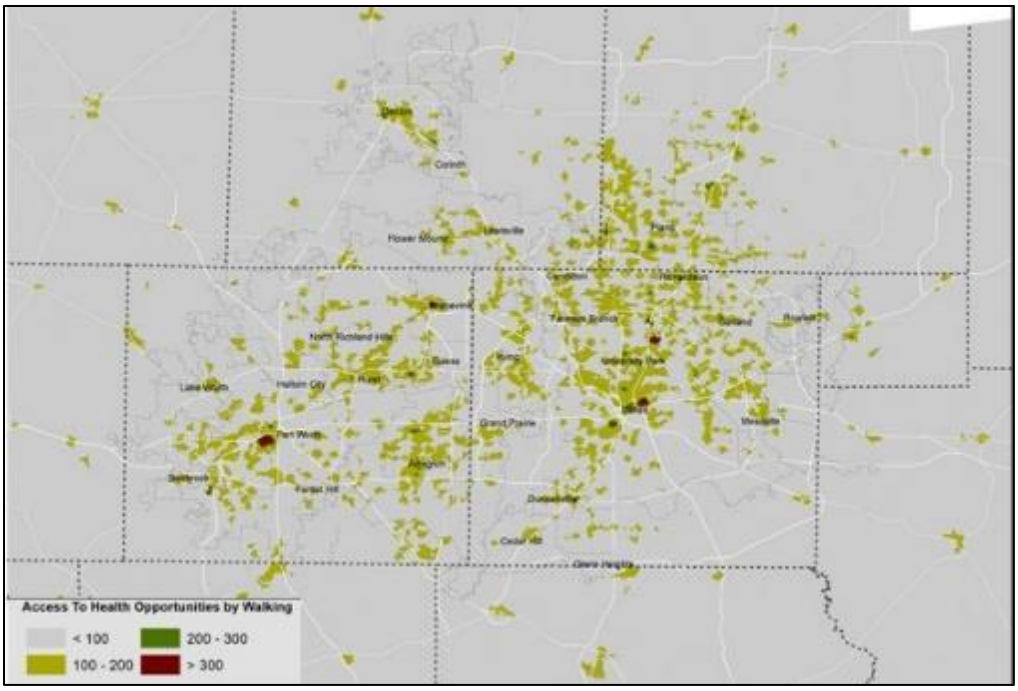

Figure 3-12 Access to Health Opportunities by Walking

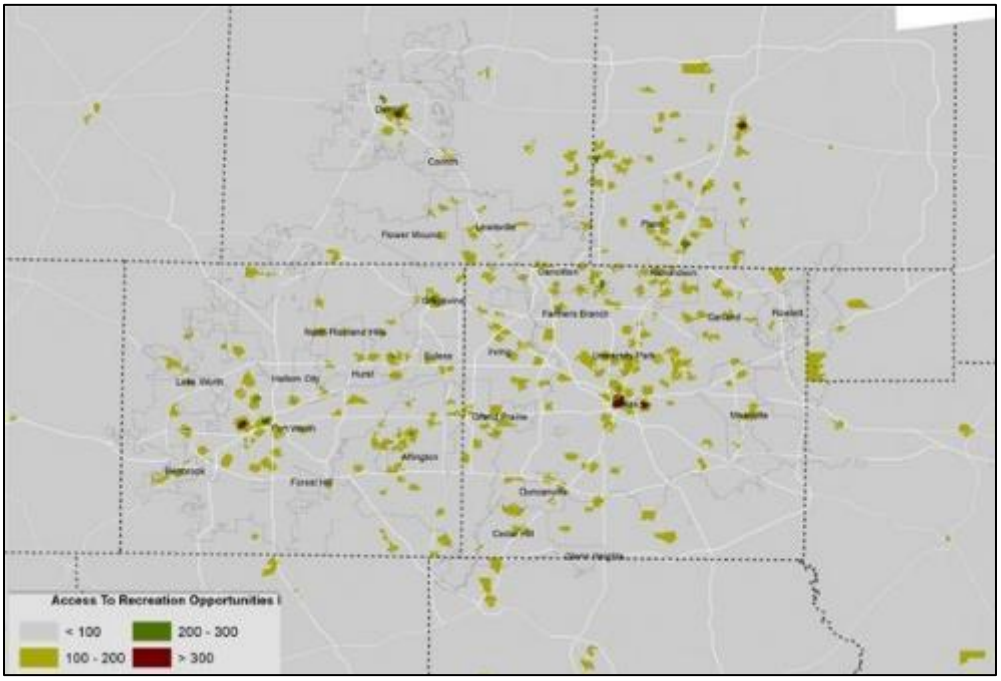

Figure 3-13 Access to Entertainment and Recreation Opportunity by Walking

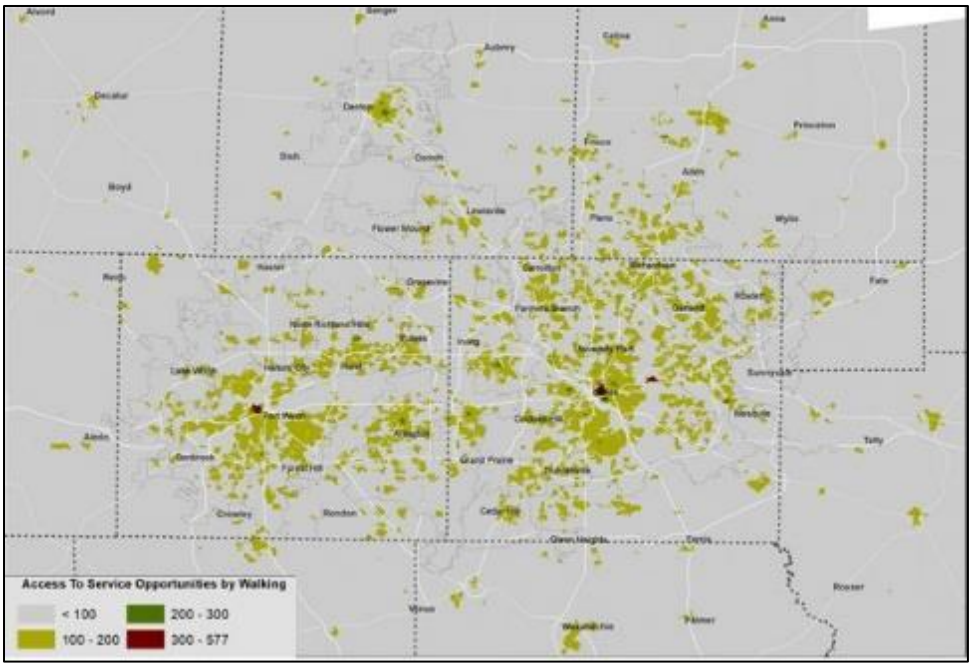

Figure 3-14 Access to Service Opportunity by Walking

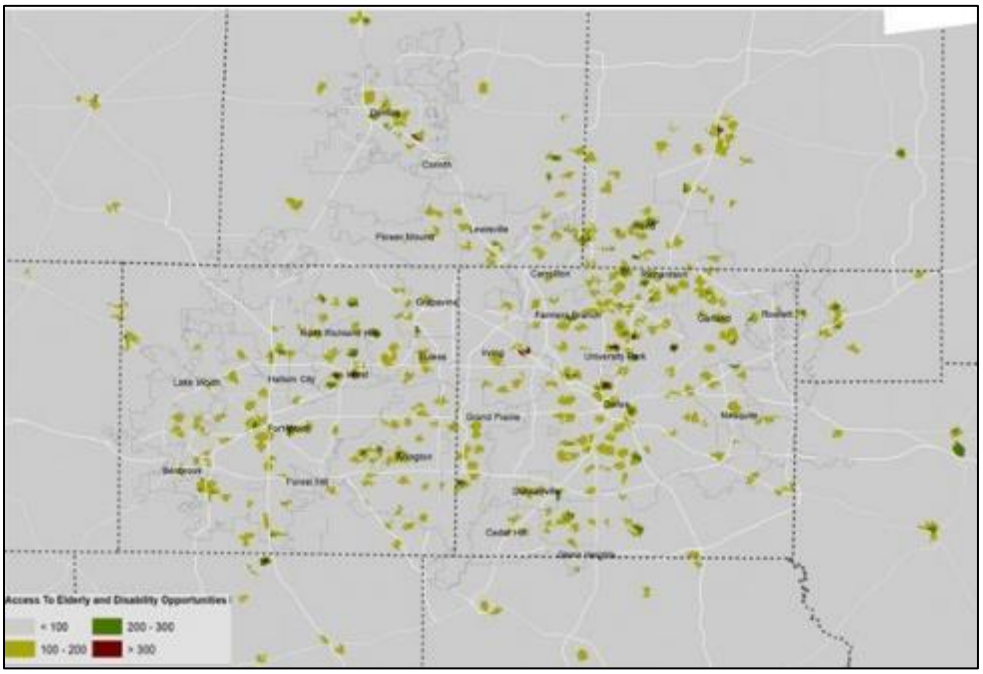

Figure 3-15 Access to Elderly and Disability Opportunities by Walking

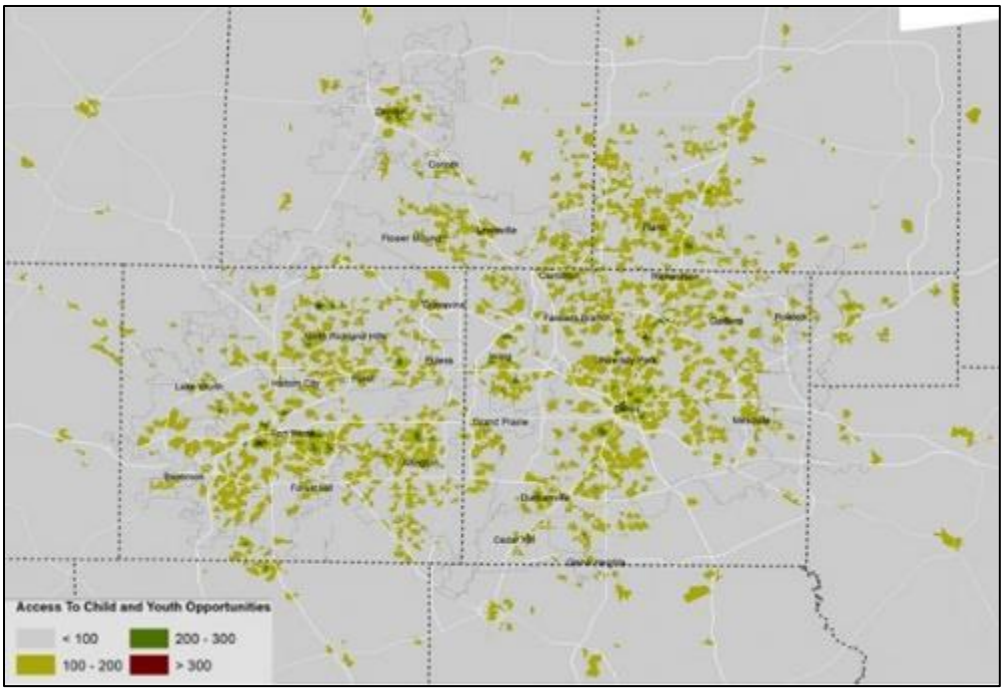

Figure 3-16 Access to Child and Youth Opportunities by Walking

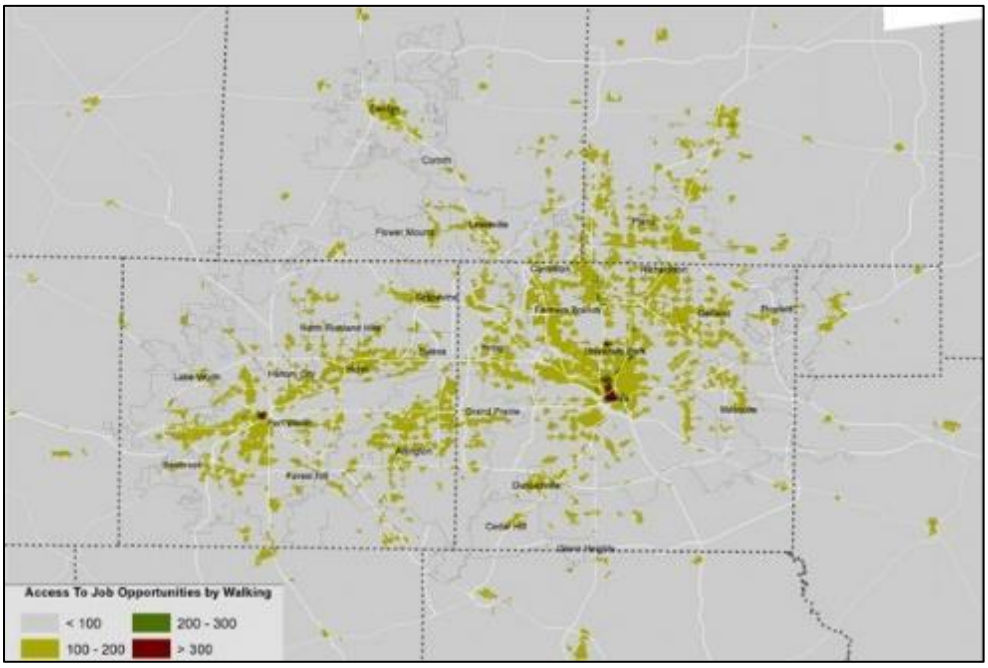

Figure 3-17 Access to Job Opportunities by Walking

– *Access To Opportunities By Driving*

Table 3-10 presents the percentage of population that are living in areas with a better access to opportunities by driving (the score higher than 100, as the average for the region) for the top 15 cities in DFW for driving.

For access to all major opportunities by driving, City of Carrollton ranks the highest. The city ranks the highest for access to all opportunities. Almost the entire populations are living in areas with high access to opportunities.

Table 3-10 Percentage of population living in high access to opportunity by driving for the top 15 largest cities in DFW

Rank	City Names	Access to All Opportunities	Access to Jobs	Access to Health	Access to Food	Access to Education	Access to Entertainment	Access to Service	Access to Child and Youth Care	Access to Elderly and Disability Care
1	Carrollton	100%	100%	100%	100%	100%	100%	100%	100%	100%
2	Garland	100%	79%	100%	100%	96%	99%	96%	99%	100%
3	Irving	100%	88%	99%	100%	100%	99%	100%	99%	99%
4	Dallas	98%	83%	97%	99%	99%	99%	99%	98%	99%
5	Richardson	97%	93%	98%	98%	96%	97%	95%	97%	98%
6	Plano	97%	93%	98%	97%	93%	97%	84%	97%	97%
7	Lewisville	97%	91%	99%	96%	89%	92%	81%	94%	87%
8	Grand Prairie	94%	80%	91%	95%	96%	92%	96%	95%	94%
9	Arlington	86%	60%	74%	89%	91%	76%	95%	93%	87%
10	Mesquite	76%	28%	74%	80%	76%	75%	80%	77%	79%
11	Frisco	70%	42%	87%	68%	53%	84%	43%	74%	71%
12	Allen	58%	58%	69%	56%	39%	66%	20%	64%	60%
13	Fort Worth	40%	40%	29%	42%	45%	33%	53%	49%	37%
14	McKinney	18%	23%	32%	15%	3%	31%	3%	23%	23%
15	Denton	0%	0%	0%	0%	13%	0%	0%	0%	0%

However, the city of Denton presents the lowest rank. None of the city population are living in areas of high access scores. The city shows the least score for access to all opportunities except education. Also, access to education opportunities is very low for the residents in the City of McKinney and only 3 percentages of them enjoy high access. The city of Fort Worth, as the second largest city in the region, offers high access to destination to only 39 % of the residents.

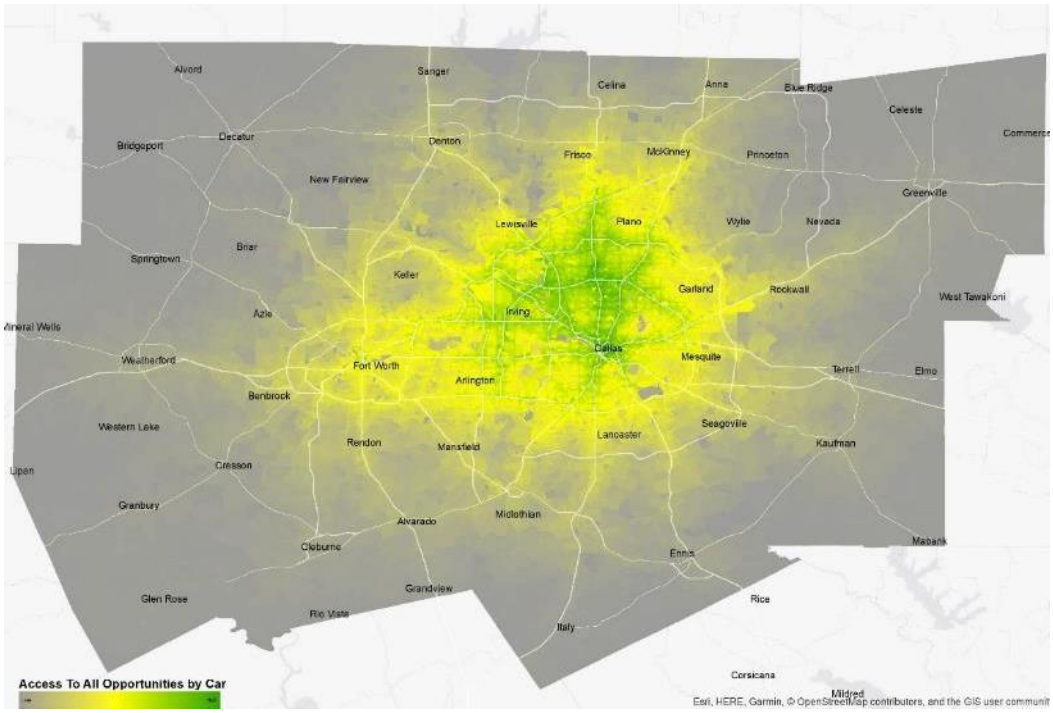

Figure 3-18 Access to All Major Opportunities by Driving

Overall, the status of access to opportunities in DFW is better compared to other two modes: walking and transit (Figure 3-18). For elderly and disability opportunities, except Denton, McKinney and Fort Worth, most of the population have high access to opportunities. (Figure 3-19). Access to education opportunities by car is also high except the City of McKinney in which only 2 % of regional schools and universities are located

(Figure 3-20). The distribution of child and youth facilities in DFW makes the destination accessible by car to almost 77 % of the population. However, Cities of McKinney and Denton are not offering high access to this destination to the residents (Figure 3-21). Driving has a better access to health care opportunities than walking and transit in all cites except McKinney, Fort Worth and Denton (Figure 3-22). Almost all the population in Denton live in areas with low access. Only 3 % of regional health facilities are in this city. Also, Fort Worth is the house for only 10 % of pharmacies, health care providers and fitness centers. In Dallas, pocket of high access is found in North Dallas Neighborhoods, North West Dallas and central neighborhoods.

Food opportunities are also well accessible by car in DFW, presenting the same pattern as other opportunities with the residents of McKinney and Denton having less number of their population living in high access areas (Figure 3-23). Sprawling pattern and insufficient distribution of healthy and unhealthy food in Fort Worth make this destination accessible less than half of the population. Access to service opportunities for the residents of the cities of McKinney, Frisco, Allen and Denton is also poor (Figure 3-24). However, about two third of population are experiencing areas with good access to recreation opportunities by car (Figure 3-25).

About 36 % of the residents in the fifteen cities are not getting benefit from access to job by car. The cities of Carrollton, Plano, Richardson, and Lewisville are giving the chance to experience high access to job to more than 90% of their population (Figure 3-26).

Generally, the residents have better access to their destination opportunities by car than the two other modes. Also, as evident from figures 3-19 to 3-26, the accessibility pattern is almost the same for the whole region meaning that high access areas (areas with score above 100) are mostly concentrated in the center of the region, in Dallas,

Carrollton, Plano, Irving and Garland. Concentration of high access scores by car are mostly around north side of Dallas county around highways such as US 75, Dallas North Tollway, I-35, 635, and President George Bush Turnpike.

While residents of east of Fort Worth and Northern Arlington are experiencing high access by car, the rest of these two cities are suffering from low access to the opportunities.

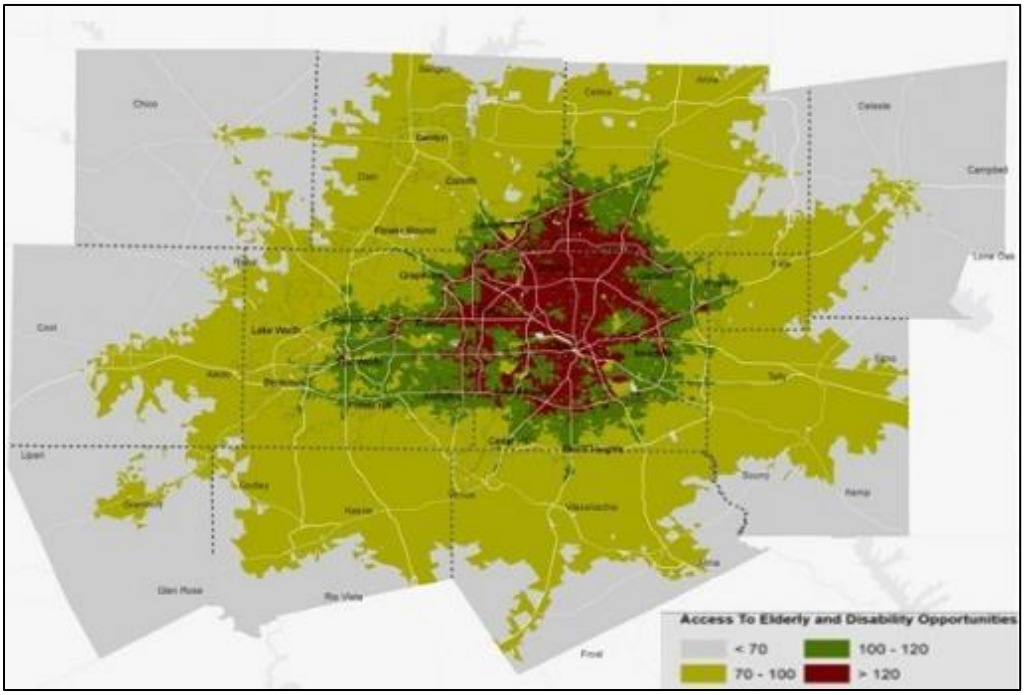

Figure 3-19 Access to Elderly and Disability Opportunity by Driving

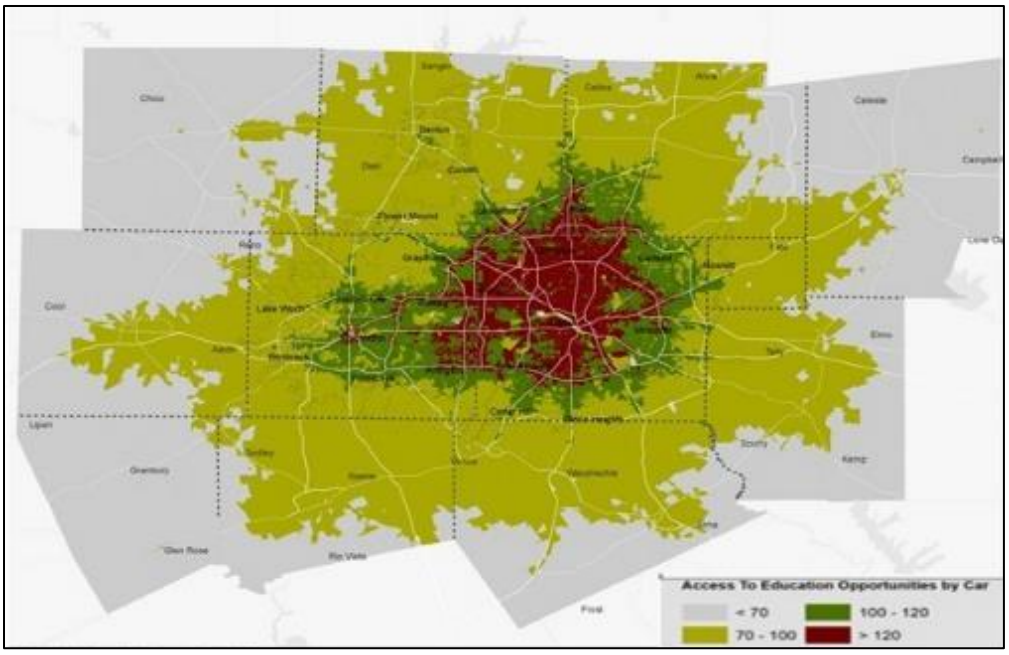

Figure 3-20 Access to Education Opportunity by Driving

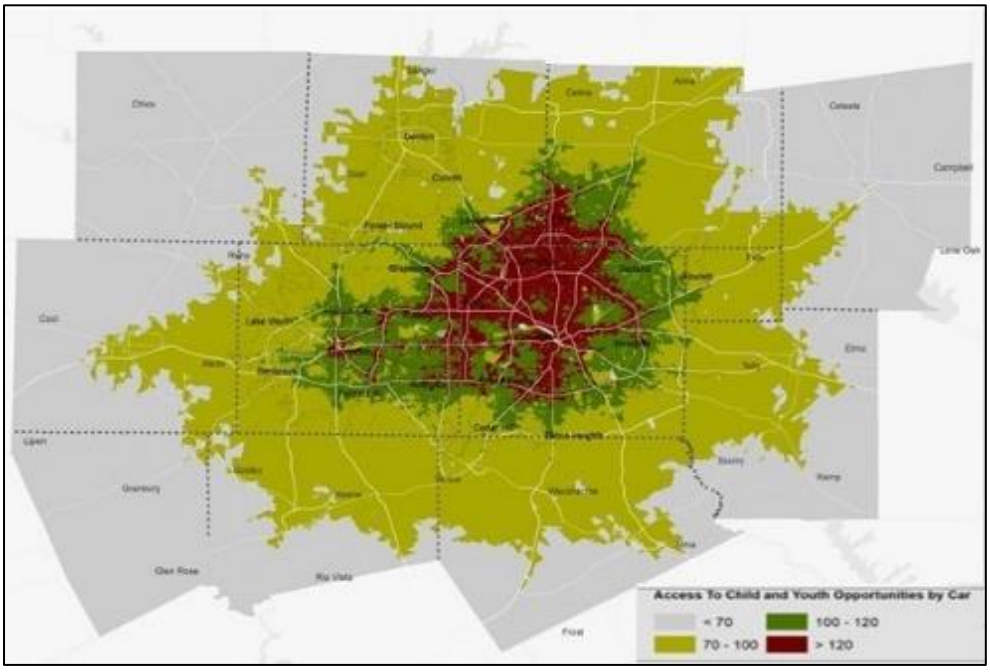

Figure 3-21 Access to Child and Youth Opportunity by Driving

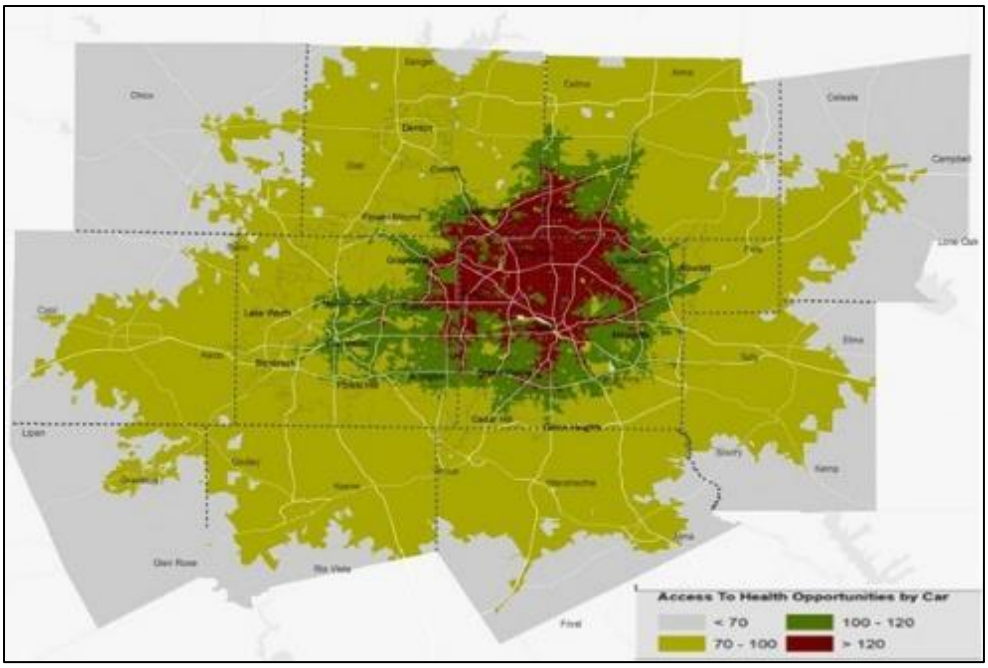

Figure 3-22 Access to Health Opportunity by Driving

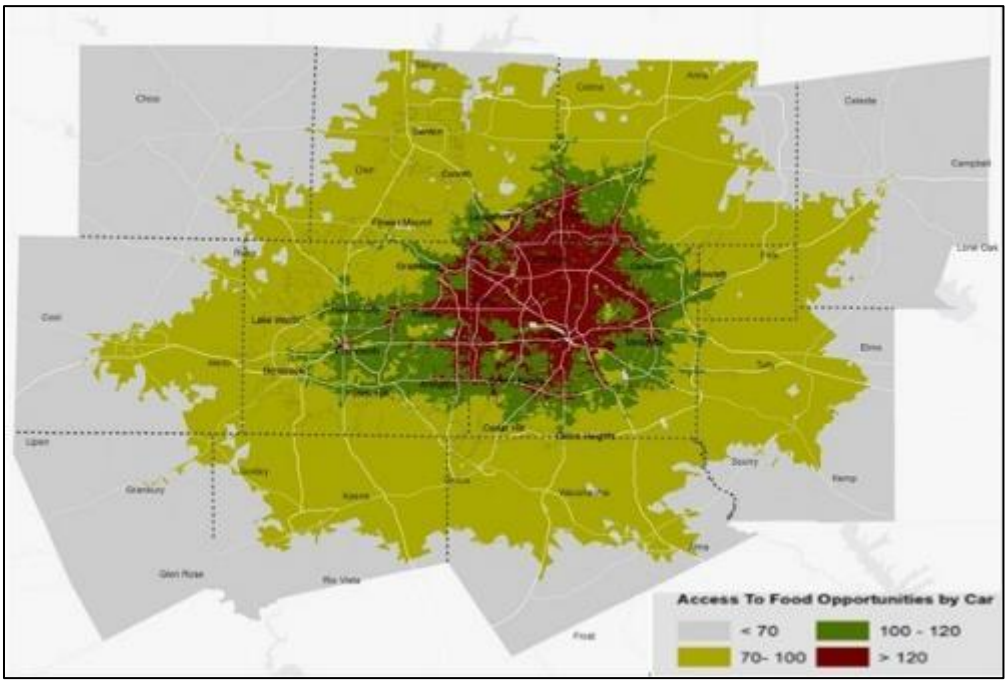

Figure 3-23 Access to Food Opportunity by Driving

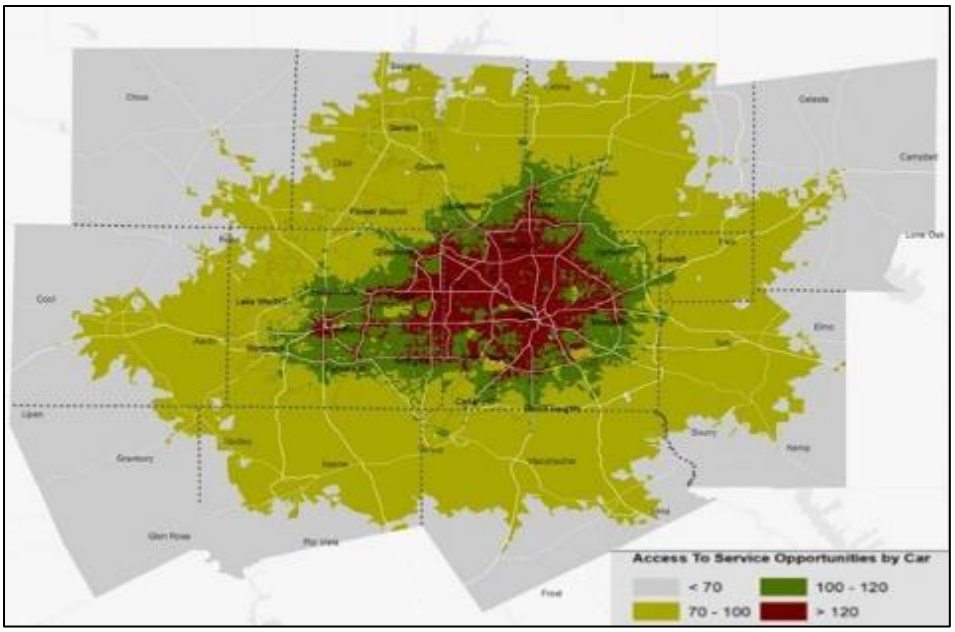

Figure 3-24 Access to Service Opportunity by Driving

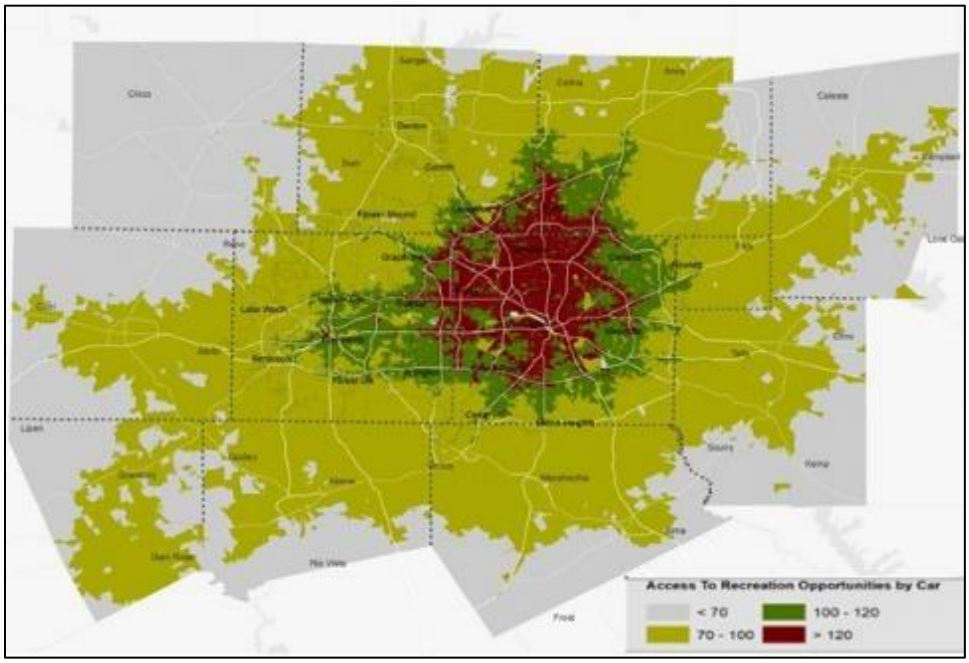

Figure 3-25 Access to Entertainment Opportunity by Driving

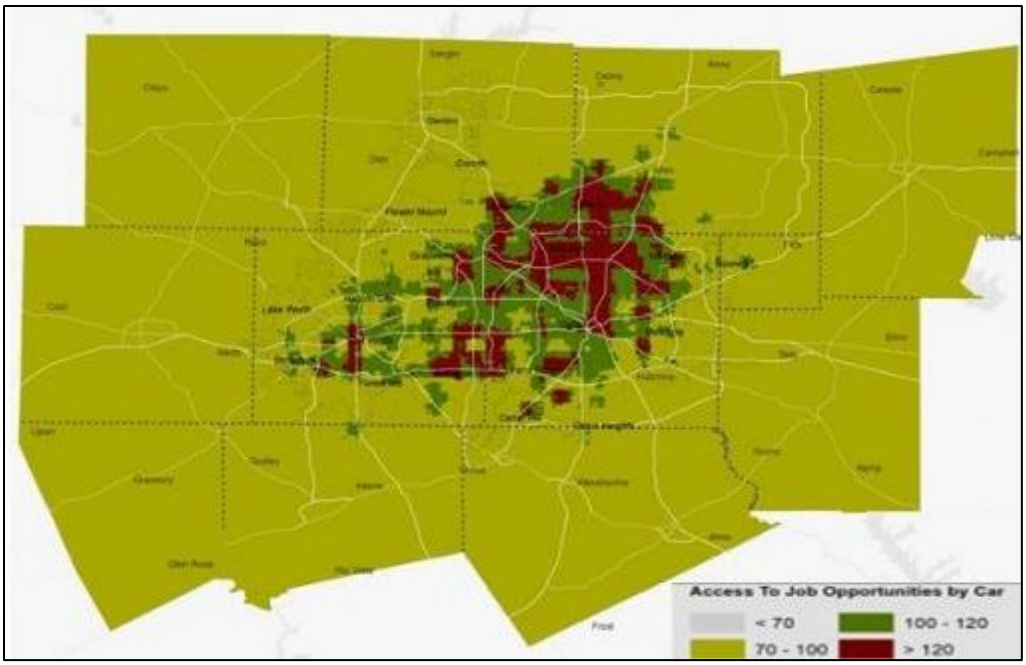

Figure 3-26 Access to Job Opportunity by Driving

– *Access To Opportunities By Transit*

Table 3-11 presents the percentage of population living in census blocks with high access to opportunity score (score higher than regional average (100)) for the top 15 cities in DFW for transit. City of Dallas, as the biggest city with the largest concentration of transit services in the region, holds the highest rank. About 79 % of population are enjoying high access to opportunities by transit.

The city yields the highest rank for access to job, health, food, education, service, youth and childcare, elderly and disability care opportunities by transit for almost more than 70 % of the residents.

Table 3-11 Percentage of population living in high access to opportunity by transit for the top 15 largest cities in DFW

Rank	City Names	Access to all Opportunities	Access to Jobs	Access to Health	Access to Food	Access to Education	Access to Entertainment	Access to Service	Access to Youth and Child Care	Access to Elderly and Disability Care
1	Dallas	**80%**	73%	76%	80%	81%	67%	82%	82%	78%
2	Irving	**75%**	70%	75%	77%	72%	36%	76%	78%	63%
3	Richardson	**72%**	71%	75%	70%	73%	71%	70%	73%	78%
4	Garland	**69%**	63%	63%	72%	72%	48%	70%	69%	70%
5	Carrollton	**46%**	48%	44%	49%	39%	30%	38%	53%	29%
6	Fort Worth	**41%**	35%	33%	42%	39%	23%	42%	48%	29%
7	Plano	**39%**	38%	39%	37%	33%	26%	23%	39%	29%
8	Denton	**31%**	29%	30%	28%	33%	33%	27%	30%	33%
9	Lewisville	**14%**	24%	13%	20%	9%	16%	5%	14%	21%
10	Mesquite	**2%**	2%	2%	3%	3%	1%	3%	3%	2%
11	Grand Prairie	**1%**	1%	1%	1%	1%	0%	1%	1%	1%
12	Arlington	**0%**	0%	0%	0%	0%	0%	0%	0%	0%
12	McKinney	**0%**	0%	0%	0%	0%	0%	0%	0%	0%
12	Frisco	**0%**	0%	0%	0%	0%	0%	0%	0%	0%
12	Allen	**0%**	0%	0%	0%	0%	0%	0%	0%	0%

The city of Irving holds the second ranks with the 75 percentage of its population living in high access to all major opportunity. The city of Richardson ranks the third by providing 72 percentages of its population to have access to all major opportunities by transit. The city ranks the highest for access to entertainment opportunities by transit. In contrast, the cities of Arlington, McKinney, Frisco and Allen have the lowest scores for access to all opportunity by transit. Almost all their population are living in areas with opportunity scores below average for all destinations.

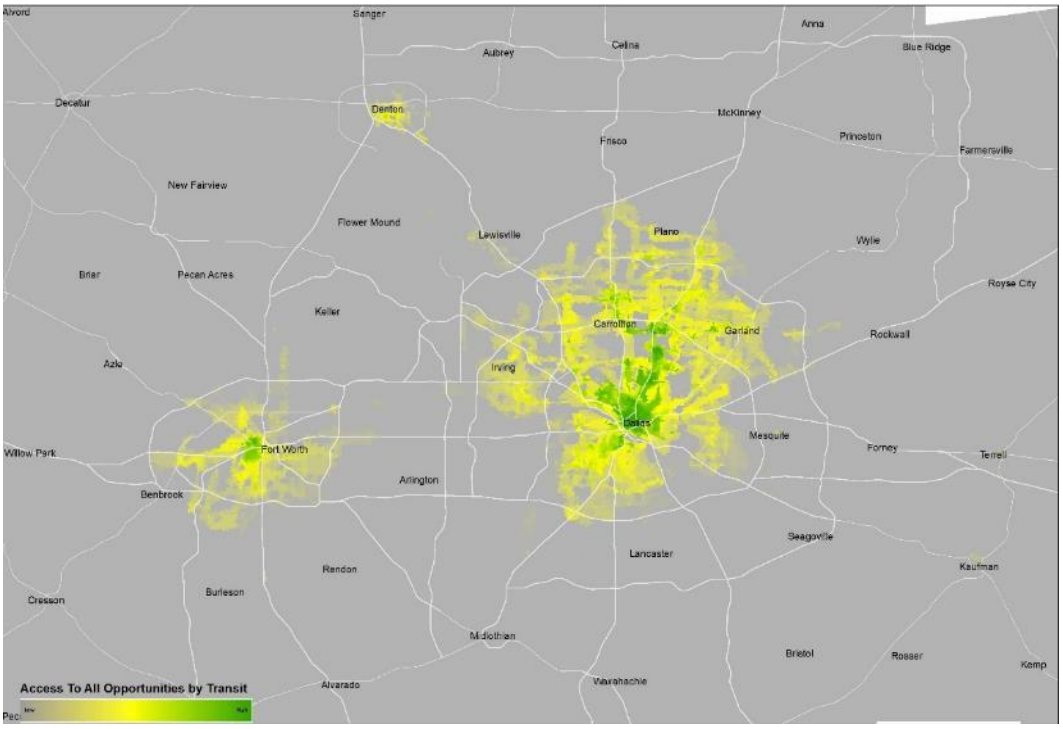

Figure 3-27 Access to All Major Opportunities by Transit

Overall, access to health opportunities by transit is weak throughout the region, indicating that the destinations are out of reach for the residents who rely on transit (Figure 3- 28). Transit services in Dallas, Richardson and Irvin provide a better access to health opportunities to about one third of their population. City of Fort Worth, as the second largest city in the region, provides higher rate of transit access for health opportunity for one-third its residents.

Access to entertainment and recreation opportunities is confined to small clusters (Figure 3- 29). Except the cities of Richardson and Dallas, the rest are giving high access to this opportunity to less than half of their population. Almost the entire residents of Grand Prairie, Arlington, McKinney, Frisco and Allen live in areas with no transit access to this destination.

Lack of transit service in most of the cities in DFW has created barriers for access to education opportunities (Figure 3-30). Transit services in this region make schools, universities and colleges reachable to only about 30 % of the population in these cities. Generally, areas of fewer opportunities are spread throughout the region. Almost all the residents of the cities of Arlington, McKinney, Frisco and Allen live in neighborhoods with less than average for transit access. In Dallas, southeast, southwest and north neighborhoods are examples of least access score.

With regard to food opportunities, about 31 % of the population in these fifteen cities enjoy high access to healthy and unhealthy foods. The city of Dallas offers areas with higher access to almost 80 % of the residents. Except for Dallas, Irving, Garland and Richardson, less than half of their residents are experiencing areas with relatively higher access to food opportunities (Figure 3-31).

For access to child and youth facilities, most of the population in the region are experiencing areas with scores below average (Figure 3-32). However, about two third of population in the cities of Dallas and Richardson are getting benefit from higher access to elderly and disability facilities. Nevertheless, some neighborhoods such as Southern neighborhoods, South East and South West in Dallas are out of transit access to these facilities (Figure 3-33). For access to social service, the majority of residents in the top 15 cities in DFW are living in low access areas access to banks, credit unions and insurance opportunities are insufficient (Figure 3-34).

Access to job opportunities by transit is similarly poor in DFW (Figure 3-35). Only 30 % of the population in these cities are enjoying high access to job opportunities. Again, residents of Arlington, McKinney, Frisco and Allen have almost no access to job opportunities by transit.

Overall, as the similar patterns from figures 3-28 to 3- 35 shows, access by transit is limited to the Dallas, Richardson, Farmer Brach, Garland, university Park, Irving and some portion of Plano, Fort Worth, Rowlett, Lewisville and Denton.

However, although Denton, Fort Worth and Dallas enjoy the services from transit agencies, southern section of Dallas, North, east and West of Fort Worth are not within the access of transit. In Denton, only central section of the city is having good access.

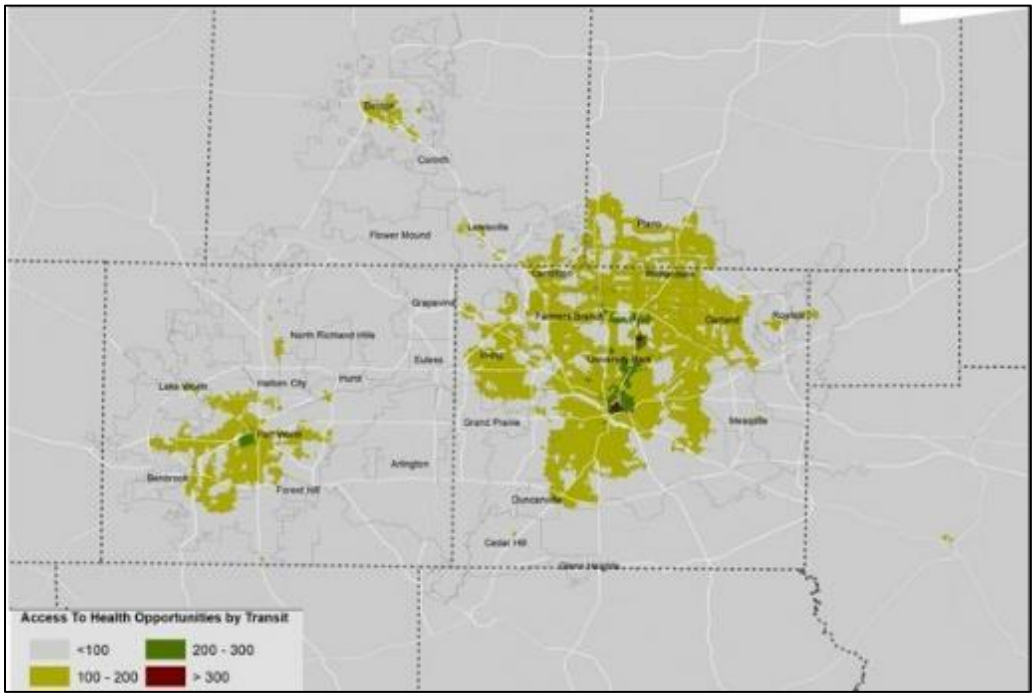

Figure 3-28 Access to Health Opportunities by Transit

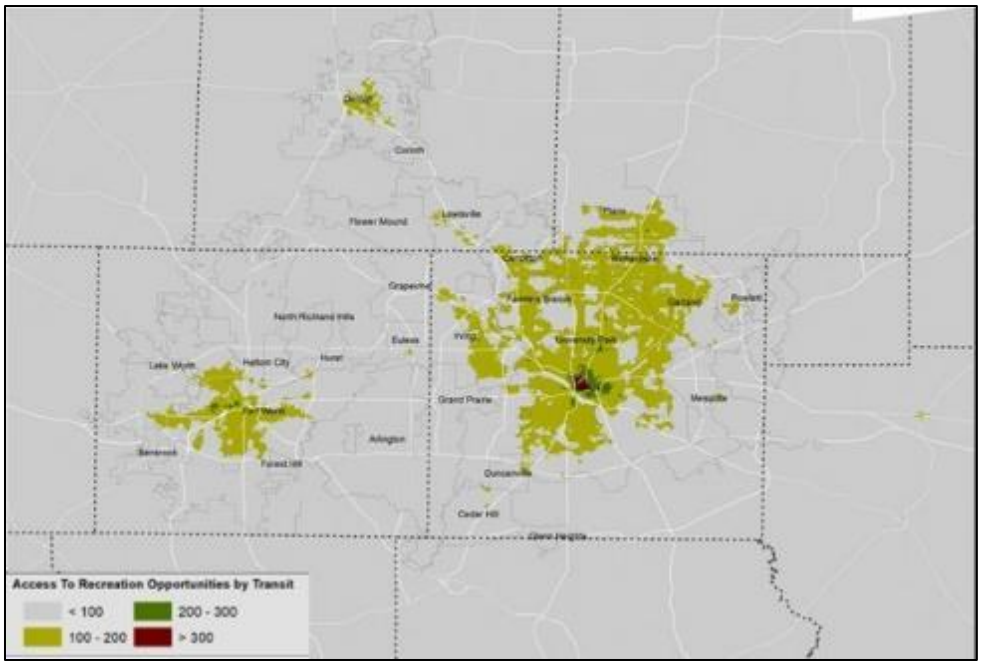

Figure 3-29 Access to Recreation Opportunities by Transit

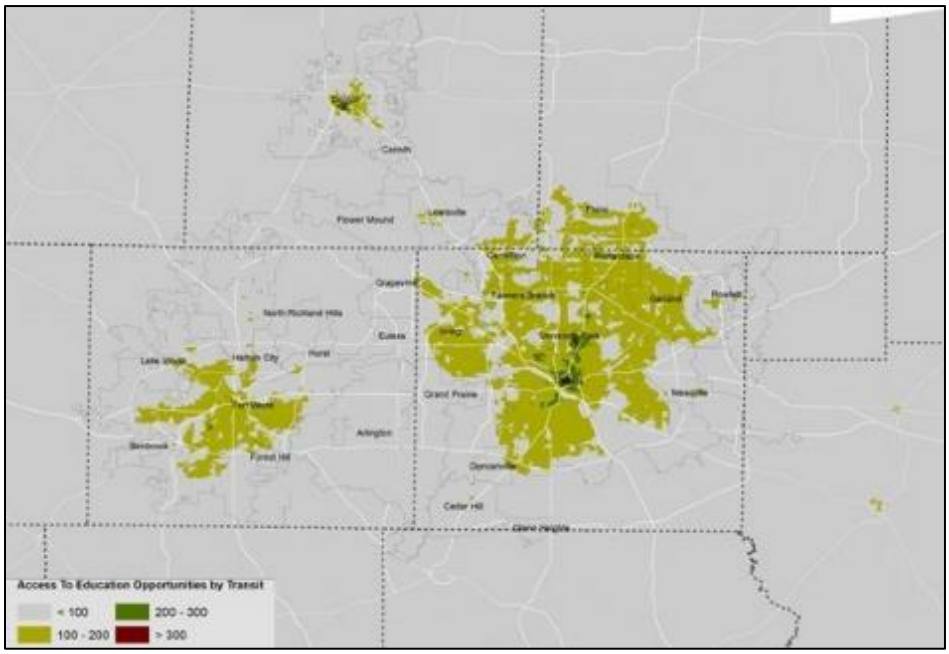

Figure 3-30 Access to Education Opportunities by Transit

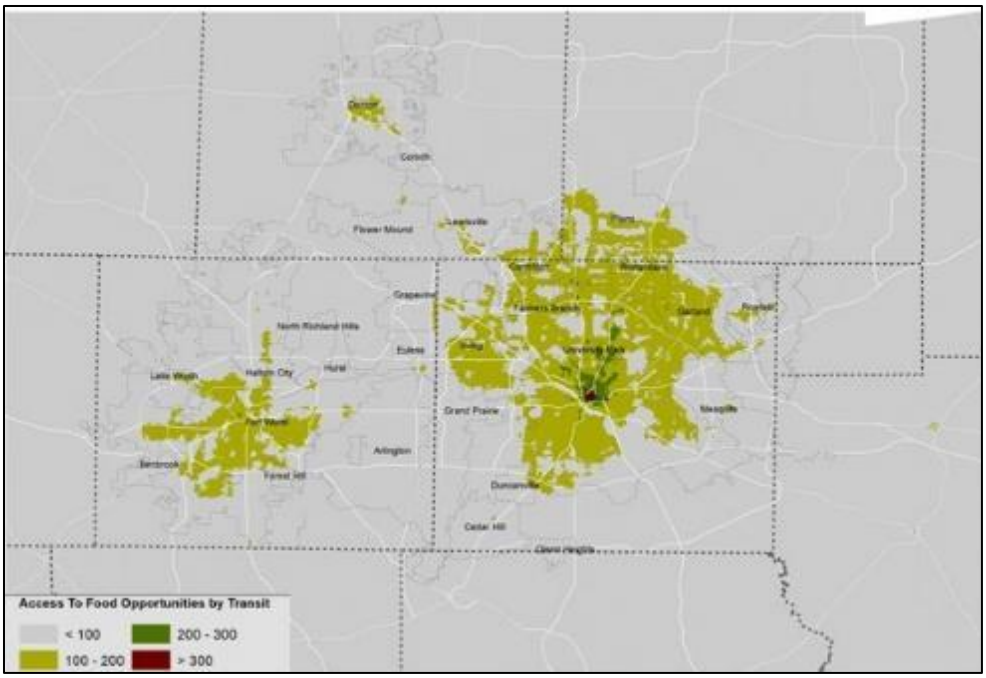

Figure 3-31 Access to Food Opportunities by Transit

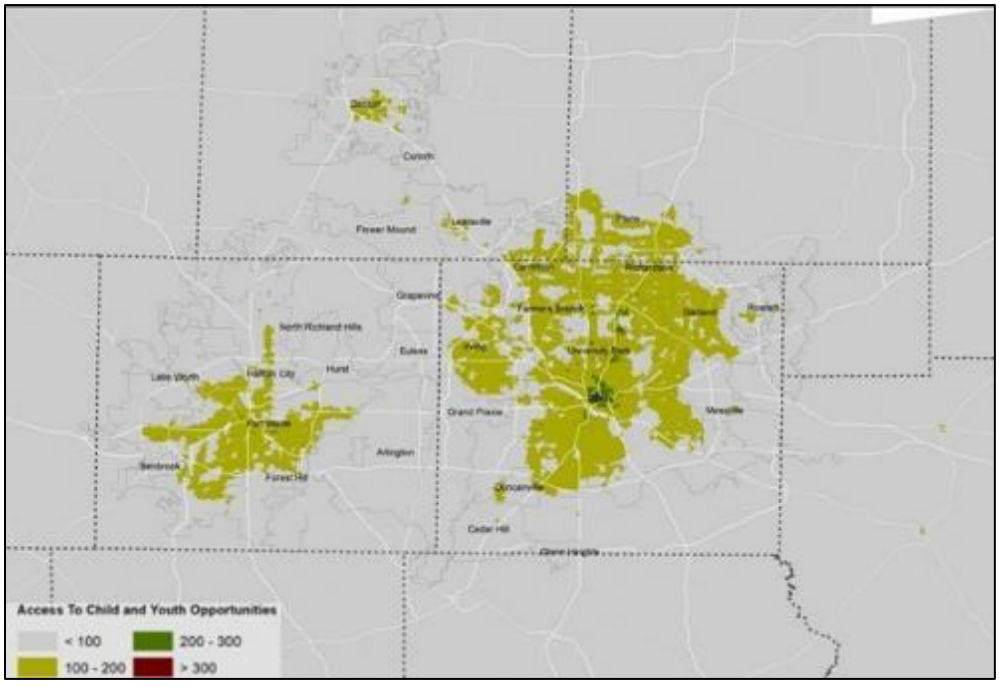

Figure 3-32 Access to Child and Youth Opportunities by Transit

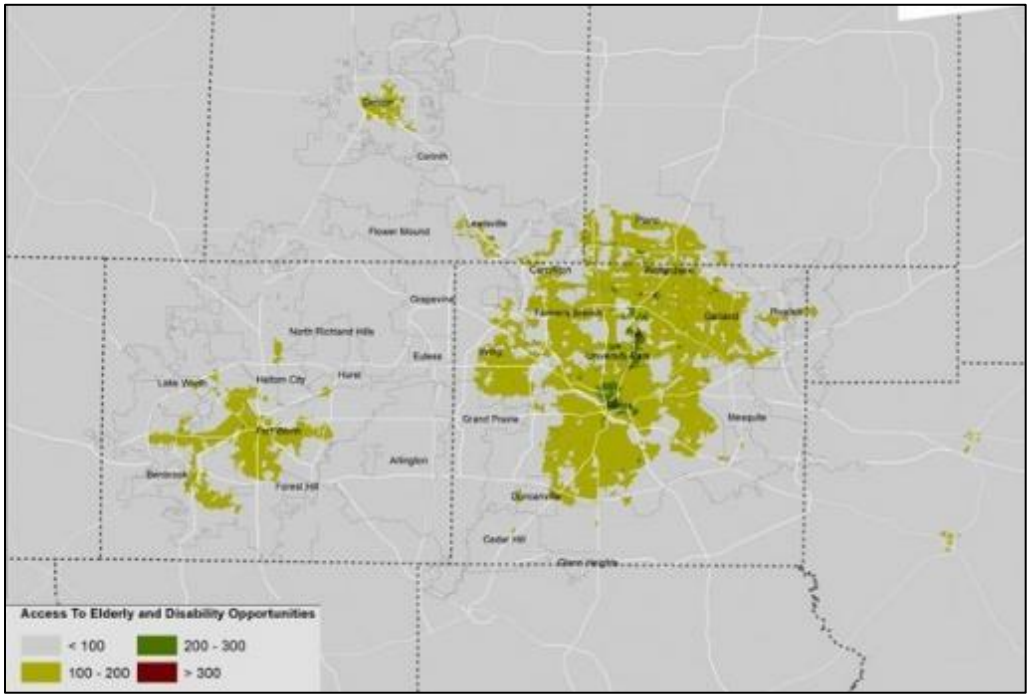

Figure 3-33 Access to Elderly and Disability Opportunities by Transit

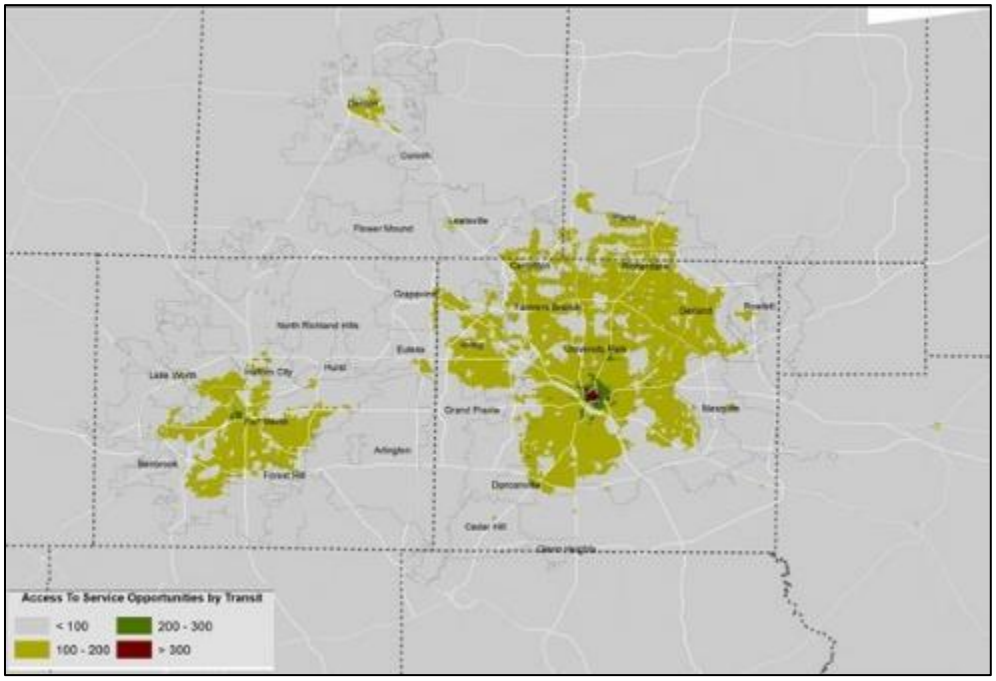

Figure 3-34 Access to Service Opportunities by Transit

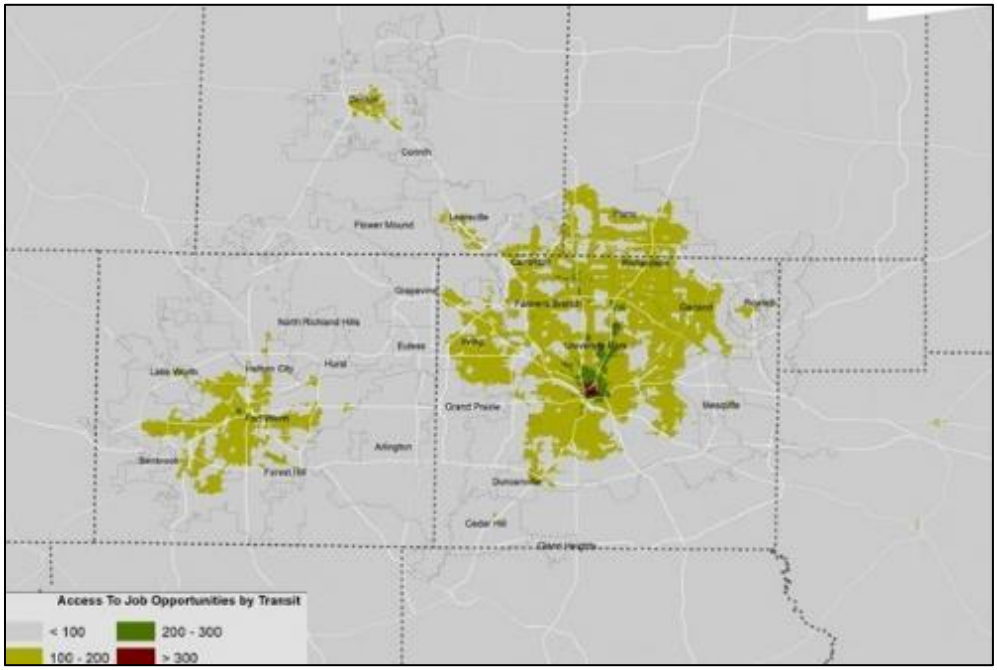

Figure 3-35 Access to Job Opportunities by Transit

– *Comparison Of The Three Transportation Modes Among Cities In DFW*

Table 3-12 compares the average opportunity scores by three modes for the top 15 cities in DFW. For access to opportunities by driving, Irving with the score of 132 stands at the top of other cities. The city has the highest rank for access to service, education and food opportunities. Also, Carrollton takes the second rank since it has the highest rank for access to health and child and youth opportunities by driving. Dallas has the highest rank for elderly, disability, and entertainment access and Richardson has the highest for job opportunity access by drive. Among these cities, however, Denton gets the least score for driving access to opportunity since for all the opportunities, this city has the lowest score.

Taken access to opportunity for transit, Dallas with overall score of 134 stands at the top of other. As expected, the city stands at the top of the list for all destinations.

However, McKinney, Arlington and Allen take the least rank among the cities since they take the least score for access to all destinations.

Access to opportunities by walking, however, shows a diverse pattern since for each destination, different cities get the highest score. Dallas takes the first rank since it has the highest score for service, child and youth and food opportunities; Denton takes the highest position for access to education and Richardson takes the highest rank for access to job, elderly, and disability opportunities, which puts the city in the third rank for the overall opportunity. Also, for access to health and entertainment, Plano and McKinney get the highest rank, respectively. The least access to major opportunity score, however, is for Grand Prairie since it has the least score for health and child and youth destination. Frisco took the second least rank for total opportunity score since it has the least score for walking access to food, job, and education opportunities. Cities of Lewisville, Carrollton and Allen, correspondingly, take the least score for service, entertainment and elderly & disability opportunities.

Overall, the City of Dallas shows to have a good status; however, this is in comparison to other cities in DFW region.

Table 3-12 City scores for access to opportunities by three modes

Mode	Opportunities	Dallas	Fort Worth	Arlington	Plano	Garland	Irving	Grand Prairie	Mesquite	McKinney	Carrollton	Frisco	Denton	Richardson	Lewisville	Allen
Driving	Service	131	108	118	112	113	137	122	118	92	124	102	83	119	109	98
	Health	129	98	108	128	117	132	114	113	99	137	114	88	132	123	108
	Education	132	105	117	117	113	133	120	115	92	126	105	92	124	113	100
	Job	125	103	113	125	112	117	117	98	93	124	102	86	129	120	104
	Child & youth	128	106	116	124	114	130	119	115	97	131	111	83	126	118	107
	Elderly & disability	131	101	112	125	119	129	117	116	97	130	109	85	131	113	106
	Entertainment	133	100	110	123	115	131	117	115	100	129	113	88	126	116	107
	Food	130	103	114	122	117	133	119	117	96	131	109	84	127	116	105
	All Major	131	102	113	123	116	132	118	114	96	132	110	86	128	118	105
walking	Service	112	108	102	98	103	102	100	104	102	98	95	106	102	95	96
	Health	108	105	103	108	99	102	98	102	101	102	102	106	107	101	106
	Education	106	104	105	102	104	102	98	100	101	99	98	116	106	98	101
	Job	107	107	104	109	102	105	100	100	106	104	99	107	109	103	102
	Child & youth	108	108	105	108	101	103	98	104	102	105	102	106	104	103	108
	Elderly & disability	105	100	100	103	104	101	102	99	106	98	101	105	107	101	95
	Entertainment	105	102	99	101	98	98	99	99	111	97	104	107	102	98	101
	Food	112	105	105	106	101	102	100	102	102	101	99	107	105	101	102
	All Major	112	107	104	107	101	103	99	102	104	101	100	109	108	100	104
Transit	Service	134	109	89	97	111	108	90	90	89	100	89	96	110	91	89
	Health	131	106	90	107	108	107	90	90	90	102	90	96	123	93	90
	Education	133	106	89	100	114	108	89	90	89	101	89	107	118	91	89
	Job	130	104	90	104	108	106	90	91	90	104	91	96	117	94	90
	Child & youth	134	111	88	105	112	110	88	89	88	105	88	97	122	92	88
	Elderly & disability	133	103	89	105	119	104	89	90	89	98	89	100	131	92	89
	Entertainment	128	104	92	99	104	101	92	92	92	100	92	101	112	94	92
	Food	134	105	89	103	113	108	89	90	89	103	89	96	119	92	89
	All Major	134	106	89	103	111	107	89	90	89	102	89	98	120	92	89

Discussion

This study has used gravity equation method to measure access to opportunity accounting for distance and time for each mode. For driving and transit, 45-minute travel time from the center of all census blocks in DFW were used. Also, 15 minutes walking time was used to calculate access to opportunity for walking.

I have measured access to opportunity by three modes for 8 destinations including services, jobs, healthcare, education, child and youth, elderly and disability and entertainment and food using PCA. The study also used the PCA to operationalize an overall score for access to all destinations.

The scores placed the city of Dallas at the top for access to opportunities by walking and transit and city of Carrollton for access to opportunities by car. Generally, access to opportunities by transit is poor in DFW since most of the region are not covered by any transit services. Aside from that, transit services are limited to some large cities such as Dallas and Fort Worth. Fixed route transit services do not reach some cities such as Arlington and Allen and only some cities are served by demand route services. Overall, although DFW has enough number of jobs, transit access to the jobs are poor. A study by the university of Minnesota ranked the region the fifth in the nation for total employment but it was ranked 16th for access to job by transit within one hour (Formby, 2015).

Also, waking accessibility has a poor status in the region. Dallas-Fort Worth ranks among the least walkable metros in the United States (Christopher and Loh, 2018); however, as a car-oriented region, it has a good status for access to opportunities by car.

In DFW, concentrations of high poverty rate are in Central Fort Worth, East of Arlington, and South Dallas (US Census, 2013). These are the areas where access to opportunities with modes such as walking, and transit are important and critical for

households' saving on transportation. Based on my analysis in this chapter, these areas, especially south Dallas, are areas that lack transit access to the destinations. Expansion of transit services such as demand-based services through these areas is of high importance for these neighborhoods.

Also, improving walking infrastructure to encourage pedestrian access would help. Aside from that, the distribution of resources and creating a balance between job and housing might address the issue.

Sprawling pattern and insufficient distribution of services in the region make a weak performance for some cities in the region in term of access to opportunities. The opportunities and services are not equally distributed in DFW. More than 67 % of the jobs are located in two counties of Dallas and Tarrant. The pattern is the same for other destination opportunities as well. This unequal distribution of resources and services make barriers to access to opportunities.

Chapter 4

Spatial Distribution of Affordable Housing Projects in Areas of Opportunity

Introduction

Although HUD has aimed to provide housing welfare participants with access to economic, social, and recreational opportunities (Welch, 2013; Welch, & Mishra, 2013), little is known on how well these housing programs spatially match low-income residents with high-access-to-opportunity areas.

This study seeks to investigate location efficiency and access to opportunity for 1,028 major housing assistance programs in the DFW metropolitan area. I employ access to opportunity scores developed on previous chapter to investigate to what extent the affordable housing projects in DFW are located in high access versus low access to opportunity areas. For this purpose, I used spatial analysis and ANOVA. This study informs regional and local planners on location-efficiency of affordability of housing projects and directing subsidies to more accessible, walkable, and transit-served locations.

Research Design

- *Sample of the Study*

For this study, I have selected major affordable housing programs in DFW. While the region is the magnet for business growth and corporate headquarters with relatively lower costs of living, there is a growing concern for transportation equity and location efficiency in DFW area. A recent study showed that affordable housing unit residents are spending a higher percentage of their income on transportation in this region compared to the national average (Hamidi et al, 2018). About 69% of DFW housing projects unaffordable since accessibility features was not incorporated in their location decisions.

Also, job inaccessibility by transit has increased especially in large cities in the region such as Dallas (Hamidi et al, 2016) since there is less understanding on public transit access to opportunities. To address the issue, this study seeks to evaluate location efficiency of the major affordable housing programs in DFW in term of access to opportunities by two non-driving modes, walking and transit. This research seeks to identify long-term affordability and opportunities for upward mobility for all census blocks in the Dallas-Fort Worth metropolitan region. I produced a series of “Catalyst Areas” maps. Catalyst Areas represent areas with adequate access (by modes other than driving) to major destinations such as educational facilities, healthy food, health care facilities, public transit, and job opportunities. This would help low-income households to not only spend less on transportation, but also, by providing access to opportunities, increase their chance of upward mobility.

The sample includes 1,028 affordable housing units in Dallas Fort Worth (DFW) covering all major affordable housing programs except the Rent supplement and below market interest rate Section 236 due to the lack of enough case in the study area. As shown in the figure, HCV and LIHTC are the largest category of the projects while the PRAC811 is the smallest category.

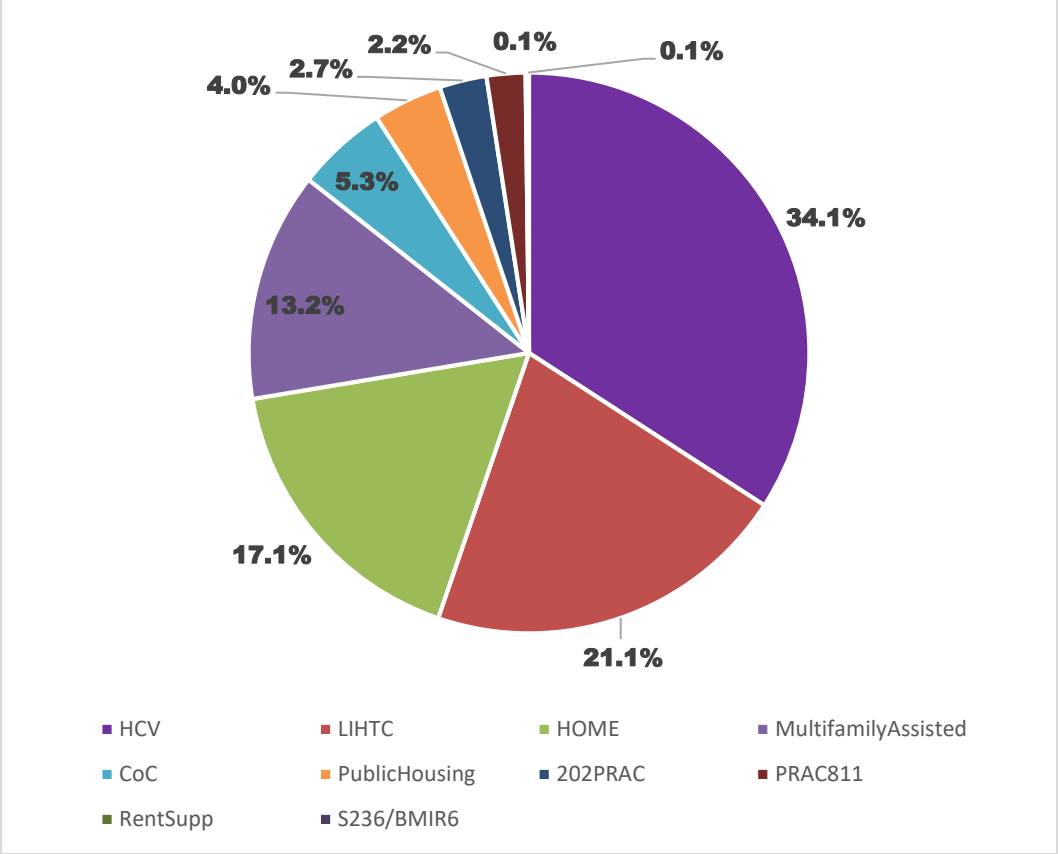

Figure 4-1 Frequency of Affordable Housing Units by Program Types

Also housing units are mostly located in Fort Worth (35 %), Dallas (19%) and Arlington (10%). HCVs, CoC, PRAC811, are in mostly located in Fort Worth, and 202PRAC, LIHCT, HOME, Multifamily Assisted, and Public Housing are mostly in Dallas (Figure 4-1).

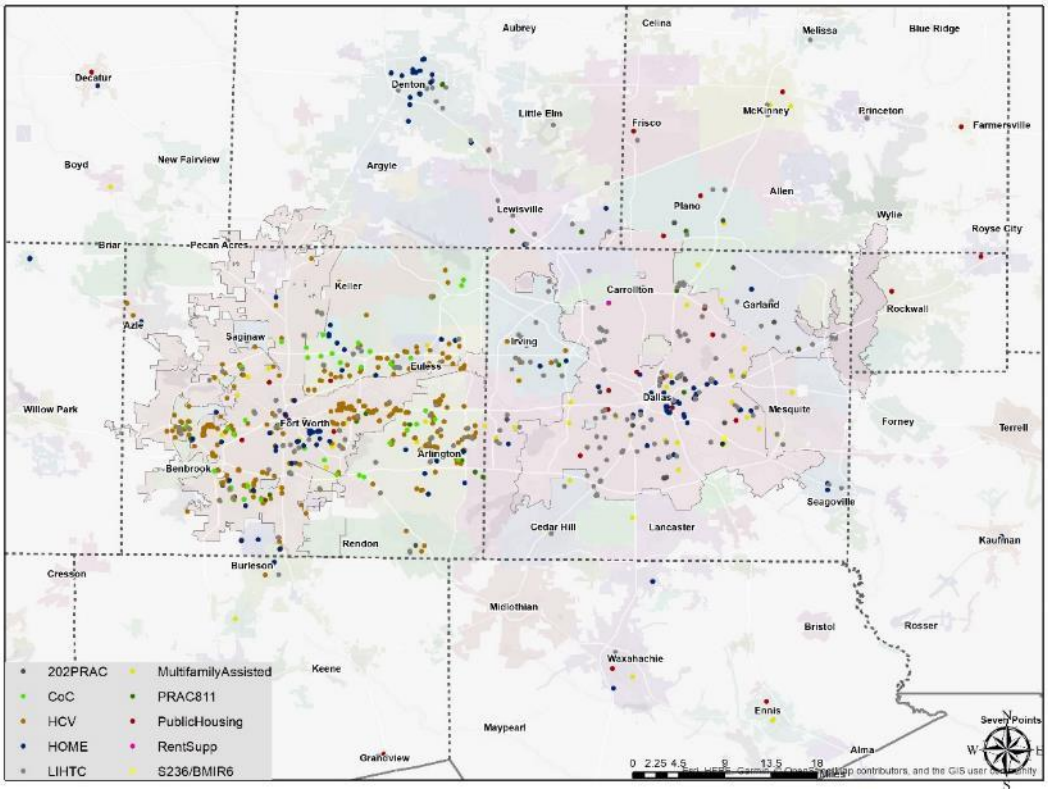

Figure 4-2 Location of Affordable Housing Units

– *Data and Variables*

For this section, I geocoded the address of major affordable housing assistance programs in DFW, gathered from multiple sources. To extract the location of Multifamily Assisted properties, HOME Investments Partnerships (HOME) and Public Housing properties, I used HUD Geospatial Data. The data for Public Housing, Section 8 Project Based Rental Assistance, Rent Supplement, Section 202 Supportive Housing for the Elderly Program (S202 PRAC), Section 811 Supportive Housing for Persons with Disabilities (S811 PRAC), Below market interest rate - section 236 (S236/BMIR), Low Income Housing Tax Credit (LIHTC) and HOME Investment Partnership Program (HOME) are extracted from HUD Picture of Subsidized Households. Also, for Housing

Choice Vouchers (HCV) and Continuum of Care (COC) programs, the contracting data from local Housing Agencies in DFW were used.

Table 4-1 Source and Types of Data for the Sample of the Study

Source	Data Type
HUD Geospatial Data	Multifamily Assisted, Public Housing, HOME
HUD Picture of Subsidized Households	Section 8, RentSupp, S236/BMIR, S202 PRAC,811 PRAC, HOME, LIHTC
DFW Local Housing Agencies	HCV, COC

Table 4-2 Descriptive Statistics of Access to Opportunity Scores for Affordable Housing Units in DFW

Modes	Min	Max	Mean	Std. Deviation
Walking	86.22	545.10	108.03	30.99
Transit	89.01	371.56	108.04	28.78
Driving	67.24	159.83	108.78	17.50

As table of descriptive statistic shows, the projects are getting a mean of 108. The minimum score is for driving and maximum is for walking. Also, figures 4-3 to 4-5 show the frequency histogram of access to all major opportunity scores for affordable housing units in DFW by three modes. As shown, for the transit and walking modes, the values are skewed right (positively skewed). This is because most of the units have the values less than average for access by these two modes. However, driving access scores are more normally distributed.

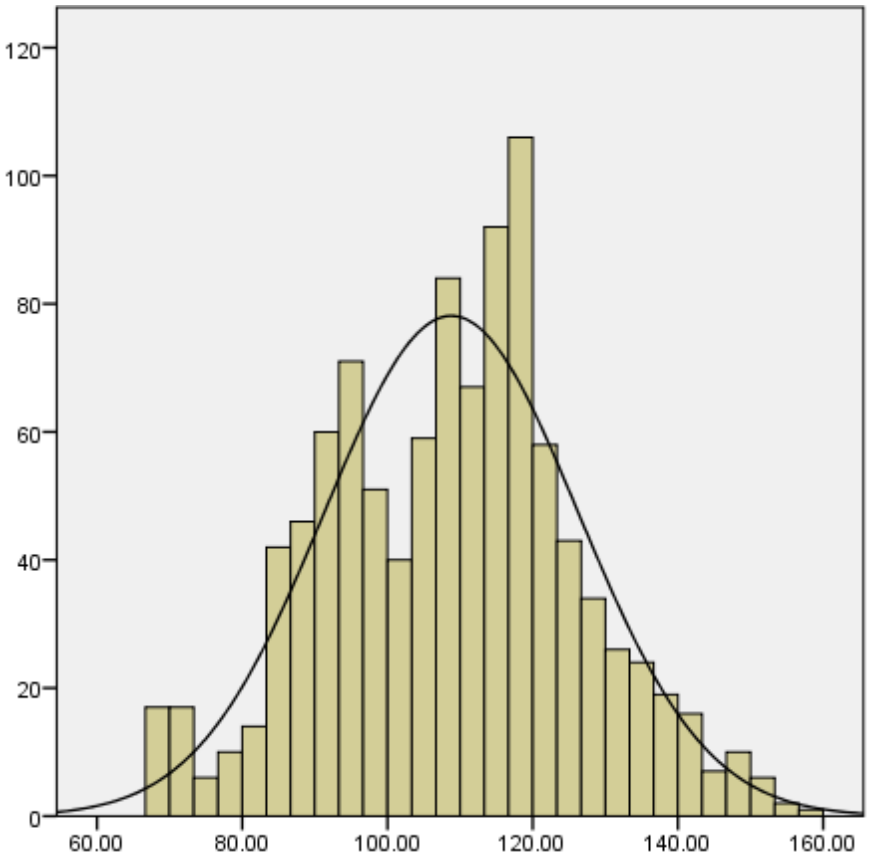

Figure 4-3 Frequency Distribution of Driving Access to opportunities for Affordable Housing Units in DFW

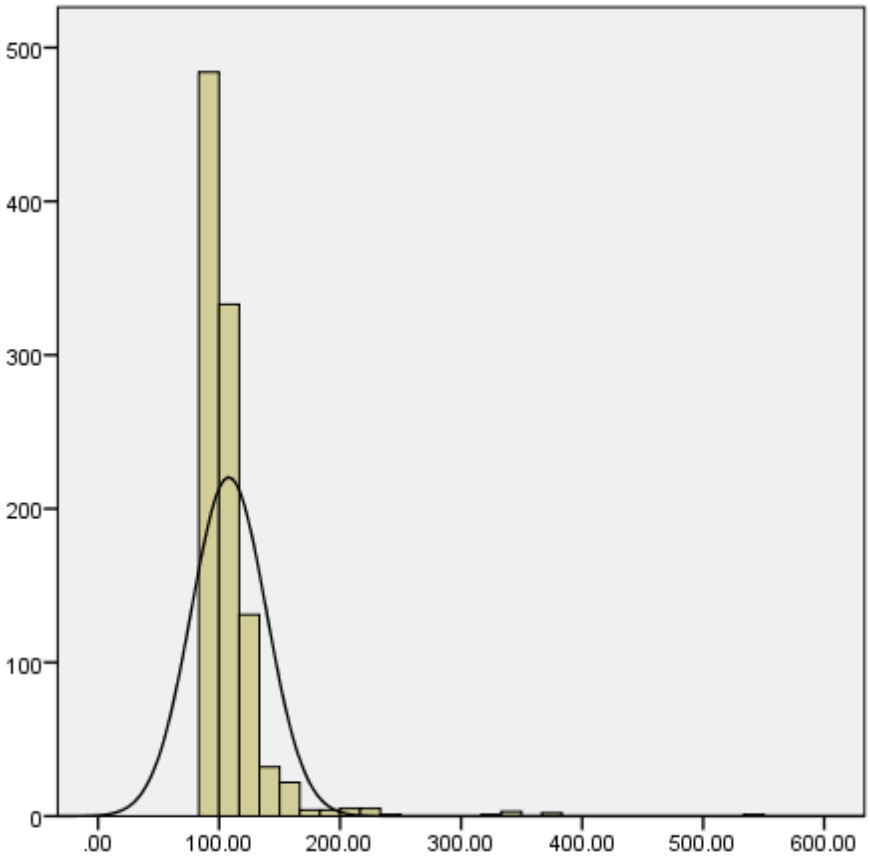

Figure 4-4 Frequency Distribution of Walking Access to opportunities for Affordable Housing Units in DFW

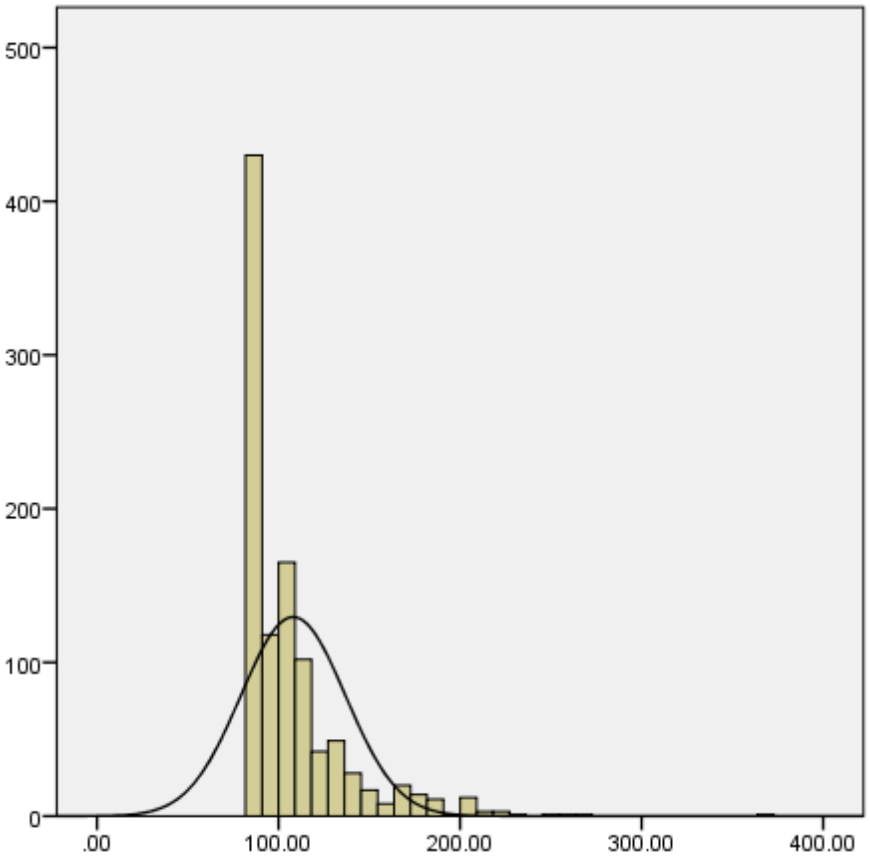

Figure 4-5 Frequency Distribution of Transit Access to opportunities for Affordable Housing Units in DFW

Analysis and Results

This section focuses on analyzing the spatial distribution of affordable housing units in term of access to opportunities for three modes in DFW. The analysis includes program types of Housing Choice Voucher (HCV), Continuum of Care (CoC), Section 811 Project Rental Assistance (PRA) Program (PRAC811), Multifamily Housing Assistance, Section 236 or Below Market Interest Rate (BMIR), HOME Investment Partnership (HOME) and Low Income Housing Tax Credit (LIHTC).

– *Spatial Distribution of Affordable Housing projects in Areas of Opportunities by Walking*

Table 4-3 shows the percentage of affordable housing units in areas of access to opportunity by walking. As evident, less than 1 % (7 projects) of the total units are happening in areas with scores above 300. Also, about 47 % of them are located in areas less than regional average score for walking (less than score of 100).

More than half of PRAC811 (61%), which constitutes less than 2 % of the total housing units, are located in low access by walking. Also, 34 of the total housing units are HCVs but about half of them are in accessible by walk. Although 202PRAC and public housing constitutes a small portion of the total projects, more than half of them are located in areas with scores above 100. Based on the analysis, LIHTC housing units show a better status than HCVs. While 51 % HCVs are in high opportunity areas, 56 % of LIHTC are in high access areas.

Table 4-3 Frequency of the Affordable Housing programs in Areas of Opportunity Access by Walking

Programs	< 100		100 to 200		200 to 300		> 300		Total
HCV	171	48.7%	173	49.3%	5	1.4%	2	0.6%	**351**
LIHTC	95	43.8%	120	55.3%	1	0.5%	1	0.5%	**217**
HOME	81	46.0%	90	51.1%	4	2.3%	1	0.6%	**176**
Multifamily	65	47.8%	69	50.7%	0	0.0%	2	1.5%	**136**
CoC	27	50.0%	26	48.1%	1	1.9%	0	0.0%	**54**
Public Housing	18	43.9%	22	53.7%	0	0.0%	1	2.4%	**41**
202PRAC	12	42.9%	16	57.1%	0	0.0%	0	0.0%	**28**
PRAC811	14	60.9%	9	39.1%	0	0.0%	0	0.0%	**23**
RentSupp	0	0.0%	1	100.0%	0	0.0%	0	0.0%	**1**
S236/BMIR6	1	100.0%	0	0.0%	0	0.0%	0	0.0%	**1**
Total	**484**	**47.1%**	**526**	**51.2%**	**11**	**1.1%**	**7**	**0.7%**	**1028**

I also used ANOVA to test if there is a significant difference in the performance of affordable housing unit programs in terms of access to opportunities by walking. The F-statistic is low, which indicates that variance between groups is lower than within groups (Table 4-4). The ANOVA analysis proved no significant difference between HUD programs in terms of their performance with regard to location efficiency ($p < 0.14$). In other words, the ANOVA test indicates similar patterns of location inefficiency for all affordable housing programs in DFW.

Table 4-4 ANOVA Results for Variance among Affordable Housing Program Types in Areas of Opportunities by Walking

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1743.67	703	2.48	1.11	0.14
Within Groups	725.22	324	2.24		
Total	2468.88	1027			

As figure 4-6 shows, more number of the projects in Fort Worth, Dallas and Arlington are located in areas with scores above average but less number of housing units in the cities such as Denton, Irving and Euless are in high opportunity areas.

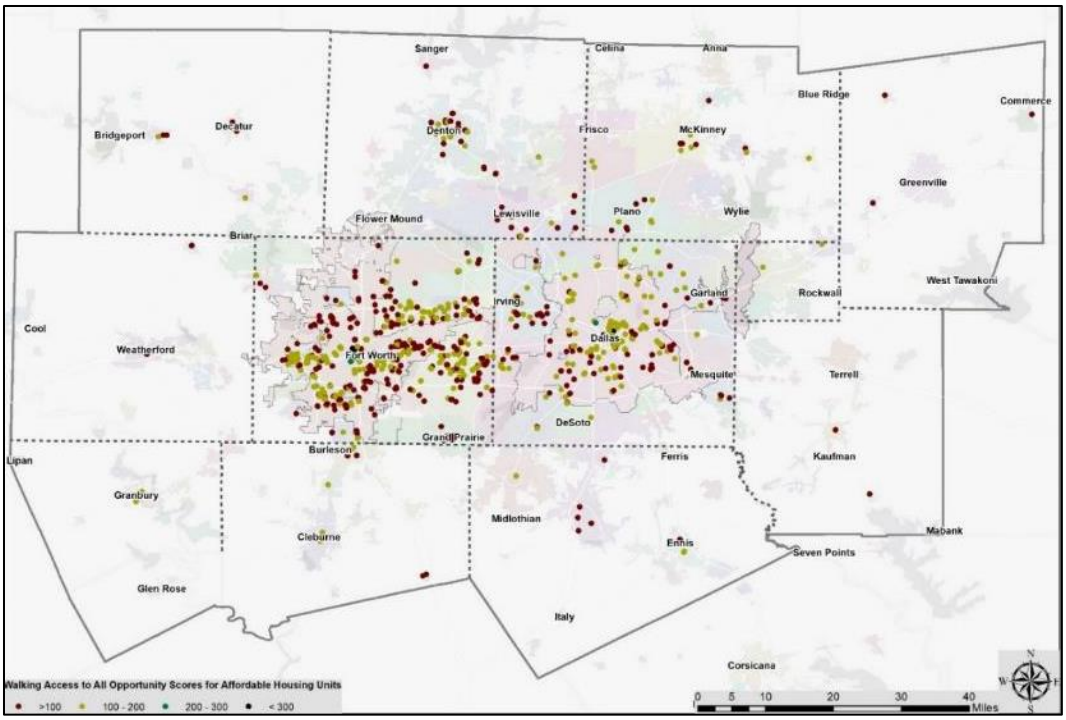

Figure 4-6 Spatial Distribution of Affordable Housing Units in Areas of Opportunity Access by Walk

– *Spatial Distribution of Affordable Housing projects in Areas of Opportunities by Transit*

As for distribution of affordable housing units in areas of opportunity access by transit, more than half of HCVs are in low access areas (below mean of 100) (Table 4-5). The HCVs with low walking access score are evident mostly in Fort Worth (34%), Arlington (30%), Euless (7%) and Hurst (6%). Also, CoCs are only 5 % of the total housing units but 61 % of them are in low access areas. The CoCs with low access score are located mostly in Arlington (27%), Fort Worth (18%) and North Richland Hills (12%).

Table 4-5 Frequency of the Affordable Housing programs in Areas of Opportunity Access by Transit

Programs	< 100		100 to 200		200 to 300		>300		Total
HCV	229	65.2%	121	34.5%	1	0.3%	0	0.0%	**351**
LIHTC	91	41.9%	116	53.5%	10	4.6%	0	0.0%	**217**
HOME	80	45.5%	88	50.0%	7	4.0%	1	0.6%	**176**
Multifamily	69	50.7%	65	47.8%	2	1.5%	0	0.0%	**136**
CoC	33	61.1%	21	38.9%	0	0.0%	0	0.0%	**54**
Public Housing	22	53.7%	18	43.9%	1	2.4%	0	0.0%	**41**
202PRAC	10	35.7%	18	64.3%	0	0.0%	0	0.0%	**28**
PRAC811	13	56.5%	9	39.1%	1	4.3%	0	0.0%	**23**
RentSupp	0	0.0%	1	100.0%	0	0.0%	0	0.0%	**1**
S236/BMIR6	1	100.0%	0	0.0%	0	0.0%	0	0.0%	**1**
Total	**548**	**53.3%**	**457**	**44.5%**	**22**	**2.1%**	**1**	**0.1%**	**1028**

However, the analysis showed a better status for 202PRAC, LIHTC, and HOME for higher number of them in areas with good access to opportunities by transit. Only 3 % of the total housing units are in this type but 64 % of them are located in areas with score above 100. The projects are mostly in the cities of Fort Worth, Dallas and Plano.

Moreover, based on the analysis, HCVs are at the lowest rank for the number of them happening in areas of opportunity access by transit. The distribution of HCV housing unit types in areas with high access score for transit are mostly in Fort Worth (94%) and Irving (5%).

Overall, as figure 4-7 shows, less than half (47 %) of the housing units are located in areas with scores above average (100). Examples of the cities with more number of the housing units in high access areas are Fort Worth, Dallas, Irving and

Plano. However, in Denton, although Denton County Transportation Authority (DCTA) serves it, most of the housing projects are not within the reach of transit.

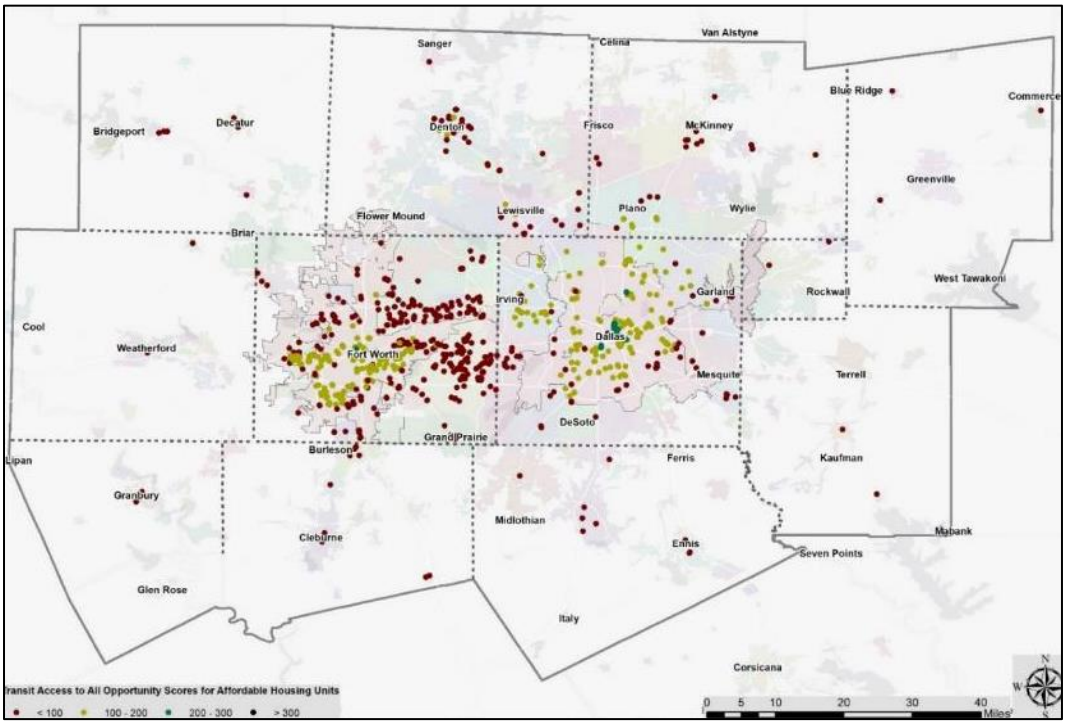

Figure 4-7 Spatial Distribution of Affordable Housing Units in Areas of Opportunity Access by Transit

The result for ANOVA (Table 4-6) shows that, the variances in both modes in the program types amongst affordable housing units in the areas of opportunities were not statistically significant ($p < 0.79$).

Table 4-6 ANOVA Results for Variance among Affordable Housing Program Types in Areas of Opportunities by Transit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	992.22	431	2.30	0.93	0.79
Within Groups	1476.66	596	2.48		
Total	2468.88	1027			

– *Spatial Distribution of Affordable Housing projects in Areas of Opportunities by Driving*

The percentage of affordable housing units in areas of access to opportunity by car is presented in table 4-7. As evident, most of the affordable housing units are located in areas where access is better the two other modes. Less than 2 % of the total units are happening in areas with scores less than 70, while about 68 % of them are located in areas with scores above 100.

Table 4-7 Frequency of the Affordable Housing programs in Areas of Opportunity Access by Car

Programs	< 70		70 to 100		100 to 120		> 120		Total
HCV	0	0%	112	31.9%	197	56.1%	42	12%	**351**
LIHTC	0	0%	46	21.2%	83	38.2%	88	40.6%	**217**
HOME	8	4.5%	66	37.5%	57	32.4%	45	25.6%	**176**
Multifamily	2	1.5%	42	30.9%	53	39%	39	28.7%	**136**
CoC	0	0%	17	31.5%	33	61.1%	4	7.4%	**54**
Public Housing	6	14.6%	16	39%	9	22%	10	24.4%	**41**
202PRAC	1	3.6%	8	28.6%	9	32.1%	10	35.7%	**28**
PRAC811	0	0%	10	43.5%	6	26.1%	7	30.4%	**23**
RentSupp	0	0%	0	0%	0	0%	1	100%	**1**
S236/BMIR6	0	0%	0	0%	1	100%	0	0%	**1**
Total	**17**	**1.7%**	**317**	**30.8%**	**448**	**43.6%**	**246**	**23.9%**	**1028**

HOME program has the highest number in areas with score less than 70 while LIHTC has the highest number of their units in areas with scores above 120. Units located in low access areas by car are mostly in low density and small cities in DFW. However, the distribution of LIHTC units with scores above 120 are in cities of Dallas and Irving (Figure 4-8).

As for HUD largest affordable programs (HCV and LIHTC), LIHTC has a better status than HCV in term of location efficiencies by car. About 79 % of LIHTC units are in areas with scores above 100 while 68 % of HCVs are in high access areas.

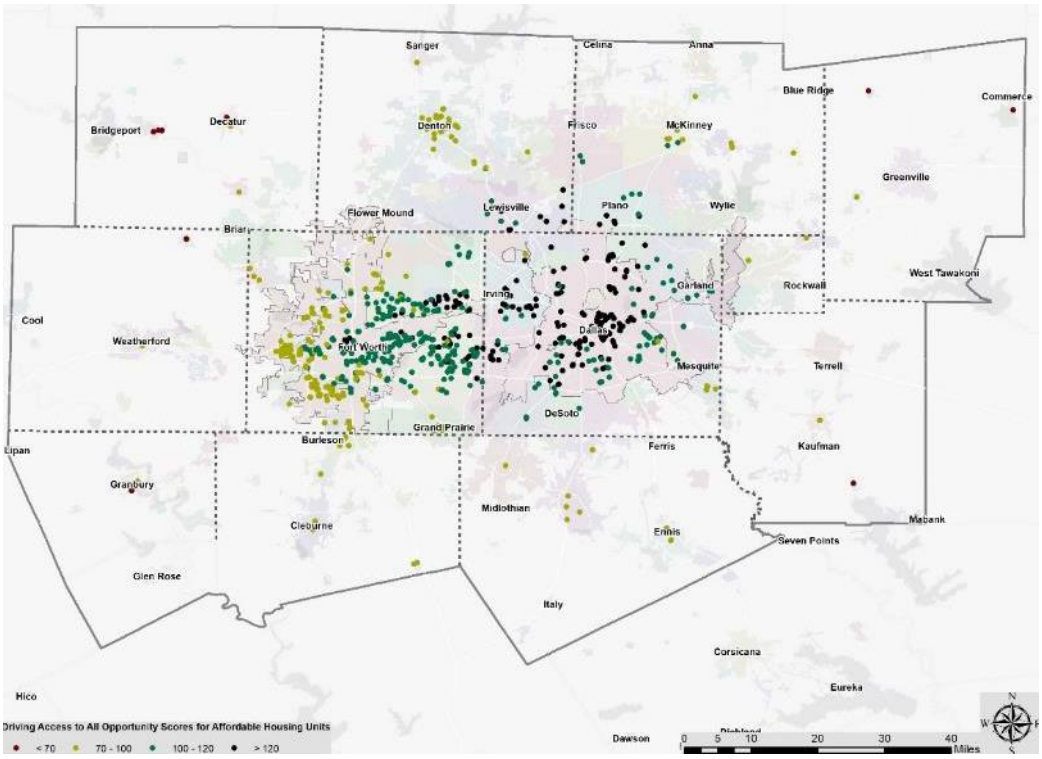

Figure 4-8 Spatial Distribution of Affordable Housing Units in Areas of Opportunity Access by Car

I also used ANOVA to test if there is a significant difference in the performance of affordable housing unit programs in terms of access to opportunities by car (Table 4-8). The ANOVA tests indicate similar patterns of location inefficiency for all affordable housing programs in DFW.

Table 4-8 ANOVA Results for Variance among Affordable Housing Program Types in Areas of Opportunities by Car

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1814.12	732	2.48	1.12	0.13
Within Groups	654.76	295	2.22		
Total	2468.88	1027			

Conclusions

This study seeks to investigate the spatial distribution of affordable housing units in areas of opportunity access by three transportation modes of car, walking and transit. Of particular importance is access to opportunities by walking and transit since low income residents of affordable housing units can save transportation costs through living in areas with sufficient access to the opportunities by these two modes. Overall, I observed a consistent pattern of poor performance in terms of location efficiency among all affordable housing programs in DFW. The findings indicated that the majority of affordable housing projects in DFW are located in areas with low access to opportunities by both walking and transit. However, the situation is better for access to opportunities by car.

About half of the HCV and LIHTC, the largest HUD affordable programs, are in areas with good access to opportunities by walking (score of above 100). The same pattern is evident for car and transit access to opportunities for both HCVs and LIHTCs.

The result of this study suggests that policies should help to incorporate access to opportunities in HUD affordable programs to direct the programs in areas of better access to provide the chance for low-income residents of these units to save on transportation cost (Hamidi et al, 2016).

Chapter 5

Spatial Distribution of New Development Projects in Areas of Opportunity Access

Introduction

This section has used access scores developed in previous chapter to analyze the spatial distribution of new developments in term of access to opportunities in DFW. As discussed in the literature, accessibility was identified to be one of the main factors in location decisions. Therefore, I have analyzed the efficiencies of locations of new developments in term of accessibility factors. The result of this analysis identifies successful and unsuccessful developments in term of accessibility and location efficiencies. Also, this section determines which development occurs in most accessible areas and which one occurs in the least. The analysis tends to show the frequency of project locations in low or high access areas. For this reason, I have conducted case study analysis to select commercial, residential, special use projects from 2010 to 2017. High access to opportunity is defined as the areas with scores better than the regional average (the score above 100) and low access is defined as any value below the regional average score.

Research Design

- *Sample of the Study*

For this study, I have selected the sample 452 projects. About 52 % of the projects are commercial, 41 % residential, and 8 % are special use projects (Table 5-1). Also, most of the new projects are for the two years of 2016 and 2017, mostly commercial in use.

Table 5-1 Frequency of New Development Project from 2010 to 2017

Year	Commercial		Residential		Special Use		Total Year
2010	3	1. 3%	1	0.5%	1	2.9%	5
2011	1	0.4%	0	0%	0	0%	1
2012	6	2.6%	4	2.2%	2	5.9%	12
2013	28	11.9%	5	2.7%	1	2.9%	34
2014	36	15.4%	22	11.9%	0	0%	58
2015	9	3.9%	5	2.7%	1	2.9%	15
2016	116	49.6%	34	18.5%	14	41.2%	164
2017	35	14.9%	113	61.4%	15	44.1%	163
Total	**234**		**184**		**34**		**452**
% of Total	51.77%		40.71%		7.52%		

The commercial projects include industrial, lodge, office and retail and service categories; residential projects include multifamily, single family, senior living facilities and dorms and special use type is comprised of institutional, recreation, education, government and cultural subclasses (Figure 5-1).

– *Data and Variables*

This chapter analyzes the spatial distribution of new development projects in term of access to opportunity for all three modes. The point locations of structures from NCTCOG were used. The source includes 16,321-point locations of structures of at least 80,000 square feet from 1873 to 2017. The data source includes the type and subclass of the projects, the year that structure was completed, and the status of the development as well as the address. To understand the location efficacies, I have used access to opportunity scores developed in chapter three.

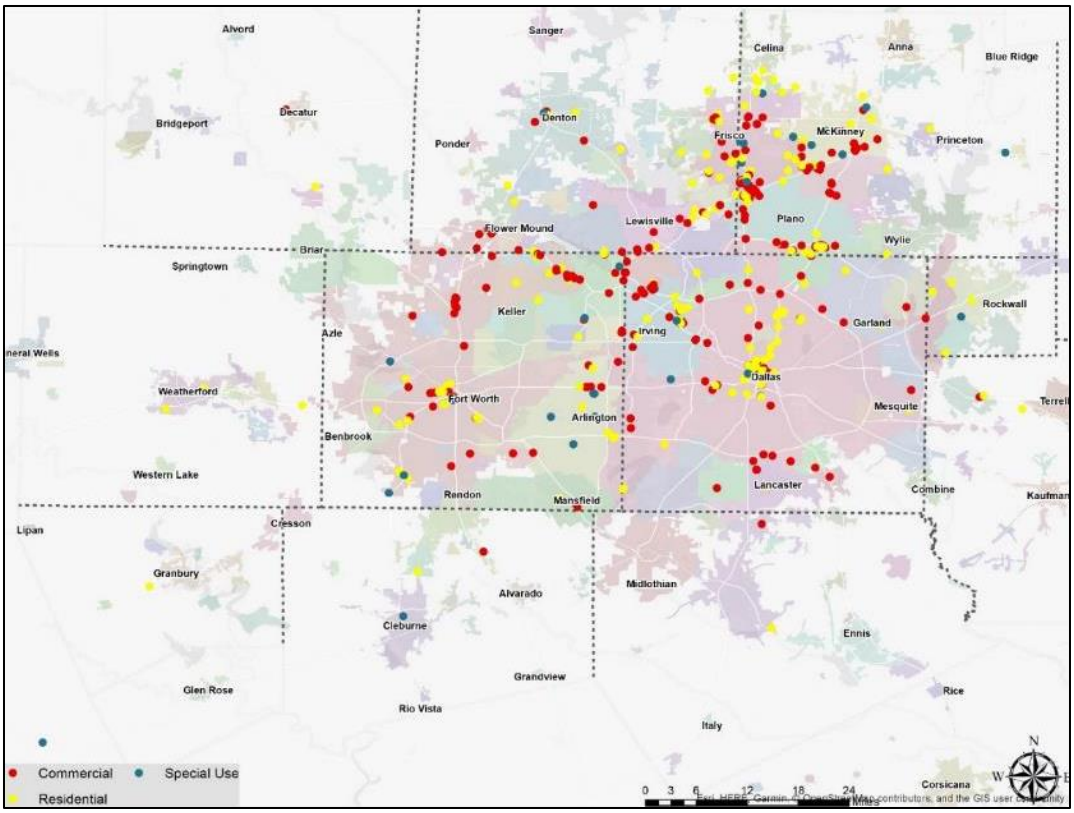

Figure 5-1 Location of New Development Samples

Table 5-2 Data and Sources for New Developments

Data	Description	Source
Development Locations	Point locations of structures and groups of structures with at least 80,000 square feet	NCTCOG
Type of Development	Type of development for structures and groups of structures with at least 80,000 square feet	NCTCOG
Opportunity Access Score	Access scores for all census blocks in which New Developments are located	Chapter 3

Analysis and Result

This section focuses on analyzing the spatial distribution of new development projects in term of access to opportunities for three modes in DFW from 2010 to 2017. The analysis includes residential, commercial, special use and transportation projects for the top 10 cities with largest number of development including Dallas, Frisco, Fort Worth, Plano, McKinney, Arlington, Irving, Richardson, Southlake and Lewisville.

- *Spatial Distribution of New Projects in term of Access to Opportunities by Walking*

Table 5-3 shows the percentage of new development projects in areas with different access to opportunity categories by walking. I also have categorized the score of the project location to analyze access to opportunities for different project types (Table 5-3).

Table 5-3 Frequency of the Projects in Opportunity Access Areas by Walking

Type	**Commercial**				**Residential**				**Special Use**				**Total**			
Year	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300
2010	1	2	0	0	0	0	0	1	1	0	0	0	2	2	0	1
2011	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2012	3	3	0	0	4	0	0	0	1	1	0	0	8	4	0	0
2013	18	8	2	0	5	0	0	0	0	0	0	1	23	8	2	1
2014	24	12	0	0	18	4	0	0	0	0	0	0	42	16	0	0
2015	6	2	1	0	4	1	0	0	1	0	0	0	11	3	1	0
2016	80	33	3	0	30	4	0	0	7	7	0	0	117	44	3	0
2017	22	10	1	2	60	42	5	6	13	2	0	0	95	54	6	8
Total	**155**	**70**	**7**	**2**	**121**	**51**	**5**	**7**	**23**	**10**	**0**	**1**	**299**	**131**	**12**	**10**

As evident, only 2 % (10 projects) of the total projects are happening in areas with scores above 300. Also, about 66 % of them (299 projects) are located in areas with

scores lower than regional average for walking. Only about one third of the projects are developing in areas with scores above average (score above 100) opportunities by walk.

Overall, the projects happening in areas above average access score are mostly commercial in type for most of the years (more than half). However, in 2017, about 80 percent of residential projects are developing in higher access areas. Also, special use projects are locating more on high access areas in 2016.

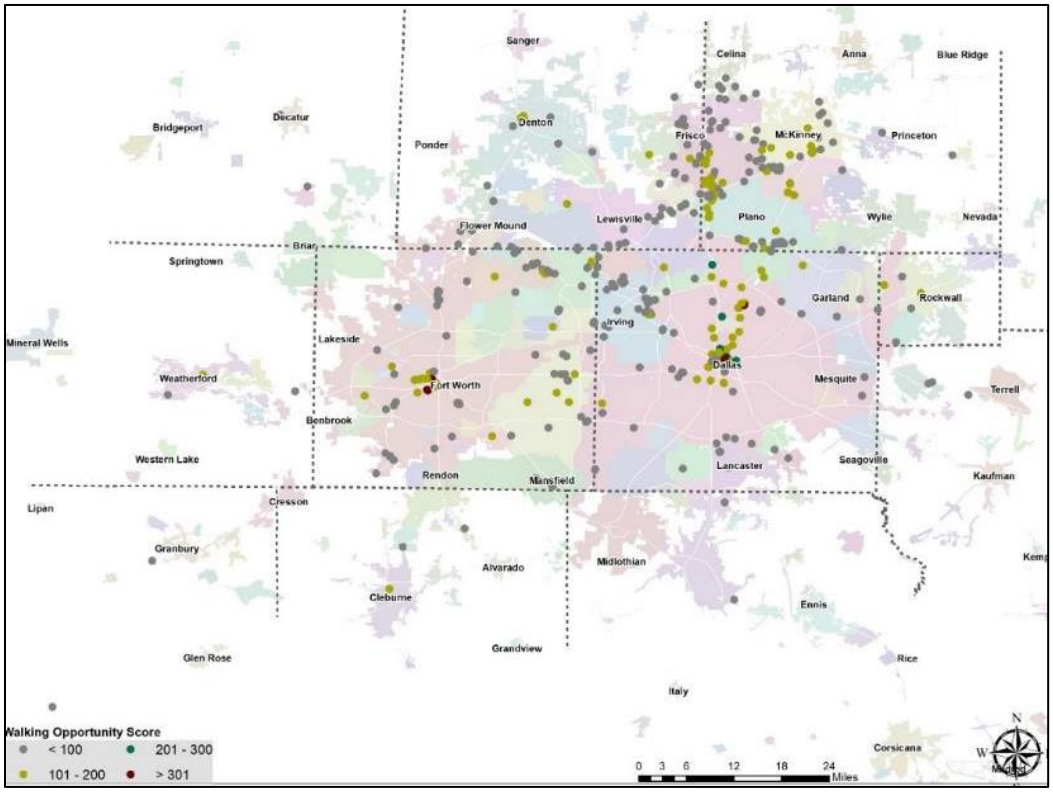

Figure 5-2 Spatial Distribution of New Projects in term of Access to Opportunities by Walk

As figure 5-2 shows, projects with low scores are spread throughout the region but the ones with scores above average are mostly in Dallas, the North of the region (South of McKinney and Frisco), central Fort Worth, Arlington.

I also used ANOVA to understand if there are any statistical differences in the number of projects in opportunity area by walking among top 10 cities in DFW. For the purpose of this section, projects with high access scores are defined as the ones happening in areas above regional average score (Score of 100).

As table of the results shows the F-statistic is high, which indicates that variance between groups is higher than within groups. The ANOVA analysis proved a significant difference among cities in terms of their projects with regard to location efficiency ($p < 0.00$). In other words, the ANOVA tests indicated a different pattern of performance among cities.

Table 5-4 ANOVA Results for Variance among Cities in term of their new projects in Areas of Opportunities by Walking

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	224379	9	24931	10	0.00
Within Groups	783027	305	2567		

Also, since table of ANOVA is significant, I used Post Hoc test to understand which city is different from other cities. As evident, Dallas is significantly different from other cities because it has higher mean differences. Frisco and Plano are also significantly different from Lewisville (Table 5-5).

Table 5-5 Post Hoc Results for Variance among Cities in term of their new projects in Areas of Opportunities by Walking

Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.
Dallas	Frisco	59.9*	Frisco	Dallas	-59.9*	Fort Worth	Dallas	-38.7*	Plano	Dallas	-57.3*
	Fort Worth	38.7*		Fort Worth	-21.1		Frisco	21.2		Frisco	2.6
	Plano	57.3*		Plano	-2.5		Plano	18.6		Fort Worth	-18.6
	McKinney	67*		McKinney	7.1		McKinney	28.3		McKinney	9.7
	Arlington	61.1*		Arlington	1.2		Arlington	22.4		Arlington	3.8
	Irving	66.2*		Irving	6.3		Irving	27.5		Irving	8.9
	Richardson	70.3*		Richardson	10.3		Richardson	31.6		Richardson	13
	Southlake	63.7*		Southlake	3.8		Southlake	25		Southlake	6.4
	Lewisville	73.6*		Lewisville	13.6*		Lewisville	34.9		Lewisville	16.3*
McKinney	Dallas	-67*	Arlington	Dallas	-61.2*	Irving	Dallas	-66.2*	Richardson	Dallas	-70.3*
	Frisco	-7.1		Frisco	-1.2		Frisco	-6.3		Frisco	-10.4
	Fort Worth	-28.3		Fort Worth	-22.4		Fort Worth	-27.5		Fort Worth	-31.6
	Plano	-9.7		Plano	-3.8		Plano	-8.9		Plano	-13
	Arlington	-5.9		McKinney	5.9		McKinney	0.8		McKinney	-3.3
	Irving	-0.8		Irving	5		Arlington	-5		Arlington	-9.1
	Richardson	3.3		Richardson	9.1		Richardson	4.1		Irving	-4.1
	Southlake	-3.3		Southlake	2.6		Southlake	-2.5		Southlake	-6.6
	Lewisville	6.6		Lewisville	12.4		Lewisville	7.4		Lewisville	3.3
Southlake	Dallas	-63.7*	Lewisville	Dallas	-73.6*	* The mean difference is significant at the 0.05 level.					
	Frisco	-3.8		Frisco	-13.7*						
	Fort Worth	-25		Fort Worth	-34.9						
	Plano	-6.4		Plano	-16.3						
	McKinney	3.3		McKinney	-6.6						
	Arlington	-2.6		Arlington	-12.4						
	Irving	2.5		Irving	-7.4						
	Richardson	6.6		Richardson	-3.3						
	Lewisville	9.9		Southlake	-9.9						

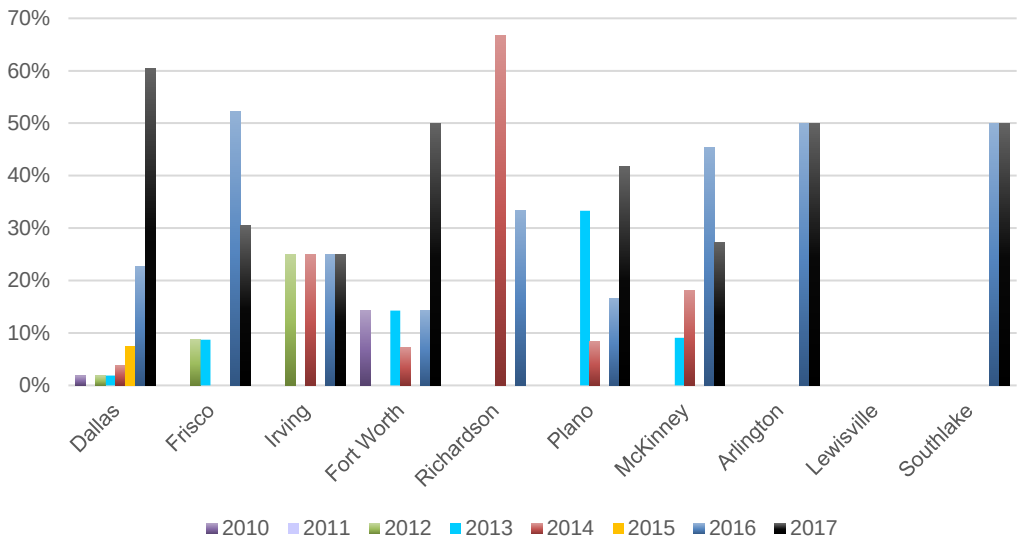

Figure 5-3 Distribution of Projects in High Opportunity Areas by Walking in 10 Cities

Overall, after 2016, more number of projects are located in high access areas by walking. The City of Dallas ranks the first for having more number of the number of the projects in high access to all opportunities by walking. About 74 % of projects in high access area by walking are in the City of Dallas. The city also has the highest number of developments in high access area in 2017 and 2015. Frisco is in the second rank among the cities for the number of projects in high access areas. About 30 % of the projects in Fort Worth are in high access to opportunity areas making it the third. The city has the largest number of the projects in high access areas in 2010. Interestingly, although less than 7 % of the regional projects are in Plano, about half of them are in high access areas. Notably, all projects in Lewisville are in low access areas (Table 5-6).

Table 5-6 Distribution of Projects in High Opportunity Areas by walking in 10 Cities

Rank[1]	Cities	2010	2011	2012	2013	2014	2015	2016	2017	# of Project in High Access	% of Project in High Access	# of Total Project
1	Dallas	2%	0%	2%	2%	4%	8%	23%	60%	53	74%	72
2	Frisco	0%	0%	9%	9%	0%	0%	52%	30%	23	48%	48
3	Fort Worth	14%	0%	0%	14%	7%	0%	14%	50%	14	30%	46
4	Plano	0%	0%	0%	33%	8%	0%	17%	42%	12	48%	25
5	McKinney	0%	0%	0%	9%	18%	0%	46%	27%	11	36%	31
6	Arlington	0%	0%	0%	0%	0%	0%	50%	50%	4	29%	14
6	Irving	0%	0%	25%	0%	25%	0%	25%	25%	4	13%	30
7	Richardson	0%	0%	0%	0%	67%	0%	33%	0%	3	12%	26
8	Southlake	0%	0%	0%	0%	0%	0%	50%	50%	2	18%	11
9	Lewisville	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	12
Total Region		**3**	**0**	**4**	**11**	**16**	**4**	**47**	**68**	**153**	**33.8%**	**452**

– *Spatial Distribution of New Projects in term of Access to Opportunities by Car*

The number of new development projects in areas with categories of access to opportunities by car is presented in table 5-7. As expected from a car- oriented region, more than two third of the projects during this period are happening in areas with opportunity scores above average by car. Only 1 % of them (4 projects) are in areas with score below 70. However, still 26 % of them do not have good access by car (118 projects).

More than 50 % of the projects are located in areas with high access to opportunities – defined as areas with scores above regional average (100). Even in 2014, 2016 and 2017, more than 70 % of them were in high opportunity areas. The projects in

[1] Ranking is based on the number of the projects in high opportunity area

high access areas are mostly commercial; through, in 2017, the frequency of residential projects in high access areas is high.

Table 5-7 Frequency of the Projects in Opportunity Access Areas by Driving

Type	**Commercial**				**Residential**				**Special Use**				**Total**			
Years	< 70	70 to 100	100 to 120	> 120	< 70	70 to 100	100 to 120	> 120	< 70	70 to 100	100 to 120	> 120	< 70	70 to 100	100 to 120	> 120
2010	0	1	1	1	0	0	1	0	0	0	1	0	0	1	3	1
2011	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
2012	0	1	2	3	0	3	1	0	0	1	0	1	0	5	3	4
2013	0	7	9	12	0	5	0	0	0	0	1	0	0	12	10	12
2014	0	3	7	26	0	9	4	9	0	0	0	0	0	12	11	35
2015	0	1	2	6	0	4	0	1	0	1	0	0	0	6	2	7
2016	1	19	41	55	2	17	7	8	0	5	5	4	3	41	53	67
2017	0	10	13	12	0	22	28	63	1	5	9	0	1	37	50	75
Total	**1**	**42**	**76**	**115**	**2**	**60**	**41**	**81**	**1**	**12**	**16**	**5**	**4**	**114**	**133**	**201**

Overall, the status of projects in high access by driving is better than other two modes (Figure 5-4). However, they are mostly concentrated in Dallas and in cities in North Dallas. Projects in low score areas (less than average) are in west and east of McKinney, Northern Frisco, Denton, Fort Worth and east of the region.

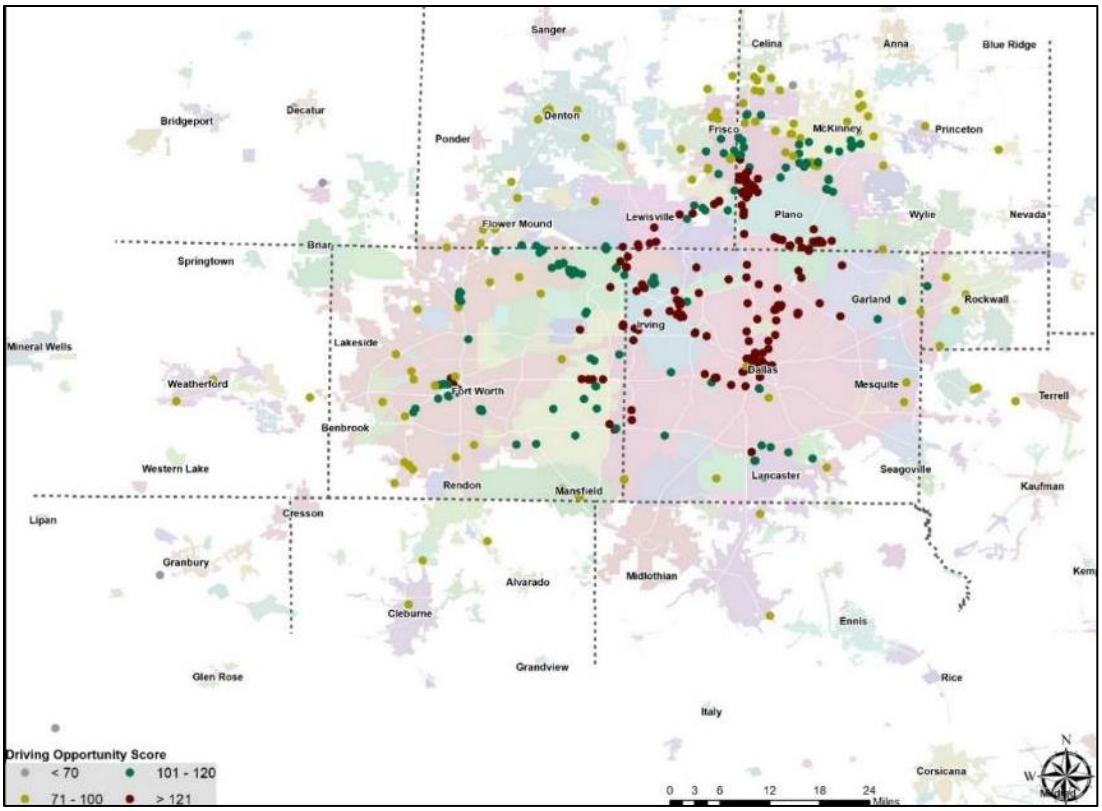

Figure 5-4 Spatial Distribution of New Projects in term of Access to Opportunities by Car

To evaluate statistical differences in the number of projects in opportunity area by car among top 10 cities in DFW, I used ANOVA. The table of the results showed a significant difference among cities in terms of their projects with regard to location efficiency ($p < 0.00$). In other words, the ANOVA tests indicated a different pattern of performance among cities.

Table 5-8 ANOVA Results for Variance among Cities in term of their new projects in Areas of Opportunities by Car

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	83151	9	9239		0.00
Within Groups	47725	305	156		

Also, since table of ANOVA is significant, I used Post Hoc test to understand which city is different from other cities. As evident, Dallas is significantly different from other cities because it has higher mean differences. In addition, Richardson has higher values than Fort Worth, Plano, Arlington, and McKinney (Table 5-9).

Table 5-9 Post Hoc Results for Variance among Cities in term of their new projects in Areas of Opportunities by Car

Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.
Dallas	Frisco	31.3*	Frisco	Dallas	-31.3*	Fort Worth	Dallas	-42.3*	Plano	Dallas	-7.2
	Fort Worth	42.3*		Fort Worth	11		Frisco	-11*		Frisco	24.1*
	Plano	7.2		Plano	-24.1*		Plano	-35.1*		Fort Worth	35.1*
	McKinney	41.8*		McKinney	10.5*		McKinney	-0.5		McKinney	34.6*
	Arlington	24.6*		Arlington	-6.7		Arlington	-17.6*		Arlington	17.4*
	Irving	9.8		Irving	-21.6*		Irving	-32.5*		Irving	2.5
	Richardson	11.6*		Richardson	-19.7*		Richardson	-30.7*		Richardson	4.4
	Southlake	31.0*		Southlake	-0.3		Southlake	-11.3*		Southlake	23.8*
	Lewisville	20.9*		Lewisville	-10.4		Lewisville	-21.4*		Lewisville	13.7*
McKinney	Dallas	-41.8*	Arlington	Dallas	-24.6*	Irving	Dallas	-9.8*	Richardson	Dallas	-11.6*
	Frisco	-10.5*		Frisco	6.7		Frisco	21.6*		Frisco	19.7*
	Fort Worth	0.5		Fort Worth	17.6*		Fort Worth	32.5*		Fort Worth	30.7*
	Plano	-34.6*		Plano	-17.4*		Plano	-2.5		Plano	-4.4
	Arlington	-17.2*		McKinney	17.2*		McKinney	32.0*		McKinney	30.2*
	Irving	-32*		Irving	-14.9*		Arlington	14.9*		Arlington	13*
	Richardson	-30.2*		Richardson	-13*		Richardson	1.9		Irving	-1.9
	Southlake	-10.8*		Southlake	6.4		Southlake	21.2*		Southlake	19.4*
	Lewisville	-20.9*		Lewisville	-3.7		Lewisville	11.2*		Lewisville	9.3
Southlake	Dallas	-31*	Lewisville	Dallas	-20.9*	* The mean difference is significant at the 0.05 level.					
	Frisco	0.3		Frisco	10.4*						
	Fort Worth	11.3*		Fort Worth	21.4*						
	Plano	-23.8*		Plano	-13.7*						
	McKinney	10.8*		McKinney	20.9*						
	Arlington	-6.4		Arlington	3.7						
	Irving	-21.2*		Irving	-11.2*						
	Richardson	-19.4*		Richardson	-9.3*						
	Lewisville	-10.1*		Southlake	10.1*						

Regionally, as the number of the new development increases, their frequencies in areas with high access to opportunities also increases. About 73 % of current regional projects are located in areas with high access to opportunities by driving.

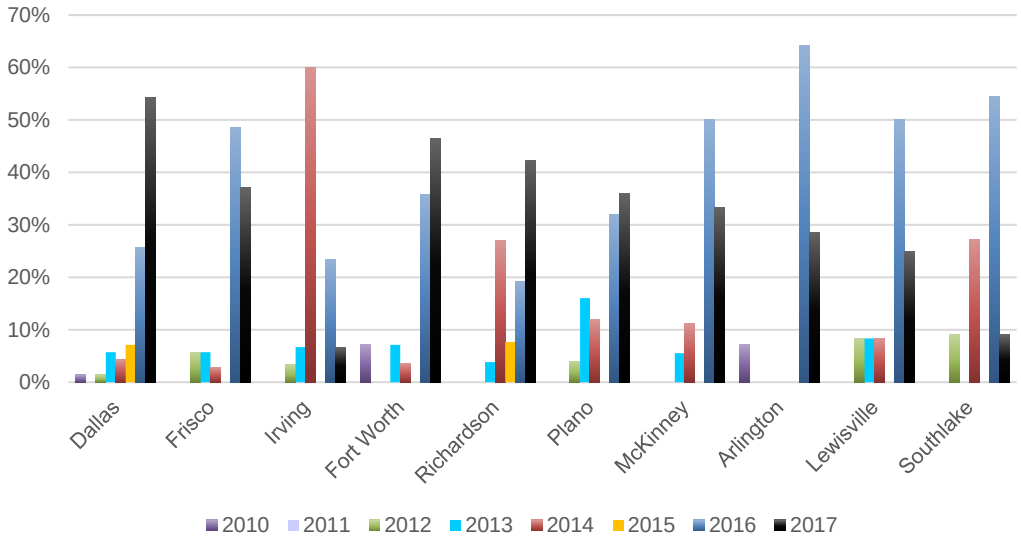

Figure 5-5 Distribution of Projects in High Opportunity Areas by Car in 10 Cities

Again, Dallas has the highest rank with only 3 % of its projects in low access areas. In 2017, the city has the highest number of development in high access area. The Cities of Irving, Richardson, Plano, Arlington, Lewisville, and Southlake have almost all the projects in high opportunity access. These are the cities with less than 7 % of the regional projects but all of them are located in areas with high access by car (Table 5-10).

Table 5-10 Distribution of Projects in High Opportunity Areas by Car in 10 Cities

Rank[2]	Cities	2010	2011	2012	2013	2014	2015	2016	2017	# of Project in High Access	% of Project in High Areas	# of Total Project
1	Dallas	1%	0%	1%	6%	4%	7%	26%	54%	70	97%	72
2	Frisco	0%	0%	6%	6%	3%	0%	49%	37%	35	73%	48
3	Irving	0%	0%	3%	7%	60%	0%	23%	7%	30	100%	30
4	Fort Worth	7%	0%	0%	7%	4%	0%	36%	46%	28	61%	46
5	Richardson	0%	0%	0%	4%	27%	8%	19%	42%	26	100%	26
6	Plano	0%	0%	4%	16%	12%	0%	32%	36%	25	100%	25
7	McKinney	0%	0%	0%	6%	11%	0%	50%	33%	18	58%	31
8	Arlington	7%	0%	0%	0%	0%	0%	64%	29%	14	100%	14
9	Lewisville	0%	0%	8%	8%	8%	0%	50%	25%	12	100%	12
10	Southlake	0%	0%	9%	0%	27%	0%	55%	9%	11	100%	11
Total Region		**4**	**1**	**7**	**22**	**46**	**9**	**120**	**125**	**334**	**74%**	**452**

– *Spatial Distribution of New Projects in term of Access to Opportunities by Transit*

Based on the analysis in table 5-11, about one third of the projects are developing in areas of opportunities (areas with scores above 100) by transit. Interestingly, these projects are mostly residential in type (15.7 % of total projects).

Overall, there are not many new projects in areas with high access by transit (Figure 5-6). This is due to lack of transit services for most of the region. The projects with scores above average are occurring in Dallas and Fort Worth and north side of Dallas where transit services reach. Although Trinity Metro is proving service to the City of Fort Worth, still most of the projects are not within the reach of transit. The concentration of poor access is also visible in Frisco, McKinney and Arlington.

[2] Ranking is based on the number of the projects in high opportunity area

Table 5-11 Frequency of the Projects in High Opportunity Access by Transit

Type	**Commercial**				**Residential**				**Special Use**				**Total**			
Year	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300	< 100	100 to 200	200 to 300	> 300
2010	1	2	0	0	0	1	0	0	1	0	0	0	2	3	0	0
2011	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2012	3	2	1	0	4	0	0	0	2	0	0	0	9	2	1	0
2013	19	8	1	0	5	0	0	0	0	1	0	0	24	9	1	0
2014	17	19	0	0	18	4	0	0	0	0	0	0	35	23	0	0
2015	4	2	3	0	4	1	0	0	1	0	0	0	9	3	3	0
2016	92	16	5	3	28	6	0	0	10	4	0	0	130	26	5	3
2017	27	5	2	1	54	41	13	5	15	0	0	0	96	46	15	6
Total	**164**	**54**	**12**	**4**	**113**	**53**	**13**	**5**	**29**	**5**	**0**	**0**	**306**	**112**	**25**	**9**

As table of ANOVA showed a significant difference among cities in terms of their projects with regard to location efficiency ($p < 0.00$), I used Post Hoc test to understand which city is different from other cities. As evident, most of the cities are significantly different from other cities. Dallas prove to be significantly different from other cities with higher mean differences. In addition, Fort Worth and McKinney have statistically lower mean differences than all the cities (table 5-13).

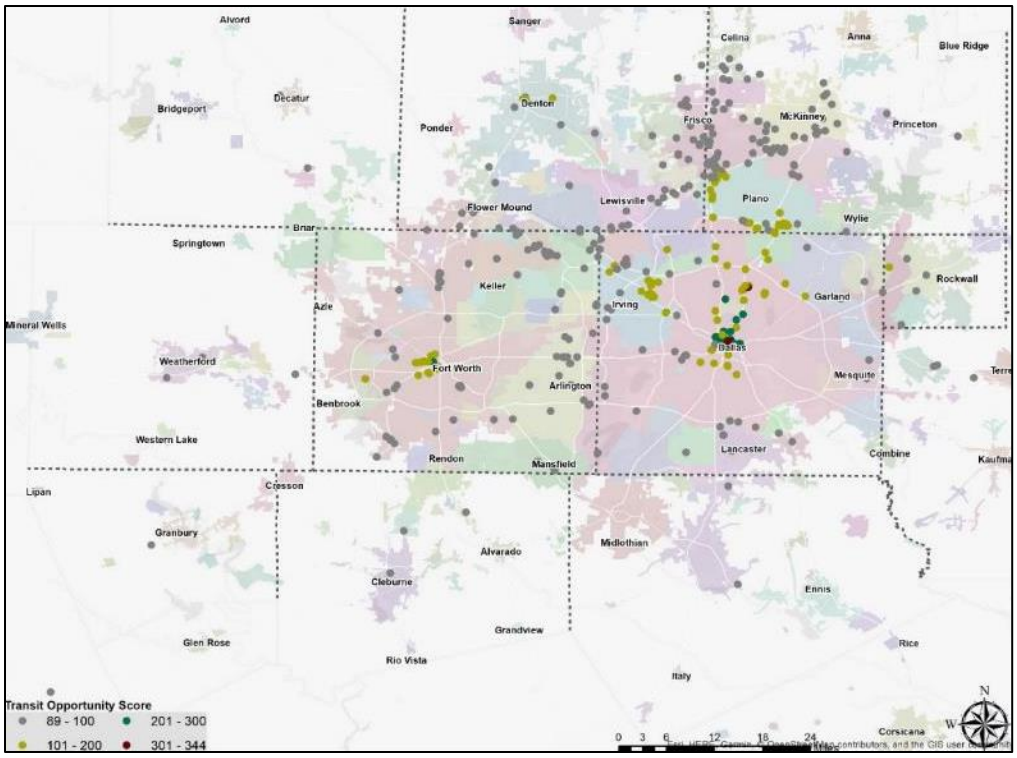

Figure 5-6 Spatial Distribution of Projects in term of Access to Opportunities by Transit

As the analysis in table 5-15 shows, the number of the project in high access to opportunities are getting better after 2016. Most of the projects in areas with high access by transit are in Dallas where 86 % of the city projects have high access to transit. Although less than 6 % of the regional projects are in Richardson, more than 90 % of them have high access to transit. Interestingly, the city of Fort Worth is the location of about 11 % of the regional project but only one third of them are in high access to transit areas. None of the new projects in the cities of Frisco, McKinney, Arlington, and Lewisville and Southlake are within the good access to transit (Figure 5-7).

Table 5-12 ANOVA Results for Variance among Cities in term of their new projects in Areas of Opportunities by Transit

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	512209	9	56912	36	0.00
Within Groups	486914	305	1596		

Table 5-13 Post Hoc Results for Variance among Cities in term of their new projects in Areas of Opportunities by Transit

Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.	Cities		Mean Diff.
Dallas	Frisco	104.8*	Frisco	Dallas	-104.8*	Fort Worth	Dallas	-78.1*	Plano	Dallas	-90.6*
	Fort Worth	78.1*		Fort Worth	-26.7*		Frisco	26.7*		Frisco	14.2*
	Plano	90.6*		Plano	-14.2*		Plano	12.5		Fort Worth	-12.5
	McKinney	104.8*		McKinney	0*		McKinney	26.7*		McKinney	14.2*
	Arlington	104.8*		Arlington	0*		Arlington	26.7*		Arlington	14.2*
	Irving	85.2*		Irving	-19.5*		Irving	7.1		Irving	-5.4
	Richardson	74.6*		Richardson	-30.1*		Richardson	-3.5		Richardson	-16.0*
	Southlake	104.8*		Southlake	0*		Southlake	26.7*		Southlake	14.2*
	Lewisville	103.2*		Lewisville	-1.6		Lewisville	25.1*		Lewisville	12.6*
McKinney	Dallas	-104.8*	Arlington	Dallas	-104.8*	Irving	Dallas	-85.2*	Richardson	Dallas	-74.6*
	Frisco	0*		Frisco	0*		Frisco	19.5*		Frisco	30.1*
	Fort Worth	-26.7*		Fort Worth	-26.7*		Fort Worth	-7.1		Fort Worth	3.5
	Plano	-14.2*		Plano	-14.2*		Plano	5.4		Plano	16*
	Arlington	0*		McKinney	0*		McKinney	19.5*		McKinney	30.1*
	Irving	-19.5*		Irving	-19.5*		Arlington	19.5*		Arlington	30.1*
	Richardson	-30.1*		Richardson	-30.1*		Richardson	-10.6		Irving	10.6
	Southlake	0*		Southlake	0		Southlake	19.5*		Southlake	30.1*
	Lewisville	-1.6		Lewisville	-1.6		Lewisville	18.0*		Lewisville	28.6*
Southlake	Dallas	-104.8*	Lewisville	Dallas	-103.2*						
	Frisco	0*		Frisco	1.6						
	Fort Worth	-26.7*		Fort Worth	-25.1*						
	Plano	-14.2*		Plano	-12.6*	* The mean difference is significant at the 0.05 level.					
	McKinney	0*		McKinney	1.6						
	Arlington	0		Arlington	1.6						
	Irving	-19.5*		Irving	-18*						
	Richardson	-30.1*		Richardson	-28.6*						
	Lewisville	-1.6		Southlake	1.6						

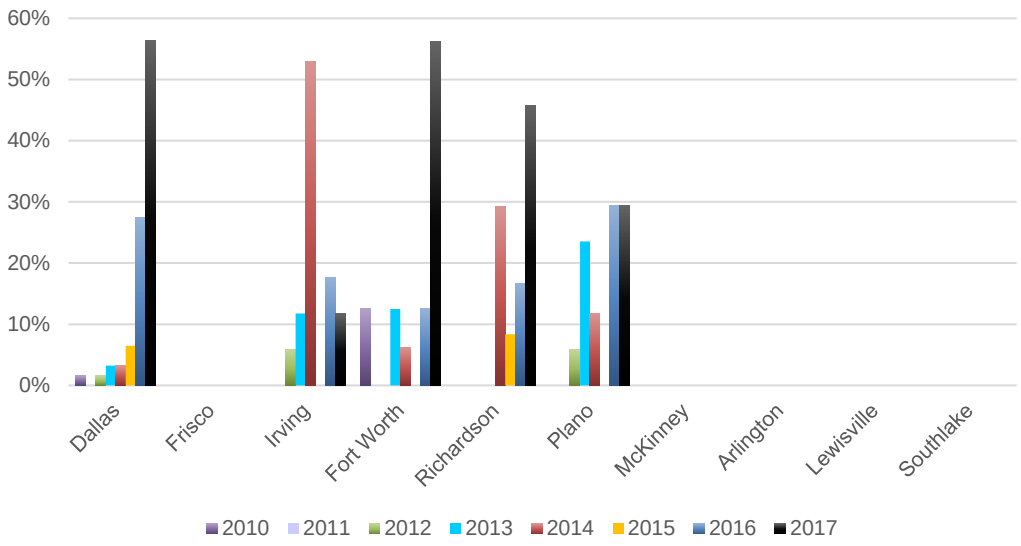

Figure 5-7 Distribution of Projects in High Opportunity Areas by Transit in 10 Cities

Table 5-14 Distribution of Projects in High Opportunity Areas by Transit in 10 Cities

Rank[3]	Cities	2010	2011	2012	2013	2014	2015	2016	2017	# of Project in High Areas	% of Project in High Areas	# of Total Project
1	Dallas	2%	0%	2%	3%	3%	7%	27%	57%	62	86%	72
2	Richardson	0%	0%	0%	0%	29%	8%	17%	46%	24	92%	26
3	Irving	0%	0%	6%	12%	53%	0%	18%	12%	17	57%	30
3	Plano	0%	0%	6%	24%	12%	0%	29%	29%	17	68%	25
4	Fort Worth	13%	0%	0%	13%	6%	0%	13%	56%	16	35%	46
5	Frisco	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	48
5	McKinney	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	31
5	Arlington	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	14
5	Lewisville	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	12
5	Southlake	0%	0%	0%	0%	0%	0%	0%	0%	0	0%	11
Total Region		**3**	**0**	**3**	**10**	**23**	**6**	**34**	**67**	**146**	**32%**	**452**

[3] Ranking is based on the number of the projects in high opportunity area

Discussion

This study used access to all major opportunity scores by three modes of transportation developed in chapter three to analyze the spatial distribution of new projects in DFW. The purpose was to understand if new projects are developing in areas with high opportunity access or not. The result of this analysis identified successful and unsuccessful development in term of accessibility and location efficiency.

The result of this study showed that locations of new projects in term of access to opportunities by car were almost better than transit and car. Most of the regional projects have high access to opportunities by car. However, few of new projects were in high opportunity areas by transit and walking since about one third of them have good access by these two modes.

Accessibility is one of the major factor in location decision since it influences households' transportation cost and savings. Access to opportunities by transit or walking is especially important for low-income residents since it provides them a chance to save on transportation costs. Therefore, it is critical to determine the location efficiency of new projects especially residential to provide the fundamentals for the households to live in areas with higher access. However, as the result of this analysis showed still most of residential projects are happening in areas with low access by walking and transit.

The result of this study suggests that policies to direct and to invest development in areas of higher opportunity access. It is important for the city officials and developers to collaborate to avoid any new developments in areas with low access especially for residential housing projects.

Chapter 6

Impacts of Multimodal Access to Opportunities on Housing value

Introduction

This section has used access to opportunity scores developed in chapter 3 to model the impacts of access to job opportunities on housing cost with the impacts of access to other opportunities. Studies proved that households are taking more trips to access the destinations other than jobs. In addition, there is a new trend to use more active mode of transportation such as walking and biking. Since access is one of the major determinants in housing value, any changes in that might influence the housing industry. The purpose of this study is to understand if the new trends have influenced housing market or not. For this reason, I have conducted case study to select among transactions for residential structures from 2012 to 2016. The results show the impacts of all major destinations and jobs on housing value.

Research Design

- *Sample of the Study*

This study has used the detailed microdata on residential building prices in the study area (DFW) from the CoStar Group to compare the impacts of multimodal access to opportunities on housing value with multimodal access to job opportunities. CoStar is a provider of information, analytics and marketing services to the real estate in the Unites states, Canada, and the UK, Germany and Spain. The company provides information on sale prices, tenant information and structure features.

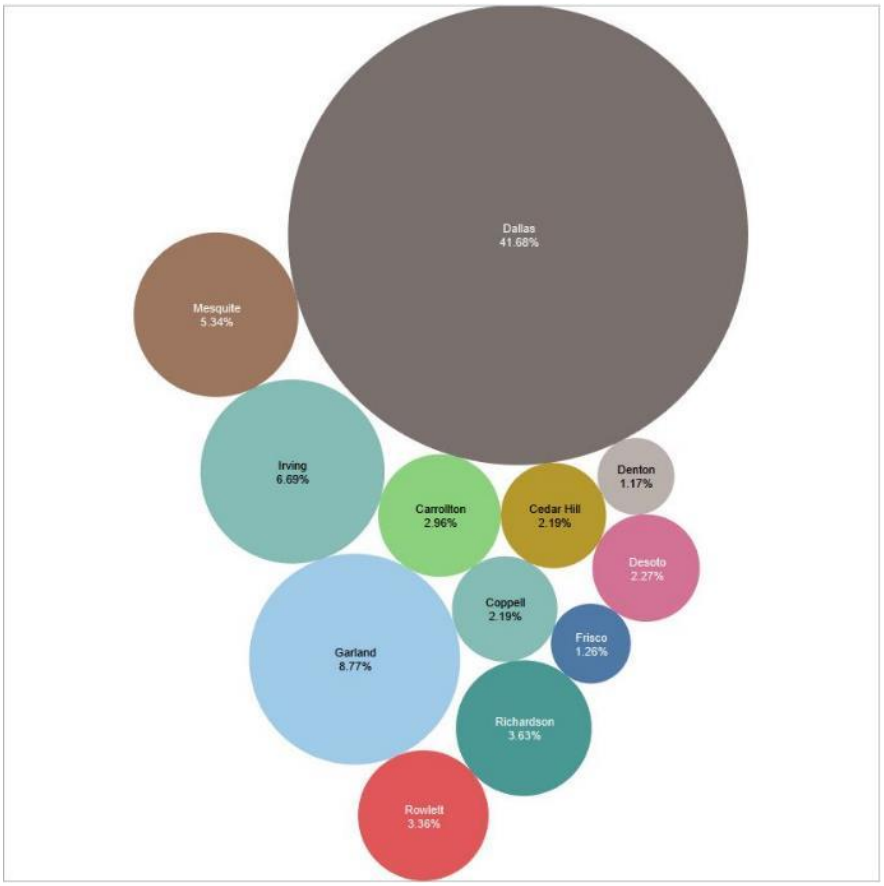

Figure 6-1 Frequency Distribution of Sampled Housing Structures in the Cities in the Study Area

The dataset selected for this study was based on some threshold. Any records for sale prices below 10,000, bedrooms above 15 and square footage below 100 were removed from the data. This study included data from 2012 to 2016 based on the transaction variations in the cities and access to a larger sample size. Figure 6-1 shows the percentage of the transactions in each city in the study area.

Table 6-1 Data Variables and Sources

Variable	Definition	Data Source	Year
Level I (Housing Structure): Dependent Variable			
lnprice000adj	Ln of adjusted transaction price by 1000	CoStar	2012-2016
Level II (Block Groups): Independent Variables			
WGALLDST	Weighted Average Access to major opportunity scores by all modes	Chapter 3	2016
WGJOBMOD	Weighted Average Access to job scores by all modes	Chapter 3	2016
Level I (Housing Structure): Independent Control Variables			
FIREPLACE	Number of fireplace for housing property	CoStar	2012-2016
BEDROOM	Number of bedrooms for housing property	CoStar	2012-2016
BATHROOM	Number of bathrooms for housing property	CoStar	2012-2016
SFAMILY	1 if it is a single family, 0 if it is not a single family	CoStar	2012-2016
SQFT	Square feet of housing property	CoStar	2012-2016
GARAGES	Number of garages for each housing property	CoStar	2012-2016
AGEBUILD	Age of the structure	CoStar	2012-2016
Level II (Block Groups): Independent Control Variables			
LNINCOME	Ln of Median Household Income	(ACS), 5-year estimates	2010-2014
ACTDENMI	population and employment divided by land area	ACS,5-year estimates/LEHD	2010-2014/2015
SCHLIDX	Quality of school system is in a neighborhood	HUD USER	2017
RACEDIVI	The likelihood that two randomly chosen persons have the same race or ethnicity	US Census	2010
ENTROPY	Land use mix (entropy)	LEHD	2015
Level III(CITY): Independent Control Variables			
CITYPOP	Number of Population by land Area	ACS,5-year estimates	2010-2014
VCRIMR00	Total number of Violent Crimes divided by city population in 1000	UCR	2012
TAXR	Total tax rates	TCPA	2012-2016

– *Data and Variables*

This study models the impact of multimodal access to major opportunities on housing value by constructing two models: one for access to major opportunity impacts and the other for the impacts of access to job opportunities.

In both models, the dependent variable is the sale price for housing structures. However, in the first one the independent variable is multimodal access to major opportunity score and in the other one, the independent variable is multimodal access to job opportunities. Moreover, this study includes control independent variables. Table 6-1 includes the descriptions of some of the variables in the model.

d. Dependent Variable

The dependent variable in the two models is the sale price of housing structures from 2012 to 2016. The source of the data is from CoStar, which offers transaction data for housing structures as well as their attributes. Since the sale price is reported for different years, this study measured the average change over time in the price through the Consumer Price Index (CPI) formula to adjust the values. For this purpose, January 2016 was selected as the base to develop the inflation rate for each year. The rate was generated using Bureau of Labor Statistics calculator. The sale price for each year was adjusted by multiplying the value by CPI rate.

Table 6-2 CPI Inflation Adjusted Rate for $1.00

Source: (BLS, 2018)

Year	Rate
2012	$1.05
2013	$1.03
2014	$1.01
2015	$1.01

The sale price, however, was not normally distributed. To account for the issue, this study has used natural logarithm (Ln) of the sale price. Figure 6-2 (a. and b.) shows

the distribution of the adjusted sale price in 1000. As shown, the dependent variable is not normally distributed. Therefore, Ln of the dependent variable was used to have normally distributed values.

As the histogram in figure 6-2 b. presents, the values are positively skewed (skewed to the right) since the mean of the ln of adjusted price is greater than the median.

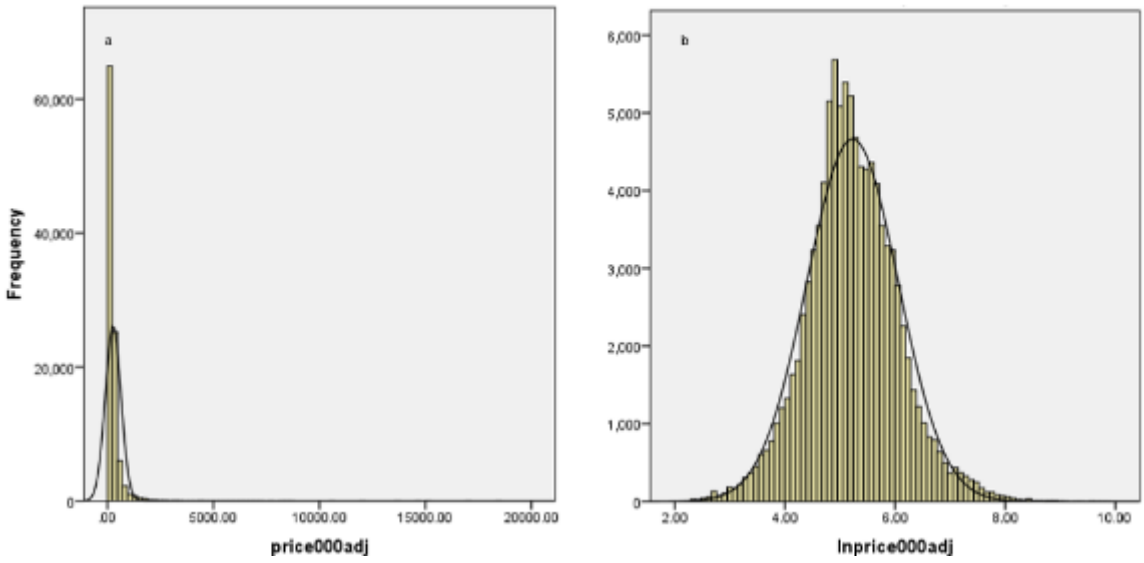

Figure 6-2 a. Histogram of Price Adjusted in 1000 b. Histogram of Ln of Price Adjusted in 1000

Table 6-3 presents descriptive statistics for independent variables used in this study. As shown the variable has the minimum of 2.30 and the maximum value of 9.83. In addition, figure 6-2 shows the frequency distribution of the dependent variable in the studied years. As evident, less number of transactions has happened in 2016 since the data was purchased in early 2016.

Table 6-3 Descriptive Statistics of dependent Variable

Dependent Variable	N	Minimum	Maximum	Mean	Std. Deviation
LNPRICE000adj	97,242	2.30	9.83	5.23	0.83

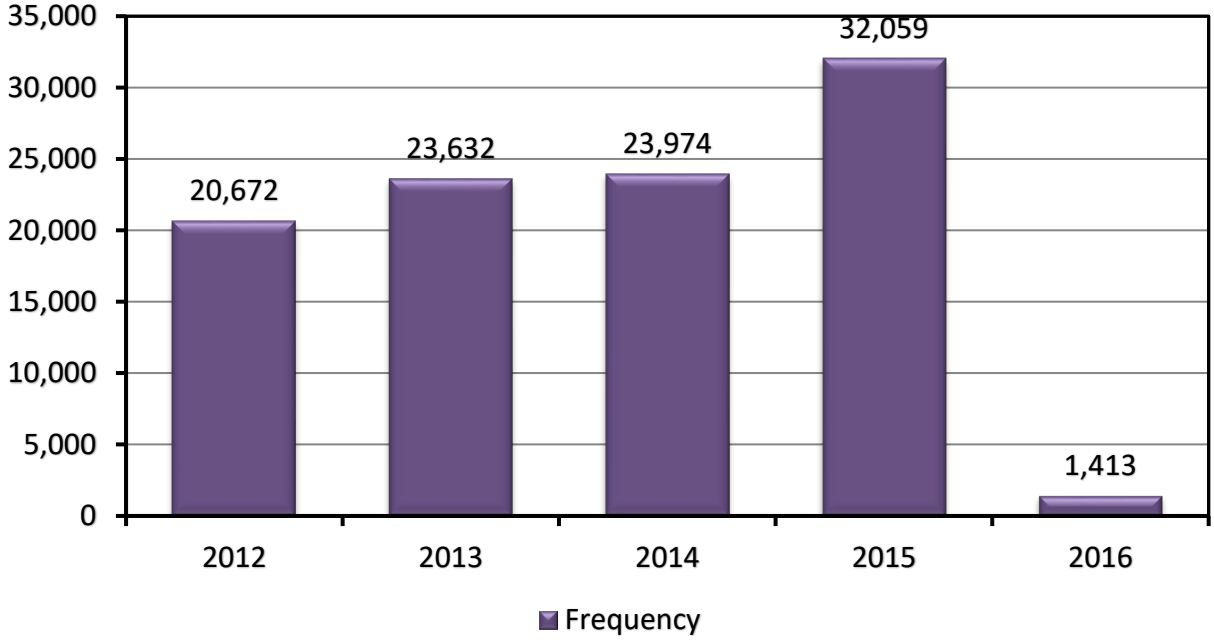

Figure 6-3 Frequency Distribution of LNPRICE000adj in the Years

e. Independent variables

For the independent variables, this study used the measured access to opportunity scores for walking, driving and transit to generate one score that includes all modes. I used Principal Component Analysis (PCA) to transform the scores into an index of multimodal access to destinations (other than jobs) and multimodal access to jobs. Then, I normalized the values with a mean of 100 and a standard deviation of 25. After generating the score, weighted population average formula was used to create the independent variables.

Table 6-4 presents descriptive statistics for independent variables used in this study. With the minimum of 0.15 and maximum value of 167.55, access to all major opportunities (WGALLDST) has the range of 167.4. Also, access to jobs by all modes has the range of 153.43.

Table 6-4 Descriptive Statistics of Independent Variables

Independent Variables	N	Min	Max	Mean	Std. Deviation
Weighted Access to All Opportunities by Three Modes (WGALLDST)	1,805	0.15	167.55	6.87	8.93
Weighted Access to Job Opportunities by Three Modes (WGJOBMOD)	1,805	0.16	153.59	6.56	8.56

f. Controlled Independent variables

This study also includes controlled independent variables, categorized into three including housing structure, neighborhood and city attributes.

- Housing Structure Variables

The housing structure features for this study include number of bedrooms (BEDROOM), fireplace (FIREPLACE), garage (GARAGES), age of the building (AGEBUILDING) and square footage (SQFT). Also it specifies if the structure is single family or not (SFAMILY). For all these variables, I expect to observe a positive significant relation to housing value.

- Neighborhood Variables

Neighborhood variables for this study include ln of median household incomes (LNINCOME), racial diversity index (RACEDIVI), entropy (ENTROPY) school performance (SCHLIDX) and activity density (ACTDENMI). I expect a positive relation between median household incomes, percentage of owners of housing units, household size, entropy, school performance and activity density and housing value. However, it is

expected that the model shows a negative relation between percentage of poverty rate and racial diversity index and sale price.

For socioeconomic characteristics, activity density, median household incomes, racial diversity, and poverty rates have been used to model the impacts of socioeconomic variables on housing values. The data from American Community Survey (ACS), 5-year estimates (2010 to 2014) have been used for median household incomes, percentage of poverty rate, percentage of owners of housing units and household size,

Racial and ethnic diversity index was generated from US Census 2010. The index shows the likelihood that two randomly chosen persons have the same race or ethnicity. The index “zero” represents an area with one race group and one ethnic group, and a diversity index of “100” shows racially/ ethnically diverse neighborhoods.

Table 6-5 NAICS Codes and Categories used for entropy

Categories	Variable Name	Description
Retail	cns07	Number of jobs in NAICS sector 44-45 (Retail Trade)
Personal Service	cns10	Number of jobs in NAICS sector 52 (Finance and Insurance)
	cns11	Number of jobs in NAICS sector 53 (Real Estate and Rental and Leasing)
	cns19	Number of jobs in NAICS sector 81 (Other Services [except Public Administration])
Education	cns15	Number of jobs in NAICS sector 61 (Educational Services)
Health Care	cns16	Number of jobs in NAICS sector 62 (Health Care and Social Assistance)
Entertainment	cns17	Number of jobs in NAICS sector 71 (Arts, Entertainment, and Recreation)
	cns18	Number of jobs in NAICS sector 72 (Accommodation and Food Services)

This study has used School Proficiency Index developed by HUD USER to represent the quality of school system in a neighborhood. The values are percentile ranked ranging from 0 to 100. The index has developed using Great Schools (proficiency

data, from 2013-2014) and Common Core of Data (4th grade school addresses and enrollment 2013-2014) (HUDUSER, 2017).

Entropy was calculated for one-mile buffer of the center of block groups. For that, I have used five NAICS categories of retail, personal service, education, health and entertainment for calculating entropy. Table 6-5 shows the NAICS sectors used in this study and the descriptions.

Entropy was computed using the following formula:

$$-\sum_j P_j * \ln P_j / \ln J$$

Where

P_j = the proportion of land in the jth land use category

J = the total number of land use categories.

Values lies between 0 and 1 where “0” represents homogenous land use, and “1” indicates equally distributed land use types (Diao, & Ferreira, 2010).

In addition, activity density was calculated by summing population and employment divided by land area.

- City Variables

For city variables, I have included city population (CITYPOP), property tax rate (TAXR) and violent crime rate (VCrimR000). For tax rate, the data from Comptroller’s Property Tax Assistance Division (PTAD) was used. The website publishes annually lists of total tax rates reported by at different scale level of city, school district, county and special districts (Comptroller, 2017). In addition, for violent crime rate, the date from The Uniform Crime Reporting (UCR) has been used.

Table 5-6 presents the descriptive statistics of the controlling independent variables used in this study. As shown, the minimum value is for BEDROOM,

AGEBUILD, SFAMILY, FFIREPLA, GARAGES, ENTROPYB, SCHL_IDX and EMPDENMI and the maximum value is for CITYPOP.

Table 6-6 Descriptive Statistics of Controlling Independent Variables

Scale	Variable Name	N	Min	Max	Mean	Std. Deviation
Housing Units	SQFT	97,242	277	73,120	2,106.41	1,076.87
	BEDROOM	97,242	0	11	3.18	0.88
	AGEBUILD	97,242	0	157	35.28	21.42
	SFAMILY	97,242	0	1	0.84	0.37
	FFIREPLA	97,242	0	9	0.85	0.64
	GARAGES	97,242	0	9	1.63	0.86
Neighborhood	RACEDIVI	1,805	4.8	93.6	63.11	20.86
	ENTROPYB	1,805	0	0.93	0.57	0.19
	SCHL_IDX	1,805	0	99	47.17	27.93
	ACTDENMI	1,805	104.46	194,717.93	7,587.27	9,231.23
	POPDENMI	1,805	59.79	56,789.85	5,546.81	4,587.42
	EMPDENMI	1,805	0	186,203.41	2,040.46	7,889.00
	LNINCOME	1,805	8.89	12.43	10.94	0.58
City	TAXR	50	0.22	1.12	0.61	0.18
	CITYPOP	50	683	1263775	87,212.50	208190.03
	VCRIMR000	50	0.2	83.68	6.39	15.41

– *Unit of Analysis*

This study has three units of analysis. To model the relationship of access to major opportunities by three modes on housing value, sale price of housing structure is dependent variable, which is at the scale of housing properties. In addition, building structure features such as number of bedroom, number of bathroom, number of garage and age of structure are all at housing property level.

The second unit of analysis is block group including school proficiency index, racial and ethnic diversity, income, attainment and land use mix (entropy). Finally, the third unit of analysis is city variable, which includes population density, crime rate and property tax rate. This nesting structure of the data would influence selection of the statistical method.

– *Methods: Multilevel Modeling*

For this research, I examine the relationship between access to all opportunities by the three modes of transportation and housing value. The data for this study has three levels: housing structure data (level 1) resides in distinct neighborhoods (level 2) which in turn are located in specific city (level 3). Data are implicitly 'hierarchical' and there is nesting of 'lower level' units within 'higher' level units (Perera, et al., 2016). The goal of this model is to simultaneously estimate the effect of group-level and individual-level variables on individual level outcomes (housing value) accounting for the within-group non-independence observations.

There are several reasons for using multilevel hedonic modeling. First, spatial dependencies (correlation and residual) - which refers to the likelihood that the values of a variable influence the value of the other units in the proximity (Orford, 2000) - is common in hedonic modeling. This violates the assumption of ordinary least square (OLS) model for independent distribution of errors. This in turn leads to a smaller estimation for standard errors (Type I error). With a multilevel model, the house price and other housing structure characteristics can be regressed on neighborhood level features to account for housing feature dependency. Multilevel models account for the spatial error autocorrelation (dependence of the residuals) by distinguishing between housing unit errors and neighborhood errors (Orford, 2000). Using the model that does not

consider this dependency would lead to the underestimated value for standard errors of the independent variables (Snijders and Bosker, 1999).

Second, non-stationarity issue refers to the existence of a “heterogeneous (non-constant) relationship between dependent and independent variables across geographic space” (Treg, C., 2010, p 20). The average effect for an attribute – known as a global effect- does not represent the spatial local differences in the study area. Considering random effect, instead of fixed effect, would allow the variable to vary across neighborhoods. The random effect can be constructed using Empirical Bayesian techniques which changes the estimate for neighborhoods with few observations based on the overall mean (Raudenbush and Bryk, 2002). Empirical Bayesian variation in slope between neighborhoods is another important advantage of multilevel modeling (Subramanian, 2001).

Third, heterogeneity between neighborhoods needs to be different from the heterogeneity among individual properties. When higher-level data is included in the model of individual housing value, the interaction of group level data is based on the individual data (O'Neill et al. 1986). For example, the relationship between housing value and age at the property level is different from the relationship between housing value and population density at block group level. Multilevel hedonic models account for this varying relationship in housing value.

Fourth, multilevel model accounts for heteroscedasticity (unequal variation in the residuals) across neighborhoods. Multilevel models control for heteroscedasticity in the residual of level 1 by expanding the random part of the model with an additional random term for the single housing variable that shows large variation across the neighborhood. The model allows each level-1 coefficient to vary across neighborhoods either randomly or by the interaction with level-2 variables or through both options (Orford, 2000).

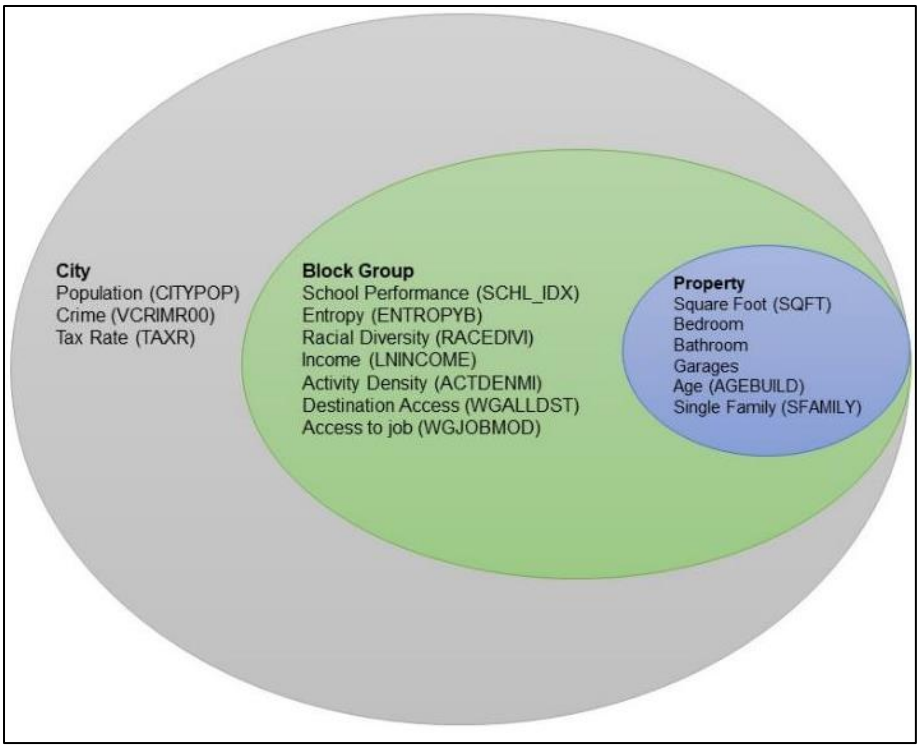

Figure 6-4 Nesting Structure of the data modeling the impacts of access to opportunity on housing value

Multilevel Modelling (MLM) would produce a more accurate coefficient and standard error estimates since it accounts for relationships between predictor and outcome variables through providing level-1 and level-2 and (level -3) regression relationships (Woltman, et al., 2012). In this research, housing structure (level 1) data includes numbers of bedrooms, garage, age of structure, single family. Neighborhood variables (level 2) data include school performance, racial and ethnic diversity, median income, land use mix (entropy) and activity density. Moreover, city data (level 3) includes population, violent crime rates and total tax rates (Figure 6-4). In the analysis for this study, the housing value (level 1) is regressed on neighborhood features in the level-2 model and level 2 intercepts and coefficients is regressed on city characteristics in the level-3 models. Therefore, the model produces lower standard error estimates.

Analysis and Result

I estimated multi-level regression models using HLM 6.08. The results of the best-fitted model are presented in table 6-7. The coefficients of most variables are significant and have the expected signs.

Table 6-7 Multi-level regression analysis of housing sale price and access to destinations (other than jobs) and access to job

Variables		Access to Destinations				Variables	Access to job			
		Coefficient	Std. error	T-ratio	P-value		Coefficient	Std. error	T-ratio	P-value
Intercept		-0.9867	0.28	-3.49	0.001	**Intercept**	-1.0021	0.28	-3.55	0.001
WGALLDST		0.0030	0.00	2.84	0.005	**WGJOBMOD**	0.0040	0.00	3.67	0.000
Building Structure	**SQFT**	0.0002	0.00	137.08	0.000	**SQFT**	0.0002	0.00	137.09	0.000
	BEDROOM	0.0776	0.00	41.01	0.000	**BEDROOM**	0.0776	0.00	41.01	0.000
	AGEBUILD	-0.0030	0.00	38.52	0.000	**AGEBUILD**	-0.0030	0.00	38.52	0.000
	SFAMILY	0.3448	0.01	68.85	0.000	**SFAMILY**	0.3449	0.01	68.87	0.000
	FIREPLACE	0.0504	0.00	23.30	0.000	**FIREPLACE**	0.0504	0.00	23.30	0.000
	GARAGES	0.1216	0.00	77.00	0.000	**GARAGES**	0.1216	0.00	77.00	0.000
Neighborhood	**RACEDIVI**	-0.0022	0.00	-3.86	0.000	**RACEDIVI**	-0.0022	0.00	-3.93	0.000
	ENTROPY	0.2449	0.05	5.21	0.000	**ENTROPY**	0.2426	0.05	5.17	0.000
	SCHLIDX	0.0041	0.00	10.73	0.000	**SCHLIDX**	0.0041	0.00	10.60	0.000
	ACTDENMI	0.0000	0.00	13.76	0.000	**ACTDENMI**	0.0000	0.00	13.41	0.000
	LNINCOME	0.4630	0.02	21.45	0.000	**LNINCOME**	0.4644	0.02	21.58	0.000
City	**TAXR**	-0.9692	0.17	-5.56	0.000	**TAXR**	-0.9654	0.17	-5.56	0.000
	CITYPOP	0.0000	0.00	1.85	0.071	**CITYPOP**	0.0000	0.00	1.84	0.071
	VCRIMR00	-0.0036	0.00	-1.03	0.308	**VCRIMR00**	-0.0036	0.00	-1.04	0.305
Max. Likelihood		-26667.18				-26664.46				
Chi-Square		116166.32				115837.33				
Pseudo R^2		0.6498				0.6512				
Deviance		53334.35				53328.93				

Based on the analysis for the two models, multimodal access to destinations (other than jobs) and multimodal access to jobs both had significant and positive relation

to housing sale price. However, with little variation in Pseudo R^2 and t-ratio of the dependent variables of the two models, multimodal access to jobs was a slightly better fitted model than multimodal access to destinations (other than jobs). The model presented a Pseudo R^2 of 0.65 for access to job. This finding agreed with the literature claiming that access to job opportunities has always been a positive determinant in real estate market (Edlund, et al. 2015; Giuliano, et al. 2010; Du and Mulley 2012). In addition, in models of residential location decision, households' decisions were based on job accessibility and commute costs (Gorg and Strobl, 2006; Basile et al., 2009).

The study found that housing sale price is positively and significantly associated with multimodal access to jobs by all modes. Any unit increase in weighted job access translates into 4 units increase in ln of sale price.

In the model, the most significant variable of housing value was structural qualities with square footage being at the top. As expected, they showed to be significantly related to housing selling value. Except for age of the building, all of the building structure variables were also positively associated with the dependent variable. This finding was in line with the works of Can (1990, 1992), Tian, et al. (2017), Tseng et al. (2005) and Cortright, (2009). In the model, any unit of increase in square footage of the building was associated with 0.2 unit value increase in the ln of house price. Single family house and bedroom were associated with 345 and 78 units raise in sale price. However, as the age of the building increases, the ln of price of the structure tend to decreases by -3.

At the neighborhood level, the findings regarding the significance of socioeconomic determinants on housing price were mixed. Income presented the most significant determinant of housing value. This factor was positively related to housing value which simply means that that high income families tend to live in expensive houses.

The model for this study presented a significant correlation with activity density. While the results of studies for higher activity concentration were mixed (Lobo et al. 2011; Ciccon & Hall, 1993), this study presented a positive relation for this factor. School quality and entropy were also positively and significantly related to the dependent variable. However, racial diversity was negatively related to housing value.

The model for this study showed that a unit increase in racial diversity in a neighborhood is associated with 2 units decrease in ln of sale price. However, it presented unit increase of 243, 4 and 464 for entropy, school index and Ln of income.

Finally, at the city level, the study was in the same line as previous studies. They all showed to influence housing value significantly. However, while population had a positive relationship to housing value, crime rate and tax rate showed a negative association. This is in agreement with Oates (1969) and other studies that recognize tax programs as a negative indicator of property values. This study estimated 965 drop in ln of housing price through any unit increase in city tax rate. Crime is also regarded as a dis-amenity in the housing market. In this study, crime, although not a significant factor, showed a negative relationship to property values as well.

Discussion

While housing value studies focus mostly on access to job, households travel to access other destinations. Also, recently, households have used more active mode of transportation for commuting purposes. These trends in accessibility should be reflected in housing studies. This research compared the relationship between access to major opportunities with access to job opportunities on housing value to understand the scale of the impact of both determinants and determine if the housing market has been influenced by these changes.

According to my analysis, with very little variation with access to destination, access to job opportunities had the greatest impact on housing value. Although people travel more for other purposes than their job, the housing industry is still influenced by access to jobs more than other destinations. This finding has been also supported by the theory of rational choice model which claimed that people tend to maximize their utilities and minimize their costs by the tradeoff between the location of work and travel costs (Kain, 1962; Alonso, 1964; Muth, 1969; Mills, 1972, Osland, 2008).

Also, the result of this analysis agrees with household survey preferences. According to National Association of Realtors (NAR) 2015, 55% think that jobs should be within walking distance in a good neighborhood and 70% would consider living close enough to their job site. In addition, in 2017 more number of people considered this factor to be important for their location decisions (NAR, 2017).

Housing structure factors were still the most important drivers of housing premium with square footage being the most important one. Based on Lancaster's theory (1966), the utility of the consumer originates from different characteristics that the goods themselves offer. Therefore, the good characteristics of housing structure such as number of bedroom and garage influence the price positively; however, the age of the structure is inversely related to sale price since older housing structures are inferior in qualities with lower price than a new one.

Among the neighborhood variable, household income was the most influential factor for housing value since as household income increase, they are more willing to pay for higher housing value. Also, school quality, diversity, land use mix and activity density significantly influenced housing premium positively. People tend to account for neighborhood features such as racial homogeneity and school quality for choosing a place to live (Chhetri, et al., 2006; NAR, 2000b). They prefer neighborhoods with access

to high quality schools (Hur & Morrow-Jones, 2008; Karsten, 2007). They also tend to pay higher to live in socially homogenous neighborhoods (Gabriel & Rosenthal, 1989).

Raising the land tax rate however, showed few undesirable effects since consumers prefer to live in communities that offer tax programs that maximize their utilities (Tiebout, 1956); therefore, as proved by this study, tax rate had a negative impact on housing value.

Chapter 7

Conclusion and Policy Recommendation

Conclusion

This dissertation developed a new score for access to opportunities that incorporated 15 major destinations as well as all jobs for three modes of transportation. The study developed health care, food sources, educational facilities, service opportunities, elderly and disability facilities, child and youth opportunity scores as well as job opportunity scores. To develop the health care score, it included non-mental specialists, mental specialists, laboratories, hospitals and clinics, pharmacies and fitness destinations. For food opportunity scores, it included the location of healthy and unhealthy food stores. Education scores were developed out of K1-12 and higher education destinations. Also, service opportunities were developed out of bank, credit unions and insurance and social and religious services. Access to all opportunity score were developed by incorporating all these destinations as well as jobs.

The new score was used to determined areas with the high and low access opportunities for 15 biggest cities in DFW. Based on the analysis for this research, access to opportunities for walking and transit is poor in DFW region. Defined as the areas with the scores above regional average, the City of Dallas stood at the top for providing the residents with high access to all opportunities by walking and by transit. However, driving showed a different pattern from the two other modes. For access to all opportunities by driving, the City of Carrollton ranked the first.

Unequal distribution of sources and services as well as a lack of a strong pedestrian and transit network might be reasons for poor access to opportunities for the residents in the DFW region. In DFW, most of services are distributed in large cities.

Also, only big cities such as Dallas get benefit from transportation system while most of the region is not in the boundary of a single transit service providers.

The developed access to opportunity scores were employed to evaluate the spatial distribution of affordable housing units in areas of opportunity access by three transportation modes of car, walking and transit. Access to opportunities especially by transit and walking is important for the residents of the affordable housing units since it affects their savings on transportation costs. Overall, the analysis for this study proved a consistent pattern of poor performance in terms of location efficiency among all affordable housing programs in DFW. The findings indicated that the most of affordable housing projects in DFW are located in areas with low access to opportunities by both walking and transit, but they have a better status for access by car.

Also, the new scores was applied to understand the spatial distribution of new development projects in regards to access to opportunities. Based on the analysis, most of the projects are happening in areas that have low access to opportunities by walking and transit, but they have good access by car. Also, most of residential projects are happening in areas with low access through walking and transit. The City of Dallas ranks the first for more number of the projects in high access to all opportunities.

Finally, the new scores was used to compare the impacts of access to opportunities with the impacts of access to job opportunities. New trends in household travel behavior should be reflected in housing value. However, although most of household trips are for purposes other than work, the result of this study showed that housing value are still mainly influenced by job accessibility.

Policy Recommendation

Recently, the issue of housing affordability is under focus at both local and national levels. For example, the federal government annually spends about 50 billion

dollars to provide housing assistance specifically for low income families (Congressional Budget Office, 2015). However, according to National Association of Home Builders, housing affordability has been declining in DFW area since 2013 (Federal Reserve Bank of Dallas, 2017). Also, a study by Hamidi et al (2018) showed that most of the residents in the housing affordable unit in DFW are spending a higher percentage (15.1% to 26%) of their income on transportation and these are properties that are locate far from downtown with less accessibility by transit. This section provides some policy recommendation for both existing affordable housing properties and any future ones.

– *Policy Recommendations for the Existing Affordable Housing Properties*

The finding of this research encourages policy maker to improve neighborhood status for access to opportunity to enhance quality of life and upward mobility for the residents. The investment in infrastructure, public transit and vital services can help to ensure better service investments in areas of need and better access status in areas, which have little access to services. HUD Choice Neighborhoods program aims to support local strategies for struggling neighborhoods with distressed public or assisted housing units through a comprehensive approach to transform the neighborhood. The program helps communities transform their neighborhood by revitalizing housing units and critical improvements in the neighborhood such as provision of services and schools (HUD, 2018). Access to opportunity scores can be used to recognize areas of less service and access. HUD can use access to opportunity data to provide specific investment incentives to transform the distressed neighborhood.

Moreover, using access to opportunity data, city officials can ensure access to a variety of services by multimodal transportation network through zoning regulations or improving infrastructure. For example, in areas with poor access to food opportunities, they can provide variety of food options such as local grocery stores or food trucks.

Additionally, in areas with poor access to financial services, they can locate services such as postal banking (Barth et al., 2016). Or in areas with poor access to entertainment facilities, they can locate local parks with facilities such as playing fields, and bike paths. Also, in areas of poor walking access to opportunities, they could prioritize the improvement in the sidewalk infrastructure.

Also, in low opportunity areas, transit agencies need to improve the frequency of the system as possible through fixed route or demand route system (KFH, 2013). A study by Hamidi et al (2016) showed the low income residents have faced challenges to access jobs due to spatial mismatch between jobs and housing. Neighborhood transit accessibility scores can help transit agencies improve or change service frequencies Also, areas with low access in which affordable housing units are located are the areas that need investment in transit services either through fixed route or demand route systems. Therefore, the results of this study urge for incorporation of access to opportunities in transportation programs and plans.

- *Policy Recommendations For Future Affordable Housing Developments*

National and local government support is the key to address the provision of housing and transportation affordability. The finding of this study suggests decision makers should collaborate to plan for the best use of areas with higher opportunity access. Planners and city officials can control the land market by banking the lands in areas of higher opportunity for the purposes of affordable housing projects. They can use the modelled transit access to opportunity as a tool to bank the lands for the use of affordable housing projects.

As affordability of transportation matters for low-income residents of affordable housing units, there is a need to understand areas that offer better access to opportunities especially by transit or walking. To address the issue, policies need to

connect individual needs and location of daily services (Welch, 2013; Allard 2008). The findings of this study urge the Metropolitan Planning Organization (MPO), state planning officials, HUD and other housing authorities to collaborate to incorporate access to opportunity factors in their decision making processes to ensure true housing and transportation affordability in DFW. For example, housing policy makers can use access to opportunity score to recognize the areas with high access by transit for low-income housing projects to provide more transportation access choices. This will allow many households to reduce their transportation costs through taking pedestrian and transit trips rather than by car.

HUD and housing agencies should place emphasize on the development of affordable housing units in walkable and transit-served areas to increase access to opportunities and to reduce spatial mismatch for the resident. On the action side, they can use transit access to opportunity score to recognize the areas with high access to invest on low-income housing projects to provide more transportation access choices. This suggests HUD and local agencies to invest Multifamily Assisted, Public Housing, PRAC811, CoC and HCV programs in a more transit served area.

The HCV and LIHTC programs are the most popular federal housing assistance programs. Also, it is relatively easier to modify the design of these programs to incorporate the location efficiency factors (Hamidi et al, 2018). Although findings of this research indicate the location of LIHTC is relatively better than other affordable housing programs in DFW, to ensure true affordability of LIHTC for low-income households, the quality of access to opportunities should be included in the selection criteria for Qualified Allocation Plans (QAPs). Moreover, state QAPs can focus on providing housing in location efficient areas where multimodal access to daily necessities is provided (Adkins et al. , 2017). In addition, as the developers can benefit from a 30% increase to develop

their housings in Difficult Development Areas (DDAs) and Qualified Census Tracts (QCTs) (Lang 2012, Dawkins, 2013), the factors to determine QCTs and DDAs should be revised to include availability and access to everyday facilities.

The finding of this study, also, showed that HCV program does not consider access to opportunity criteria to determine the eligible locations and rental subsidies for households. In HCV programs, the voucher recipients can select their housing units and neighborhood to live. This study recommends local housing agencies to direct rental subsidies toward more accessible neighborhoods. Moreover, local housing agencies can provide more incentives for the properties in walkable and transit served areas. I also recommend housing authorities to use the opportunity score for transit and add transit accessibility for eligibility criteria to renew the existing contracts or to revise the market rent of properties especially for HCV voucher users that they can find their preferred housing unit. In addition, the study provides recommendations specific to each program to incorporate access to opportunities factors in the in the design and mechanism of these programs to ensure true affordability for their residents. These polices can guide the residents of affordable housing units in areas of better access that can lower transportation costs.

Also, housing agencies has a wide range of programs designed to increase the supply of affordable housing for low-income households including ownership and rental housing programs. For all these program, they have determined some location criteria, beside socioeconomic, to allocate the fund. The scores developed by this study can help them to determine location efficient areas for investment decisions. As an instance, for the PRAC 811 program, the administrators can guide the housing authorities through financial assistance procedures to purchase, construct, or rehabilitate housing units in walkable, accessible, mixed land use and service-oriented areas. Assumingly, these

population are transit dependent and therefore housing should be available for them in areas where paratransit service is available. For this program, HUD regulations mentioned the need for housing units to be located in areas with accessibility to civic facilities that travel time should not be excessive for residents (Hamidi et al., 2017). The findings indicate the program is not successfully following this HUD regulation and thus needs careful reevaluation regarding the transportation components during their development. On the action side, access to senior and disability opportunity scores created by this study can be used to identify transit and pedestrian higher opportunity access areas that are mostly appropriate for the decisions regarding the location of disability and elderly senior housings units.

Similarly, the CoC program is specifically designed to support homeless individuals and families. Though the program plan emphasizes the assessment of housing for the homeless, their access to daily facilities is not properly addressed. The findings call for the revision of the program plan to consider transportation accessibility for homeless individuals and families. From the policy standpoint, HUD and housing agencies should place emphasize on the development of such housing services in walkable, accessible and transit-served areas. In providing rental assistance under this program or to renew contracts for existing CoC properties, administrators of the program should consider the access factor in calculating the share of rent for a household. This can help households to be located in areas within reasonable distances of transit services.

Overall, to address the issues in low opportunity areas, policy makers need to connect people and opportunities. This study recommends the use of access to opportunity data for several decisions: 1) to locate more services and opportunities in areas with low scores; 2) connect people to their opportunity destinations by improving

the pedestrian friendly network as well as transportation network company (TNC) vouchers; 3) avoid investment decisions in area with low access and low services; 4) encourage investments in high access areas.

Policies should also incentivize investment in location efficient areas and discourage investments in inaccessible low opportunity areas. Government can create specific tax reduction programs for individual developers to locate their project in more accessible areas. Since development of land in areas of opportunity are expensive, financial tools should be supplemented with federal money to incentivize the development of affordable housing projects in high accessibility areas. For example, Tax Increment Financing (TIF) can also be supplemented with programs such as National Housing Trust Fund and the Neighborhood Stabilization Program for investment in areas of higher opportunities. Moreover, policy makers can incorporate access to opportunity data to ensure multimodal access for any future investment in location any new services such as medical, education, food, child and youth and elderly and disability facilities.

Finally, the result of the model for this study proved the importance of multimodal access to job for housing value for tax assessment of the properties since ignoring location efficiencies in term of accessibility values might result in errors (Ottensmann, et al, 2008).

Limitations and Recommendations for Future Research

I acknowledge that this study has some limitations. First, to develop access to opportunity score, the centers of the census blocks have been used to measure the distance between origin and destinations. Census blocks vary widely in size and the distance to reach each destination might vary throughout the boundary. In addition, the center of them might not be the center of the activities. Therefore, measuring the distance from the center of the census blocks might not represent an accurate measurement for

the whole census blocks. However, since the study covered the whole region, it was necessary to stick with the center of to represent neighborhoods in the region. Choosing a smaller scale geography to include disaggregated household data might produce more accurate measurements.

Second, access to opportunity scores do not account for peak versus off peak hours or weekday versus weekend. For road network, no specific time was selected; however, choosing a specific travel time might affect congestion on the road and the time to access the destination opportunities. In addition, transit access varies widely in weekday and weekend, peak and off-peak hours. However, transit scores for this study have been developed for weekday transit service. Therefore, the inclusion of the two periods in the model would lead to a more accurate result.

Third, access to opportunity by transit has been developed using fixed route system and it did not model demand respond transit system. The demand respond transit does not operate on a fixed route and schedule. Moreover, there is not a systematic measurement method for demand-respond transit system developed for modeling purposes. However, inclusion of the areas served by demand respond would show a better status for transit access scores.

Fourth, due to limited biking infrastructure facilities in DFW and lack of systematic modeling method, access to opportunities by biking was not been included in this study.

Fifth, this dissertation includes only major affordable housing units in DFW to evaluate their location efficiency. Moreover, HCV housing programs is limited to Tarrant County, not the whole region. The inclusion of all programs in DFW is necessary to have a true knowledge of HUD affordable housing programs.

Sixth, to choose the sample size selected to analyze the location of the new projects, I excluded projects smaller than 80,000 square feet since the scale of the study

area was DFW and inclusion of more projects was out of the limit of this study. It is recommended to include major projects of any size in smaller scale to have a better understanding of the pattern.

Seventh, this dissertation does not include the impacts of land use planning on the location of new projects in low opportunity areas. To do this requires knowing the land use regulation and change process for each development, which was out of the limit of this study. Inclusion of that would allow us to have a better understanding of the reasons for the location of new projects and the role of the land use policies in low access areas.

Eighth, the sample size for housing structure is not evenly distributed in the study area. Housing units are mostly concentrated in the two counties of Dallas and Denton making less variations for the neighborhood and city level data. Inclusion of more data are necessary to account for this issue.

Finally, due to multi-collinearity for the access to opportunity scores, it was impossible to include scores for different destinations and different modes to compare the result for this study.

It is recommended for future studies to account for these limitations. A further recommendation for future study is to include demand-based transit services in developing access to opportunity for transit to have a more comprehensive access scores. Moreover, comparing the scores for weekend, weekday, off-peak and peak would create different perspective for accessibility scores. Moreover, as part of pedestrian access to destinations, the inclusion of biking infrastructure would add to the value of the research.

In addition, it is necessary to conduct a qualitative research on the reason for the location of new projects in low access areas. Developing some interviews with policy makers and designing surveys might add to the knowledge of understanding of the

decision-making process. For this purpose, researchers are recommended to include analysis of planning perspectives in different cities with successful and unsuccessful projects in term of addressing access to opportunities.

Appendix A

Percentage of Population With Access to Major Opportunities by Three Modes

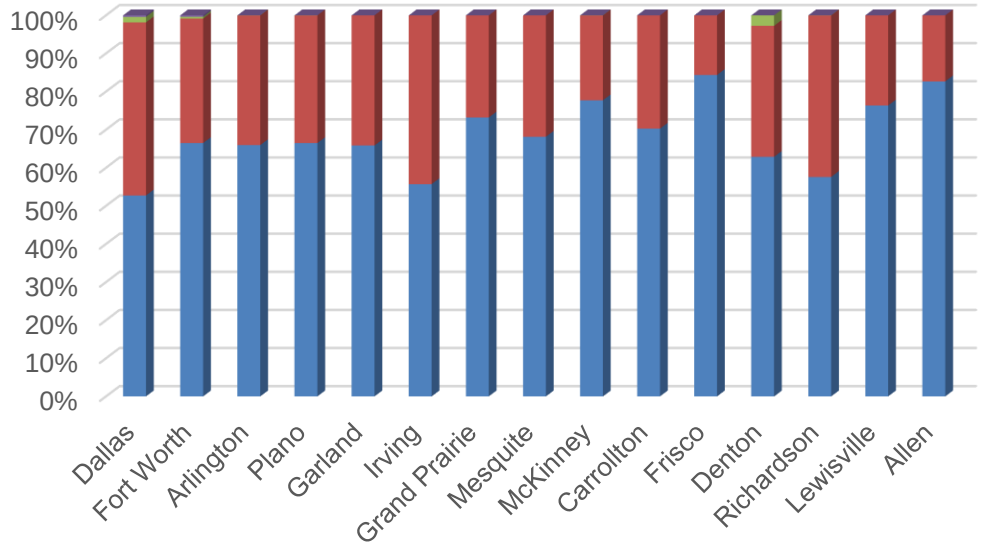

Figure AppA-1 Population with Access to All Opportunities by Walking

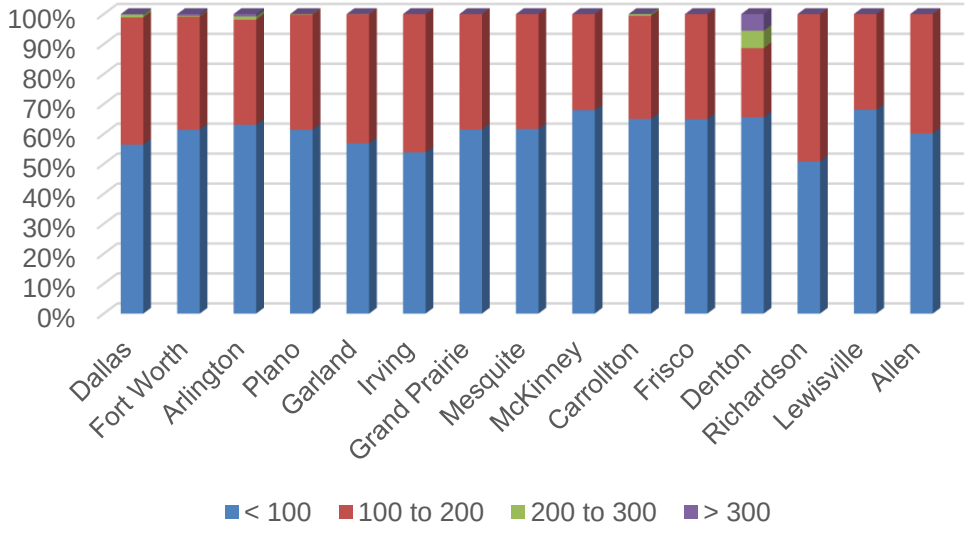

Figure AppA-2 Population with Access to Education Opportunities by Walking

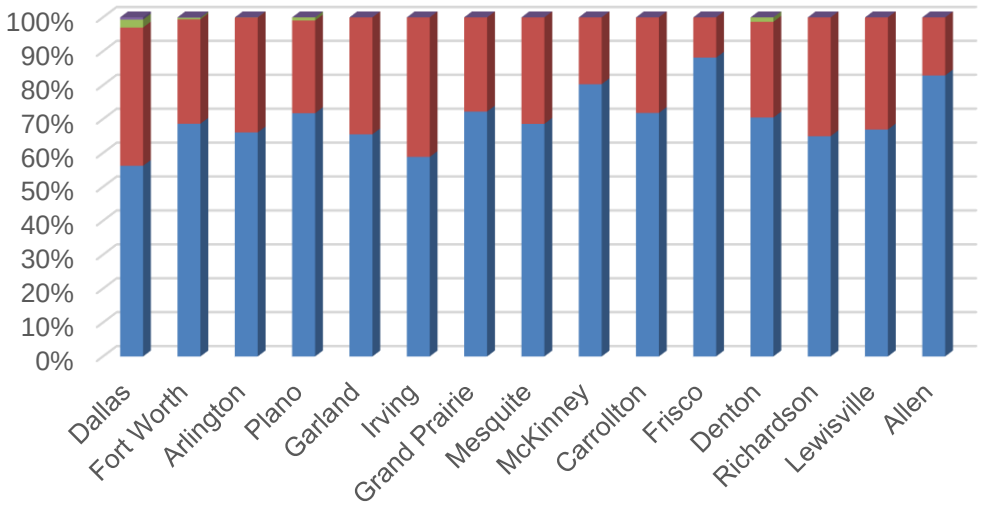

Figure AppA-3 Population with Access to Food Opportunities by Walking

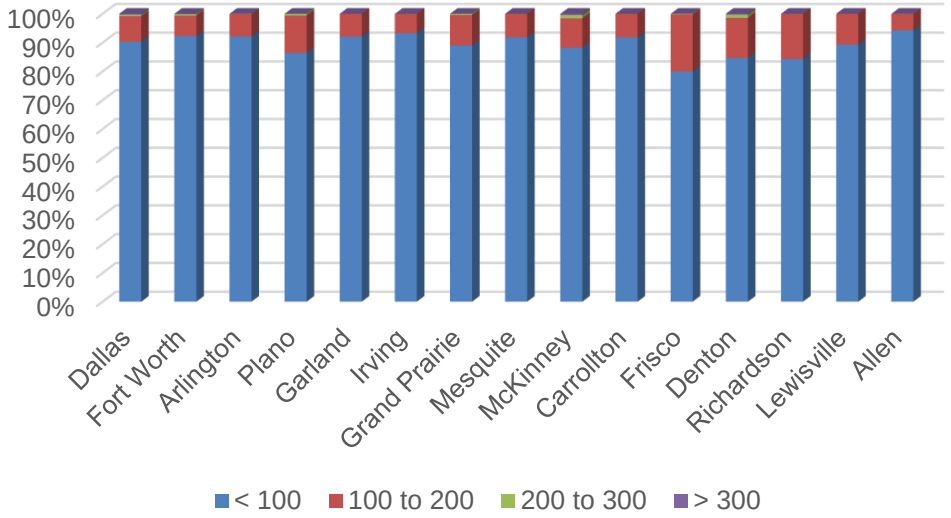

Figure AppA-4 Population with Access to Entertainment Opportunities by Walking

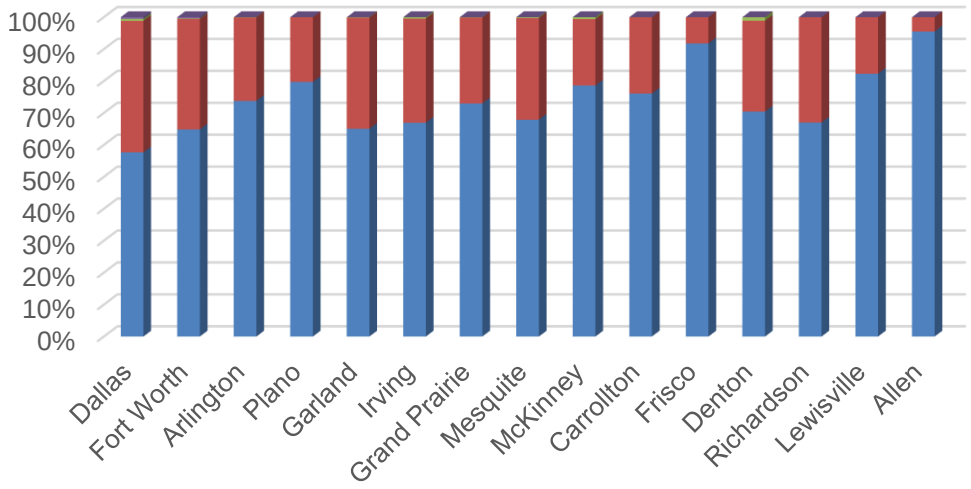

Figure AppA-5 Population with Access to Service Opportunities by Walking

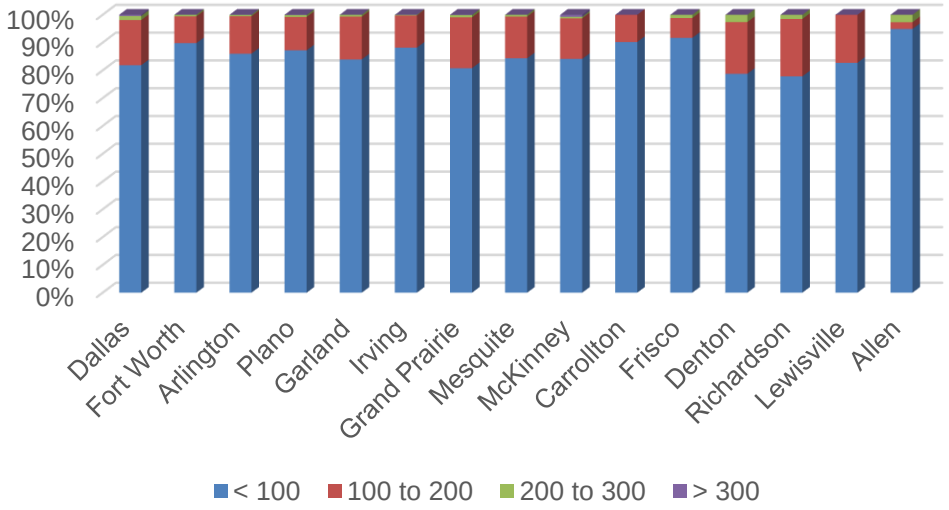

Figure AppA-6 Population with Access to Elderly Opportunities by Walking

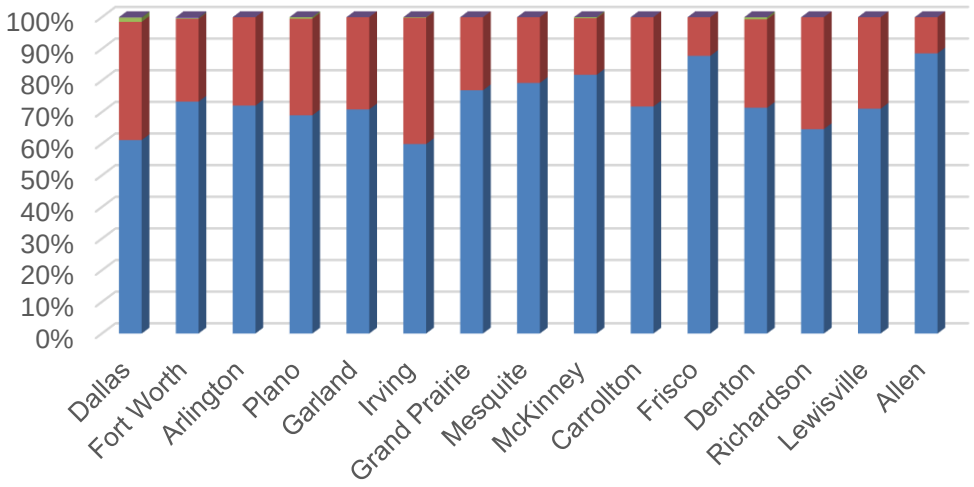

Figure AppA-7: Population with Access to Job Opportunities by Walking

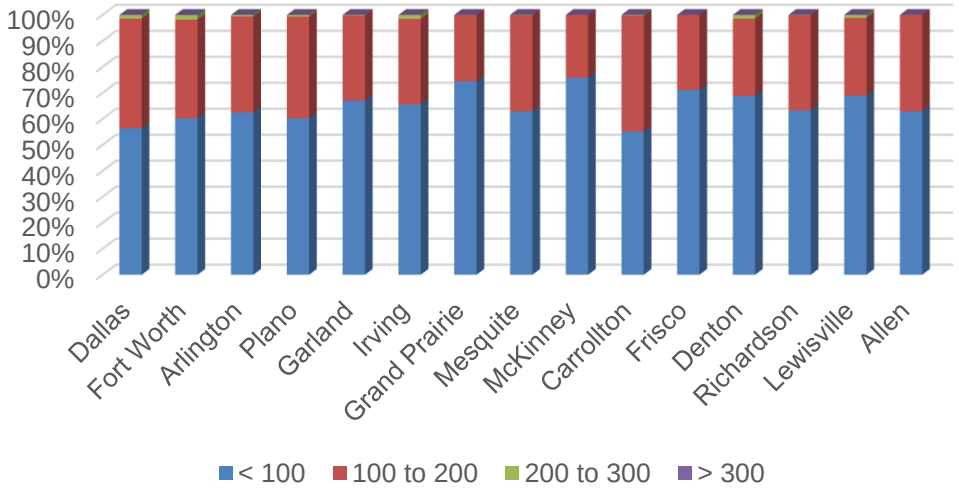

Figure AppA-8 Population with Access to Child and Youth Opportunities by Walking

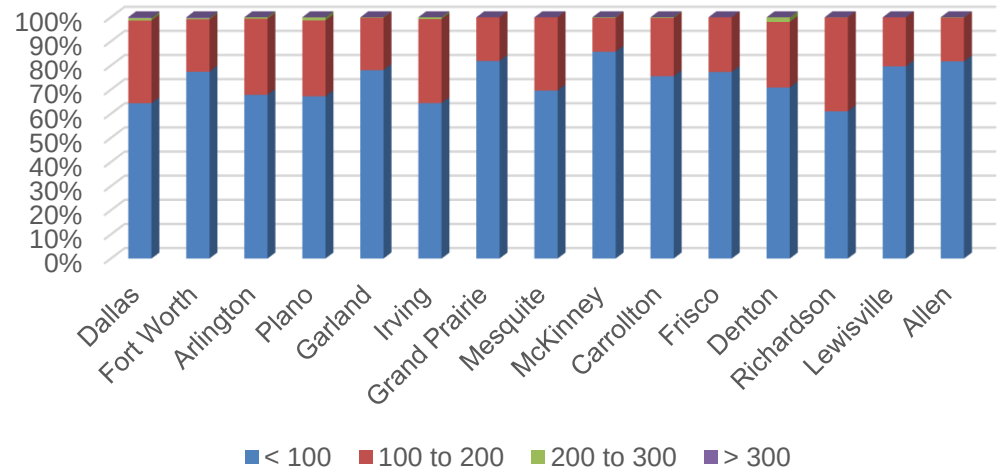

Figure AppA-9 Population with Access to Health Opportunities by Walking

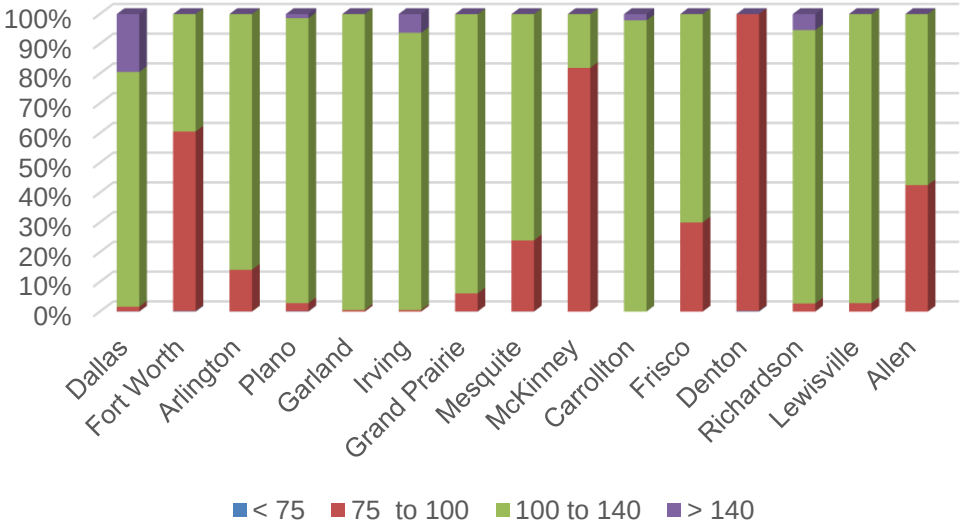

Figure AppA-10 Population with Access to All Major Opportunities by Car

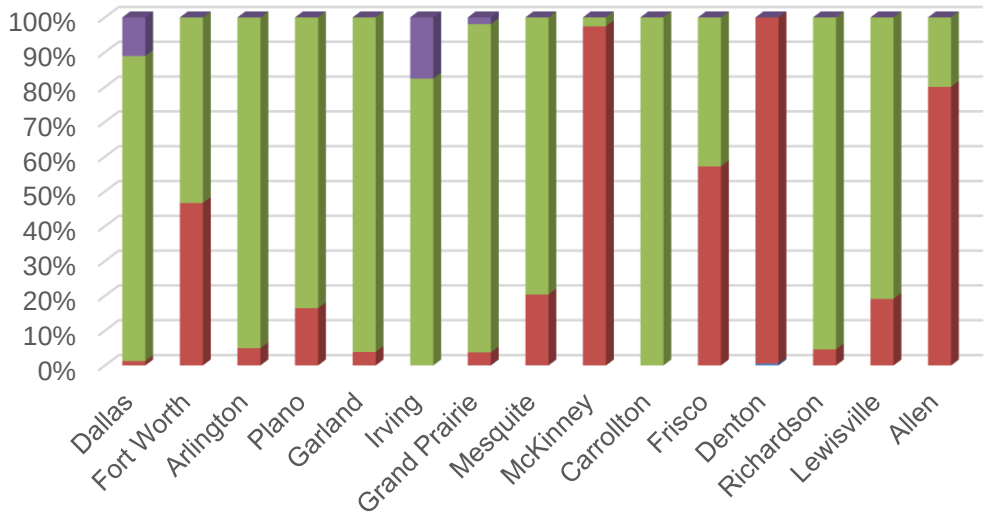

Figure AppA-11 Population with Access to Service Opportunities by Car

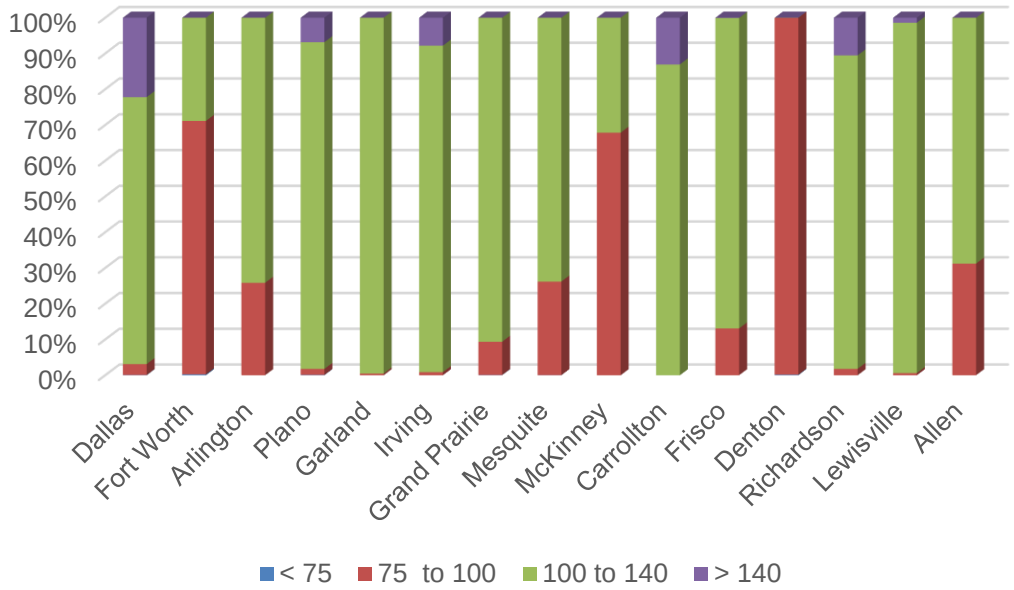

Figure AppA-12 Population with Access to Health Opportunities by Car

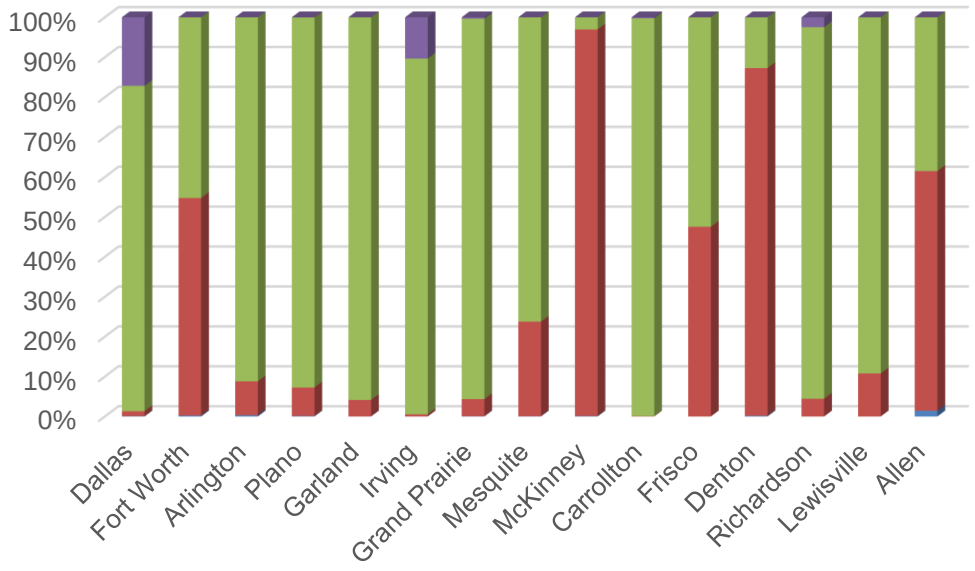

Figure AppA-13 Population with Access to Education Opportunities by Car

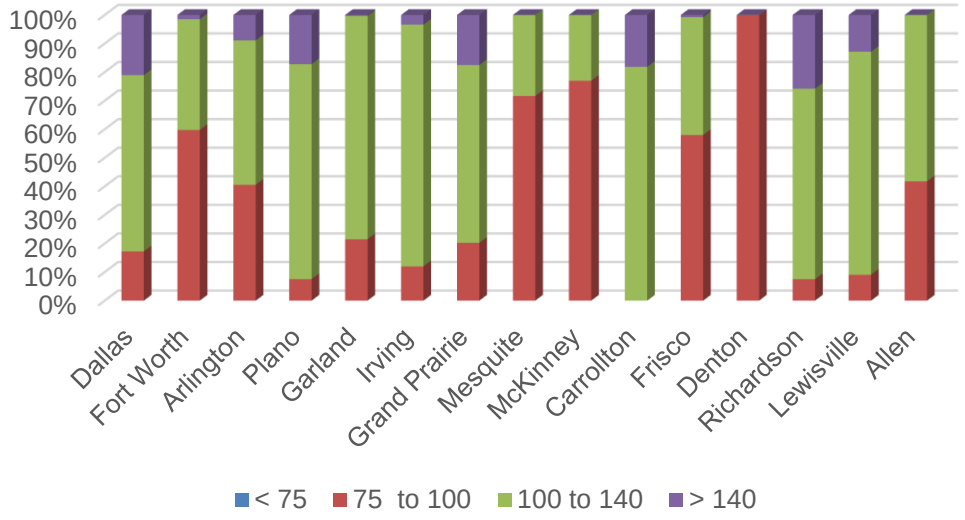

Figure AppA-14 Population with Access to Job Opportunities by Car

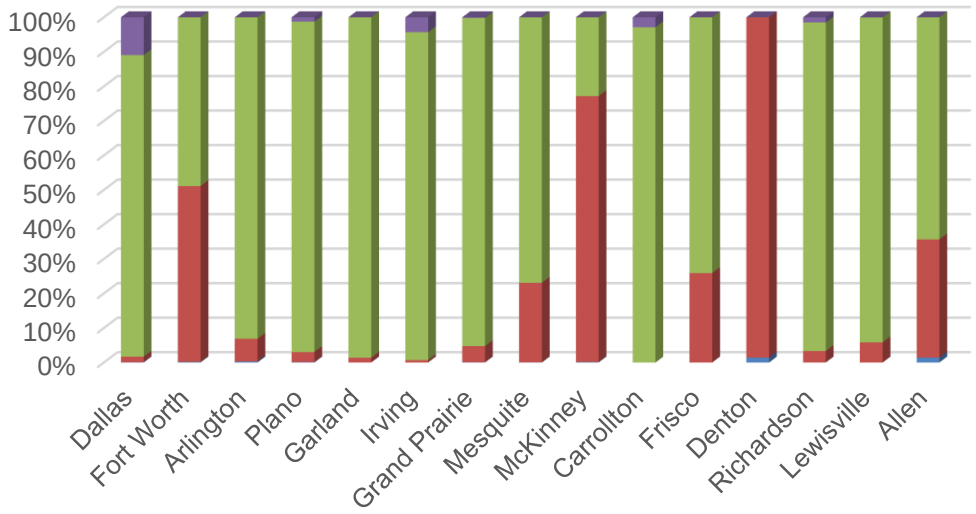

Figure AppA-15 Population with Access to Child and Youth Opportunities by Car

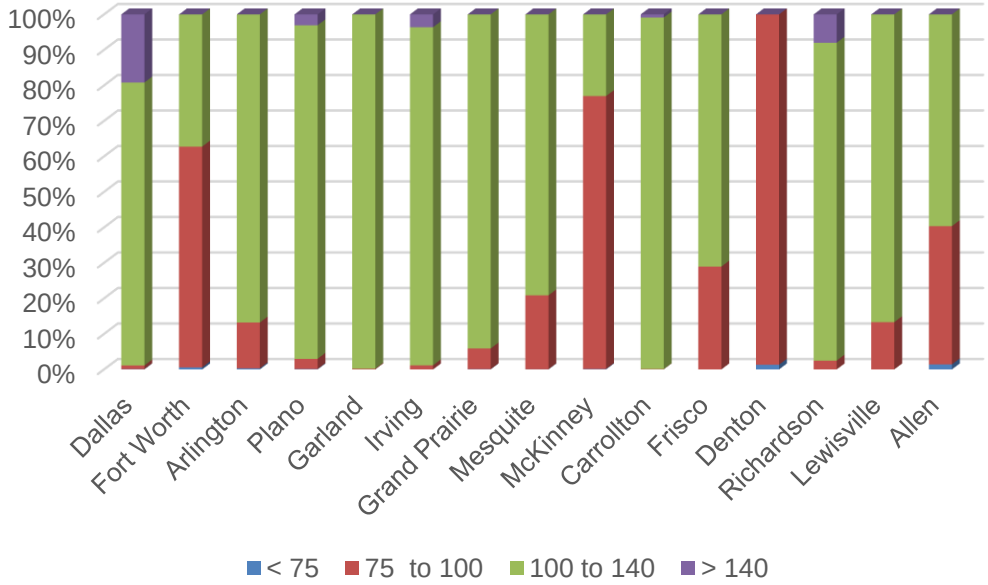

Figure AppA-16 Population with Access to Elderly and Disability Opportunities by Car

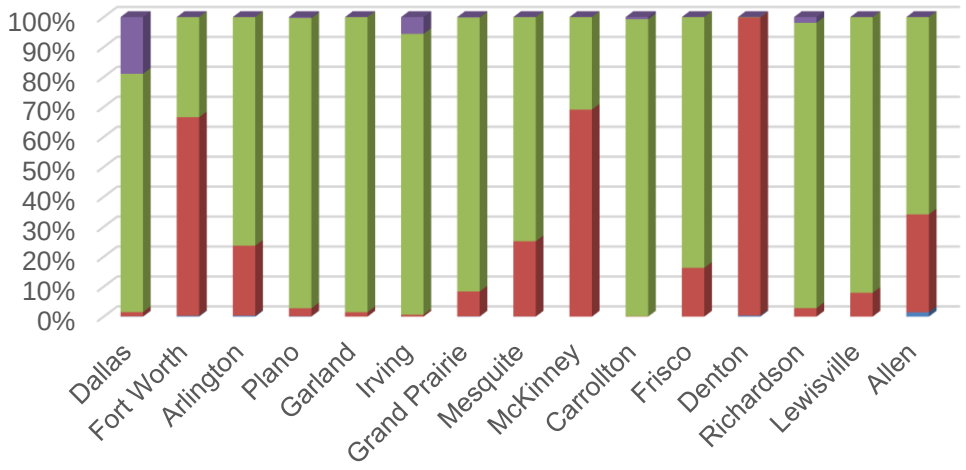

Figure AppA-17 Population with Access to Entertainment Opportunities by Car

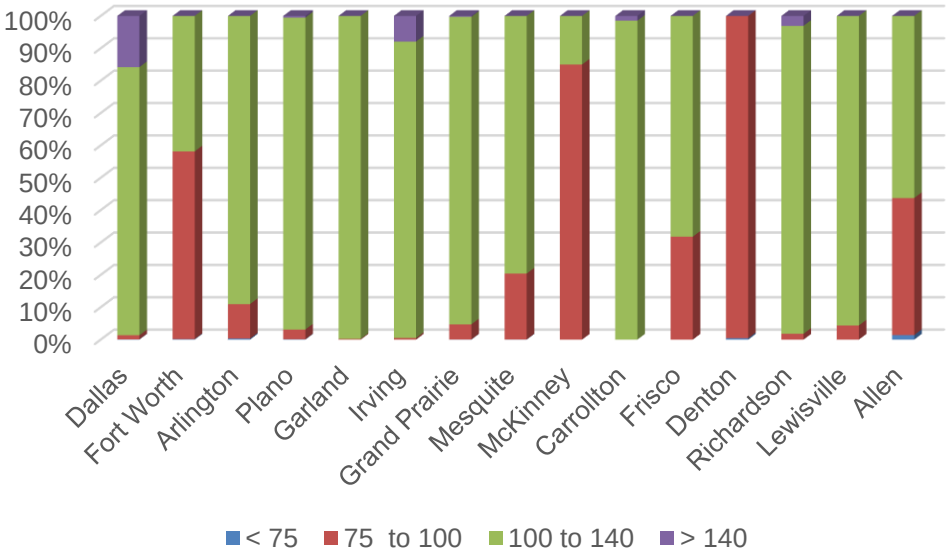

Figure AppA-18 Population with Access to Food Opportunities by Car

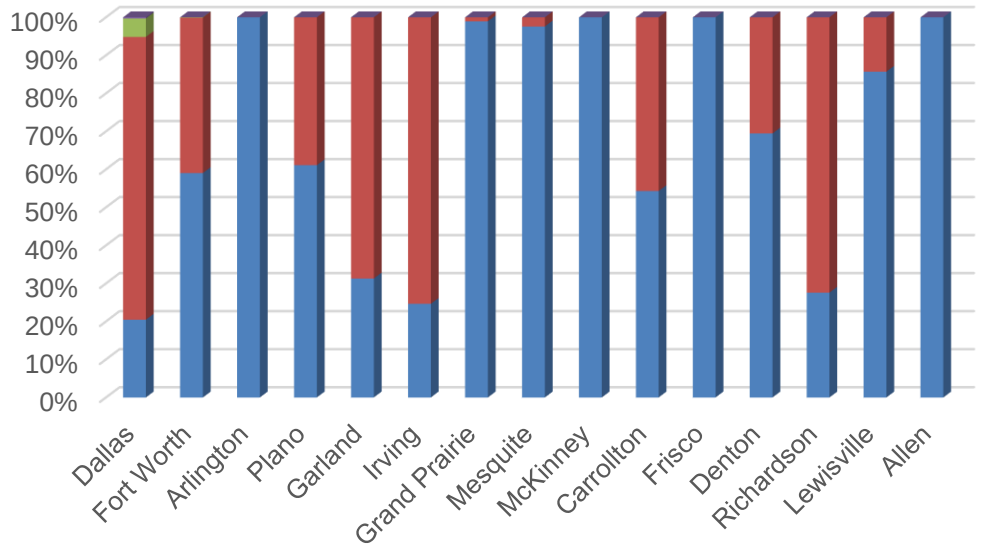

Figure AppA-19 Population with Access to All Major Opportunities by Transit

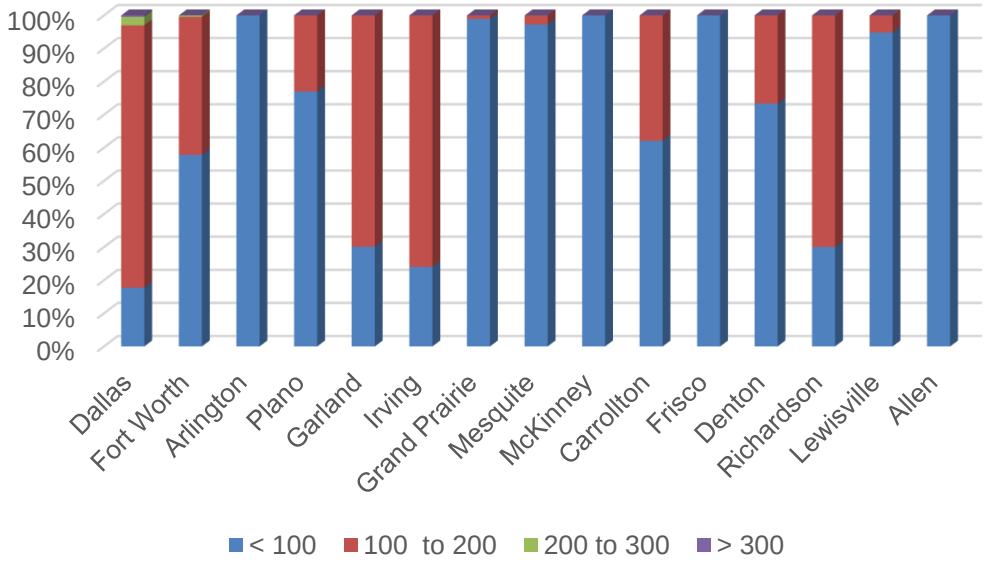

Figure AppA-20 Population with Access to Service Opportunities by Transit

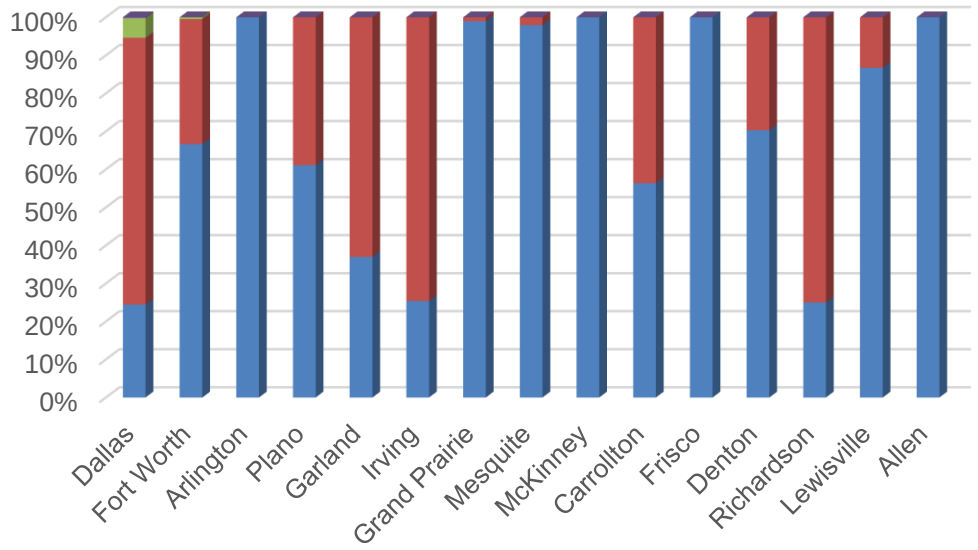

Figure AppA-21 Population with Access to Health Opportunities by Transit

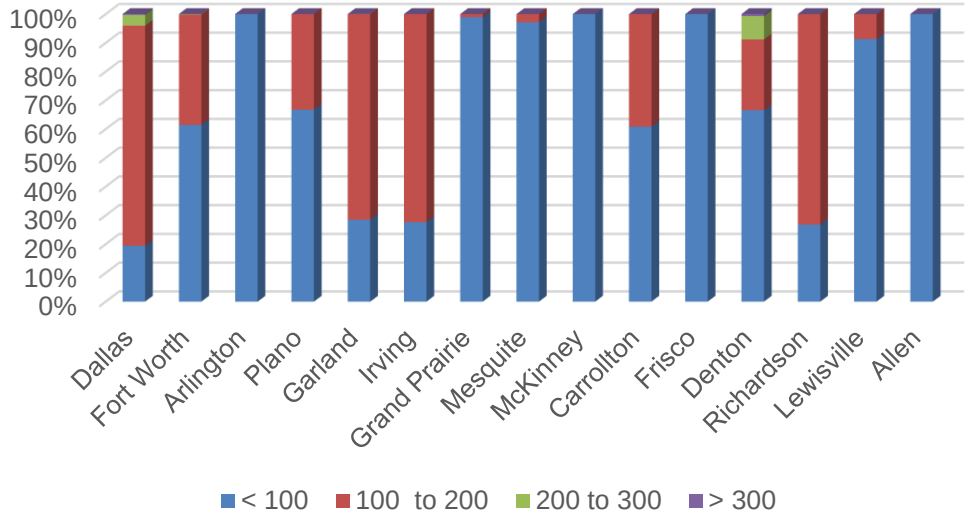

Figure AppA-22 Population with Access to Education Opportunities by Transit

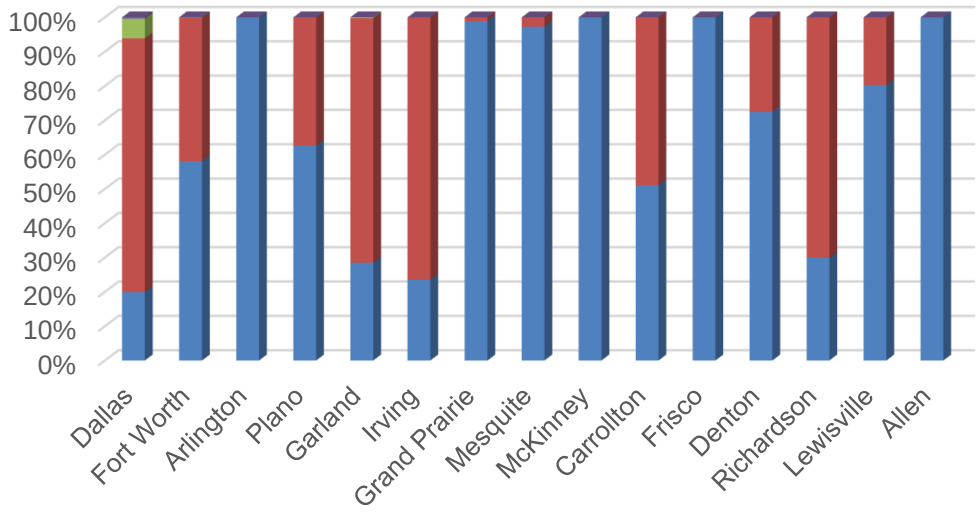

Figure AppA-23 Population with Access to Food Opportunities by Transit

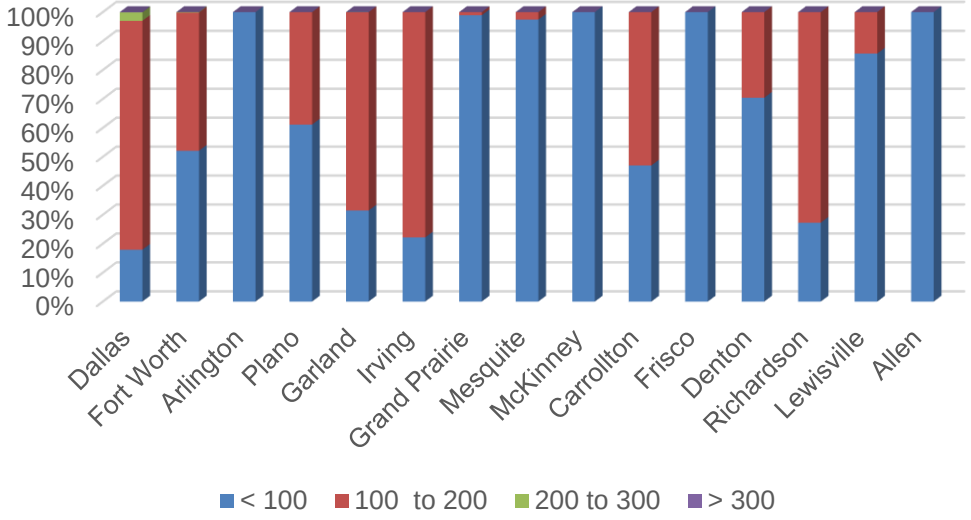

Figure AppA-24 Population with Access to Child and Youth Opportunities by Transit

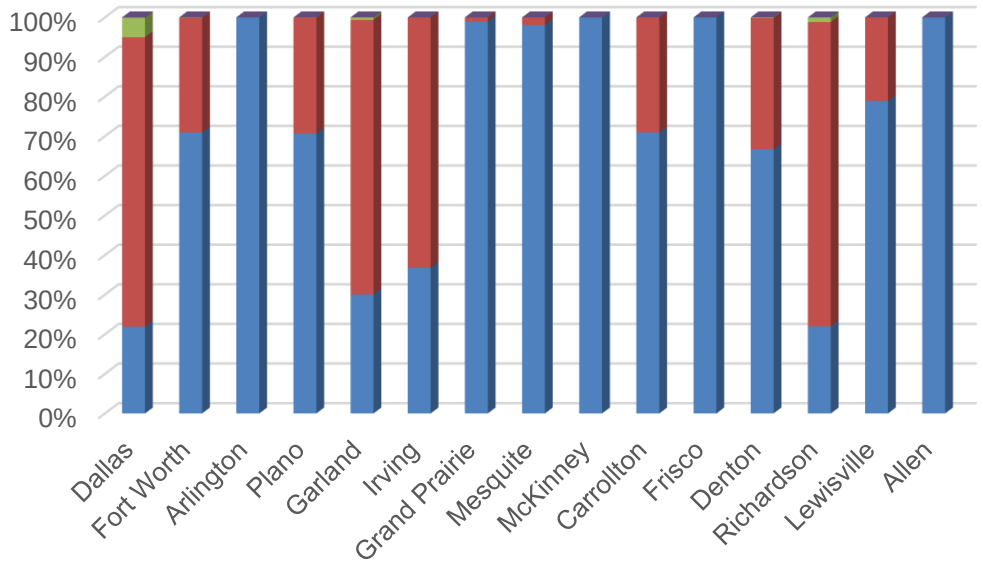

Figure AppA-25 Population with Access to Elderly and Disability Opportunities by Transit

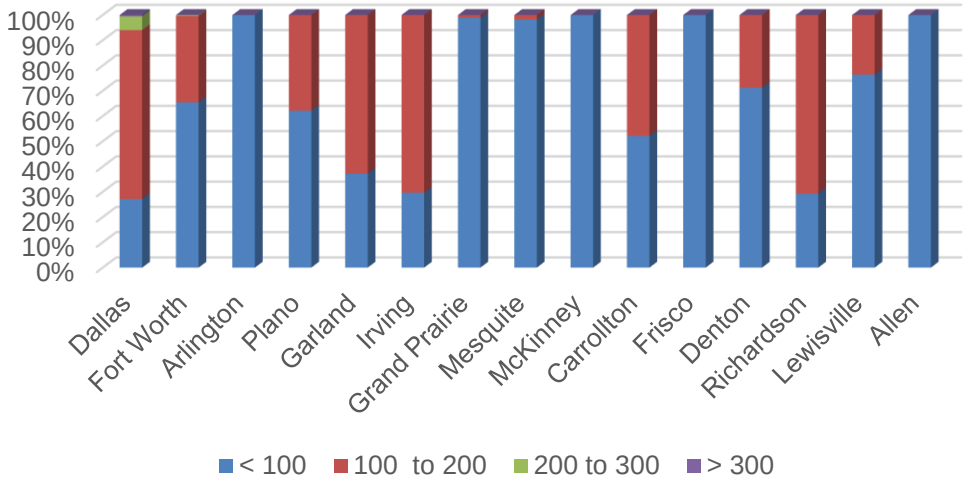

Figure AppA-26 Percentage of Population with Access to Job Opportunities by Transit

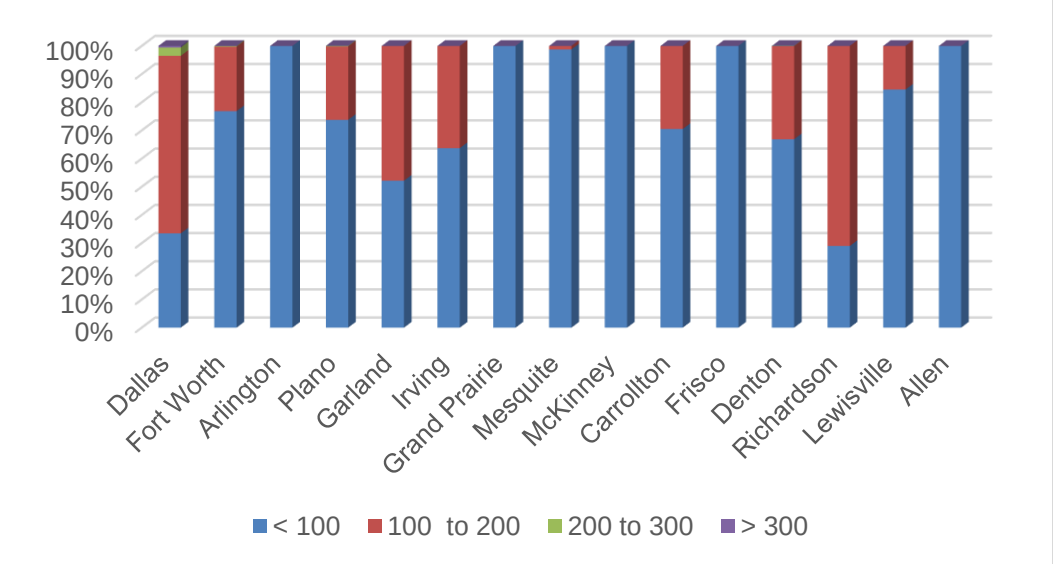

Figure AppA-27 Population with Access to Entertainment Opportunities by Transit

Appendix B

Access to Major Opportunity Scores by Three Modes

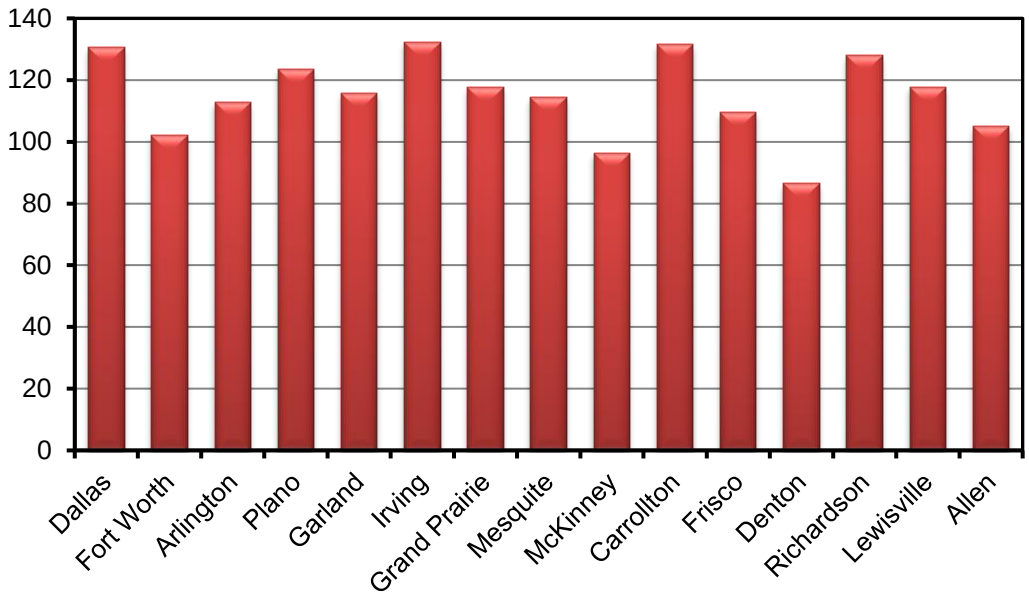

Figure AppB-28 Access to Major Opportunity Scores by Car

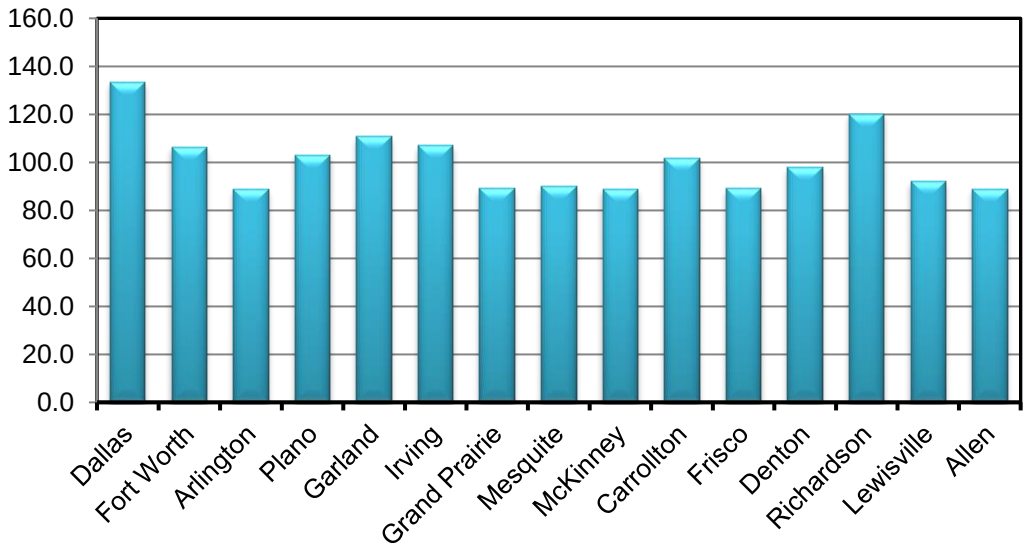

Figure AppB-29 Access to Major Opportunity Scores by Transit

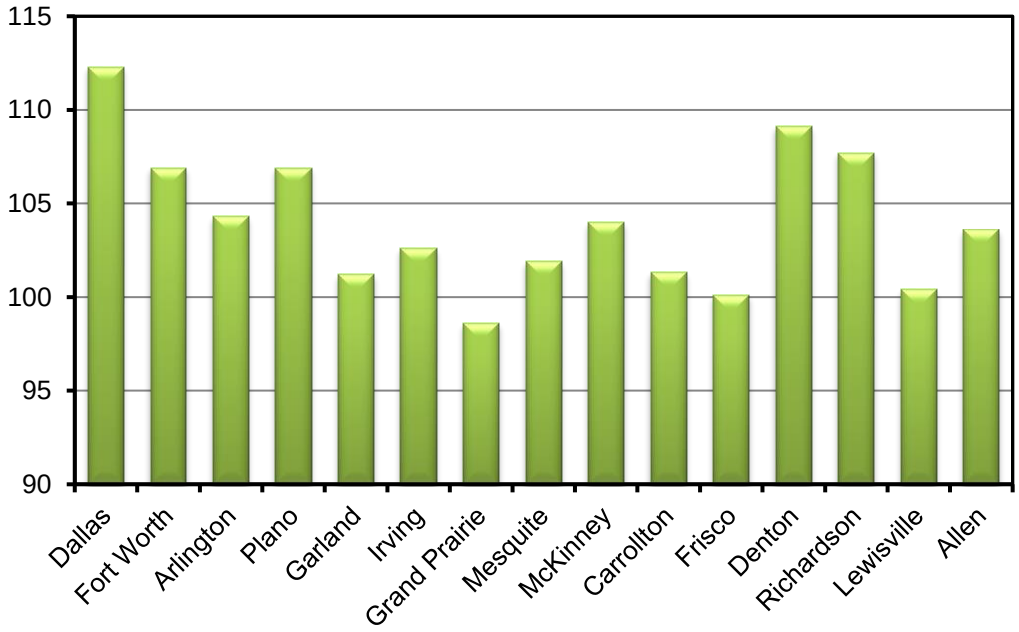

Figure AppB-30 Access to Major Opportunity Scores by Walk

Appendix C

Projects Occurring in High Access to Opportunity Area by Three Modes

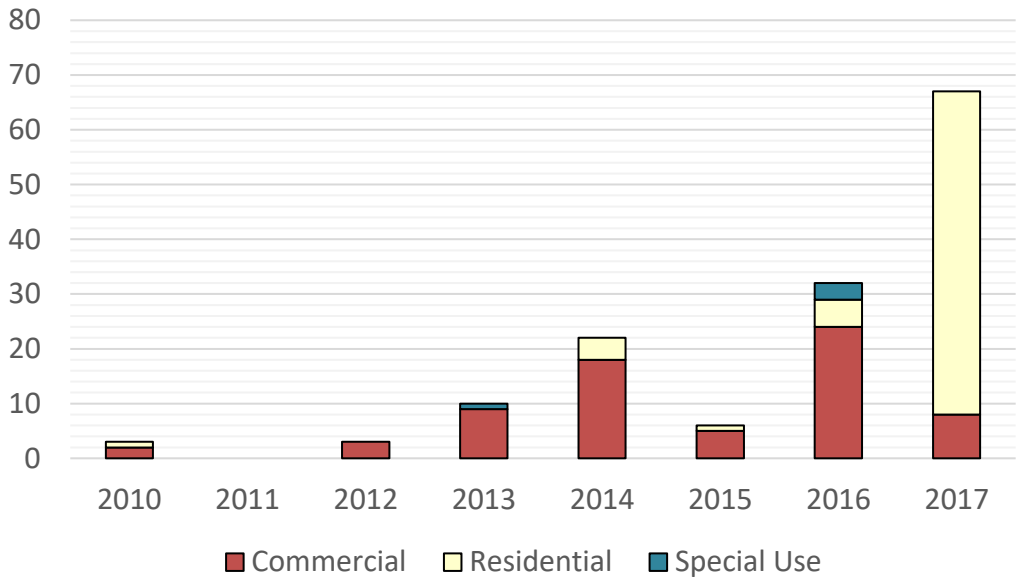

Figure AppC-31 Projects Occurring in High Access to Opportunity Area by Walk

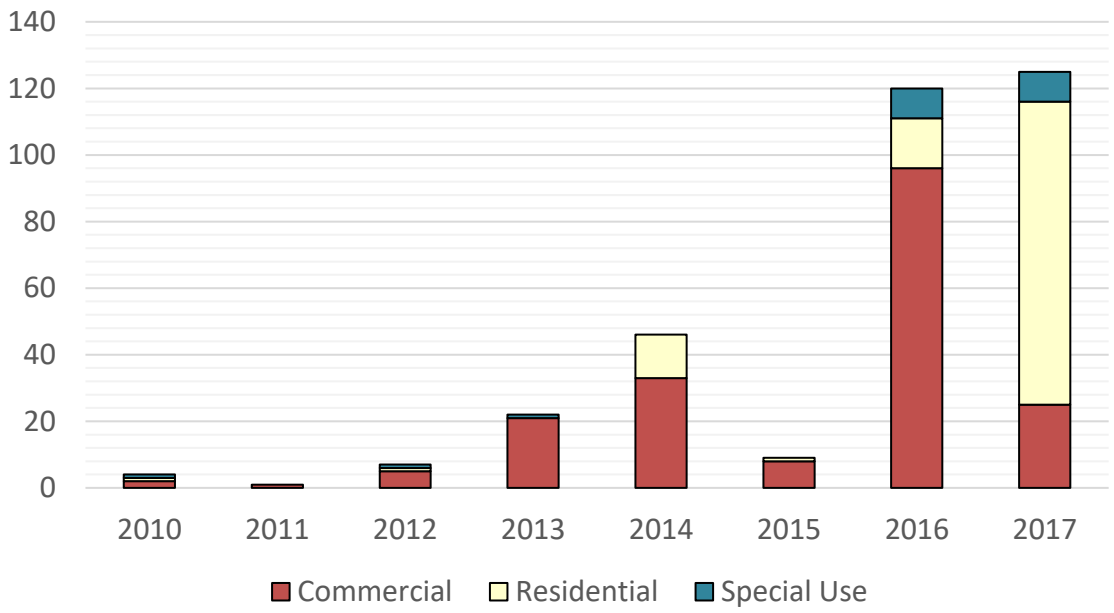

Figure AppC-32 Projects Occurring in High Access to Opportunity Area by Driving

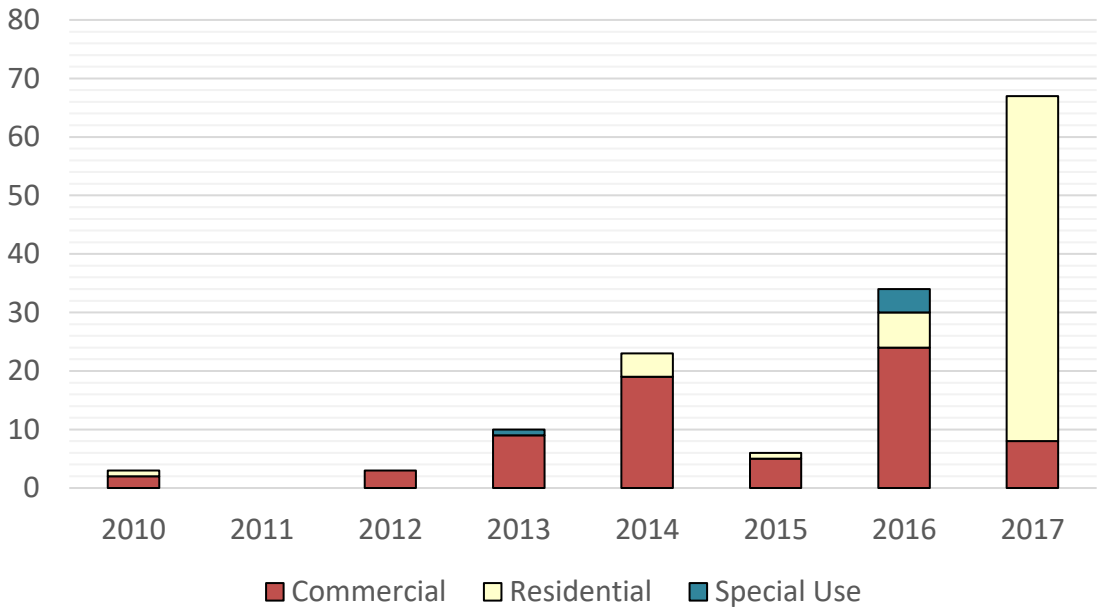

Figure AppC-33 Projects Occurring in High Access to Opportunity Area by Transit

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Somayeh Moazzeni, Ph.D. earned her M.A. degree in Geography and Urban Planning from Payame-Noor- University of Tehran, and her Ph.D. in Urban Planning and Public Policy from the University of Texas at Arlington. She joined Dallas Rapid Area Transit (DART) in 2018. She has been involved in a variety of planning and transportation projects including walkability study, performance analysis of regional transportation system, performance analysis of affordable housing projects and equity in transportation system. She received the U.S. Department of Transportation as the 2017 outstanding student of the year for C-TEDD. She plans to continue working in transit agencies to benefit the practical system and developing her research knowledge.